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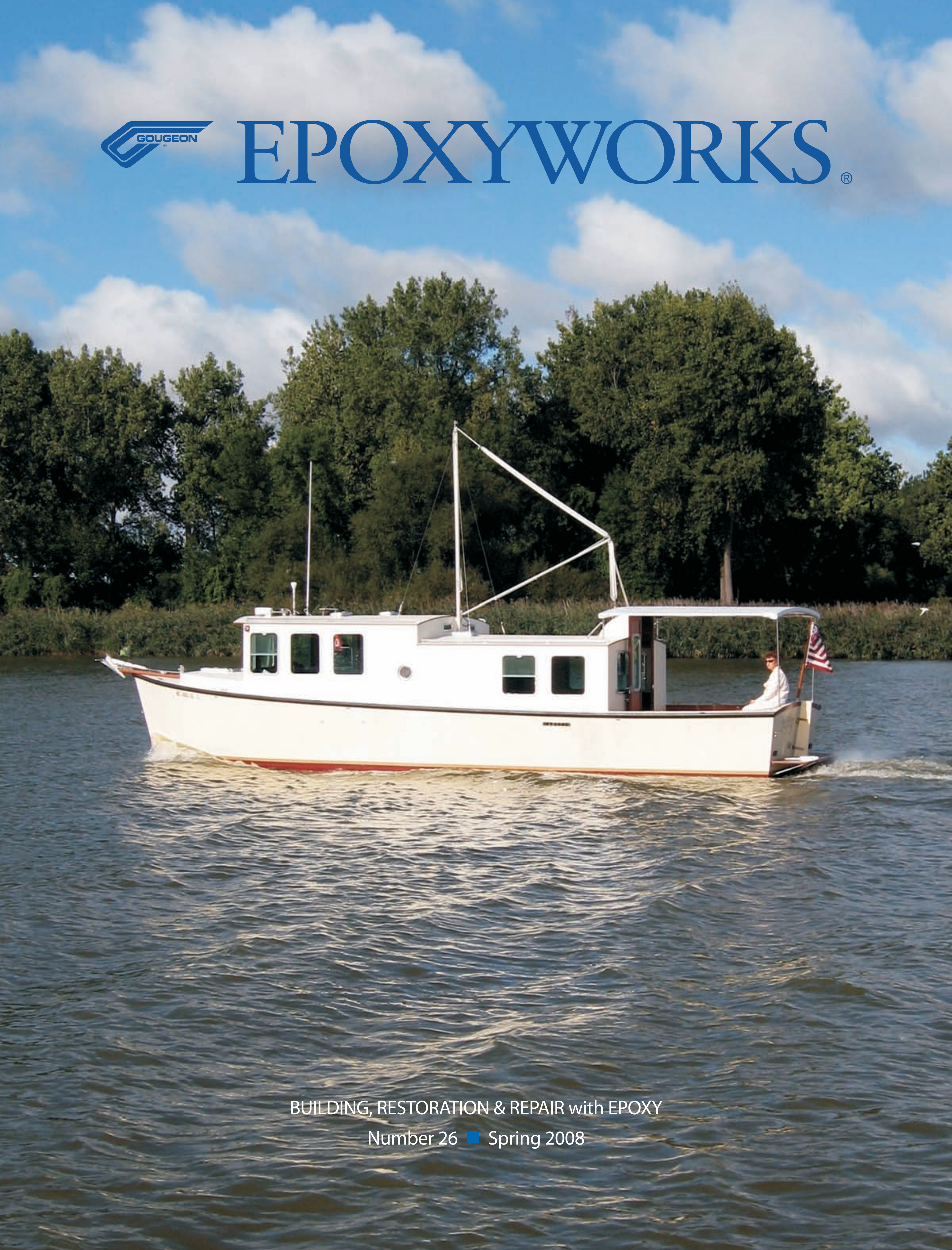

BUILDING, RESTORATION & REPAIR with EPOXY

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In this issue

EPOXYWORKS®

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Building the *Fifty Plus*

By Grace Ombry

A 37' powerboat is a bit of a luxury for a self-employed handyman and jack-of-all-trades like Carl Puehl. But he'd always wanted to build a boat, and he decided to fill the gap between what he wanted and what he could afford.

What he wanted was Ted Brewer's design #244, Quiet Times. It sparked Puehl's imagination when he saw it featured in *The Boatbuilder* magazine. He studied the design and said, "I can do that."

Puehl saved that issue of *The Boatbuilder* and started thinking seriously about how to make Quiet Times a reality.

He already owned an aging powerboat. Unfortunately, it burned fuel at the impractical rate of 23 gallons per hour. Motoring up to Tawas, a resort town on Lake Huron about 80 miles from his home in Saginaw, Michigan, cost him $400 in gas alone. With an eye toward retiring from working sixty-hour weeks, he yearned for a boat he could afford to take out on the water frequently during Michigan's temperate months. His other criteria were that the boat be comfortable, reliable, and have a low environmental impact.

The Quiet Times design

Puehl ordered the plans and started modifying the boat's design with Ted Brewer's approval. He said Brewer was very accessible, just a phone call away when Puehl needed to ask him about making design changes.

As designed, Quiet Times is a 34', long-range inland waters cruiser with a sharpie-type plywood hull and a skeg rather than a keel. The interior design is generous enough for a couple to live aboard and can be built to accommodate either inboard or outboard power.

Brewer designed the craft to be an economical and easily built displacement cruiser for the conservative yachtsman to explore North America's numerous inland rivers and lakes. In many ways, this makes it the perfect yacht for a Great Lakes boater like Puehl.

Brewer gave Quiet Times classic 1920's styling to attract positive attention and prevent it from becoming dated. The design employs marine plywood on sawn framing. All is fastened with epoxy, bronze screws, and barb nails. She has a strong arc bottom that is as easy to build as a flat bottom.

Cover story

Fifty Plus **is pulled from the water after her second season. The arc bottom and skeg are inspected after a quick powerwash and she is ready for winter storage.**

Puehl hauls *Fifty Plus* home for the winter to store in his pole barn. With its flat bottom, the boat loads easily on a custom built trailer.

Left—Puehl pauses after completing the first few mahogany frames in the spring of 2002—the beginning of what would become a five-year long project.

Right—The hull frames and stringers are completed. The hull's port side ½" plywood sheathing is installed with 12" wide butt blocks between the stringers.

Puehl applies the last of 3 layers of ¼" plywood to the bottom, before adding a layer of 6 oz fiberglass cloth to the hull's exterior.

In November of 2002, using an ingenious tackle arrangement, Puehl turned the hull over to begin work on the topsides.

The deck is completed and the cabin sides take shape. The deck is two layers of ¼" plywood, the sides, one layer of ½" plywood. In 2003, the engine installation was also completed.

In addition to being spacious enough for a live-aboard couple, there is room for occasional guests as well. The boat offers plenty of stowage throughout, and the aft cabin is large enough to accommodate a good-sized dinghy.

The design modified

Puehl stretched the design from its original 34' to 37', spreading the additional three feet over the length of the boat, because, he jokes, "at 34' it would be for short people, and I have long feet."

He also moved the engine from its original position in the rear cockpit to beneath the aft stateroom berth. This left the rear cockpit unobstructed. Doing so allowed him to install a straight-drive shaft in place of the V-drive shaft the original design calls for. This modification saved him about $3,000: the difference in price between a straight-drive shaft and a V-drive shaft.

Brewer designed Quiet Times to offer maximum fuel efficiency with either an inboard diesel of 25 to 40 horsepower, or twin 4-stroke outboard motors. She has a prismatic coefficient of .642, perfect for running at 8 or 9 knots at moderate throttle.

Puehl chose a 24-horsepower Bukh diesel. The shiny red engine was air-freighted from Denmark to Puehl's front door for only $500 in shipping.

He raves about the Bukh's mileage: it burns a mere 3 quarts of diesel fuel per hour compared to the 25 gallons per hour of regular gas the average 37' powerboat can be expected to guzzle.

In two seasons, he's put 2,700 miles on the craft and reports the boat has averaged 9 miles per gallon.

Brewer's design features an open bow cockpit and an enclosed aft cabin. Puehl flipped this arrangement, leaving the aft cabin open and enclosing the bow cockpit to create a cuddy cabin guest berth. He said he did so "for reasons anyone familiar with the Great Lakes would readily grasp."

Indeed, on the often choppy waters of Lake Huron an open bow cockpit might provide an inhospitable environment in all but the best of weather.

He trimmed the bow cabin with a warm, almost glowing, unidentified (possibly gum, he said) wood salvaged from the Sixties-style living room walls of a home he'd helped remodel. He said he'd had the wood for years and always knew he'd use it for something special.

The rest of the interior is bright-finished mahogany and all wood is encapsulated in WEST SYSTEM® epoxy.

The modified open rear cockpit creates a generous platform perfect for fishing, grilling, and sunbathing.

Puehl meticulously recorded each step of the construction process with photographs. The earliest shows him posed with the first boards of mahogany shipped to his home. In total, he used 60 4×8 sheets of Philippine mahogany plywood, ¼", ½", and ¾" thick. The bottom is constructed of three layers of five-ply mahogany, and the hull is protected by 15 mils of epoxy on 6 oz fiberglass on the outside.

Construction

Alone in the pole barn behind his modest home, Puehl worked doggedly for five years, putting in an estimated 5,000 hours—in addition to working 60-hour weeks—to complete the trawler he would christen *Fifty Plus*. The only outside assistance came from a friend who helped him machine and weld the rudder and drive shaft.

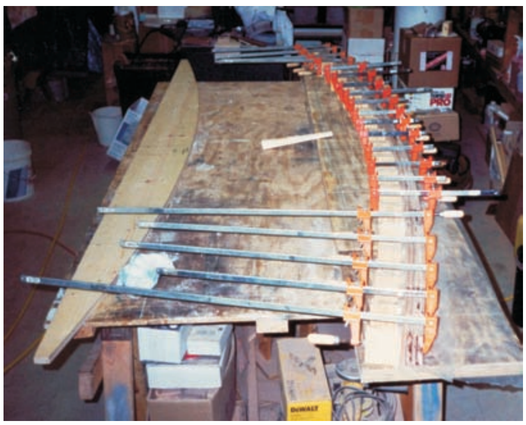
The galley under construction. Throughout 2004 work continued on the interior cabinetry and building of the fuel, water and waste tanks.

Building a boat this size is "grueling work," he said.

Fifty gallons of WEST SYSTEM epoxy went into the construction. The resulting craft is incredibly solid.

"This boat doesn't squeak," Puehl said. "It's a monocoque structure, like an airplane. You hear stuff crashing around (under heavy weather), but no squeaking. The bulkheads are all glued in. It's extremely rigid."

