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In this issue

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Birth of the Gougmarans

By Meade Gougeon

In 2003, my brother Jan and I began talking about building a motorboat. This would be a first for the brothers, who up to this point have focused all our efforts on sailboats. Just a few years ago, it would have been inconceivable that we would ever take up power boating. But time and circumstances change one's views, especially as we enter our senior years. We have always regretted that major parts of our home waters, the Saginaw Bay of Lake Huron, Michigan, have been too shallow for our sailboats. Some of the most attractive parts of the Bay with the best wildlife have been off limits to boats that draw more than 18 inches.

Then we both acquired winter residences on St. Joseph's Sound, which extends from Clearwater Beach north 12 miles to Tarpon Springs on the west side of Florida. This shallow body of water features a series of protective barrier islands that are uninhabited with sandy beaches and abundant wildlife, some out as far as five miles. The islands are popular destination points, but we needed the proper craft that could transport a crowd of people over these shallow waters and land them safely on the beaches.

We were also attracted to potential cruising. Much of the west coast of Florida is off limits to larger powerboats with normal draft, as they must stay within the dredged inland waterway that runs from Tarpon Springs down to Marco Island, where the Everglades begin. Most sailing is done out into the Gulf. If one wants to really explore the west coast of Florida including the Everglades, the shallowest possible draft would be necessary.

With our minds focused on both our summer and winter waters, we began to establish a set of design criteria for our new craft. These can be summarized as follows:

- Achieve lowest possible draft.
- Use the best high-tech sailboat technology to build the lightest weight structure possible.
- Build for maximum seaworthiness to withstand higher winds and waves encountered in coastal waters.
- Build the largest boat possible that can be practically trailered behind a Honda Odyssey™ van, with all up boat and trailer weighing no more than 3,000 lb.
- Achieve high efficiency with maximum mileage per gallon of petrol. Speed would be secondary to efficiency, with lowest noise and vibration from the engine. Incorporate fuel tanks to support a reasonable cruising range.
- Carry a load of up to 2,000 lb at reasonable efficiency.
- Develop a "landing craft" type of front end that can be lowered for easy passenger offload.
- With the addition of auxiliary live bait well and rod holders, provide a first-rate fishing platform.
- Have a stand-up enclosed head.

Cover story

Meade's *Gougmaran* was launched July 8, 2004. Jan's version, *Magic Carpet,* followed a few weeks later.

Left—The Gougmarans under construction. Meade's *Gougmaran* is in the foreground; Jan's *Magic Carpet* is above.

Right—*Magic Carpet* before the bows are covered. The hulls are connected with an 8' 6" wide composite deck built of 1½" honeycomb core sandwiched between 3-ply okoume plywood. The flat deck curves up at the bow to form an anti-dive/wave deflector.

The Hulls

Based on our earlier success with the Gougeon 32 sailing catamaran, we quickly decided on a two-hulled catamaran configuration of about 32' length with a trailering-capable width. The project got a time-saving boost when we discovered that some ideal hulls that could fit our needs already existed. Famed multihull designer Dick Newick had designed some 32' hulls for Still Water Marine that were incorporated into a powered catamaran configuration to function as chase boats for rowing shells. The design goal had been for a craft that could follow an 8-man rowing shell at speeds up to 15 mph with minimum wake. We knew that low wake equates to high efficiency, so we called Dick, a long-time friend with whom we have collaborated on many projects. Dick sent us designs details, which showed hulls with a high prismatic coefficient together with low wetted surface, further suggesting high efficiency. Of equal importance was the fact that each hull was capable of supporting 2,000 lb at a little over 11" of draft. This was perfect for our needs of a fully loaded craft at 3,500 to 4,000 lb with less draft than we initially believed would be possible.

We quickly struck a deal with Dick Perelli, president of Still Water Design, to build us four hulls in his existing molds to our specifications using our Pro-Set® Resins[1] and the vacuum bagged laminate schedule that we had developed for our G-32 sailboats some years before. We took delivery of these hulls in February 2004 and were delighted when they weighed in at slightly less than 200 lb each. We were off to a good start and only needed to get the rest of the construction right to reach our goals.

***Gougmaran's* bow showing the wave deflectors and the walk-on ramp in the down position.**

Assembly

We began by building a large, mostly flat, deck mold that had a pronounced curve forward. This would be the front of our anti-dive/wave deflector for safe handling in a rough seaway, especially downwind. The mold was constructed of simple plywood over frames and stringers made airtight so that a vacuum bag could be utilized for compaction. The deck laminate measured about 22'×8'6" and was to be made in one piece in a gentle curve that fit the gracefully curved sheer line of the hulls. The laminate itself was composed of two pre-scarfed panels of 3-ply okoume plywood. The upper panel was 5 mm and the lower panel was 4 mm with a 1½" honeycomb core separating the two completed panels. This laminate was the largest and heaviest part of the structure.

With appropriate framework and beams incorporated within, it was estimated to weigh close to 350 lb when completed.

Meanwhile, the hulls were prepared for final assembly into a catamaran configuration. Fore and aft main bulkheads and robust sheer clamps with maximum gluing area were installed. The hulls were then set in their proper location for joining, and a trial dry fit with the deck took place. When a proper fit was assured, we did a massive one-shot gluing operation with our slowest setting Pro-Set® Adhesive[1].

When the cure was completed, after several days, the joined hulls proved to be incredibly rigid with the deck laminate serving as a giant torque box. At this point, we estimated our beginning catamaran structure at around 800 lb; we were right on our target for an all up weight of 1,500 lb for the finished craft. We then joined a second set of hulls and deck for brother Jan's boat. These benefitted from the learning curve, being a little lighter. Other than that, they were an exact duplicate of the first.

Alternate Approaches

From this basic platform, Jan and I had different ideas as to what to build to suit our individual tastes and needs. I wanted a protected steering station that could keep one out of the sun and weather with a permanent top to which we could lash canoes or windsurfers. I also envisioned a framework which could support an awning and a large tent for cruising. This all came at the expense of weight and windage. Thus, Jan favored a smaller steering station with a windshield and traditional fold-down bimini. Jan also wanted permanent side panels for looks and to keep the beer cans from blowing away. Because of the extra weight of my steering station and upper structure, I opted to use a weight-saving traditional sailboat lifeline system around the boat perimeter; this has worked surprisingly well.

The Engine

Weight placement, we learned long ago on our sailboats, is all important to maximize the efficiency of displacement hulls. We began by placing the engines forward of the transoms by 4'6". The steering station, fuel tank, battery, and storage were also placed well forward, and the anticipated weight was carefully balanced over Newick's designed waterline. We chose an 18 gallon tank to give us reasonable cruising range. Fully fueled, it weighed just under 200 lb.

With their shallow draft and efficient displacement hulls, the Gougmarans leave very little wake, even at top speed.

The hull allowed for a step-down, stand-up, enclosed head, a useful feature given the boat's cruising range and capacity for passengers.

The chosen engine was a three cylinder 30 hp Yamaha™ 4 stroke. This high torque, low rpm engine turns a large 12" diameter prop with a 9" pitch. It has proved to be a good marriage with Newick's displacement hull design. Both engine and hull seem perfectly tuned at 12 to 15 mph, dependent on wind and wave direction. At this speed, the engines are unusually quiet and smooth and the hulls seem to be in their maximum efficiency zone. Dependent on wind, waves, and load, the miles per gallon at this pace seem to range between 8-12. Maximum performance has been recorded in calm waters at 19 mph, but gas mileage drops precipitously.

Prop depth of the engine is adjustable with the use of a hydraulic jack plate that can raise the engine straight up 8" so that the 12" prop just breaks the surface. If run at idle speed, the prop in this position will power the Gougmaran forward at 4 to 5 mph without cavitating. Thus, the crowning achievement for the Gougmaran is that it can function with good efficiency in waters as shallow as 12"–14".

[1]Pro-Set is a registered trademark of Gougeon Brothers, Inc. Pro-Set brand epoxies are designed for the fabrication of lightweight composite structures. Pro-Set Adhesive is a non-sagging, two-part epoxy designed for secondary bonding of composite parts.

GOUGMARAN'S First Cruise

Photos: Hugh Horton

Meade's *Gougmaran* fully rigged, with the tents up and the canoes stowed on top.

The Gougmarans were launched in 2005 and performed their intended functions well for the first two seasons; several modifications and tweaks were made to both boats. Both have been fitted with centerboards located well forward to improve handling in tight areas. Meade also installed a flip-up rudder in hopes of utilizing a "kite sail" in the future.

The real test of the Gougmaran concept came this spring with a trip down the west coast of Florida from Tarpon Springs to the Florida Everglades. This two-hundred mile plus venture south had been in the planning stages for the past year with myself, brother Jan, and sailing canoe guru, Hugh Horton. The basic plan was to take the inland waterway down through the Marco River to the 10,000 Island regions of the Everglades. We would then cruise the Everglades with both Meade's *Gougmaran* and the sailing canoes. Finally, we would return home going outside, along the Gulf of Mexico shoreline.

This trip would challenge the flexibility concept of turning a day boat into a live-aboard cruiser that could also take along 3 fully rigged sailing canoes together with enough supplies, gear, and fuel for an extended trip. Altogether, this collection added about 1,300 lb to the normal day boat weight. With crew, this pushed our 2,000 lb maximum payload capability.

The trip began on March 25, 2007, with a launching at Marino's Marina at our home port of Ozona, Florida, on St. Joseph's Sound. The first day's run on the inland passage to Sarasota was uneventful with smooth waters and moderate beam winds. After a pleasant overnight stay at the Sarasota Sailing Squadron, courtesy of our friend and noted local sailor, Charlie Ball, we motored south to our first gas stop. We were delighted when we topped off the tank with just 7 gallons. Up to that point, we had motored about 6 hours and come about 70 miles—ten miles per gallon at a little over a gallon an hour burn. We were overjoyed, but this good news was not going to last. By early afternoon, a building southeast wind began gusting up into the high 20s right on our nose. We reduced our speed, but our tent was acting like a big sail. It seemed to be taking a terrible beating, but it was holding up. We had discussed this potential problem with Rob Kolb, our tent builder, and he said not to worry because most of the covers and side curtains he makes are for boats that go way faster than ours. Over the next three days as the wind continued to blow hard right on the nose, we gained confidence in our tent structure and finished the trip with our tent intact after an unusually windy 8-day voyage.

Head winds also impacted our gas mileage. The burn rate increased to 1.5 gallons per hour with speeds down to 10–11 at 2,000 rpm. This equated to a drop to 7 miles per gallon, which was understandable but disappointing.

