Penetrations and Closeouts

We look at methods and materials for preventing water intrusion in new cored-panel construction and in retrofits.

by Bruce Pfund

Has the recent coverage of water in core materials—both in *Professional BoatBuilder* and in the consumer boating press—got your attention?

In my experience, water in core materials—whether balsa, any type of foam, plywood, honeycomb, or anything else—is not a good thing. Even if no deterioration of the core occurs, decomposition of microorganisms in the water itself can be enough to trigger big problems for the vessel owner and builder. Boats don't operate in distilled water; lakes and oceans are a living soup of plants and animals; and who knows what's in harbor water?

Have you ever opened up an older cored panel or transom, perhaps to install a through-hull fitting or transducer, only to have quantities of foul water drain out? Did that water smell like PVC foam, balsa, honeycomb, or plywood? If not, it might have had a vague hydrogen-sulfide or "sewer gas" odor, from the decomposition of those microscopic plants and animals common to both fresh- and saltwater boating environments.

The decomposition requires oxygen to start the decay process, and fresh air is abundant—at least temporarily—in the kerf system. A bit of agitation often speeds chemical reactions; hull-rocking at anchor or running in a seaway may accelerate the rate of

And Then There's Baltek Gold

Recent issues of *Professional BoatBuilder* have carried prominent advertisements from Alcan Composites for its new Baltek Gold balsa core, which carries a 10-year limited warranty against rot and deterioration. The ad notes, "Properly laminated skins always kept water away from balsa cores." Although the new Gold-grade product is specially treated to resist fungal decay, Baltek director of marine markets Rob Mazza emphasized that workmanship remains a critical component in the warranty terms. "The warranty," he told me, "is not a license to install core improperly, but rather an encouragement to builders to do it correctly."

Mazza continued, "The warranty is carried by the builder, and backed up by Alcan Baltek. For the first 10 years after a boat is built, any problems with our core are covered, for labor and materials to replace it, for up to three times the cost of the core. After a decade, we cover the cost of core replacement only. To qualify for coverage, the core must be correctly segregated from all skin penetrations, and ideally the kerfs should be filled completely, too."

That comment led me to ask Mazza a further question: What about hand-layup processes, where complete kerf fill is highly unlikely?

The water in the core kerfs of this large motoryacht developed an unpleasant smell and blackened the PVC foam core in less than 18 months. Shown here is a leak into the master head's vanity at a self-tapping screw location.

decomposition by sloshing around the kerf contents. Foul-smelling water draining to the hull or house exterior may be noticed by the crew or maintenance workers, but when it gets inside a large yacht's compartments and the owner notices, there's trouble ahead. In one recent case, such a set of circumstances led a builder to buy back a multimillion-dollar yacht that was in all other respects in almost perfect low-hours condition. More on that vessel, below.

How Water Gets In

How does water from a cored part's exterior get into the core's kerf system? Through a hole, of course. How water gets *in* is only part of the equation; air has to escape *from* the kerfs, too. Strategies for keeping water out of kerf systems will be incomplete if only a single component of the problem is addressed. I'll look at the air side of the wet-core equation in a moment. Let's begin with water.

Imagine this simple model to demonstrate water intrusion into a closed space: a clear plastic drinking straw in a glass of water. Place the tip of your index finger over one end of the straw and immerse the other end in the water. The water rises up into the straw only to the extent that its hydrostatic pressure compresses the air trapped in the top of the straw. Now lift your fingertip and watch the water flood up into the straw, to the level of the waterline in the glass. This basic experiment shows that two conditions are necessary for water to get into an empty space below the waterline such as a core's kerf system: a point of water ingress and a point of air venting.

There may be one or more locations at which water enters the core. And, there may be one or more escape paths for the air in the kerf system to escape as water displaces it. The points at which air gets into the core may both inhale and exhale, which can refresh the oxygen that gets depleted by decomposition.

Note that the air- and water-flow paths in the kerf systems of contour-cut cores may be complex, discontinuous, or in some cases—particularly with flat panels made with kerfed balsa cores—self-sealing. (The tiny slots between the knife-cut blocks close up as the balsa swells slightly when exposed to liquid water; the water can get in, but has a harder time leaving.) Understanding bleed paths and possible locations for water flow or retention becomes even more complicated in areas of "never-bonds"—locations where the core block faces are not effectively bonded to their adjacent skins.