He said he was most surprised that even when *Fifty Plus* is pulled out of the water on a boatlift, she doesn't groan or creak as most large vessels do.



Puehl laminated the deck and cabin roof beams in a custom jig. The jig produced beams in an arc with a 21' radius.

Left—The laminated cabin roof beams are in place.

Right—The cabin top, two layers of ¼" plywood, is installed. The boat was close to taking up all of the available space in one side of Puehl's pole barn.

Left—Windows and hatches are installed and building of the interior cabinetry is well underway.

Right—The exterior begins to look more finished with the rub rail installed and the bottom painted. In the spring of 2005 *Fifty Plus* was sitting on her custom trailer and moved the roomy, center bay of the pole barn.

A custom-shaped sink fits a tight spot in the head. The seams of the plywood sink are joined with fillets and it is encapsulated in epoxy.

Puehl had a fifth-wheel trailer custom made for *Fifty Plus*, and he stores the boat in his pole barn. Because of this arrangement, the boat doesn't need antifouling paint. The hull is instead coated with Graham Ceramic™ house paint. He finds the ceramic paint easy to keep clean with a scrunge pad.

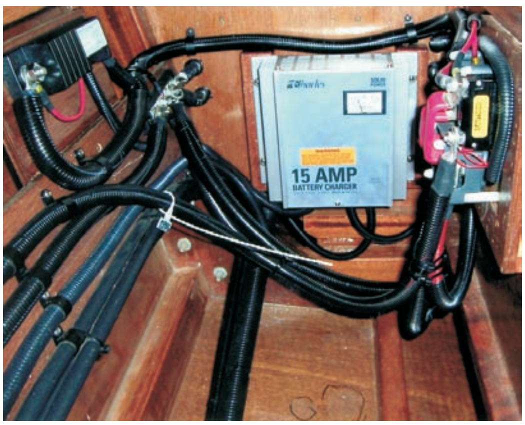
Comfortable accommodations were important to Puehl. He put a lot of thought and attention into the interior details. He sewed all seat and berth cushions himself on a quilting machine. They are expertly made and covered in a soft, stain-resistant microfiber fabric.

He also made all the window treatments of mildew-resistant lawn chair canvas he bought on sale at a fabric store. He designed them to attach with Velcro, negating the need to install curtain hardware.

One nifty custom feature is the custom-shaped sink Puehl constructed for the head. He made it out of wood encapsulated in epoxy. The seams are joined with fillets.

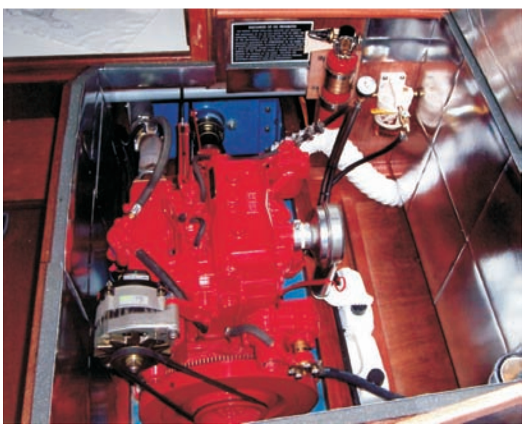
The boat has "great livability," he said. The autopilot, when set to about seven miles per hour, allows him to wander around the boat once he's out in open water.

Puehl's meticulous nature is evident in the detail of his electrical and plumbing systems.



Left—The little engine that could—the 24 hp Bukh diesel, designed strictly as a marine engine. It turns a 3-bladed 18" diameter prop.

Right—All of the systems are controlled at the steering station in the cabin.



The gauges he ordered came with a 9' wiring harness, which was 17' shy of the 28' the wiring needed to travel. Fortunately, as a licensed electrician, Puehl was equipped to rebuild the harness with fatter wire to go the full distance from the cockpit to the engine.

Some of the environmentally friendly and economical finishing touches he put on *Fifty Plus* include a high-efficiency refrigerator, which he insulated, and incandescent-corrected fluorescent lights to illuminate the interior. A pair of 6-volt golf cart batteries supplies all of the boat's electrical power.

One of Puehl's proudest moments came when his insurance company's marine surveyor inspected the boat and awarded it an "A" rating.

The boat was launched in 2006 at Bay Harbor Marina in Bay City, Michigan. Puehl's children came to the event and helped him christen *Fifty Plus* with a bottle of Asti Spumanti.

Puehl's advice for would be boat builders: "If you don't like sanding, don't build a boat."

Quiet Times Specs (modified)

LOA—40'
LWL—35'
Beam—10'
Draft—2' 10"
Displacement—12,000 lb
Power—24 hp Bukh diesel
Propeller—3 blade, 18"d × 12"p
Tanks—water, 95 gal; fuel, 105 gal; waste, 69 gal. ■

The open cockpit of the original Ted Brewer design was replaced with a cozy V-berth.

In the spring of 2006, the nearly finished *Fifty Plus* is unveiled. Everything is complete except the painting of the cabin roof, which was finally completed outside of the confines of the pole barn.

Of forests and fresh water

Gougeon Brothers, Inc. is located on the banks of the Saginaw River in Bay City, Michigan, which was briefly the lumber capital of the world. A vast forest of white pine in the region supported more than a hundred sawmills along the river. But the lumber boom of the nineteenth century lacked an ethic of stewardship and within a few decades the forest and the industry had disappeared.

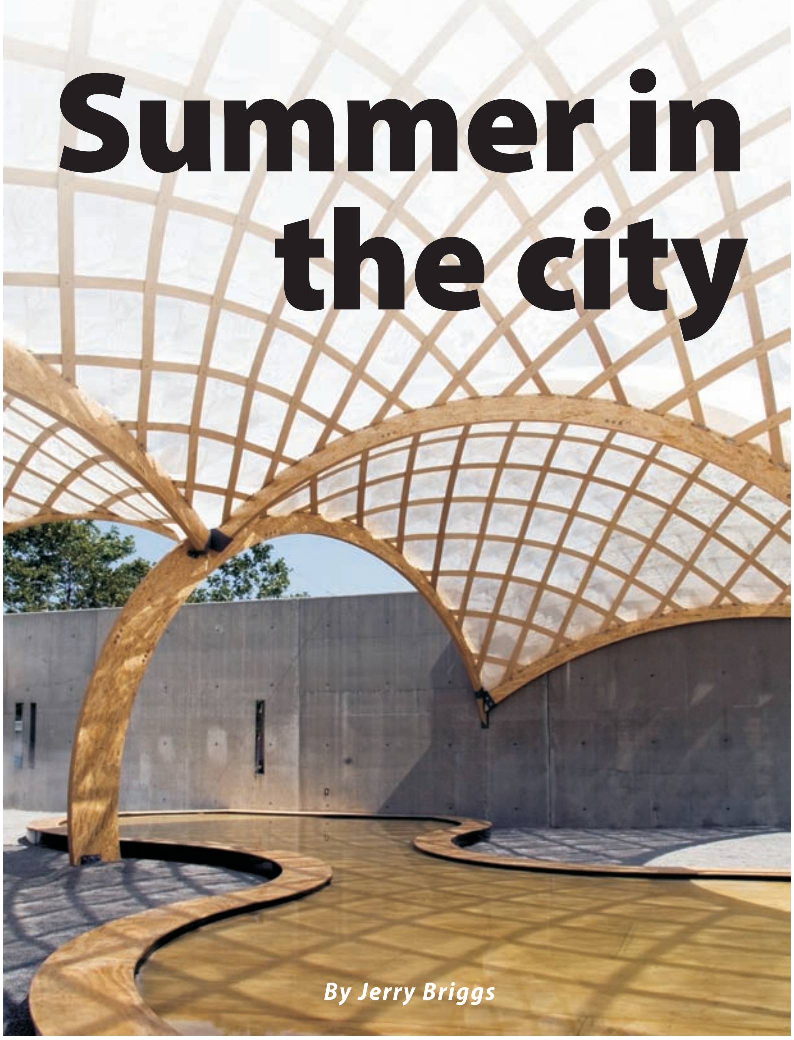
With this history so much a part of our local culture, we have been looking for ways that we can promote environmental stewardship. You hold in your hands one of the fruits of that effort: *Epoxyworks*. This is the first issue printed on paper certified by the Forest Stewardship Council (www.fsc.org), an international organization promoting stewardship of forests worldwide. FSC certification means the forest, paper producers, paper merchant and printer are all FSC certified and that the paper has been tracked through FSC's chain of custody. Look for the FSC logo on the inside front cover.

ALLIANCE FOR THE GREAT LAKES
ENSURING A LIVING RESOURCE FOR ALL GENERATIONS

We have also offered our support to an amazingly effective non-profit organization dedicated to protecting and preserving the world's largest freshwater resource. In 2007, *The Alliance for the Great Lakes* blocked 2,000,000 pounds of industrial waste from Lake Michigan; championed legislation to stop invasive pest species from damaging freshwater habitats; and organized 5,000 volunteers to clean 28,996 pounds of trash from 234 miles of Great Lakes beaches.

The Alliance has offices in Michigan, Illinois and Wisconsin, and works closely with legislators in all eight Great Lakes states and the Canadian provinces of Ontario and Quebec.

This year, we're donating 2% of the proceeds from every sale of WEST SYSTEM® 105-B Resin, to support *The Alliance for the Great Lakes*.



Summer in the city

By Jerry Briggs

Figure 1—A large, walled triangular outdoor gallery space was partially covered with seven shells and included two shallow tidal pools. The structures and pools were manufactured in a workshop and later deployed on site.

Each year The Museum of Modern Art iand P.S.1 Contemporary Art Center conduct what is known as the P.S.1 / MOMA Young Architects Program. The competitors vie for the opportunity to build a temporary architectural project in the17,000 square foot outdoor galleries of P.S.1 in Queens, New York. The structure serves as a venue for the popular outdoor music series, "Warm Up" which runs from June though September each year and boasts attendance in excess of 100,000 visitors per season.

In April of 2006, Jennifer Lee and Pablo Castro of Obra Architects, winners of the Young Architects Program competition contacted Gougeon Brothers Inc. Obra had an innovative design for the P.S.1 courtyard project that included the use of wood and foam construction techniques and were a natural application for WEST SYSTEM® products.

The two major features of their project, known as "Beatfuse", were seven interconnected domes made of plywood with polypropylene mesh roofs and two wooden tidal pools. The wooden tidal pools are where WEST SYSTEM came in handy. Obra designed two pools that were constructed of foam and wood laminated to create both the pools and the chaise lounges that appear as the "spokes" in Figure 4. The pools had to be durable since they would be visited by thousands of people over the summer without a great deal of supervision. In addition, the pools were located outside and had to withstand the elements while retaining water-tight joints. All wood pieces were laid out and formed using CNC technology.