Left—Meade's *Gougmaran* is prepared for her first trip to Florida. The fold-down roof is in the lowered position for travel.

Right—After launching at Marino's Marina in our home port of Ozona, Florida, on St. Joseph's Sound.

Left—The three sailing canoes are stowed on racks mounted to the roof.

Right—One of the sailing canoes beached near the *Gougmaran*. The *Gougmaran's* fold-down ramp allows for easy access to the beach and launch of the canoes.

However, our return trip outside in the Gulf balanced this out. With a following wind and waves, we were able to make a return passage of 145 miles in slightly less than 10 hours with a burn of 14 gallons. This put us back in the 10 mpg category, which could have been better had we slowed down to wave speed. At 15 mph, we were continually powering up the backside of waves that were going much slower.

Over the entire trip, we traveled about 490 miles, using 61 gallons of gas in 47 hours of motoring. Thus, we averaged a little over 8 mpg in less than ideal conditions with strong winds over most of the 8-day trip. In more ideal conditions, we think an average closer to 10 mpg is possible. We also want to experiment with different pitch props for any refinements in applying power that could help.

Overall, this trip proved that the biggest success of the *Gougmaran* was simply its shallow water prowess. At one point, we went hard aground on a gravel bar that was not visible because of muddy water. We all stepped off into the water not much over our ankles and were able to shove the *Gougmaran* off the bar and into deeper water with relative ease. We were drawing about 10" of water in the loaded condition. With the jack stand up to max, the 12" prop just broke the surface, allowing us to go just about anywhere we wanted to with reasonable confidence. We did carry an extra prop and 2 hp Nissan™ outboard as a backup.

As we got down into the heart of the Everglade National Park and explored the interior passages, we came out into the Gulf to Turtle Key where we found a protected anchorage with a nice beach to serve as an ideal site to launch the canoes and hang out for a few days. At night, we would strategically anchor the *Gougmaran* upwind of the island to avoid mosquitoes and no-see-ums. We successfully avoided these pests with our floating movable campsite approach for the entire trip. This is no small victory since this scourge is the only downside to an otherwise unspoiled wilderness where one can wander for days in total peace.

Left—The main tent where Hugh and Meade slept and all of the cooking and food handling took place.

Right—Jan setting up his portable tent/cot on the front deck

The tent approach worked very well with Hugh and Meade sleeping in the main tent and Jan in his portable tent/cot that was lashed to the front deck and then easily dismantled and stored each morning. All cooking and food handling took place in the tent area.

Overall Jan and I are pleased with the performance and versatility of the *Gougmaran* on this first cruise. The learning curve was steep, and some changes in the *Gougmaran* will be made before the next voyage. But they are all minor. The basic architecture of the boat for its intended purpose seems at this point to be right on. Keeping the concept flexible for a multitude of uses with pieces and parts that can be added or deleted is still paramount. The next goal is to outfit the *Gougmaran* so that it can become a first-rate fishing platform that can support 4 to 6 anglers in a variety of fishing venues. This will also be a new challenge as neither of us has had much time to fish these past 40 years, but we are eager to engage in this new activity that we can enjoy well into our senior years with friends and family.

There has been a lot of interest in the Gougmaran concept with some outright offers to buy our boats. Jan and I are both too old to get back in the boat business, but we are happy to keep experimenting with the concept and sharing our knowledge with others who are interested. At this point, the Newick hulls can be special ordered from Dick Pereli of Still Water Design for those who would like to build their own boat. As this concept matures, we suspect that some semi-custom builders will respond to whatever demand develops.

For more information about the Newick hulls, contact Dick Pereli at Still Water Design, 781-608-3079, or visit stillwaterdesign.com. ■

Tech Staff questions and answers

Depth sounder installation

Q Jim Costello of Dallas, Texas, recently asked the Tech Staff about mounting a transducer to the hull of his 1983 Bayliner Capri Classic. "The user manual for my new Hummingbird fish finder says that the transducer can be installed in the hull with a slow curing epoxy. It says to try to eliminate all bubbles. I have 105, 206, 404, and 406 on hand. What if I just mix up some peanut butter thick paste and use that? Or do you have any other suggestions? I can mount the transducer on a part of the hull that is thin enough for the application, according to Hummingbird. Thanks."

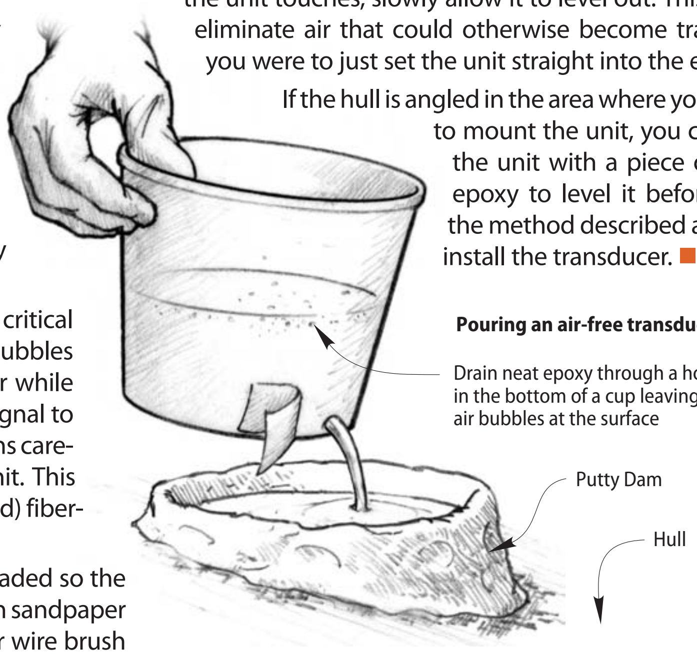
A Depth sounder manufacturers generally recommend using low viscosity, slow curing epoxy when their transducers are installed in fiberglass hulls. This is because air bubbles interfere with a transducer's signal and low-viscosity epoxies are less likely to trap air bubbles between the transducer body and the hull than higher viscosity types or those thickened with powders.

Placing the transducer in the ideal location is critical for the transducer to operate properly. Air bubbles that can form between the hull and the water while the boat is moving will weaken or cause the signal to be lost. So follow the manufacturer's instructions carefully to identify the proper location for the unit. This method should only be used on solid (not cored) fiberglass. Cored hulls will interfere with the signal.

The area you select needs to be clean and abraded so the epoxy will stick well. Abrading can be done with sandpaper or a fresh wire brush. Norton® makes a circular wire brush called a Rapid Strip Brush™ that mounts in a drill motor and will work nicely for this.

Installation instructions recommend creating a circular putty dam that is slightly larger in diameter than the transducer itself. Into this area pour enough slow curing epoxy (WEST SYSTEM® 105 Resin and 206 or 209 Hardeners) to bridge gaps between the transducer and the hull. To install the transducer, tilt the unit on a 30° to 40° angle above the epoxy and slowly lower it into the epoxy. As the corner of the unit touches, slowly allow it to level out. This should eliminate air that could otherwise become trapped if you were to just set the unit straight into the epoxy.

If the hull is angled in the area where you intend to mount the unit, you can shim the unit with a piece of cured epoxy to level it before using the method described above to install the transducer. ■



Pouring an air-free transducer base

NEW 320 Small Batch Epoxy Scale

Mixing very small batches of epoxy just got easier

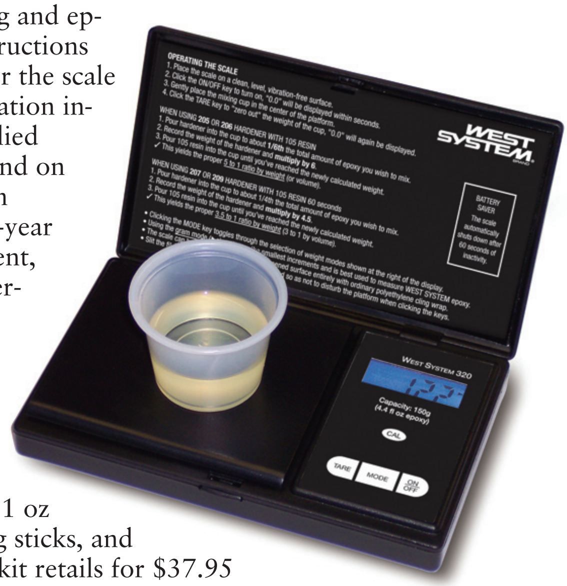
Product news

WEST SYSTEM® recently introduced a new scale configured especially for measuring epoxy in very small amounts. The new 320 Small Batch Epoxy Scale accurately measures the correct ratio of resin and hardener for batches smaller than one 300 Mini Pump stroke. It allows for the accurate dispensing of epoxy resin and hardener in a range from 4.4 fl oz down to just a few drops of mixed product.

The scale was designed for those projects requiring small batches of epoxy. Model builders, patternmakers, lure makers, artists, and hobbyists will find it particularly helpful. The scale can also be used to confirm the accuracy of your 300 Mini Pumps and to add pigments or other additives consistently.

The scale's dimensions of 5"×3"×¾" make it highly portable. It is sturdily built, yet sensitive enough to measure as little as .1 gram (a standard paperclip weighs .4 gram). It is battery operated and features a LCD readout display.

Complete operating and epoxy measuring instructions are imprinted under the scale lid. Simple recalibration instructions are supplied within the carton and on the westsystem.com website. A full two-year repair or replacement, limited warranty certificate is also provided.



The scale is presented as part of a kit consisting of dispensing bottles, 3¼ oz and 1 oz plastic cups, mixing sticks, and pipe cleaners. The kit retails for $37.95 and can be purchased at your local WEST SYSTEM dealer. For information on locating a WEST SYSTEM dealer, call 866-937-8797 or visit www.westsystem.com. ■

309 and 309-3 Gear Pumps upgraded

The popular WEST SYSTEM Gear Pumps get a face lift

309 Gear Pump

Gone are the plywood base and the welded, painted steel reservoirs. The newly designed pumps now have stainless steel reservoirs and lids, a more durable plastic composite base, and a metal handle. The pump housing will remain painted—green for the 3:1 version and beige for the 5:1 version—so the color of the housing easily identifies what ratio the pump is.

The cost of the pumps will remain the same. Pumps sent in to be rebuilt will also get the upgraded parts at the same cost. The stainless steel reservoirs are seamless. This will reduce or eliminate the color change that generally occurs on the hardener side due to the influence of iron in the soldered seam in the old reservoirs. Additionally, the stainless steel reservoirs do not need to be welded in place, thus eliminating occasional leaks at the welds. The new plastic composite base is much more durable than the plywood base. The handle makes it easy to move the pump from place to place in the shop. The plumbing and gear drive system will remain unchanged.