Discontinuous bleed paths often become apparent when a series of exploratory, test-coupon, or drying holes are drilled in wet panels. On one project, I first drilled holesaw rings through the outer skin at approximately 6' (1.8m) intervals, and the drainage rates at each hole were drip by drip. I then drilled another

In my experience, hand layups with regular-grade balsa, with unfilled kerfs, remain in great shape for decades—*as long as water does not get to it*. "One-hundred-percent kerf fill is of course impossible with many build processes," he commented, "but if our core-priming instructions are followed, there shouldn't be any problems. Hand-layup cored construction works fine if it's done correctly, and if panel penetrations are done correctly, too."

I also asked Mazza about holes into cores that come through a hull or deck's inner skin. "Inner-skin penetrations should be treated exactly the same as any other hole through a skin and into the core. Applying some sealant on the fasteners is a good idea, and mounting pads on top of the inner skin an even better one. Inner-skin holes down in the bilges obviously deserve more care and attention than holes well above the waterline." Both Mazza and I are in favor of adhesively bonded mounts and hangers, with no inner-skin penetrations at all.

I asked Mazza if the anti-fungal treatment on Gold-grade core required special precautions during handling or sanding. "It took us quite a while to find a material that's as safe as we wanted. The treatment we developed is noncarcinogenic and nonirritating, but of course," he added, "boatbuilders should always wear respiratory protection when sanding any type of core material."

Mazza's comments about core warranty claims should be of interest to those builders considering a switch to Alcan Composites' Gold-grade material. "When push comes to shove in a warranty claim, we'll look at the builder's construction practices in great detail. If the builder, its dealers, or third-party repairers have failed to follow our instructions for kerf priming, filling, and core segregation at penetrations, there will be no warranty coverage."

—Bruce Pfund

Upper left—*On the cored boat pictured here, the author first drilled holesaw rings through the outer skin at approximately 6' (1.8m) intervals, and the drainage rates at each hole were drip by drip. He then drilled another hole halfway between the first two (labeled 1A), and the aft hole's (#5) drainage rate increased to a steady stream, indicating a discontinuous bleed path between the two original holes.*
Above—*Another through-hull penetration, on the same boat as the upper left photo. Core around the hole had been removed and the hole backfilled—apparently with a glass-fiber-filled putty—but only to a depth of about 3/16" (4.8mm). The putty collar is cracked, as are its bonds to the inner and outer skins—probably caused by over-tightening of the through-hull during installation. Backfilling to 3/4" (19mm) or more would have provided bigger bondlines and improved compressive strength.*
Upper right—*Two 1/4" (6mm) holes were drilled into this contour-cut panel's kerfs, approximately 8' (2.4m) apart. A shop vac was hooked up to one hole, a lit cigarette placed in the other. The cigarette glowed bright red and disappeared about 10 seconds after the shop vac was turned on—a graphic demonstration of cross-flow in an unfilled core-kerf system.*

hole halfway between the first two, and the aft hole's drainage rate increased to a steady stream. It was not until I drilled another hole forward of the original front one that the aft hole began to drain at the same speed as the others.

My interpretation of this is that the partial vacuum affecting the kerf system adjacent to the aft hole was not broken when I drilled the second hole 6′ forward. My drilling the intermediate hole, though, broke the vacuum. Let's return to the plastic-straw demo for a moment. Immerse the open straw in the water, let it fill, then seal the top with your fingertip. Next, withdraw the straw from the water, and note that very little water escapes—until you unseal the straw's top by lifting your fingertip, thereby releasing the vacuum. The fact that the forward hole drained slowly until I punched another hole forward of it indicates a discontinuous bleed path between the two original holes; there was no airflow into this region from core penetrations farther aft.

I observed a similar phenomenon in another boat in which the core passed across the hull centerline, effectively connecting port and starboard bottom panels. The kerf system was totally filled with water from two leaky engine-raw-water intakes—not a big surprise, because they were punched directly through the core. I drilled a 2″-holesaw (51mm) coupon through the outer skin and into the core just to the inner skin on the port side, and water dripped out of the slot. When I made a similar boring into the starboard side, the water flow out of the port side became a steady stream.