The first step was to laminate the structural foam layers by spreading mixed epoxy on the opposing surfaces and clamping with screws. The foam chaises required seven layers of foam while the pool bench sides took three layers.

After the laminates cured overnight, the next step was to lay glass cloth on the side profile of the foam that would form the pool sides. The cloth lay-up was covered with release fabric to achieve a smooth appearance. After the cloth lay-up cured, the release fabric was removed and the sides were coated with epoxy mixed with graphite powder *(Figure 2)*. The graphite filled coat was followed by two additional coats of epoxy. The sections were then flipped over and the other sides were treated using the same method.

The next step was to add the plywood tops and bottoms to the foam pool wall sections.

Figure 2—Left, a worker coats one of the foam and wood laminated chaise lounges with epoxy tinted with graphite powder.

Figure 3—Right, a worker coats one of the interlocking sections that make up the sides of one of the pools. The sections are laminated foam and wood.

The foam sections were sanded to open the pores to promote better adhesion. The mating surfaces of the foam bottom sections and the plywood were coated with a slurry of epoxy thickened with a structural filler and then secured with screws until they cured *(Figure 3)*.

The sections were then flipped over and the same procedure was followed for the top sides. The same procedure was used for assembling the sections that would make up the bottom of the pool. The top of the pool sides and the top of the pool bottom sections were all covered with three coats of epoxy and one layer of fiberglass cloth.

All of the bottom sections had narrow lap joints built into the adjoining sections during construction which were covered with release fabric after the last epoxy coat was applied. When the epoxy cured, the release fabric was removed exposing a surface that required no surface preparation before bonding the sections together, saving valuable labor time.

All of the sections of the pool sides were cut with dovetail joints where the sections met end to end. A similar joint in the center of each section where the side walls meet the pool bottom made a solid connection between the sides and bottom.

To complete the assembly, all sections were staged in place *(Figure 4)* before the joints were bonded with epoxy thickened with a structural filler. All of the seams on the pool bottom were sealed using 3" cloth tape and three coats of epoxy *(Figure 5)*. The seams on the side walls where the wall sections were joined were handled in the same fashion. Finally, a fillet was used to create a water tight seal on the inside of the pool where the side wall and the pool bottom meet to ensure that the structure was water tight. Since the project was temporary and 207 Hardener, which contains some UV inhibitors, was used, there was no need to apply a clear varnish top coat.

As the photos on the right demonstrate, Beatfuse and Warmup were a big success *(Figure 6)*. Obra Architects have been recognized in the architectural design community with articles appearing as far away as Japan in the prestigious "A+U" (Architecture and Urbanism) magazine. Pablo Castro and Jennifer Lee created a warm and inviting space in a bare courtyard in Long Island, Queens. We at Gougeon Brothers were very pleased that our products and technical assistance could play a small part in such a visionary and successful project. ■

Figure 4—All sections were staged in place before they were bonded with epoxy thickened with a structural filler.

Figure 5—All of the seams on the pool bottom were sealed using 3" cloth tape and three coats of epoxy.

Figure 6—Large crowds enjoyed the "Warm Up" music series, as well as the inviting space and cooling tidal pools of the Beatfuse project.

Figure 7—The Museum of Modern Art and P.S.1 Contemporary Art Center, site of Beatfuse, the winner of the 2006 Young Architects Program competition. Beatfuse was designed by Jennifer Lee and Pablo Castro of Obra Architects of New York, www.obraarchitects.com.

Building composite tubes
with WEST SYSTEM® epoxy and braided fibers

By Captain J.R. Watson

Tubes are used on boats for hard tops, T-tops, Biminis, dodgers, bows, bow and stern pulpits, rails, canoe and kayak paddle shafts, boat hooks, and so on. Composite tubes built with epoxy and reinforcing fibers offer advantages over metal in terms of light weight, custom shapes and sizes, and corrosion resistance. Composite tubes can be faired and painted to produce a seamless appearance to match the boat, or left to show the carbon fiber. I've been experimenting with approaches to building a variety of composite tubes. Following are some things I've tried (some that worked and some that did not) that you may find of value if you want to produce composite tubes yourself.

For all of these composite tube projects, I chose WEST SYSTEM 105 Resin and 207 Special Coating Hardener. The hardener choice was driven primarily by the desire for plenty of working time, fast wet out of the fiber reinforcement (as I was often unsure how long it would take to accomplish what I had in mind), and the option of a clear finish.

The real challenge in building composite tubes is in creating the mold or mandrel (the core around which material can be cast, molded, or otherwise shaped) and releasing the composite successfully from the mold. Fiberglass over a metal tube is a typical approach; however, I also experimented with using foam pipe insulation as a molding surface. To form the composite tube, braid is slipped over the mandrel, wet out with epoxy, and then reinforced with additional fiber/epoxy laminates to the desired thickness. The composite tube is then released from the mandrel, and the sections are joined together if needed.

Figure 1—Typical braided tube of carbon fiber. The length-to-diameter ratio can be altered like a Chinese finger trap.

Braided fibers

Braided fibers are a good choice for composite tubes. Braids are available in fiberglass, aramid, carbon fiber, and other materials. A sleeve or tube of braided material behaves like a Chinese finger trap (*Figure 1*). Because the fibers are woven together at 45°, you can simply pull the braid to lengthen it. This also reduces the fiber orientation to about 35°. The material to lengthen is "stolen" from that formerly used to keep it wide. Total surface area remains constant, so the more you lengthen it, the more the diameter shrinks (i.e., tightens). The reverse effect is that if the ends are pushed, the diameter increases with a likewise increase in the fiber orientation to about 55°. This, of course, is how the finger trap is removed; because the diameter is now larger, it slides off your fingers. This expansion and compression of the braided tubes can be utilized in the construction process.

In these projects, I used carbon fiber braids. Specifically, I chose 3K (3,000 fibers per bundle) .06 oz/ft carbon fiber braid purchased from CST, The Composites Store and A & P Technologies. These companies also carry braids in tape form, rather than sleeves. Tapes behave like biaxial but are much more controllable as the braid yields a straight edge that does not unravel. Tapes go around a corner nicely and can be manipulated like the sleeves by pulling or pushing to alter fiber angle.

Molds for straight tubes

Fiberglass over a metal pipe or tube

My simplest and most successful approach to creating molds for composite tubes is to laminate a thin layer of fiberglass over a smooth metal pipe or tube (could be aluminum, chrome, steel, etc.) that serves as a mandrel. Wax the tube. It must be very smooth to facilitate removal. Apply a thin layer of fiberglass with epoxy. After this thin layer has cured, cut the laminate along the tube's length with a utility knife and pop it loose but still on the mandrel. Rotate it a little to make sure it is free.

Then, continue with the desired laminate schedule. The fiberglass has already been released, so the composite tube will slide easily off the mandrel.

Rope and Foam

A second approach uses rope and foam pipe insulation (with a self-sealing slit) that looks like a doughnut in section. The foam has a slippery surface to which the epoxy does not bond very well, facilitating removal when used as a molding surface.

I strung a length of low stretch rope (about 25% greater than the desired tube length) between two points tensioned with tackle. Initially, I left the rope unattached on one end. Alongside the rope, I also strung 50 lb monofilament fishing line. I covered the rope and monofilament with 1¼" OD slit foam used for pipe insulation. It comes in 4' lengths and is sized for about an ⅝" diameter pipe. I ran the monofilament line over the end of the foam and back down over the outside of the foam.

I fed one layer of braided sleeve onto the foam. I followed this with a second layer. However, the second layer was gathered at the "long end" where the 25% extra rope was situated. Then I tensioned the rope to reduce any curve or sag and worked the braid toward the ends of the tube to tighten it against the foam. Next, I wetted out the braid with WEST SYSTEM® 105/207. I placed layers of 703 Unidirectional Carbon Tape over the braid and wet it out with more epoxy. In this way, I could step-taper these layers to achieve a buildup of thickness in the center with less on the ends. Once I had achieved the schedule I wanted, I slid the outer braid up over the unidirectional laminations using waxed twine so I could pull and work one end of the braid toward the opposing end and tie it off *(Figure 2)*. Once the braid was smooth and secure, I wet it out and let the tube cure overnight.

After everything had cured and I removed rope, I pulled the 50 lb monofilament running through the center of the foam to cut it into segments and allow removal. I was eventually able to get the foam out, but not without some difficulty as it was stuck to the inner carbon braid. This approach works on sections up to 10', but may not for longer lengths. Considering how little weight the foam represents, it may not be worth the effort to remove the foam.

Polyethylene Terephthalate (PET)

Another approach I tried was to cover foam pipe insulation with PET plastic braid, commonly used to cover cables or electrical wiring, with the intent to force the foam to become more round. Tests where I tried to bond to the PET resulted in what I wanted—the epoxy didn't bond to it, which seemed to allow easier removal of the foam, although the PET remained inside the composite tube *(Figure 3)*.

Fluorescent light tubes

An approach I tried that didn't work was to laminate over a fluorescent light tube. I liked the idea as the inside surface would be perfectly smooth. I applied mold release to the glass tube and laminated the carbon fiber braid and unidirectional fiber as described above. The plan was to break the bulb (they implode) and vacuum the particles out. However, I was disappointed when I broke the end and the bulb did not implode but stayed attached to the carbon fiber. Evidently, there was too much surface area to allow removal. So I have a carbon fiber tube that is glass lined.

Figure 2—Making a composite tube using foam pipe insulation, rope, and monofilament fishing line.

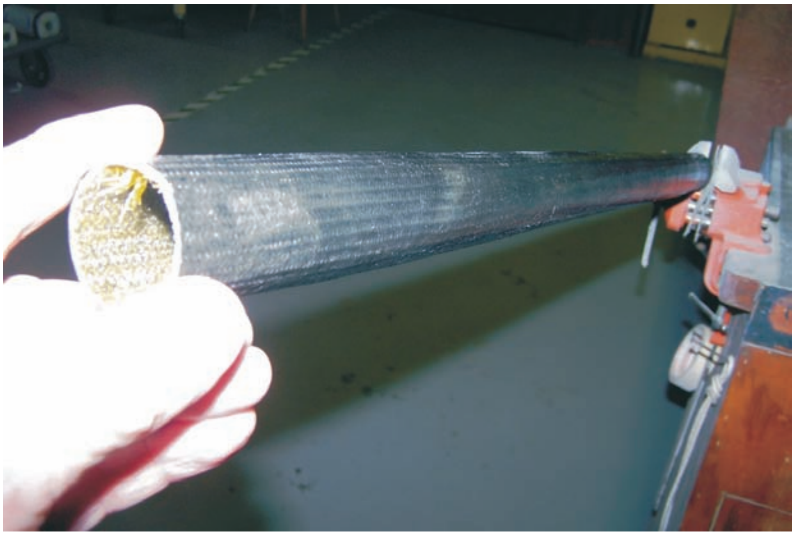


Figure 3—A 6' tube built over a mold of foam pipe insulation. The PET plastic braid that remained is visible inside the carbon fiber tube.