These pumps are designed for large projects and manufacturing operations. With a continuous rotation of the crank, the metered resin and hardener can be delivered at up to five quarts per minute. Reservoirs hold two gallons of resin and one gallon of hardener. For information, call 866-937-8797 or visit www.westsystem.com ■

Moisture Exclusion Effectiveness

Accelerated testing in our environmental huts

By Bruce Niederer

I get mad at my computer fairly often these days when it takes more than a few seconds to open a file from an obscure site on the other side of the planet. Who has that kind of time to waste!? Don't even ask about photo files!! There's no point in arguing about it—we live in an accelerated world. We hate waiting for anything. Putting the social implications of this aside, a business that is involved in technical applications and products cannot afford to wait for real time field test results. We need data and we need it yesterday!

As promised in the last *Epoxyworks*, my focus for this second article on accelerated testing will be how we test the ability of a coating applied in a relatively thin film to resist water transmission. This test is called Moisture Exclusion Effectiveness (MEE). It is based on a method developed by the USDA Forest Products Laboratory. Since we use two of our three environmental huts for this test, I'll describe the huts first.

Our Environmental Huts

One hut is called the hot/dry hut or, more affectionately, the Arizona room (*Photo 2*). Although the temperature may be changed occasionally, the Arizona room is kept at 100°F with relative humidity (RH) close to 0%, so it's perfect for drying wood samples. The next hut is called the hot/wet hut or the Florida room (*Photo 3*). It is kept at 100°F and 100% RH. The heat is supplied by heating a 55 gallon drum of water. The remaining hut is called the cool/humid hut or the Seattle room. The temperature and RH are variable but generally kept between 50°F–65°F and 70–80% RH. Test samples of nearly any material can be tested in each of these huts on an accelerated time schedule.

The Moisture Exclusion Effectiveness Test

The MEE test begins with Douglas fir plywood blanks 3"×5"×⅝" with the corners and edges sanded round (*Photo 1*). A small cup hook is installed in each end. The sample blanks are then conditioned in the Arizona room for about 2 weeks or until the moisture content of the blanks levels out close to 0%. This is easily done by tracking the weight lost over time in the room. Then the blanks are removed from the hut, allowed to assume room temperature, and weighed very accurately to 4 decimal places. This is recorded as the dry weight.

Next, the blanks are coated with whatever product is being tested—we always test our products, as well as competitors' products,

Photo 1—Above, Typical MEE test blank. MEE blanks are dried out in the Arizona room and, after coating, saturated in the Florida room.

Photo 2—Left, The Arizona room. The readout says it all, on this day105°F.

Photo 3—Right, The Florida room, normally kept at 100°F and 100% humidity.

whether they're epoxy or another product (paints, polyesters, vinyl esters, etc.). Generally, we make 5 samples each with 1, 2, and 3 coats for a total of 15 pieces for each test material. Five samples generate an acceptable average, and the increasingly thicker coating allows for a curve to be generated for each test material. The resulting data (*Figure 1*) yield a more accurate characterization of how effective any given material is at resisting moisture transmission.

After the coatings are properly cured, the weight is again recorded. Then, the samples are hung in a rack and placed in the Florida room (*Photo2*). The weight gain is measured each week for approximately 6 weeks or until the curves shown in Figure 1 begin to flatten out. As with any good test procedure, control samples left uncoated are run alongside the test samples.

(If you would like a more detailed description of this test procedure, contact us and ask for 002-745 *Moisture Exclusion Effectiveness*.)

This is an accelerated test because the Florida room conditions create water vapor, and water vapor is much more energetic than liquid water. This energized water vapor will penetrate a semipermeable membrane much faster than liquid water will.

Because all coatings are semipermeable membranes, we can generate curves that compare the relative permeability of various coatings. As shown in Figure 2, WEST SYSTEM® 105/205 performs quite well relative to the other materials tested (the product names were omitted to protect the innocent!).

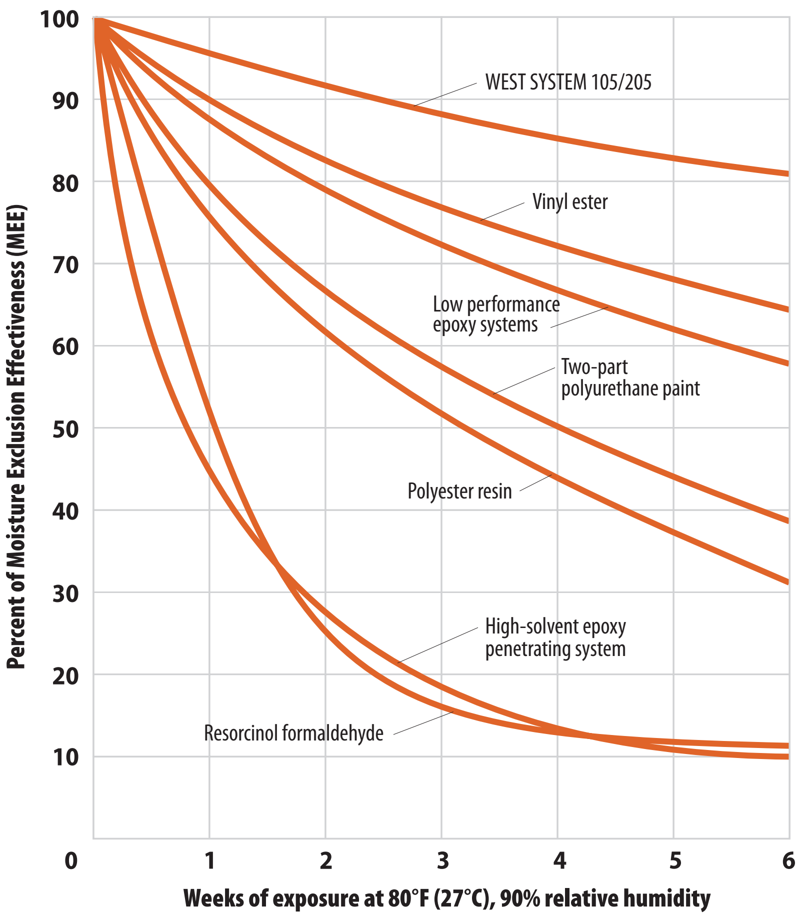
If you are interested in further reading, see the Forest Product Laboratory Research Paper FPL-482 "The Moisture Excluding Effectiveness of Finishes on Wood Surfaces," published in 1985 and available from the National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161. This details a study which investigated multiple variables for a broad range of wood finishes. Of note is the observation that two-component sheathing epoxy adhesive was second only to complete encapsulation in paraffin wax as a moisture excluding barrier.

Jeff Wright describes another accelerated test method for creep in this issue. In the next issue, I'll describe the accelerated test we do to measure the effects of UV radiation on various coatings. ■

Specimen	% Weight Gain above initial weight after coating				
105/205	**@ 1 day**	**@ 1 week**	**@ 2 weeks**	**@ 3 weeks**	**@ 8 weeks**
LC (uncoated)	8.59	14.41	19.44	19.96	23.41
L1 (1 coat)	4.82	12.58	17.62	18.98	22.68
L2 (2 coats)	0.77	3.68	7.02	9.52	18.11
L3 (3 coats)	0.32	1.34	2.57	3.61	8.02
HC (uncoated)	7.30	14.69	19.38	19.88	21.66
H1 (1 coat)	3.73	12.31	17.37	18.95	21.95
H2 (2 coats)	0.41	2.04	4.00	5.56	11.59
H3 (3 coats)	0.28	0.96	1.9	2.60	5.85
105/205/422					
LC (uncoated)	7.92	14.78	19.15	19.33	20.22
L1 (1 coat)	1.77	9.39	15.34	17.43	20.79
L2 (2 coats)	0.27	1.20	2.29	3.39	7.55
L3 (3 coats)	0.25	0.92	1.56	2.36	5.17
HC (uncoated)	7.15	13.61	18.65	24.85	26.47
H1 (1 coat)	1.24	8.14	15.28	21.05	28.97
H2 (2 coats)	0.29	1.43	2.77	4.81	11.98

Figure 1—Typical results of MEE tests of WEST SYSTEM 105/205 and 105/205 with 422 Barrier Coat Additive on high-density and low-density wood test blanks.

Figure 2—The result of numerous tests are compiled into a chart that compares the Moisture Excluding Effectiveness (MEE) of various marine coatings.



Installing a removable hatch

By Tom Pawlak

Meade Gougeon installed the original hatches on his *Gougmaran,* but he wasn't convinced he had selected the ideal locations. Prior to installation he thought about how difficult it would be to remove and relocate them if he used one of the flexible adhesive/sealants made for this purpose. There had to be a better way, one that would allow hardware to be easily removed yet seal out water.

Meade hatches an idea

He decided to install his hatches with WEST SYSTEM® epoxy thickened to a mayonnaise-like viscosity with 410 Microlight Filler. He reasoned that the lower-density epoxy/410 combination would be flexible enough to stay attached to the epoxy-coated plywood deck and to the plastic trim ring that defines the perimeter of the hatch. The trim ring bottom edge had grooves to help bedding compounds adhere and assist in sealing out water. He did have some concern about the differing coefficients of thermal expansion for the plastic trim ring and the plywood deck. Common flexible sealants handle this nicely in that "they go along for the ride." He was not sure if the epoxy/410 would be able to handle these forces, but the hatch would be installed with a number of screws that would address these loads nicely.

Photo 1—The hatch was easily removed with no damage to the hatch or deck.

Photo 2—One side of the new larger hatch was in the same location as a side of the old hatch. The low-density epoxy/410 Microlight mixture along that edge was easily removed with a low-angle block plane.

Two years went by with the hatches performing successfully with no problems. That is to say, no leaks.

In 2006 though, Meade decided it was time to upgrade the hatches. He needed a larger opening so camping equipment could be stored in the compartments. After removing all of the mounting screws, he was delighted to find that if he just lifted up on one of the corners of the hatch, the whole thing came away with little effort (*Photo 1*). All the epoxy originally used to install the hatch was left on the deck with an exact molded profile of the bottom edge intact. Obviously, the bond between the plastic flange and the epoxy was not very strong, but it was adequate to not allow any leaks over the two years of service. The epoxy/410 Microlight mixture was easily removed with a low-angle block plane (*Photo 2*). Epoxy thickened with Microlight carves and sands like low-density wood.