Leak-detection work I've done on cored boats has been fascinating—especially when it made sense. Occasionally, though, the results were contradictory and downright baffling. When such work goes as planned, there's a lot to be learned. Sometimes air- and water-flow paths in the kerf system are extensive and easy to determine. If you hook up the vacuum side of a Shop-Vac to a small vacuum bag sealed around a running light mounted on the topsides, and you're able to collapse soap bubbles applied to a hawsepipe cutout 30′ (9m) away, the two are connected.

When tracing a leak, use only gentle vacuum—never air or water pressure. If you're running a vacuum pump, it should have good filtration and liquid-collection systems to protect it from the crud that may emerge from the kerf system. Water-rated Shop-Vacs are usually a safe bet, and draw only weak vacuum levels, but at very high flow rates, which is helpful when there are lots of leaks. Choose leak-detection fluids carefully; some—even certain soapsuds types—may compromise the secondary-bond properties between the core and skin of a sandwich panel.

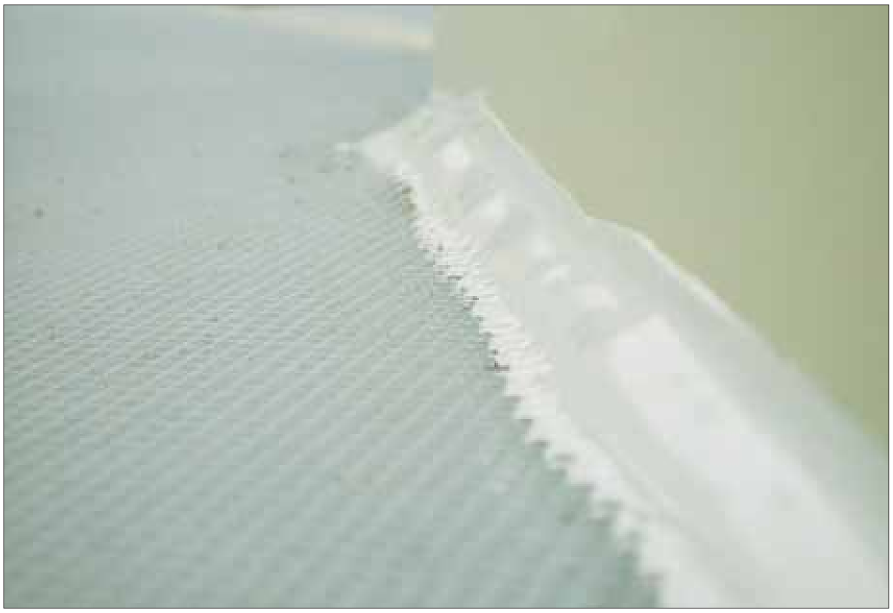
Above the Waterline

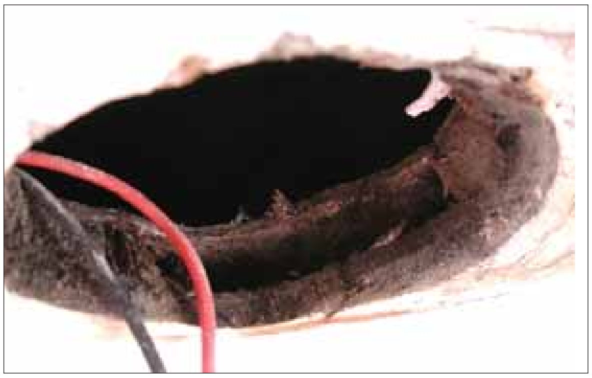
Hydrostatic pressure is not the only force that causes water to enter a core's kerf system. Above the waterline, where hydrostatic pressure is effectively zero, daily heating and cooling from sunlight and shadows, or temperature differences caused by ship's HVAC systems, can also drive water ingress.

Consider a light-colored cored panel in Florida—say, a sailboat's cabintop, which has a slight crown and therefore slightly opened-up kerfs at its core. At the peak of daytime solar heating, the cabintop temperature may approach 140°F (60°C), while at night the temperature drops to about 70°F (21°C)—about a 70°F swing. Let's assume that the cabintop holds approximately 0.25 cu ft (7.08dm^3) of air in its kerfs. If that air expands and contracts just 10%, it will generate significant pressure and vacuum levels inside the panel.