Based on this lesson, I tried a different approach. I bonded a light layer of fiberglass fabric over the florescent tube with mold release on the surface. When cured, the single layer of fiberglass is flexible enough that you can break the bulb and remove the broken glass. I then laminate enough fabric to the outside to yield the required stiffness. Now I have a composite tube that is perfectly smooth and round inside.

Making curved and tapered tubes

To make curved tubes, I bent ½" diameter copper tubing to about an 8" constant radius. Then I placed pipe insulation foam over the copper tubing and proceeded with the laminating. When everything was cured, the copper tubing slid out. Again, I used monofilament to cut the foam to allow removal in pieces.

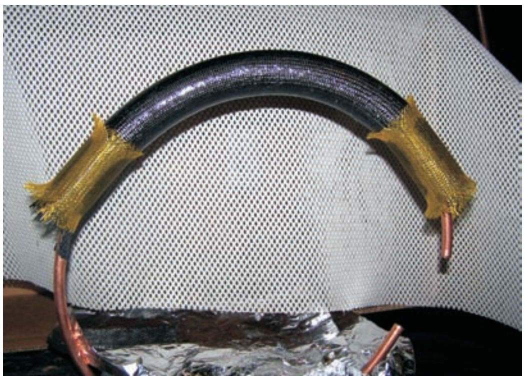


Figure 4—PET is used on the outside of a carbon sleeve to serve as "handles" to help pull the sleeve taunt.

Figure 5—A tapered tube section joined to a curved section.

To make a tapered tube, I placed pipe insulation foam over a metal tube that was greater than the size the pipe insulation was intended for, which opened the slit. Then I attached eyebolts to each end of the tube and stretched two 50 lb monofilament lines. I aligned one end of each with the edge of the open slit of the pipe insulation and the other end on the foam away from the edge to form a desired taper. Using the line as a guide, I then cut along the lines and remove the long thin wedges of foam along the open slit. I placed the trimmed foam over a taut rope as described earlier. When I sealed the slit shut, I had a tapered molding surface to laminate over.

Joining tube sections

To create one continuous tube, sections—straight or curved—can be joined to other sections. I wanted matching diameters within a 1⁄16" so I could easily blend the sections to become visually "joint-less."

I've used two approaches for joining tubes and both involve fabricating a sleeve that fits in the ends of the tubes. The sleeve length should be about four times the diameter of the tubes you are joining—half of the sleeve length goes into each adjoining tube.

Figure 6—A short sleeve used to join two sections has a smaller diameter than the sections.

The first approach to create a sleeve is to follow the procedure described above for laminating one layer of fiberglass over a polished metal tube and then cutting the laminate to free it. After that, add a couple more layers to get the outside diameter needed to match the inside diameter of the tubes to be joined.

The other approach I used was to laminate a sleeve over a thin wall (1⁄16" or less) aluminum tube mold. The outside diameter of the aluminum tube represents the inside diameter of the tubes to be joined less the thickness of the sleeve. After sanding and polishing the aluminum tube, I wrapped it in fiberglass tape saturated with epoxy. Then I heated the aluminum and the laminate to accelerate the cure and also expand the aluminum.

After all was cured, I placed the laminate in a snow bank (a freezer will work) to shrink the aluminum. A 70°F temperature drop is usually sufficient to allow the cured laminate to slide off the aluminum tube. I sanded the sleeve to adjust the fit and then bonded it to the inside of the tubes to be joined with thickened epoxy.

Composite tubes offer lots of possibilities. I hope you find some of these approaches helpful. ■

Repairing a walnut gun stock

By Randy Barkley

1

2

This is how I repaired an obviously serious break in the stock of a 1956 Winchester Model 88 rifle (1) using a WEST SYSTEM® 101 Handy Repair Pack.

I soaked the broken ends in acetone for about 5 minutes and brushed with a tooth brush a couple of times to remove any gun oil from the wood surface. Besides the breaks, the grain on the back stock splintered (2).

I started with the major breaks first. I mixed some walnut sawdust with a105 Resin/205 Hardener mixture and added a little 406 Silica.

3

4

I gave all of the surfaces a thick coat of epoxy (3). The 30 minute working time was needed, as aligning some of the splinters in the checkering was difficult (4).

It was tricky to get clamps to hold. The surface is round, the epoxy is slick, and I used plastic wrap to keep the clamps from adhering to the stock (5).

Although some of the clamps are big, very little clamping pressure was used to avoid driving too much epoxy out of the joints. I cleaned up the epoxy that did squeeze out with a paper towel.

5

6

With the stock back together, I put a 105 Resin and 205 Hardener packet in warm water before mixing to increase its flow rate. The mixed epoxy was poured into the raised grain cracks and then lightly clamped (6).

The repaired raw stock came out looking very good. I used dental tools to clean up the checkering and used furniture stripper on the old polyurethane finish. A fine sanding with 400 grit paper completed the stock preparation (7).

7

8

I sealed the stock with 20% tung oil and 80% mineral spirits. Then I sanded it 6 times with 50% tung oil and 50% mineral spirits. I waited 1-2 days between each application and sanding. Lastly, I used rubbing compound to knock down the gloss and bring out the satin finish (8).

The finished gun

After one box of shells, the finished stock is still holding solid. The worst side of the break and the repairs look great. I don't think it could look any better given the nature of the breaks.

I am very pleased with the outcome. ■

Readers' projects

This photo was sent to us by Trudy Herbst, Director of Development at the Door County Maritime Museum in Sturgeon Bay, Wisconsin. This is a Shellback Dingy and the boatbuilding students who built it in classes at the museum in the spring of 2006. The dingy and a Wee Lassie II built in another class were the 8th and 9th boats built in classes there. Visit www.dcmm.org to find out more about the museum.

"It is a time consuming method, but you come away with a solid boat that doesn't leak." That is how Daniel Fry describes the process he used to build this 13' 4" cold-molded, Melonseed skiff. The hull of the Marc Barto design is constructed of three layers of 1/8" okume plywood. This is Fry's second boat project. His first was a 15' Joel White catboat. Fry sails the Melonseed on a lake near his home in Williamsport, Pennsylvania.

Clare & Peter Averill receive *Epoxyworks* courtesy of ATL Composites in Queensland, Australia, who were very helpful in supplying information about West System products which the Averills used to successfully build this Michael Storer designed canoe. The Eureka is 15'6" long with a beam of 34". They were very happy when, from the selection of lightweight wood and the judicious use of West System epoxy, the finished canoe weighed only 15.5 kg (34.2 lb). For more information on the Eureka, visit Michael Storer's website, www.storerboatplans.com.

Saratoga County Arts Council in Saratoga Springs, New York, sponsored a public art event that involved the transformation of fiberglass horses by regional artists. Thirty-four unique creations were on display in the summer of 2007. This horse is the work of artist Jenny McShan who used West System epoxy in the coating of her creation.

Dave Scott's first boat design & building project was this 22' skiff built over 1500 hours. Scott, of of Merville, British Columbia was inspired by Tolman's Alaska skiff and the *Nectar*, featured in the December '03 *WoodenBoat* magazine. The stitch & glue project used Aqua Teck Meranti plywood, LVL stringers and WEST SYSTEM® epoxy. Powered by a 225 hp Yamaha™ 4 stroke, its top speed is 45 knots.

Chris and Henry Snyder of Ada, Michigan, designed and built this wooden truck. It includes parts from a lawn tractor, an old trailer, a snow blower, a wind generator and a weed whacker. A lot of wood, WEST SYSTEM epoxy (105/205) and ingenuity also went into it.

Meade Gougeon, a long time WEST SYSTEM epoxy user from Bay City, Michigan, built this carrier designed for the back of a tandem, recumbent bicycle. The carrier is built of ³⁄₃₂" okume plywood using stitch and glue construction. Dubbed the Truckbike, the aerodynamic carrier can haul a good eighty pounds of food and gear, for extended trips.

Jocelyn Belleville is a woodworker from St-Émélie de l'Énergie in Quebec, Canada. Belleville has been making wooden baths, showers and sinks like these above, for more than two years, using WEST SYSTEM epoxy to make the fixtures watertight. She says she first made canoes with epoxy and didn't want the water leaking in, now she doesn't want it leaking out. Contact Jocelyn Belleville at 450-886-9701.

Storm the castle

Robbie loads the trebuchet for another practice shot before the competition.

By Tom Pawlak

A while back, my nephew Robbie, about 15 years old at the time, asked for help building a trebuchet (a form of catapult) for an upcoming Science Olympiad competition that his school was involved in. He had located a nice set of plans online that were based on a lattice-type structure using hardwoods. The website offered a fairly detailed plan and included project photos to help during the build. Like many high school students, Robbie waited a bit long to get started (I was the same way when I was in high school), which meant that once again I was part of a school project that involved cramming to get the job done. I knew we needed to speed up the process in order to have any hope of getting the trebuchet built in time to allow for firing practice before the competition. We decided to use G/5 Five-Minute Adhesive® for the many glue joints involved. Given the fast cure time, we were able to quickly reuse our clamps and keep the assembly process moving along.

The release pin at the end of the throwing arm allows one end of the sling to release at exactly the right moment, so the tennis ball makes a smooth exit. The pin is a bent nail, glued in with G/5 and wrapped with fiberglass strands saturated with G/5.

Reflecting on this project, long since completed, I believe G/5 Adhesive is ideal for building Science Olympiad projects, especially those involving wood. The competitions involve not only building trebuchets but also wooden towers and bridges to name a few examples. Towers and bridge competitions are judged by how strong the structure is. In other words, how much weight can they support before everything comes crashing down? G/5 Adhesive is ideally suited for these sorts of projects because it cures quickly, needs no clamping pressure and creates strong glue joints even if the fits are less than perfect. These qualities allow a project team to build a strong structure in a little bit of time.

The trebuchet competition requires that a projectile (usually a tennis ball) be thrown via a sling at a cardboard castle. Event scoring is based on distance and accuracy. The counterweight and the projectile are provided at the competition site, and the trebuchet team is given time to adjust the placement of their machine for distance and accuracy. There are a number of rules and measurements that the trebuchet must be built to in order to qualify for use in the competitions. Be sure to locate an up-to-date copy of the rules, because rules at local competitions can vary. The web also offers a large number of excellent sites that feature a wide range of kits, designs, and construction details. Some designs are complicated while others are simple.