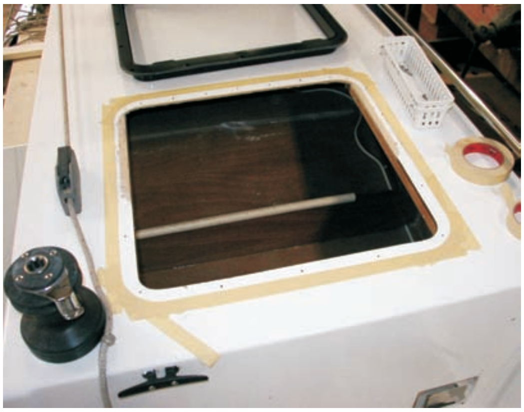
After removing the first of two hatches, Meade felt that his goal of easier hardware removal had been realized. He didn't say it, but he must have been thinking "It's great when a plan comes together."

Hatch installation

Here's the process Meade used to install his new hatches:

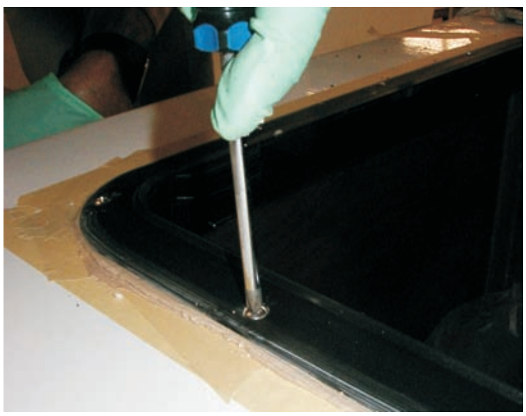
1. Cut opening to size.
2. Dry fit the hatch.
3. Mask off the surrounding deck with wide masking tape (*Photo 3*).
4. Sand the deck to give the epoxy something to stick to.
5. Use trim ring as drill template and drill the pilot holes for mounting screws.
6. Apply mold release to the parts of the hatch frame that are not being glued down to assist in removing residual cured epoxy later. Mold release can be cooking spray, Vaseline™, or shiny plastic packaging tape.

7. Seal edges of exposed wood core and the drilled holes with unthickened resin/hardener mix.
8. Thicken epoxy with 410 Microlight to mayonnaise consistency.
9. Apply thickened epoxy to the bottom of the mounting flange, filling the grooves.
10. Brush a 4–5 mil coating of thickened epoxy to the deck around the perimeter of the opening (*Photo 4*).
11. Position the hatch over the opening and press it into place, squeezing out any excess epoxy (*Photo 5*).
12. Install the screws, taking care to snug the screws only slightly (*Photo 6*).
13. Clean off excess epoxy from the perimeter of the flange with a sharpened wood stir stick or use one of the molded plastic 804 Reusable Mixing Sticks that already have a chisel point feature (*Photo 7*).
14. Clean up excess epoxy on the deck and flange with a plastic spreader or putty knife.
15. Pull up masking tape while the epoxy is uncured.
16. Use alcohol and cheesecloth to clean up remaining epoxy residue. ■



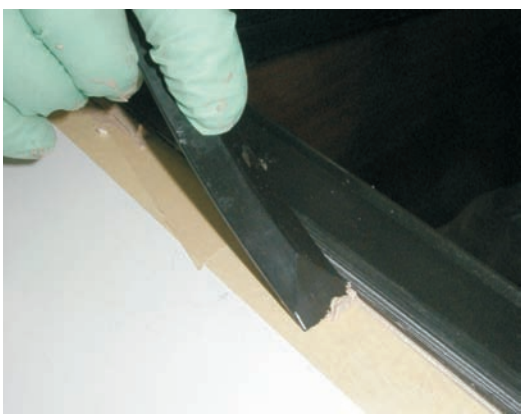
← Photo 3—Mask off the surrounding deck with wide masking tape.

→ Photo 4—Brush a 4–5 mil coating of thickened epoxy to the deck around the perimeter of the opening.



← Photo 5—Position the hatch over the opening and press it into place, squeezing out any excess epoxy.

→ Photo 6—Install the screws, taking care to snug the screws only slightly.



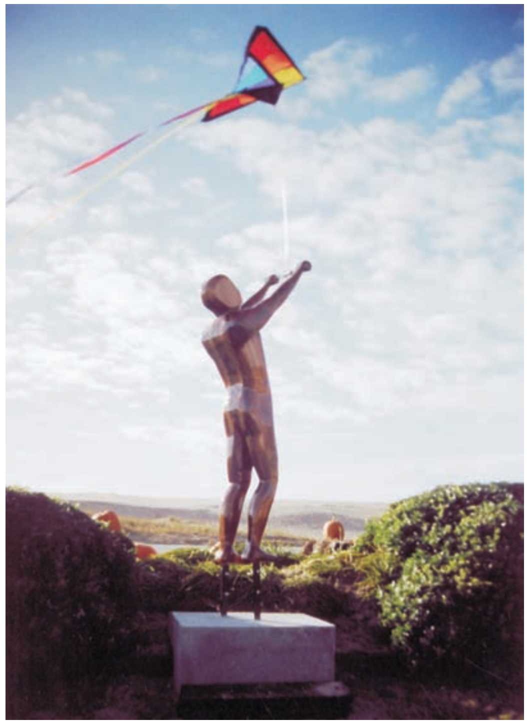
← Photo 7—Clean off excess epoxy from the perimeter of the flange with the flat end of an 804 Reusable Mixing Stick.

→ Photo 8—The finished hatch.

Starting with ⅛"×1" pieces of A2 tool steel, Pohan Leu makes these Japanese style Tanto Blades, which are chisel ground on the right side only. Each blade is tempered three times before grinding to a final razor sharp edge. A nylon black round cord is tied around the tang, leaving a ½" before the blade starts. A wider ⅝" flat black cord is then wrapped around the round nylon cord in a diamond (samurai battle wrap). He then saturates the cord with WEST SYSTEM 105/207 and applies additional coats to build up gloss and hardness. Pohan Leu lives in Irvine, California.

Readers' projects

Cedar the Kite Flyer **is the larger than life-sized work of Robert Crowell of Boone, North Carolina. It stands at Kitty Hawk Kites, next to where the Wright Brothers first flew at Nagshead, North Carolina. It is made of laminated cedar boards using WEST SYSTEM® 105/206, coated with 105/207 and then varnished.**

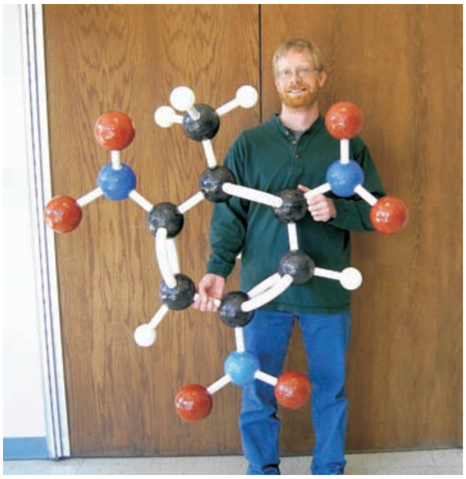


Lyle Watters recently completed this kayak built from a Waters Dancing Boat Kit. He used WEST SYSTEM 105/207 to build the hull and laminate 6 oz fiberglass cloth on the inside and outside of the hull and 4 oz on the deck. The outside is coated with four coats of epoxy, finished with four coats of Z-spar Flagship™ varnish.

This is the Shallow Water Drifter 15, offered by Billy Linesiders Wood Boat Building Company of Fort Lauderdale, Florida. This heavy-duty fishing boat is built of marine plywood (¾" bottom, ½" sides, 2×¾" transom) on fir frames, glued together and barrier coated with WEST SYSTEM epoxy. It is powered by a 25 hp outboard. Contact Bill Hendry at Bhendry789@aol.com.

Armand Charlebois of Embrun, Ontario, built this Weston Farmer designed steamboat. The *Sara C,* shown here on the Ottawa River, is 25' long with a 7' beam. The hull is cedar strip-planked over oak frames with a fiberglass skin. The interior and deck are clear coated and varnished. A home-built 'Porcupine' boiler operating at 100 psi supplies steam to a 5 hp single cylinder engine, which turns an 18" propeller. Charlebois called our Tech Staff several times during the five year project and says the advice and information he received were helpful and appreciated.

Rick Felkel is a luthier from West Monroe, Louisiana. These are some of the 50 acoustic instruments he builds in a year using WEST SYSTEM® epoxy. He prefers epoxy over traditions glues because it improves the instrument's resistance to moisture and heat. Felkel laminates a two-piece neck to avoid the grain run-out of carved one-piece necks. He is the proprietor of Elloree Guitars, 318-388-2635, www.elloreeguitars.com.



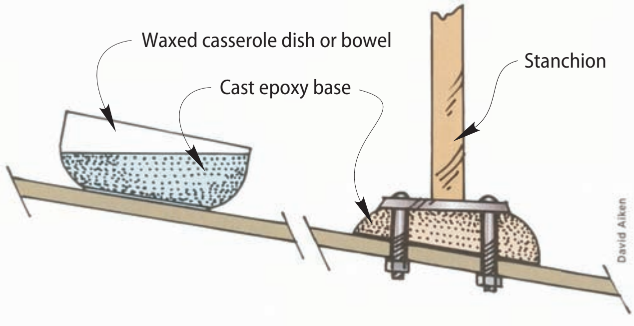
Craig McClure is an Assistant Professor of Chemistry at the University of Alabama at Birmingham. He had trouble finding an extra large molecular models kit to use for lectures, so he decided to make his own. He used Styrofoam™ balls coated with WEST SYSTEM epoxy for atoms. He mixed in marking chalk for color variations. PVC pipes and flexible tubing are the bonds between the atoms. He has a kit with 45 atoms and is able to make a number of molecules. He is shown here holding a model of trinitrotoluene (TNT).

Casting a level deck fitting base

Courtesy of Jan Mundy, DYI Boat Owner magazine

Q: I'm reattaching the stanchion base on my Grampian 30 and the deck is uneven. Any suggestion on leveling the surface with epoxy resin? Roy Mitchell, Tweed, Ontario

A: You can use wood to make a wedge-shaped base, but that takes a lot of fitting time. Instead, make one out of epoxy resin. Find an appropriately sized, low-sided casserole dish. Spray the inside with nonstick cooking spray or coat it with paste wax to prevent the epoxy from bonding to the dish. Mix up a batch of epoxy resin thickened with microballoons. Set the dish on deck in the place where you want to install the fitting. Pour the epoxy into the dish to the amount required. The resin will flow naturally and level out on top. When it hardens, pop it out of the dish and turn the blob upside down. The angle side now matches the deck slant and the dish-bottom side is a true horizontal surface for your fitting base. Sand and paint, then glue and fasten the base to the deck and attach the fitting.—*Jan Mundy*



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New product

WEST SYSTEM® launches G/flex® Epoxy

By Tom Pawlak

G/flex Epoxy adds a degree of flexibility to the WEST SYSTEM lineup.

G/flex Epoxy is a toughened, resilient two-part epoxy engineered for a superior grip to metals, plastics, glass, masonry, fiberglass, and wet and difficult-to-bond woods. Introduced in June 2007, G/flex Epoxy is currently available in two consistencies: G/flex 650 Epoxy, a liquid epoxy, and G/flex 655 Epoxy Adhesive, a pre-thickened epoxy. Both have an easy-to-use 1:1 mix ratio.

G/flex Epoxy gives you 46 minute pot life and a long open or working time of 75 minutes at room temperature. It will reach an initial cure in 3–4 hours and a workable cure in 7–10 hours. Wait 24 hours before subjecting joints to high loads.

G/flex is available in three convenient packages:

G/flex 650-8 Includes 4 fl oz-G/flex 650 Resin, 4 fl oz-G/flex 650 Hardener (8 fl oz of mixed epoxy), and handling and repair instructions.

G/flex 650-K Kit contains 4 fl oz-G/flex 650 Resin, 4 fl oz-G/flex 650 Hardener (8 fl oz of mixed epoxy), 2 reusable mixing stick/applicators, 2 12 cc syringes, 4g of adhesive filler, 4 mixing cups, 1 pair of disposable neoprene gloves, 4 alcohol cleaning pads, and complete handling and repair instructions.

G/flex 655-K Kit contains 4.5 fl oz-G/flex 655 Resin, 4.5 fl oz-G/flex 655 Hardener (9 fl oz mixed epoxy), 2 reusable mixing stick/applicators, 4 alcohol cleaning pads, 1 pr disposable neoprene gloves, 10 mixing palettes, and complete handling and repair instructions.

Even as we introduce the new G/flex, we want to emphasize that our existing WEST SYSTEM 105 Resin-based epoxies can't be beat for versatility and reliability. WEST SYSTEM 105 Resin mixed with the appropriate hardeners and different additives allows you to create an epoxy for a variety of applications like gluing, sealing, fairing, and sheathing. No other epoxy is more reliable for such a huge spectrum of end uses.

However, as a marine-grade glue that can be accurately mixed in small batches, G/flex Epoxy offers important benefits.

Benefits of G/flex Epoxy

- **Toughness and flexibility** G/flex has been toughened. This gives G/flex the ability to make structural bonds that can absorb the stresses of expansion, contraction, shock, and vibration. G/flex is resilient and impact resistant. With a modulus of elasticity of 150,000 psi (WEST SYSTEM 105 Resin/205 Hardener has a modulus of elasticity of 450,000 psi), G/flex is more flexible and can deflect further before breaking than WEST SYSTEM 105/205, while being *much* stiffer than typical adhesive sealants.
- **Adhesion to wet and damp surfaces** G/flex has the ability to glue damp woods. It can be used on wet surfaces, even underwater when applied with specific techniques.
- **Excellent adhesion to hard-to-bond woods** G/flex adheres tenaciously to difficult-to-glue hardwoods, both tropical and domestic varieties. This is important since many of the exotic and tropical species now being used to replace traditional woods present bonding challenges.

- **Bonds well to a variety of materials** G/flex® is ideal for bonding a variety of materials, including dissimilar ones. G/flex has a superior grip so that it can be used to bond to metals, plastics, glass, masonry, and fiberglass. G/flex is ideal for repairs to aluminum boats and polyethylene and ABS canoes and kayaks. It can also be used to wet out and bond fiberglass tapes and fabrics.
- **Ease of use** G/flex is a simple two-part epoxy system. Resin and hardener are mixed in a 1-to-1 mix ratio by volume. G/flex provides a relatively long open working time, yet it cures quickly and can be used in cool temperatures. Because it is simple to mix and use, G/flex is an excellent starting point for customers new to epoxy use.
- **Versatility** G/flex can be modified with WEST SYSTEM® fillers and additives if you need to meet particular bonding needs. Adding G/flex to other WEST SYSTEM epoxies can improve their toughness and flexibility.

Development of G/flex Epoxy

G/flex is the result of years of experimentation to develop a formula for a toughened epoxy. We wanted something that was simple to use, viscous enough not to drain out of a joint, and adhered tenaciously to a variety of materials under difficult conditions. As explained more fully later (see *Understanding Flexible Properties*, p. 17), material properties of an epoxy form a complicated web. When you formulate for specific end properties (like high elongation), you usually have to give up other properties in order to achieve it. Some of us thought that if you formulate an epoxy with five to six times the tensile elongation of other WEST SYSTEM epoxies, the new product would be poor at dealing with constant or long duration loads. Yet when we tested G/flex under long duration loading with our exclusive Creep Test, it performed admirably—nearly matching the 105 Resin-based epoxy.

We also wondered if an epoxy with this much elongation would perform poorly in heat resistance. Yet ASTM-D648 (Heat Deflection Under Load or HDUL) revealed G/flex performed even better than 105 Resin-based epoxies. (G/flex like all WEST SYSTEM resin/hardener combinations can handle temperatures up to 200°F repeatedly. At this temperature, it will be more flexible and less resistant to heavy durational loads than at room temperature, but it returns to full strength as it approaches room temperature.) Well, what about through cure? Usually flexible systems take days to achieve the majority of their physical properties. Our testing revealed that G/flex's 24-hour through cure is similar to that of WEST SYSTEM 105 Resin and 205 Fast Hardener.

Adhesion Testing

How does G/flex adhere to woods and metals? Adhesion testing using the PATTI (Pneumatic Adhesion Tensile Test Instrument) on the same pieces of wood (with the wood sanded parallel to the grain with 80-grit sandpaper but no solvent wash) revealed that G/flex adheres to wood at least as well as any other WEST SYSTEM epoxy. With hardwoods and the often difficult-to-glue species such as white oak, Ipe, teak, greenheart, purpleheart and salangan batu, G/flex performed as much as 30% higher.

Adhesion testing with G/flex Epoxy on metals also yielded excellent results, typically exceeding the adhesion results achieved with 105 Resin-based epoxies (*see Figure 1*).

G/flex Epoxy has the ability to bond not only to wood and aluminum, but plastics, exotic hardwoods and wet wood.

Figure 1—Tensile adhesion results for PATTI test of G/flex and various materials.

Material	G/flex Epoxy	Surface prep / conditions	Tensile adhesion (psi)
G-10 high-density laminate	650	80-grit sand / dry surface	3459
	655	80-grit sand / wet surface	2473
		80-grit sand / underwater surface	1772
1018 steel	650	80-grit sand / dry surface	3562
	655	80-grit sand / wet surface	1175
Galvanized steel	650	100-grit wet sand	2562
	655	100-grit wet sand	2929
	655	Scotch brite™ pad wet sand	2913
Aluminum 2024 T3	650	80-grit sand, 860 etch / dry surface	2731
	650	Grit blast, 860 etch / dry surface	1856
	655	80-grit sand / wet surface	1503
	655	Grit blast, 860 etch / dry surface	2153
Copper	650	80-grit sand	2334
	655	80-grit sand	2685
Bronze	650	80-grit sand	2782
	650	Scotch brite™ pad sand	2962
	655	80-grit sand	2936
HDPE plastic	655	Alcohol wipe, flame treat	1885
ABS plastic	655	80-grit sand	1535
Lexan™	655	80-grit sand	1870
Ipe	650	60-grit sand	2134
	650	Plane, isopropyl alcohol wipe × 3	2223
Teak, vertical grain	650	80-grit sand parallel to grain	1413
	655	80-grit sand parallel to grain	1381
	655	80-grit sand, alcohol wipe × 2	1503
White oak, vert grain	650	80-grit sand	1935
	655	80-grit sand	1780
	655	Alcohol wipe × 2	2212
Purpleheart	650	60-grit sand parallel to grain	1731

We also found that G/flex® 655 Thickened Epoxy Adhesive adheres to wet and damp surfaces well. Obviously gluing to wet surfaces, especially when dealing with absorbent substrates like wood, is less than ideal because water is taking up the spaces where epoxy otherwise would find its way in; however, G/flex worked surprisingly well. Technique plays an important role in how effective a wet surface adhesion (even underwater repairs) will be. The epoxy must be thick enough to displace the water to ensure a good bond. Pre-thickened G/flex 655 Adhesive (or G/flex 650 that has been thickened with 406 Colloidal Silica to a mayonnaise consistency) is needed.

G/flex Kit instructions include a number of short "how-to's" on gluing to damp and wet surfaces, performing underwater repairs, and repairing plastic boats, including crack repairs and making skid plates for worn ends on plastic canoes.

Expand the versatility of other WEST SYSTEM® epoxies

Adding G/flex to WEST SYSTEM 105 Resin-based epoxy improves toughness and tensile elongation. Using it this way expands the utility and versatility of the WEST SYSTEM product line even further. G/flex can also be used with WEST SYSTEM G/5 Five-Minute Adhesive to extend the working time. The more G/flex added to G/5, the slower the cure and the tougher the cure properties become.

Do I still need 105 Resin?

With all the attributes and improved properties of G/flex, you might be asking whether you still need WEST SYSTEM 105 Resin-based epoxy? The answer is that G/flex can't do some things as well as 105 epoxy. Examples include barrier coating and fiberglassing with heavier fabrics. Although G/flex flows nicely when spread out on a surface, it is less than ideal as a coating because of its higher viscosity. WEST SYSTEM 105 epoxy is better for wetting out fiberglass cloth, especially for clear finish projects like wood strip canoes and kayaks. WEST SYSTEM 105 epoxy is also a better base for creating fairing putties because its lower viscosity allows you to add more low-density filler to it. This translates into a fairing putty that sands and carves more easily because of the higher filler loading.

Several articles follow that will help you further understand our new G/flex toughened epoxy and its properties. We encourage you to read these and then experiment with G/flex as we are doing. We think you will find many projects for which the particular properties of G/flex are ideally suited. As always, our Technical Staff is available to answer your questions, and we will be eager to hear about your projects and repairs using the new G/flex Epoxy. ■

WEST SYSTEM® products

This is a good time to clarify that there are now three different epoxy types in the WEST SYSTEM product line. (*see page 24.*)

1. What we previously referred to as WEST SYSTEM epoxy are the four resin/hardener combinations based on 105 Resin (105 Resin mixed with 205, 206, 207 or 209 Hardener).