The most challenging part of the build, in my opinion, was the design and fabrication of the trigger that released the arm with a minimum of movement introduced into the structure. Another challenge was the fabrication of the release pin located on the end of the pivoting arm that allows one end of the sling to release so the ball makes a smooth exit *(Photo left)*.

How did Robbie fair at the competition? He took first place, scoring the longest throws and outdistancing his competition by 20'. He also struck the tower in two out of three attempts. Congratulations, Robbie! ■

Quick lawn mower repair

By Tom Pawlak

I hesitated to write this article because my friends accuse me of being a cheapskate. The text and photos to follow will only strengthen their argument. That being said, I can't be the only person who would prefer to fix something rather than buy new. Besides, I can't resist the opportunity to experiment with WEST SYSTEM® epoxy.

Two years ago when I went to cut my mother-in-law's lawn for the first time in the season, I discovered one of the wheels on her mower was leaning badly and rubbing on the deck. I attempted to bend the metal near the wheel to create clearance for it to spin freely. Unfortunately, the metal surrounding the wheel had corroded and was too weak to keep the wheel from flopping against the deck (*Photo 1*).

1 Break

I blame myself for the problem because I was not disciplined about removing wet grass clippings from the under deck at the end of mowing sessions. This likely caused the metal to corrode and weaken.

I hated to junk the mower just because the deck was bad. My options for repair were to weld or braze in some new metal, or use fiberglass cloth and epoxy to reinforce the area. The weld or braze option would require that I locate a shop willing to do the job since I did not possess the equipment or expertise to do it. What I really wanted was to use the mower later the same day so I would have to fix it myself and I needed the epoxy to cure quickly.

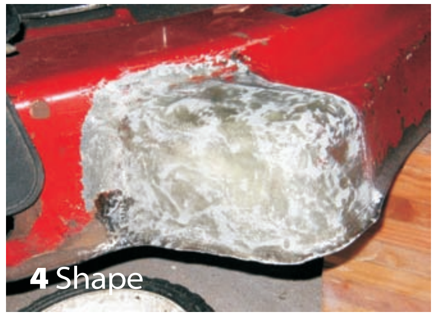
2 Clean

I could have used WEST SYSTEM 105 Resin with 205 Hardener with fiberglass and heated the repair so it would cure quickly, but that wouldn't be nearly as much fun as trying something new. In the end, I opted to experiment with blending our G/5 Five Minute Adhesive® with 105 Resin and 205 Hardener. I had experimented with this combination in the lab, and I knew it would cure very fast compared to 105/205 alone.

When blending G/5 Adhesive with 105/205, it is important to meter the G/5 resin/hardener mix at the correct ratio and the 105/205 epoxy at the correct ratio before blending them together. For this repair, I used a blend of equal parts of the G/5 (resin/hardener mix) and 105/205 mix. This reduced cure time by half compared to the 105/205 combination alone.

This blending was done in an effort to slow down the cure of the G/5 just enough to allow time to apply several layers of 4oz to 6oz fiberglass cloth. It also served to lower the viscosity of the G/5 Adhesive for wetting out the fiberglass cloth. The photos pretty much tell the repair story. I did the repair in the morning and by early afternoon I was cutting grass once again. I painted the repair the following day. The experimental repair has held up fine over the last two cutting seasons, and I expect it will continue to work well for years to come.

3 Glass



4 Shape

5 Paint

We've tested this epoxy blend to identify its strength and moisture resistance characteristics. It turns out compression strength and moisture resistance are better than those of G/5 alone, but not as good as 105/205 on its own. With that in mind, we want you to think of 105 Resin-based epoxy as a good way to extend working time for G/5 Adhesive rather than thinking of G/5 as an accelerator for 105 epoxies. Our Tech Staff has been experimenting with G/5 and 105-based epoxy blends for some time now on a variety of home projects, and we love the ability to change cure speed by mixing the two products together. *See page 23 for more details.*

We do not recommend adding G/5 to any of the four 105 Resin-based epoxies for applications that require a continuous long-term emersion in water. ■

Gluing plastic with G/flex®

By Tom Pawlak and Jeff Wright

G/flex news

G/flex has been out for a year now and enthusiasm continues to run high within our company and in the field because of the unique properties that G/flex offers. In this issue of *Epoxyworks* we are focusing on the ability of G/flex to bond to plastic and techniques that take advantage of this ability. No doubt articles on the benefits and many uses of G/flex will be a regular feature of future issues of *Epoxyworks*.

One of our goals for G/flex was an ability to bond to a variety of plastics. This was an ambitious goal because plastics historically have been used as mold release surfaces for epoxy, allowing it to release from the plastic when cured. While developing G/flex, we tested adhesion to a number of plastics with a variety of surface prep methods. We discovered that some plastics need only be abraded for good adhesion to take place. Other plastics required additional surface prep involving a flame treatment to form dependable bonds. We discovered that a few plastics, like polypropylene and acrylic and their molecular cousins, are difficult to glue reliably no matter how we prepared the surfaces.

Adhesion testing

Adhesion with G/flex to properly prepared plastics (other than polypropylene and acrylic) varies from about 1,700 to 3,300 psi, depending on the plastic and the surface prep used. We tested these bonds with the Pneumatic Tensile Test Instrument (PATTI).

Plastic	Surface Prep	Tensile Adhesion (psi)
ABS	Sand w/ 80-grit	1,854
	Sand w/ 80-grit + Flame treat	1,813
	Alcohol wipe + Flame treat	3,288
PVC	Sand w/ 80-grit	1,780
	Sand w/ 80-grit + Flame treat	1,813
	Alcohol wipe + Flame treat	2,081
Polyethylene	Sand w/ 80-grit	400
	Sand w/ 80-grit + Flame treat	1,890
	Alcohol wipe + Flame treat	2,312
Polycarbonate	Sand w/ 80-grit	1,870

Figure 1—Effectiveness of different surface preparation techniques on the adhesion of G/flex 655 Epoxy to various plastics

The chart above shows average adhesion achieved by G/flex 655 Epoxy to various plastics with different surface prep. In many cases the adhesion is not enough to exceed the strength of the plastic, but it is considerably better than bonds between plastic and other epoxy formulations. The chart also shows the advantage of flame treating (especially in the case of polyethylene) and the advantage of alcohol wiping over sanding before flame treating.

Joint design

It takes more than good adhesion to make a successful repair. We all know how well epoxy bonds to plywood, but it is common practice to use a scarf joint or butt block instead of a straight butt joint. Plastic joints should be treated much like plywood joints.

Our 002-550 *Fiberglass Boat Repair and Maintenance Manual* discusses the importance of grinding the proper bevel when repairing a hole or major crack in a fiberglass skin. The shallow bevel angle reduces the stress concentration between the repair and the original surface, and increases the amount of surface area for adhesion. Reducing the stress concentration often helps minimize the chance of a peel failure, which is a common way adhesives can fail on plastic surfaces. Testing has demonstrated that the same technique improves bonding strength in plastic panels and reduces the chance of a repair failing in peel.

Bevel and Round the Edges

To repair ⅛" to ¼" plastic, we recommend increasing the surface area along the joint by beveling and rounding the edges to be glued. This strategy is effective for repairing cracks

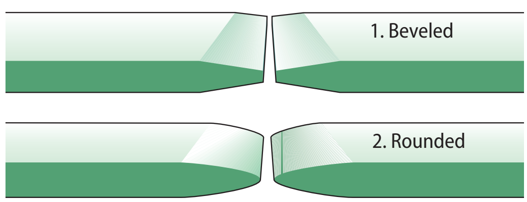
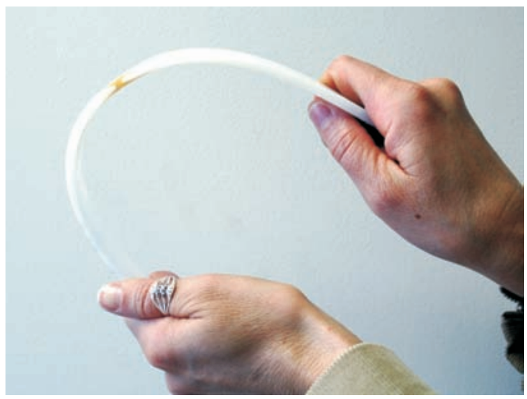


Figure 2—Above, beveling and rounding the edges of the joint increases the bonded surface area and reduces concentration of stress on the joint.

Figure 3—Below, this joint style in an edge-glued, ⅛" thick HDPE strip holds tight when deflected.



and splits in plastic canoes and kayaks. To test G/flex® for this type repair, we simulated splits in the bottom of a thermal formed plastic hull by edge gluing $\frac{1}{8}$" thick high-density polyethylene (HDPE) sheets.

By beveling and rounding the edges of the joint with a sharp object, sanding, and flame treating the surface with a propane torch, we effectively glued this plastic together. Figure 3 shows plastic being tested under deflection after repair. The Royalex™ canoe repair featured on page 20 of this issue used this same joint style.

Consider Stiffness

The thickness of a material has an exponential effect on stiffness. When repairing small plastic boats, the relatively thin hull helps reduce the stress in the repair because the entire bottom or side will often deflect a significant amount under a small load. Although the plastic hull shell has deflected significantly, the overall stress in the material is low.

A thicker, and stiffer panel can generate much higher stresses as it deflects and put more stress on the edges of the glue joint. Repairing stiffer (thicker) plastic parts requires more attention to the possible cleavage and peeling loads.

Use Fillets

Bonding surface area can be optimized with the use of fillets. Fillets are used to increase the surface area of the joint and reduce the stress concentration. The reduced stress concentration can help deal with off axis loads which can cause the joint to cleave apart. We recently performed a tensile test on polyethylene butt joints by pulling apart samples with and without fillets *(photos right)*. The samples that used fillets required almost 100% more force to pull apart.

Reaching our goal

Our formulating efforts were successful. We had an epoxy that would bond to plastics and we had a strategy for making plastic boat repairs.

As word of G/flex spread, we received lots of calls from canoe and kayak liveries. They had damaged boats made of molded plastic that needed to be repaired quickly because their season was about to begin. The damage ranged from normal wear and tear on the bottoms near the bow and stern, to cracks and splits that appeared randomly on the hulls.