2. G/5 Five-Minute Adhesive is a single epoxy resin/hardener combination.

3. We have now added G/flex Epoxy to the WEST SYSTEM product line. G/flex includes 650 (liquid) Epoxy and 655 (thickened) Epoxy Adhesive.

Wood abuse

Testing the limits of a simulated garboard plank to keel joint

Here's what you get when you glue wet wood with G/flex 655 Adhesive and allow the wood to dry out. This specimen (oak and mahogany) was glued together while the wood was dripping wet with moisture contents in excess of 20% (maxed out our moisture meter). The specimen was cycled monthly between our warm wet environmental chamber (100°F, 100% humidity), where it causes the wood to absorb moisture and swell (below)...

and our warm/dry chamber (100°F, near 0% humidity) where it causes the wood to dry out, crack and split (above). This specimen has been back and forth between the two huts several times since November of 2006 and after all that abuse the G/flex 655 still holds strong. We'll continue these tests on different types of joints. The goal after all, is to make it fail so we know what its limitations are. ■

Understanding flexible properties

By Jeff Wright

The Technical Staff at Gougeon Brothers, Inc. regularly discuss material properties in a variety of applications. For example, it is not uncommon for us to discuss with a customer how to use carbon fiber to stiffen a structure, such as the shaft of a kayak paddle, and then within minutes discuss with another how to bond a dimensionally unstable wood, such as oak, and ensure precautions are taken so that the relative movement of the wood will not cause a failure.

For the kayak paddle, the customer's concern is that the epoxy will allow the stiff carbon fiber fabric to be as rigid as possible. For bonding the unstable wood, the customer would like an epoxy that will be able to elongate more than the wood to ensure that the movement of the substrates will not fracture the epoxy. These examples highlight people's interest in the flexibility of the epoxy. However, this interest also often leads them into the world of material properties, a field they know little about. Material properties form a complicated web whose threads include not only flexibility but also elongation, stress, creep, ultimate properties, yield properties and toughness.

We have previously discussed how the flexibility of WEST SYSTEM® 105 Resin mixed with 205, 206, 207, or 209 Hardener makes it very well suited for use with common boatbuilding materials (*see Epoxyworks 16*). The many boats that have been successfully built using these 105 Resin-based epoxies with wood, carbon fiber, and fiberglass illustrate this epoxy's excellent properties. However, since we have introduced a new WEST SYSTEM product—G/flex® Epoxy—that has increased flexibility, this is a good time to review the relationship of flexibility to other material properties.

Flexibility

The stiffness of a material is often confused with its strength and toughness. Stiffness, or modulus, is simply a measurement of the ability to resist elongating when a load is applied. Stiffness and strength are separate properties. Strength is the amount of stress a material can withstand before it fails. Strength and stiffness cross paths when a material exceeds its yield strength, leaves the elastic region, and enters a plastic region.

When a material is in its elastic region, it will always "return" to its original state after stress is removed. For example, when a wooden or fiberglass boat is taken out for a ride during the day, its hull deflects each time it hits a wave, but when the boat comes back to the dock, it has the same shape as when it left. The hull spent its entire day in the elastic region, and it always snaps back to where it started. In contrast, if you see an old steel freighter with its steel shell dented in around the frames, the steel has been put into its plastic region (beyond its yield strength) and experienced enough stress that the hull shell could not return to its original shape.

> Stiffness, or modulus, is simply a measurement of the ability to resist elongating when a load is applied.
>
> Strength is the amount of stress a material can withstand before it fails.
>
> Creep stress is a material property that describes how a material resists the stress of a constant long-term load.

Since wood and most composite materials, such as fiberglass and carbon fiber, are not appropriate for use in the plastic region beyond their yield strength, we did not formulate our WEST SYSTEM epoxies to work outside the elastic region. Instead, WEST SYSTEM epoxies were formulated to enhance the performance of wood and composite materials under real-world operating conditions. We have spent over 30 years optimizing WEST SYSTEM epoxies. Even when competitors criticized our product for not having the ability to operate in the plastic region, we knew that the elongation of WEST SYSTEM epoxy was ideally suited for common boatbuilding materials. Simply making the epoxy more flexible would have reduced the overall performance of the structures that were laminated and bonded with it.

The concern about a resin's flexibility may come from an inaccurate perception that low elongation numbers imply brittleness. Most production boats are built using polyester resins. Due to the brittle nature of polyester resins, these boats often have problems with the laminate cracking. WEST SYSTEM 105 Resin-based epoxy is much tougher than polyester resins, which makes it more resistant to cracking. As an engineer, I am jealous that the makers of pickup trucks can boast about the stiffness of their truck frames without raising any concern about brittleness.

G/flex vs. polyurethane adhesive/sealants

When something is bent, it must elongate a certain amount. Since joints can fail when they are flexed, a high-elongation material would appear to be a good choice for a strong joint. Many of the polyurethane adhesive/sealant materials advertise elongations of +100%, and they have often been used, inappropriately, as bonding adhesives. Sealants are designed to withstand the movement in a gasketed joint, for example between a bronze through-hull fitting and a hull bottom. The sealant has to deal with the relative movement as the hull flexes around the rigid thru-hull fitting or when a careless mechanic steps on the through-hull, also causing it to deflect. Since the film of sealant may be less than 1⁄32" thick, a 1⁄8" movement would require 200% elongation. The sealant only needs to adhere well enough to stay in contact with the through-hull fitting and the hull bottom; the backing nut is keeping the through-hull in place, not the sealant. Although polyurethane adhesive/sealants are great materials when used as intended, these products do not have nearly the strength of epoxy.

Increased flexibility and elongation

Our newest product, G/flex®, has utilized a new chemistry that provides a very tough epoxy with greater flexibility and elongation than WEST SYSTEM® 105 Resin-based epoxies. The need for a higher elongation material was not driven by any shortcomings with 105 Resin combinations. Instead, G/flex was developed for applications for which no products are currently available. These applications include substrates that are prone to excessive flexing, hard-to-bond tropical woods, flexible laminates, and bonding to wet substrates. G/flex is an extremely tough epoxy that is more flexible than 105 Resin-based epoxies without sacrificing adhesion strength.

We do not recommend G/flex for building a stitch-and-glue kayak. In this case, 105 Resin-based epoxy is a perfect choice since the plywood will never exceed the elongation of the epoxy. However, G/flex will better match the modulus of flexible substrates, such as thin sheets of aluminum or even canvas that need to be joined. G/flex also has the ability to stretch after its ultimate strength has been exceeded, which allows G/flex to elongate beyond its elastic range. This can provide a safety factor for some bonding situations.

G/flex: resistance to creep stress

While we are proud that we developed an epoxy with more elongation, high strength, and excellent adhesion, G/flex's resistance to creep rupture is possibly the most notable achievement. Engineers typically use dimensions, strength properties, and predicted loads to calculate the stress that an assembled joint will be subjected to in service. However, the duration of the load also needs to be considered. Structural engineers who are Star Trek fans refer to this as the "Stress/Time Continuum." It is more often referred to as creep stress.

Creep stress is a material property that describes how a material resists the stress of a constant long-term load. Creep stress problems can be evident when something simply does not hold its shape, such as the roof on my 100-year-old home that has sagged from its original shape. Creep stress can also result in a complete failure, such as when a highly stressed glue joint at the stem of a boat fails months after the glue has fully cured when the boat is moored at the dock. In these cases, it can be said that the material has flowed or "crept" due to constant stress. Creep rupture often occurs at a stress below the material's ultimate strength. This is why creep loads are built into design safety factors. Creep stress is common in stitch-and-glue boats after the plywood has been bent into the desired shape and also in scarf joints in boards that are constantly bent.

Testing the creep characteristics of 105 Resin-based epoxies

Fortunately for users, our WEST SYSTEM 105 Resin-based epoxies are formulated to be resistant to creep stress. Our understanding of creep stress spans over 20 years, including studies of WEST SYSTEM 105 epoxy-bonded fasteners in 70' wind turbine blades exposed to constant high loads created by the centrifugal force of the spinning blades. Over the years, we have used several methods to test the creep characteristics of our epoxy. All the testing was done in a 95°F environment to accurately reflect the environment that many epoxy joints will experience in a boat's cabin or bilge.

Our first generation testing method was the Notched Beam Test, which is illustrated in Figure 1. The Notched Beam Test applies bending stress to a notch cut across a wooden beam that has been filled with the adhesive that is being tested. When the correct load is applied to the beam, the resulting bending moment will cause a creep rupture. Too small a load results in an infinitely long test. Too much weight results in a sudden ultimate strength failure. (For details on conducting your own notched-beam testing ask for 000-815 *Notched-Beam Test for Creep-Rupture*. This paper is available free from Gougeon Brothers. Call 866-937-8797.)

The Notched Beam Test provided very valuable data but had shortcomings. The main one was that it took a great deal of time to generate a substantial set of data points. In the 1990s, we developed the next generation creep test, affectionately referred to as the Drip and Grip. The test sample was constructed with two 3⁄4"×3⁄4"×3" wood laminate coupons that were bonded with a butt joint using an 1⁄8" glue line. This test utilized a tensile load that was increased very slowly over the span of 12 to 24 hours. Results from the Drip and Grip and the Notched

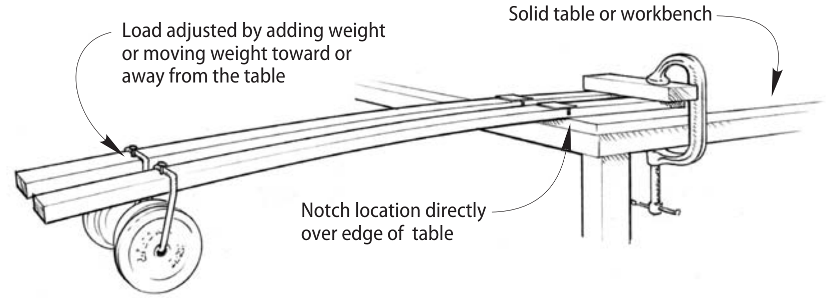


Figure 1—Original Notched Beam Creep Test—developed as a low-cost test for the home user.