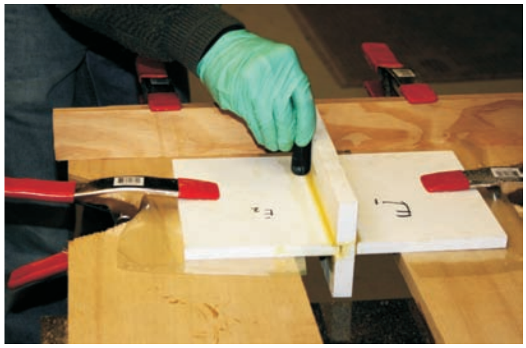


Figure 5—Making a fillet on the test sample billet of polyethylene. Fillets are used to increase the surface area of the joint.

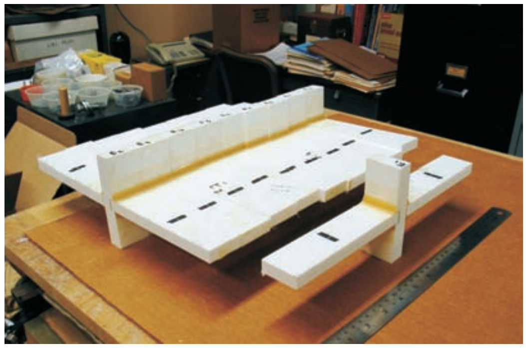


Figure 6—The billet cut into individual, consistently prepared test samples.

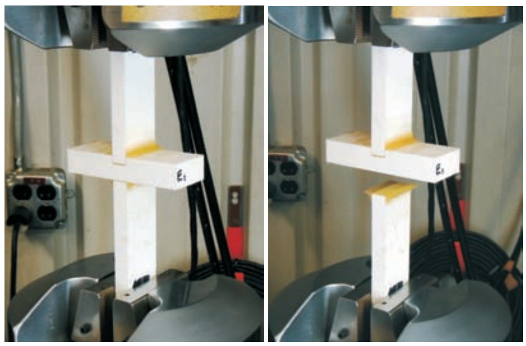
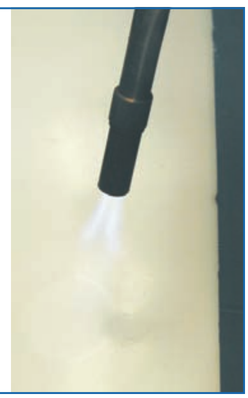


Figure 8—A test sample with a filleted butt joint in the test fixture, before and after failure.

The G/flex Epoxy kits we send them come with an instructional brochure that explains a variety of repair techniques including plastic canoe and kayak repairs and the technique for flame treating *(below)*. The following article demonstrates the effectiveness of those repair techniques on a severely cracked canoe made of ABS plastic. ■

To flame treat a plastic surface, hold a propane torch so the flame just touches the surface and move it across the surface at a rate of 12 or 16 inches per second. Keep the torch moving and overlap the previous pass slightly. When done correctly, the surface will not discolor or burn in any obvious way. This technique oxidizes the surface and improves adhesion. For best adhesion, bond to the surface within 30 minutes of treatment.



Repairing a Royalex™ Canoe with G/flex® Epoxy

By Bruce Newell and Stan Bradshaw

The wood gunwales of Royalex canoes can rip a hull apart if left out in bitter-cold temperatures. Somewhere south of freezing, the plastic body of the canoe shrinks while the dampish wood gunwales expand. Unless the screws affixing the inwale and outwale are backed out, they pin a shrinking-hull to an expanding-gunwale, and something will give. That something is always the hull.

So it wasn't a good sign in spring 2006 when our friend Paul called to ask Stan, "Do you know about repairing Royalex? Paul, lucky guy that he is, received a 16' Mad River Royalex Freedom with wooden gunwales as a wedding gift. Paul spends his winters in Montana's Blackfoot Valley which, to put it mildly, gets darn cold in the winter. Luckily, Paul had heard that he should back the screws out of the gunwales before winter hit. Unluckily, he didn't back them out far enough. His description was, "it's got quite a bunch of cracks." "Quite a bunch" turned out to be, at final count, 58 "cold cracks" Ginzu-ing the boat from sheer to beyond the chine.

After drilling and countersinking the end of each crack, we used a saber saw to widen each crack prior to beveling rounding the edges.

Stan, buffered from the reality of the thing by 80 miles of phone line and never having repaired a cold crack, said, "Sure, I can do that." If ignorance is bliss, the reality was a serious downer. The boat was a mess. In the words of a normally upbeat boatbuilding friend, "If it were mine, I'd cut it up and toss it in the dumpster."

Uniroyal's Royalex is a bonded sandwich of ABS plastic and foam. Many canoe manufactures employ Royalex to fashion a tough, attractive boat suitable for whitewater paddling. Royalex is relatively difficult to repair (everything about it resists adhesion), and our standard clunky epoxy-fiberglass tape repairs would have added six-plus ounces per crack, or somewhere in the neighborhood of twenty pounds, to the canoe.

The Freedom is a pricey, sweet moving-water canoe, and we thought it would be worth saving if there was a way to do so—besides, Bruce is retired and Stan is gullible. Our pal, Rob Monroe of Gougeon Brothers, was in Montana for his annual ski trip and thought he might have a new epoxy that could be just the ticket. The new epoxy (which turned out to be G/flex), was attractively labeled "experimental" when we used it, which made things much more exciting and reminiscent of the early days of rocket science—so, hooked on science and with Rob's help and encouragement, we got started on the job.

Prepping the wreck

We began by cradling the broken boat in slings—short sawhorse-height stands made for the purpose—and removed the breastplates, gunwales, seats, and thwarts. Without gunwales holding the hull together, the canoe flexed like a snake on muscle relaxants. After the canoe was stripped down to just the hull material, we drilled and countersunk the bottom of each crack so the cracks wouldn't get any longer, following the procedure used for cracks in metal. *(Editors note:*

Drilling holes at the end of cracks goes beyond what we recommend in our G/flex instructions for plastic boat repair, but it is acceptable and actually a good practice.)

We then used a saber saw to widen each crack. We followed this with either the corner of a 14" mill file or the corner of a chisel as a scraper to provide a widened beveled edge for each crack inside and out. (The file/chisel work was really fun, particularly when the corner of the tool would merrily skitter across the canoe, leaving decorative gouges, and we'd cheerfully cry out, "Don't tell Paul!") We cleaned up the resulting dumbbell-shaped groove with coarse sandpaper torn from an old belt and wiped everything down with denatured alcohol. The expanded crack made it easier to squeeze in a bead of G/flex 655 Adhesive and gave the glue a larger and keyed surface to which to adhere.

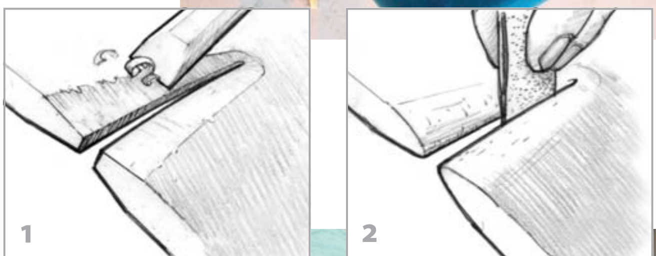
The glue job

On Rob's advice, we took care to leave the sheer untouched. We clamped each crack along the sheer to maintain the canoe's factory shape; we began each saw cut in the crack about an inch below the sheer. If we had cut from the sheer down, we would have removed a saw's width 29 times, shrinking the sheer by several inches. By puckering the sheer (inducing rocker), we would have made it difficult to return the canoe to its original shape. It's good to have smart friends—Bruce and Stan probably wouldn't have thought of this.

To keep glue off the garage floor, we used cheap clear packaging tape as a backing on the outside of the canoe, and loaded our syringe with nearly bubble-free G/flex using WEST SYSTEM® 804 Mixing Sticks. Clamps along the sheer held the now very floppy hull in its original shape.

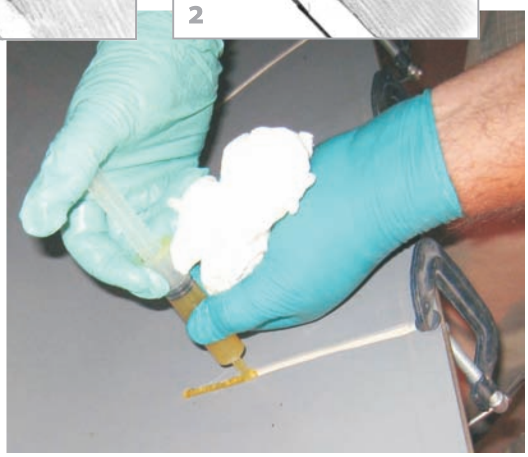
From the inside of the cradled canoe, we injected each crack with straight G/flex, taking special care to force the epoxy to the bottom and along the edges of each crack. We ran tape over the wet epoxy to control slumping, to try to create a smooth surface and to preserve a smooth garage floor. After a few trial cracks, it became clear that it was easier to get something close to a flush surface on the outside of the boat by pressing with a finger along the outside tape as the glue was applied to the inside.

Stan Bradshaw taping cracks on the outside of the canoe with clear tape, readying cracks for G/flex injection.

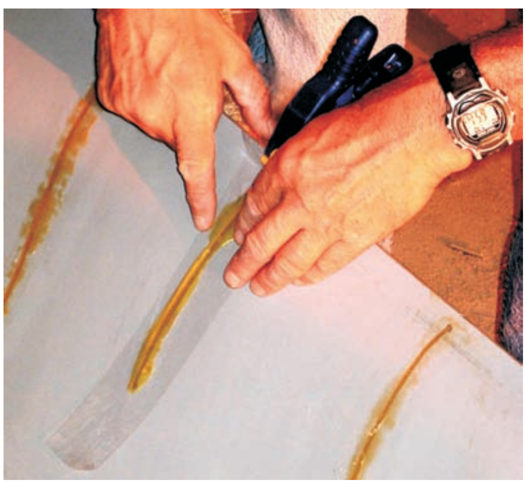


To prepare cracks for bonding:

1. **Open the crack and bevel the edges.**
2. **Round over the hard edges.**



Injecting G/flex into a widened crack. Note paper towel in hand to clean up after rampant sloppiness.



Stan running tape over freshly glued cracks to to prevent the glue from running and keep it relatively smooth when cured. Note use of simple spring clamp to keep top edge of the Royalex aligned.

After the G/flex cured, we ripped the tape off inside and out, and then we went back and filled voids where bubbles had snuck in. Epoxy isn't champagne, and bubbles just don't add much except possible areas of failure. Come to think of it, after a lot of champagne, the bubbles here too add possible areas of failure.