Figure 2—The new Creep Stress Test Machine

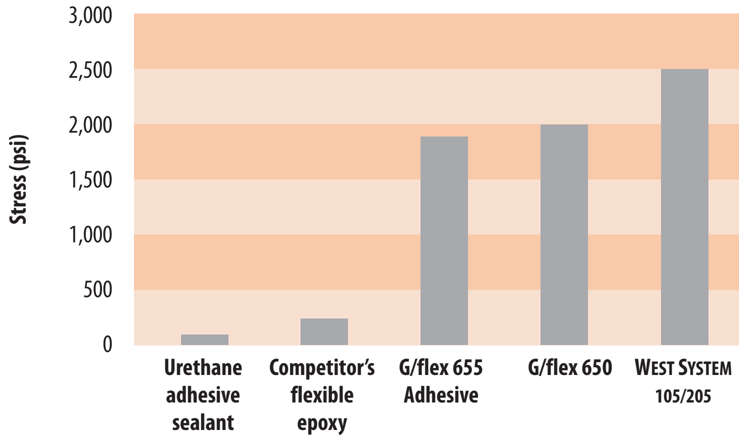


Figure 3—Comparison of creep rupture performance

Beam Test showed good correlation. This new test provided a data point every 24 hours.

Our current generation of creep test machine has been in use for 5 years. It uses the same concept as the Drip and Grip, but the load is applied pneumatically and data acquisition is computerized. We can now test multiple specimens at the same time with different load rates and capture data throughout the test. Recording the data every minute of a 24-hour test allows the engineer to have a full record of stress, load, and temperature. This ensures that any problems during the test are easily recognized. Figure 3 is a photograph of our current creep stress test machine.

Gougeon Brothers, Inc. has developed a large database of creep stress performance of our epoxy, competitive epoxies, and popular urethanes. Constantly testing for creep stress performance allows us to provide our customers with products that perform well under long duration loading. Testing has also demonstrated the risk of adding chemicals to the epoxy that make it more flexible. Testing also shows the poor creep performance of common urethane.

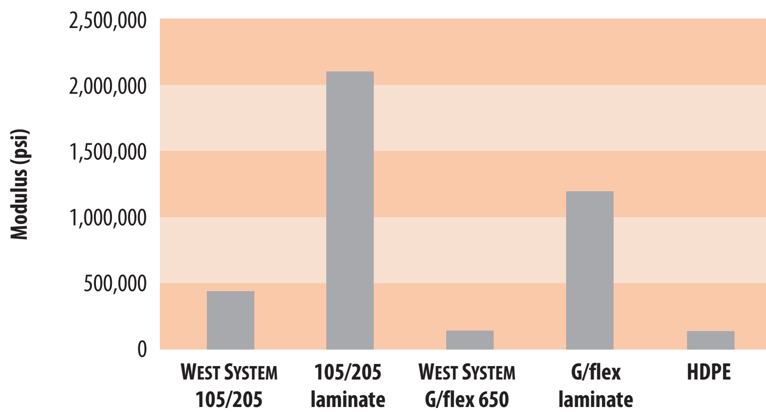
Developing G/flex®

Since many flexible adhesives have poor creep performance, the challenge has been to develop a formulation which has more flexibility than our 105 Resin-based epoxies without a significant loss in creep stress performance. Our chemists met that challenge with the development of our new G/flex Epoxy. G/flex offers a higher degree of flexibility without a significant loss in creep stress performance. This is a significant breakthrough in adhesive performance. G/flex provides long-term performance that common one-part elastic urethane adhesive/sealants can not offer. Figure 4 compares the creep performance of G/flex and other products.

As always, our Technical Staff are available to help you determine the best WEST SYSTEM product for your application. Remember that the performance of an adhesive joint can be greatly improved by avoiding peel loads, having the proper adhesive thickness, and ensuring there is enough surface area. Addressing these and other issues with our Technical Staff can help ensure a successful application. Call the Tech Staff toll free at 866-937-8797. ■

Stiffness of neat epoxies vs. laminate

G/flex can be used to bond many different materials, but it can also be used to create a more flexible fiberglass laminate. This is useful in unique applications that must bend more than a typical fiberglass laminate, such as a scupper flap or repairing a sheet-molded ATV fender. Although G/flex is not intended as a laminating system, it is useful for small projects that need to be a bit more flexible. This chart shows the **Relative Stiffness** of neat, or unmodified, West SYSTEM 105/205 and G/flex, and their respective fiberglass laminates. The stiffness of High Density Polyethylene (HDPE) is shown as a comparison.



1 Patch holes in aluminum boats with G/flex® Epoxy

ALUMINUM BOAT REPAIR

By Randy Zajac and Rob Monroe

When we started testing G/flex Epoxy as a solution to leaky seams and rivets in aluminum boats, we put out a company-wide call for test boats. John Kennedy offered his old 15' Michi-Craft canoe, saying he would bring it down from his cabin at the end of hunting season. Not smiling, he asked a few weeks later "just how big a repair we could handle." It turned out John jack-knifed his utility trailer on an icy road, punching a fist-sized hole in the stern quarter of the canoe (*Photo 1*). Ouch.

Photo 1—The hole in John's canoe presented an opportunity to test the new G/flex and develop a repair technique to go with it.

This serious hole offered several competing solutions. Recycling was one. Cut up and placed in the green city recycling bins, the canoe could be gone the next trash day. Checking the mental Rolodex for the friend with the TIG welder and the associated skill to weld such wounds in thin gauge aluminum was another option. Or perhaps finding another friend, who is convinced that a torch and brazing rod in the hands of an artist will solve almost anything. However, since John has worked for Gougeon Brothers for 26 years, he decided to try the new G/flex Epoxy.

Shape and clean the metal

First, we hammered the torn aluminum out to near shape. The metal had yielded, so we cut away enough of the torn edges to allow the aluminum to lie fair. A hammer and an auto-body bucking dolly gave us reasonable control in getting the hull close to its original shape. We drilled stopper holes at the end of each tear to reduce the potential for crack propagation. Then we softened the edges of the aluminum with 120-grit sandpaper. We used a coarse 3M® Roloc™ Bristle Disc to remove paint both inside and outside, giving ourselves plenty of bonding surface area around the hole (*Photos 2 & 3*). Finally, we used the two-part 860 Aluminum Etch Kit to prep the surfaces prior to bonding.

Make the patch

For the patch, we cut a single piece of 745 (12 oz) Episize™ Glass Fabric for the outside and three pieces (in diminishing sizes) for the inside. The outer patch and the largest of the inner patches were 6.5" by 8.5" to allow approximately 2" of overlap around the hole.

Photo 2—Left, a coarse 3M® Roloc™ Bristle Disc did a good job of removing paint around the repair after it was hammered back into shape.

Photo 3—Right, the shaped and cleaned repair. Stopper holes were drilled at the end of each tear, and the surface was prepared with the 860 Aluminum Etch Kit.

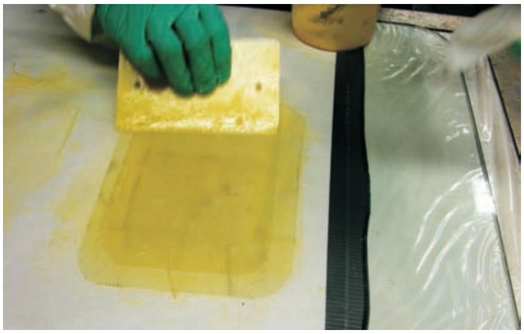


Photo 4—Left, 12 oz fiberglass patches for both the inside and outside were wet out with G/flex 650.

Photo 5—Right, Thickened G/flex 650 was applied to the repair area.

We laid out the patch pieces on plastic and wet them thoroughly with G/flex® 650 (Photo 4). We brushed both surfaces of the canoe with the G/flex, taking care to work the adhesive into the scratches and small dings. Finally, we mixed 406 Colloidal Silica with the residual adhesive in our cup to make a thickened mixture suitable for filling the holes and cutaways in the canoe (Photo 5).

Apply the patch

We started with the single layer outside patch, applying it to the hull centered over the hole and smoothing it into the thickened mixture (*Photo 6*). Working away from the canoe, we stacked up the three inner patches and squeegeed them to make sure there was no entrapped air. We then centered the stack of patches over the hole on the inside of the hull and carefully laid it into place (*Photo 7*). We squeegeed the patch very lightly to remove air. We then checked the outside of the hull to make sure that the pressure on the adhesive in the holes was not pushing the outer patch out of fair. When satisfied with the patch placement and fairness, inside and out, we let the patch cure overnight.

Fair the patch

The next day, we ground the edges of the patches to remove any roughness. We then applied a mixture of 650 G/flex and 407 Low-Density Filler to fair the patches (*Photo 8)*. This "toughened" fairing compound smoothed the outside for better hydrodynamics and the inside for cleanliness and additional scuff resistance. We found that the fairing mixture sanded easily despite the flexibility of the G/flex Epoxy adhesive. It made a fine powder and didn't seem to load up the abrasive media.

When the fairing mixture was cured, we applied a mix of G/flex and 503 Gray Pigment to supply a degree of camouflage for the fiberglass repair on an aluminum hull (*Photo 9*).

John is happy (why not, we fixed his canoe!) and has promised to drive more carefully. ■

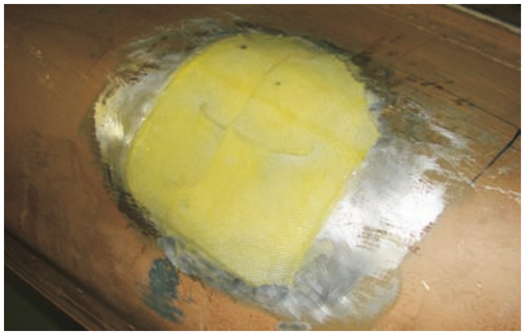


Photo 6—A single layer of glass was applied to the outside of the hull and smoothed into the thickened epoxy.

Photo 7—Three layers of glass were laid in position on the inside of the hull and lightly squeegeed to remove trapped air.

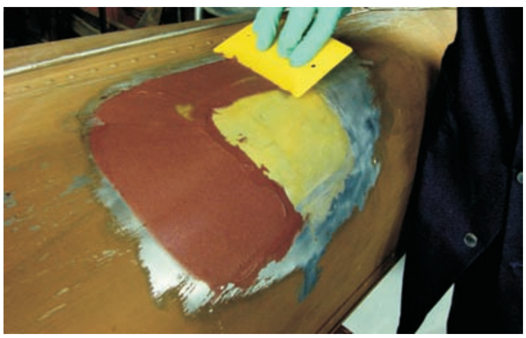


Photo 8—After edges of the patch were ground smooth, a mixture of 650 G/flex and 407 Low-Density Filler was applied to fair the patch inside and out.