Finishing

Following these repairs, the hull was rigid again, and we went back to square one, opening up the previously uncut crack from the sheer to the screw holes (usually about an inch of cracked hull), and filled it with G/flex using the same technique as described above. We used spring clamps and C-clamps to keep the hull from deforming side-to-side as we glued up these short cracks. Afterwards, we used a small rotary file chucked-up in a Dremel™ tool to fair glue lines to about 2" below the sheer, providing us a smooth hull upon which to re-attach wood gunwales.

Stan and Glenda Bradshaw in the freshly repaired Mad River, Freedom 16' Royalex canoe—repaired with G/flex Epoxy. I took the picture last August on the Blackfoot River, near Ovando, Montana, a couple miles downstream of Roundup Bar.

Each repair showed bright yellow against the turquoise hull. We had lacked the wit to weigh the boat before our repair, but our best estimate is that our G/flex added perhaps a pound or two to the canoe. We coated the wood gunwales with mixture of equal parts varnish, boiled linseed oil, and mineral spirits, and added a drop or two of Japan drier to speed things along. New color-coordinated bow and stern loops completed this extreme canoe makeover.

The test drive

After reattaching the breastplates, thwarts, seats, and gunwales, we thought it was time to test our repair. It was August, low-water time on Montana's Blackfoot River. Our favorite whitewater stretch was running clear, low, and very boney—there were rocks everywhere. Given the number of cracks repaired, Bruce thought we had at least a 50/50 chance of the boat actually floating, so he thoughtfully let Stan and his wife Glenda take first crack at padding the repaired boat. Like tipsy ranchers at a Grange dance, they slid over and bounced off more than a few rocks while dancing down a six-mile Class II+/III- stretch of enjoyable waves and eddies. To our amazement and considerable relief, the repair held. There wasn't even a hint of failure. We had a great day on the water, and G/flex proved to be a great way to cheat the dumpster and put a busted-up canoe back on the water. ■

G/flex® wins Innovation Award

In October 2007, Gougeon Brothers Inc. accepted an Innovation Award at International BoatBuilders' Exhibition and Conference (IBEX) held in Miami Beach, Florida. The award, in the boatbuilding methods and materials category, was presented by the National Marine Manufacturers Association, following judging by members of Boating Writers International. This is one of the marine industry's most prestigious honors.

WEST SYSTEM® G/flex, a high-strength, toughened epoxy available in liquid and pre-thickened versions was introduced in the summer of 2007. It was entered in the NEW products competition prior to the October show.

"It's such an honor for our unique G/flex Epoxy products to be recognized with the Innovation Award," said WEST SYSTEM founder Meade Gougeon.

D-ring pads and G/flex® Epoxy

New possibilities for HDPE boats

By Tom Pawlak

D-ring pads are often attached to flexible surfaces with urethane adhesives to gain load carrying capacity where there otherwise wouldn't be any. They are used on waterproof fabric cargo bags, heavy tarpaulins and inflatable boats. They are also sometimes used on the decks of canoes and kayaks to hold cargo in place on long trips. D-rings are not typically used on polyethylene canoes and kayaks because the urethane glues are not recommended for use on HDPE (high density polyethylene) plastic.

We decided to experiment gluing D-ring pads with G/flex 655 to HDPE plastic with that end-use in mind.

Phase I

The first part of our test was to determine if G/flex would stick to the flexible D-ring pad. D-ring pads are made of a variety of tough fabrics covered with rubber-like membranes or coverings. In our tests, we glued to three different coverings, Hypalon™ [1], PVC and urethane. With each, we tested surfaces sanded with 120-grit, roughed up with an abrasive pad, flame treated with a propane torch and one section that was left as a control with no prep. We glued the unfilled cotton side of a strip of vinyl-faced upholstery fabric to the surfaces and allowed the G/flex to cure before pulling up on the vinyl fabric tabs *(Figure 1)*. If the glue stayed attached to the D-ring pad when the cotton/vinyl tab was pulled away, we considered the adhesion adequate. From this part of the test we learned that abrading by sanding or by rubbing surfaces with a Scotch-brite™ pad worked on each of the three pads tested. G/flex always stuck to the abraded pads, so we recommended abrading with either sandpaper or an abrasive pad.

Phase II

We prepared ½" thick HDPE plastic for gluing the D-ring pads to by cleaning them with a solvent, wiping with paper towels and then flame treating with a propane torch using the technique described on page 17. We chose the thick HDPE so we could clamp the specimens into the test device.

Figure 1—Phase I, gluing upholstery fabric to the D-ring pad to test G/flex adhesion.

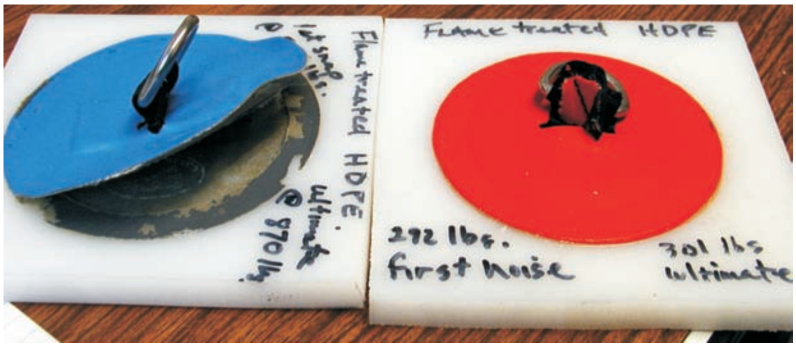


Figure 2—Results of Phase II tests. Failures occurred in the D-ring strap or in the pad itself.

We glued the pads in place with G/flex 655, the thickened version, so the glue would bridge gaps and stay put during the cure.

After allowing the epoxy to cure for a couple days, we placed the HDPE/D-ring mock ups in one of our test devices and applied load to the D-ring at 90 degrees to the glued surface until something broke. The photos describe the failure mode. In each case the failure occurred in either the strap that ran through the D-ring or in the flexible fabric pad that the G/flex was adhered to *(Figures 2 and 3)*. In other words, G/flex adhered to both the flame treated plastic and the flexible pads until the pad or the D-ring strap failed.

If you decide to use G/flex 655 to glue D-ring pads on your boat, be sure to test adhesion to the flexible membrane that typically covers the support pads. Try sanding or abrading the surface because it worked across the board on each of the three types we tested.

If you test adhesion to your D-ring pads and come to the same conclusions we have, you will feel comfortable installing D-rings pads to your HDPE canoe or kayak using G/flex Epoxy. ■

Figure 3—Another example of a pad failure in Phase II testing.

Our tests were done with D-ring pads from NRS (www.nrsweb.com), a well known outdoors sporting goods company.

[1] Hypalon is a trademark for chlorosulfonated polyethylene (CSPE) a synthetic rubber.

Upright bass repair

By Bruce Niederer

Just by luck, I was in the right place at the right time to purchase an old upright bass from the local school system for $50 because, sadly, the orchestra (stringed instruments) program was being discontinued. The bass needed strings and a new peg but was in decent shape—until I got my hands on it! As it was standing in the corner of my room patiently waiting for me to get to it, a gust of wind got there first, knocking it down and breaking the neck at the heel. My luck was in again because the break was very clean along a joint. The two parts could be easily fit back together in such a way that the fingerboard would be properly positioned. Photo **1**

I lightly sanded the flat mating surfaces with 80-grit paper to clean and scuff the wood, taking care not to sand so much that the fit would become loose. Photo **2** Then I brushed WEST SYSTEM® 105/206 onto both surfaces and fit the joint together. Enlisting some help from a friend, I used duct tape to hold the pieces together until the glue cured. Photo **3** The bass has now been given a new lease on life, and I'm ready to learn how to play. But there's no worries learning—in fact it's fretless! Photo **4** ■

Fasteners demonstrate G/flex® toughness

It all started when I got a tech call from somebody asking if WEST SYSTEM® 105/206 would accept a nail pounded in, after it was cured, with no pilot hole. I confidently said that it would not work well and in most cases cause a fracture in the epoxy. Just for fun, I went out in the shop and tried it because even though every tech advisor agreed it wouldn't work, nobody had ever actually done it. Well, we were right—the nail caused a "brittle" failure.

Then I saw a 1/8" thick piece of cured G/flex 650 epoxy sitting on my work bench that I had left over from another test. Once again, just for fun, I pounded a finish nail into the surface only to find out that it took the nail and didn't crack. Thinking it was a fluke, I did it again with no failure. At this point, I decided to do some tests with more controlled attention.

I cast a sample that varied in thickness up to ½" onto a piece of ¾" plywood. The sample took 8p nails at five different thicknesses along the sample without cracking. The sample also took #6 drywall screws at different thicknesses with no pilot hole. To rule out the chance of this property going away as it cures further, I put the samples in an oven at 120°F for the weekend. I took the samples out and let them cool back down to room temperature. When I tried again, all was the same as before–no epoxy failures.

Looking for the next step, I visited my uncle's furniture reupholstering shop. All of the samples took a 7/16" staple from an air gun, plus #4 and #6 tacks (think square cornered wedge) without cracking. G/flex is now used to fill frame members on furniture that has been reupholstered so many times that the wood is falling apart and won't hold a fastener.

Not only did these tests provide valuable data on the toughness, flexibility, and impact resistance of G/flex Epoxy, they gave us a great visual demonstration of what toughness is. —***Randy Zajac***

Mixing G/flex® epoxy with other WEST SYSTEM® epoxies

By Jeff Wright

WEST SYSTEM 105 Resin-based epoxy is a very versatile system. For years, experienced users have been blending the various products in countless ways. For example, users may blend 205 Fast Hardener and 206 Slow Hardener to make a hardener with a modified cure speed. Different uses of 410 Microlight™ Filler provide a further example. Many customers assume that the only use of 410 is to make a fairing compound—it is added to thicken epoxy to a peanut butter consistency to create a light, easily-sanded filler. However, 410 Microlight can be used in other ways. Jon Staudacher in *Epoxyworks* 22 described how he applied a "runny" mixture of epoxy and 410 to fill the weave on a composite part and reduce the amount of fairing required. *Epoxyworks* 25 described how 410 was added to make a flexible epoxy that would allow hardware to be removed easily and yet would seal out water; this was needed for installing a removable hatch. As these examples illustrate, experienced customers know that by understanding the fundamental characteristics of WEST SYSTEM fillers, hardeners, and additives, they can combine and use them in unique ways for their specific application.

G/flex further expands the versatility of WEST SYSTEM 105 Resin-based epoxies. G/flex can be used with 105 Resin and one of its four standard hardeners (205 Fast, 206 Slow, 207 Special Clear or 209 Extra Slow) to modify its cured properties. For example, you may want the tough and flexible properties of a G/flex laminate, but G/flex 650 will not easily wet out the heavier fabric being used. Adding a 105 Resin-based epoxy mixture to a G/flex epoxy mixture will greatly improve the G/flex epoxy's ability to wet out thicker fabrics.