Photo 9—A mix of G/flex 650 and 503 Gray Pigment was applied as a sealer/undercoating and a bit of camouflage.

2 Fix leaking seams in aluminum boats with G/flex® 650 Epoxy

ALUMINUM BOAT REPAIR

By Randy Zajac

We wanted to experiment with using G/flex to fix leaking aluminum boats. I was quite surprised to find that every aluminum boat owner I talked to said they had some sort of leak. Within 3 hours, I had several co-workers volunteer their aluminum boats for the experimental fix using G/flex.

Finding the leaks

The first step is to find the leak. This is fairly easy—just fill the inside with water up to the waterline. To reduce the possibility of destruction or distortion, I tilted the boat and only filled one end at a time since filling the boat up entirely might have done more damage to the seams.

On each boat I repaired, I found many rivets that merely seeped water. However, I also found at least one that poured a constant stream. These bigger leaks were the main cause of water inside the craft during normal use. One boat actually carried a bilge pump to help keep up with the bailing. I circled any leaking rivet or seam with a black marker.

Making the repair

With the leaks identified and marked, here are the techniques used for the repair.

Flip the boat over for easier access to the bottom and prepare the surface for bonding. For the seams, clean out any debris that might still be stuck inside. On the rivets, I used a wire brush in a circular motion to abrade the surface. A wire brush attachment on a cordless drill made the job even easier.

Once everything is clean and well scuffed, gather the needed materials: a handheld propane torch, a heat gun, an 804 Syringe, paper towels, and G/flex 650 Epoxy.

Mix the G/flex 650 Resin and Hardener together and fill the syringe. I cut the tip of the syringe to enlarge the hole to about 1⁄16". Heat the repair area with a propane torch (a heat gun will work) up to 180–220°F to dry out the repair area. The heat drives moisture from the seam and thins out the G/flex, allowing it to flow more easily into the seams and rivets.

Then fill the seams and rivets in this area while the aluminum is still warm. Use the heat gun (do not use a propane torch for this step) in one hand while applying the G/flex from the syringe with the other. The forced air from the heat gun keeps the repair area warm and lets you direct the G/flex where it needs to go. This lets you do the repair without flipping the boat over.

After you have applied enough G/flex, pull the syringe plunger back slightly and lay it on a paper towel for the next rivet or seam. Keep applying heat until the G/flex has gelled and no longer moves with the forced

Left—After the area around the leaky rivets is cleaned and well scuffed, heat the area with a propane torch to drive off moisture and warm the metal. Then fill around the rivets with G/flex 650 Epoxy.

Right—Apply heat with a heat gun until the epoxy has gelled. The heat initially thins the epoxy, allowing it to seep into the smallest crevice, and then speeds the gel time.

Left—Clean the area around the leaky seams. Then heat the area with a propane torch to drive off moisture and warm the metal.

Right—Force G/flex 650 into the seam with the syringe while the metal is still warm. Apply heat with a heat gun until the epoxy has gelled.

air from the gun. Then, you can either let the G/flex® cure at ambient temperature or continue using the heat gun on a lower setting until the epoxy is fully cured.

Complete heating and filling each rivet or seam section before moving on to the next to avoid too much heat loss.

Testing the results

Once the epoxy is cured, you are ready for an immediate water test. The boats I repaired in our shop were taken right out to the water and thoroughly abused. After repeated beaching and thermal cycling, the G/flex still holds strong. ■

G/flex shoe repair: A step in the right direction

By Julie VanMullekom

My good ol' faithful boots (meaning they're old and need to be thrown out but I just can't do it) blew a deep crack in each sole. I figured what a great time to try out our new G/flex Epoxy.

I found that there are a lot of things that I like about this material:

It is mixed at a 1:1 ratio, so I traced two equal, poker-chip sized circles side by side and squirted G/flex 650 Resin in one and Hardener in the other. This makes eyeing a 1:1 ratio pretty darn accurate. I then blended the two together.

G/flex gives lots of working time. I bent the boot open so I could force the epoxy into the crack. I placed the boot on a zip-lock bag and put one weight on the toe and another one inside to straighten it out. I allowed the epoxy to cure overnight.

G/flex gets its name from "flexible"—not like a rubber band but rather like a hockey puck or the rubber of my boot's sole. A perfect match, it seems. Several weeks later after walking on ice, in wet puddles, in the shop, and even in the mall, the boots are as good as new or maybe even better!

This repair worked so well, I thought I would try it on my husband's hiking boots, which were in need of a different kind of repair. These boots are from L.L. Bean™ (expensive and faithful). The boot was punctured on a hiking excursion and now leaked water. So I thought, "why not try the G/flex on it too?"

I lightly scuffed the surface with a 3M #7447 Scotch Brite™ pad and applied the G/flex 650 to the "entrance wound." I wetted a piece of 10 oz canvas material, for flexible reinforcement, and then used it to cover the hole. The boots were supported from the inside with a crunched up newspaper. I covered the wet lay-up with a zip-lock bag and applied pressure with a sand-filled bag. Then I allowed the repair to cure overnight.

The next day the boots were put to the test. The adhesion seemed to work very well, and the fix resulted in a waterproof boot with the repair area being a little stiffer than the original surface. This additional stiffness seems acceptable. Use over time and exposure to the winter elements will determine the success of the repair. While the repair may not be the most eye appealing, "It's what's inside that counts," and what's inside these boots are some very dry and very happy feet. ■

Repairing a hockey stick

By J. R. Watson

Ice hockey sticks are exposed to cold temperatures plus high shock forces from contact with the puck as well as with the ice and skates. Hockey sticks can be wood/fiberglass laminates or composites of carbon fiber or aramid. The stick blades often chip and split with use and have to be repaired (or else replaced at $50–$150 each). A customer who repairs and maintains hockey sticks for a local team had been using a conventional epoxy for repairs and found that it often chipped under such use.

To make the repair, he pries open the split and dries it with a heat gun. While it is still warm, he injects G/flex® into the split, clamps it together, and allows it to cure. After removing the clamps, he wraps the repair area with one layer of 2" fiberglass tape, wetting it as he proceeds. The tape is somewhat more difficult to wet out with G/flex due to its increased viscosity, but no other finishing is needed.

Using G/flex, the customer has found that the more flexible epoxy provides a significant improvement in durability over the epoxy which he had used previously. ■

1. Open the split, clean out any loose material, and warm the area with a heat gun.

2. Inject G/flex 650 into the split. Work the mixture into the crack.

3. Clamp the stick together with even pressure to force a small amount of epoxy from the crack.

4. Apply a layer of fiberglass tape to the repair area with G/flex 650 for additional reinforcing.

An overview of WEST SYSTEM® epoxies

Standard epoxy

105 Resin-based epoxy

105 Epoxy Resin
205 Fast Hardener
206 Slow Hardener
207 Coating Hardener
209 Extra Slow Hardener

A versatile low-viscosity epoxy system used for wooden boat building, composite construction and repairs that require high-strength, waterproof coating, bonding, and filling.

Cures over a wide temperature range with one of four hardeners.

Excellent thin-film characteristics for wetting out fabrics, penetrating porous material, and barrier coating.

Easily modified for a wide range of working conditions and applications.

The world's most reliable and widely used marine epoxy.

Specialty epoxies

G/flex Epoxy

G/flex 650 (liquid) Epoxy
G/flex 655 Thickened Epoxy Adhesive

An easy-to-use, toughened epoxy designed to make structural bonds that absorb the stresses of extraordinary expansion, contraction, shock, and vibration.

Glues resinous and wet woods, hardwoods, and a wide range of dissimilar materials.

Makes permanent, waterproof repairs to aluminum, plastic, and wooden boats.

Provides a relatively long open or working time and a quick overall cure.

Can be modified with WEST SYSTEM fillers.

G/5 Five-Minute Adhesive

G/5 865 Five-Minute Adhesive

An easy-to-use epoxy for quick repairs and general bonding.

Use for making jigs and fixtures quickly and to hold parts in position while standard epoxy bonds cure.

Not intended for continuously wet applications.

Can be modified with WEST SYSTEM fillers.

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 989-684-7286 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 with epoxy around your house and shop.

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.

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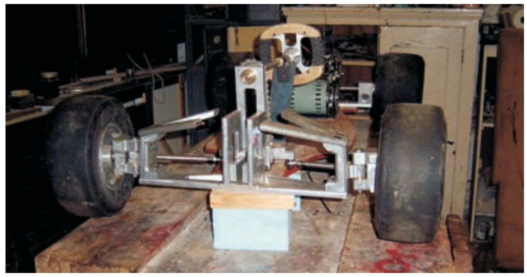
John White's grandson takes the wheel of his electric-powered, scale Ferrari.

Building a grandson's

Formula 1 Ferrari

By John White of Fife,Scotland



Top—The completed chassis prior to receiving its fiberglass body.

Middle—The plug was designed to come apart in sections. Epoxy/fiberglass body parts were laid up directly on the plug sections, then assembled and faired.

Bottom—The component body parts are assembled on the chassis. The Formula 1 is ready for a quick test drive before final finishing and a couple of coats of Ferrari red paint.

When the first grandson arrives, any grandfather knows he now has the chance to fulfil the dreams he had as a boy. A Formula 1 racing car would do for starters. A small model purchased for £4 was the starting point. The car will be ready for his third birthday so plenty of time (or so I thought).

To mold the body parts, a plug was made from large lumps of wood. This took many hours of careful carving, sanding, and finishing to achieve a shape I was finally happy with. Once the plug was shaped, I faired it using WEST SYSTEM® 105/205 thickened with 410 Microlight. Then I coated the plug with several coats of WEST SYSTEM 105/205 to seal the wood and create a gloss finish.

Due to the shape of the plug, it was designed so that it could be separated into various sections. Separate lay-ups or moldings were made over the plug's various body parts, which were then joined together into one final molding and faired to a suitable finish prior to painting. These body moldings were made using WEST SYSTEM epoxy and WEST SYSTEM Episize™ Glass Fabrics. The finished moldings were faired with WEST SYSTEM 105/205/410.

Over the course of the project, the building of a scale model Formula 1 Ferrari quickly changed from just making a child's toy. The design and construction of all the mechanical parts became increasingly complex as did the fitting of them into such a small space. Therefore, the one piece of advice I can offer is that this model should have been to a much larger scale suitable for say a 6 to 10 year old, which would have created much more space inside the moldings for all the electrical and mechanical components.

Many thanks must go to Richard Mace at Marine & Industrial LLP and Hamish Cook and David Johnston at Wessex Resins & Adhesives Limited. ■

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