When G/flex is mixed with 105 Resin-based epoxy, the properties will reflect the characteristics of both systems. As G/flex is added to a 105 Resin combination, the resulting cured epoxy will be more flexible and able to deflect more before cracking, but it will also have slightly lower strength. With G/flex, the decrease in strength is not nearly as much as when a low-density filler is used, but the change in flexibility does affect ultimate strength. The table describes how properties will be affected when G/flex is blended with a WEST SYSTEM 105 Resin-based epoxy.

We have tested several mixtures of G/flex and 105 Resin-based epoxy in a wide range of physical tests. The blended systems have properties that are proportional to the ratio of each product in the final mixture. Experienced WEST SYSTEM users can follow their intuition to decide what ratio of each system they would like to blend together, much as they do when adding fillers. **Remember however, you must follow the correct ratio for each system when mixing any of the WEST SYSTEM resins and hardeners.** (G/flex is 1:1, 105/205 or 206 is 5:1, 105/207 or 209 is 3:1). If the ratios are correct, it's not necessary to mix each system separately before mixing the two systems together.

The same principle applies to blending G/flex with G/5 Five-Minute Adhesive. In this case you will trade flexibility and strength for cure speed in proportion to the percent of each in the mixture.

Call or email our Technical Advisors with questions or to discuss your specific application. ■

Cured characteristics of blended G/flex 650 epoxy and 105 Resin-based epoxy

More G/flex epoxy	More 105 Resin-based epoxy
More Flexibility	Less Flexibility
Less Strength	More Strength
More Elongation	Less Elongation
More Toughness	Less Toughness
More Viscosity	Less Viscosity

Definitions of the terms used in the table

See "Understanding Flexible Properties" in *Epoxyworks* 25 for a more complete discussion. *Visit epoxyworks.com to read and download past Epoxyworks articles.*

Flexibility—The flexibility of a material is described by its Modulus of Elasticity. The larger the value, the stiffer the material. It is important to remember that the stiffness is not related to the strength of the material. Stiffness is the physical property that determines how much a component will deflect when loaded.

Strength—The amount of stress a material can sustain without failing.

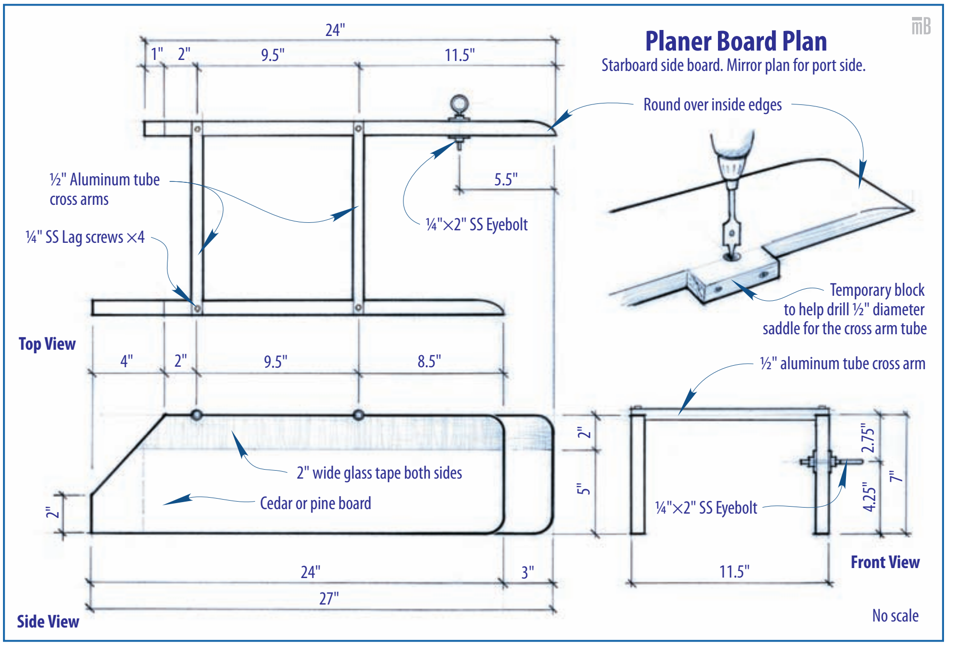
Elongation—How much a material stretches when loaded and is often written as a percentage of its original length. The ultimate elongation is the amount it has stretched when it fails.

Toughness—How well a material resists fracturing when it is stressed. A tough, strong material resists fracturing and is able to absorb energy. A very strong material may be brittle and unable to absorb energy while an extremely flexible material will not absorb energy because it will deform instead of carrying the applied load.

Viscosity—The resistance a liquid has to flow. This property does not affect the cured properties, but is important for application. A lower viscosity material will generally wet out a fabric easily, but will not fill a gap well in a bonding application.

How to build a set of planer boards

By J.R.Watson



Planer boards allow for more fishing lines to be trolled simultaneously and are used to spread lures and harnesses away from the boat when trolling at low speeds (below 2 knots). They are commonly used when fishing for walleye. You can achieve a greater dimensional spread with planer boards than with outriggers.

A good planer board should advance away from each side of the fishing boat with little effort, not present excessive drag or splashing, track well, resist capsizing in a seaway, be durable, and be painted so as to be very visible. The following is a successful design that is easy to build and requires no ballast. The planer boards are asymmetrical catamarans that are made in pairs; each is a mirror copy of the other.

Building the planer boards

Select a light wood of sufficient size. Common 1"×8" is sufficient (¾"×7½" nominal). Cedar or pine works well (plywood is too heavy). Cut the boards to size and shape the bows as shown. Drill a hole for the eyebolt in the location shown.

Tubes should be lightweight aluminum. I use discarded (kinked) ½" diameter ski poles (most are made of T6061 thin-wall alloy). Clamp a temporary wooden piece as shown and drill (using a spade cutter) to create tube saddle that matches the aluminum tube diameter.

Coat the planer board surface with a thin coat of WEST SYSTEM® 105/205 epoxy to seal the wood. Be sure to swab the inside of the drilled eyebolt hole to protect exposed end grain. A second coat may be required on the ends where the end grain soaks up the epoxy. Apply a strip of 2" fiberglass tape as shown in the area of the tube attachment. The fiberglass tape will help prevent board warping and splitting from side forces. Blend tape with a fairing mixture thickened with 410 Microlight™. Allow everything to cure. Then sand all raised grain smooth and blend everything fair. Ream the eyebolt hole as necessary for the eyebolt to pass though without force.

Cut tubes to length. Fill ¾" of the tube ends with fairing mixture and allow it to cure.

Align the two components of the planer board as illustrated, being sure to maintain a vertical and parallel alignment. Place tubes in saddles and drill through tubes and into planer boards as shown. The hole should be larger than the diameter of the lag screws so the lag screw can be pushed through the aluminum tube and into wood without having to turn the screw. Remove screws and tubes. Apply WEST SYSTEM 105/205 epoxy (neat) to saddle surface and hole interior. Then thicken epoxy with 406 Colloidal Silica to mayonnaise-like consistency and swab a sufficient amount into hole, screws, and saddle surfaces. Place tubes into their location and press all lag screws through the tubes and into the boards. Clean away excess epoxy and then allow everything to cure in the proper position overnight. The structure will be strong and rigid.

Sand all surfaces smooth with 80-grit sandpaper. File the aluminum tube ends so they are smooth and flush with the planer board edge. Paint all surfaces with several coats of sprayable sanding primer, touching up flaws for the desired finish. Follow with sign painter's 'One Shot' (it covers very well, has vivid colors, and dries fast). Install the eyebolt. The eyebolt length allows some adjustment that will affect tracking; start with a middle setting.

Last step: go fishing. ■

Material list

1–1"× 8"× 8' Cedar or pine	WEST SYSTEM 105-A Resin
4–½"×11" Aluminum tubes	WEST SYSTEM 205-A Hardener
8–¼"×2" SS Lag screws	300 Mini Pumps
2–¼"× 2" SS Eyebolts	406 Colloidal Silica
4–¼" Nuts	410 Microlight
4–¼" Large washers	Primer
60"–729 2" Glass Tape	Paint

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.

Free literature (US and Canada only)

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, stocking dealer directory, and the *Fiberglass Boat Repair* brochure.

Publications for sale at WEST SYSTEM dealers

Also available from the WEST SYSTEM Info Store at www.westsystem.info, or by calling our order department, 989-684-6881.

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.

002-550 ***Fiberglass Boat Repair & Maintenance***—Illustrated guide to repair fiberglass boats with WEST SYSTEM epoxy. Procedures for structural reinforcement, deck and hull repair, hardware installation, keel repair and teak deck installation.

002-650 ***Gelcoat Blisters-Diagnosis, Repair & Prevention***—A guide for repairing and preventing gelcoat blisters in fiberglass boats with WEST SYSTEM epoxy.

002-150 ***Vacuum Bagging Techniques***—Step-by-step guide to vacuum bag laminating, a technique for clamping wood, core materials and synthetic composites bonded with WEST SYSTEM epoxy.

002-740 ***Final Fairing & Finishing***—Techniques for fairing wood, fiberglass and metal surfaces. Includes fairing tools, materials and a general guide to finish coatings.

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

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Large scale event sculpture

Keith Tucker creates sculptures on a large scale. Most of his pieces are created for corporate events and the theater. Tucker glues together large blocks of 2 lb weight polystyrene. Tucker says it's quite dense and retains detail well.

"I first do a number of drawings from all angles for the piece that will be sculpted. I always work through subtractive sculpting—starting with blocks and removing the material," says Tucker. "It's far less forgiving and if you make a mistake you're usually stuck with it, or you have to alter the piece accordingly. But, I enjoy the challenge of that approach versus building up material. And, due to the cost and time constraints, it works great."

Tucker uses WEST SYSTEM® 105 Resin with 206 Hardener, adding 406 Silica for the foam coating. He applies several coats, and after the epoxy has cured, he sands down the pieces and applies a paint finish.

Tucker says he is now starting to incorporate fiberglass into his pieces as well. See more of Keith Tucker's work at www.keithtuckerart.com. ■

Above left—A 5' tall replica of the Lincoln Memorial sculpted for Opryland Hotel.

Left—14' Madonna and Child sculpted for the opening of a musical at the Tennessee Performing Arts Center.

Above—One of two Ramses sculptures (in progress and finished) designed and created for the Nashville Cares Event "Artrageous."

An elephant in progress—from glued together blocks...

to rough shape...

to detailed shape...

to a finished, painted elephant.

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