During the course of day–night temperature cycling, the volume of air in the panel's kerf system will expand and contract and try to inhale and exhale through any skin penetrations that connect to the kerf system. Now, imagine a midday shower, where the well-warmed cabintop is suddenly cooled by a heavy rain. In the best-case scenario, the volumetric reduction in the kerf system's air would be equalized by the panel "inhaling" makeup air through inner-skin penetrations. What will happen, though, if the panel inhales through its wet outer skin? Water will be drawn into the core's kerf system.

Water that gets in through the outer skin will drain to the lower surface of the panel and flow away from the point of water ingress. During the next heating and rapid cooling cycle,





Thermal expansion and contraction of air in a cored part can draw water into a core. ***Top—*** *On the author's boat, part of Spring refitting was to scrape each channel of the cockpit sole's nonskid texture, where the console joined the sole. The bead of 5200 would stay adhered to the console surface, but debond from the nonskid surface—even though he acetone-scrubbed it with a Scotch-Brite pad before applying new sealant.* ***Above—*** *Expanding air inside the cored console panel deflected a concave bead of sealant to this convex condition. Once the sealant hardened and was less easily deflected, the same pressure caused the sealant to release from the nonskid. When the air in the console cooled and contracted, water puddled on the sole was drawn up into the core.* ***Above, Right—*** *A bow light was installed at the upper edge of this cored sailboat's topsides. Over the years, water intrusion caused extensive core damage, because the wet core was constantly refreshed with new air as the hull breathed in and out at this high point.*

another gulp of water may be inhaled, and over time enough water accumulates to cause trouble.

Thermal expansion and contraction issues are greatest on dark-colored parts, which of course get the hottest. One European manufacturer has equipped some of its boats with a *non-return* valve. The valve is mounted on a flange. A hole is drilled in the inner skin, and then the flange is adhesively bonded to the hole. The valve exhales only; it will let air out of the kerf system but not into it. The valve helps prevent outer-skin delaminations and bubbles by developing a constant, if slight, vacuum in the kerf system.

I learned about the "thermal pumping" phenomenon firsthand on my own fishing boat. The cuddy console, which was cored with 5″-square (127mm) blocks of ¾″ (19mm) plywood, was tabbed to the cockpit sole only on the inside console faces. The outside surfaces were not bonded, but rather just "sealed" to the sole's nonskid with a thick bead of 3M 5200 polyurethane adhesive-sealant. The problem was that, no matter what I tried, the 5200 never stayed stuck for more than a few weeks at best.

In one of my repair attempts, I scraped and acetone-rubbed the surfaces with a Scotch-Brite pad, and again applied a bead of fresh 5200 to the cleaned surfaces. I ran my filleting tool down the bead to produce a lovely radius, and then went up to my shop for a cup of coffee. The sun was beating down hard on the hull. When I came back about 20 minutes later, my perfectly concave putty fillet had become a bulging convex mess, and in one thin spot had actually popped a bubble through to the surface. I finally figured out what was causing this excellent product to fail so quickly: The air in the spaces between the plywood block core was expanding as the console was warmed by the sun, and that pressure was deflecting the soft bead of uncured 5200.

I then realized what had been happening: after a new bead of sealant had hardened for a few weeks, it was forced off the nonskid. On a nice hot day, a passing shower would go by, rapidly cooling the console and the air inside it, while also depositing a puddle of water onto the cockpit sole. The air in the console core would contract, and since the core's vent to the atmosphere was underwater, that contraction caused water to be drawn up into the core. Did I mention that attaching cored consoles to decks with this method is not one of my favorite construction details?

Fasteners

Returning to the yacht with the foul-smelling interior: the water in the kerf system reached the vessel's interior through hundreds of self-tapping screw penetrations through the inner skin. Some were for securing furniture

Left—*The builder of the sailboat pictured here adhesively bonded the attachments for tie-wraps, but drilled hundreds of holes into the inner skin to secure wood trim slats throughout the boat's interior. It's unlikely that water will enter the kerf system though the screw holes in the topsides, close to the hull-to-deck joint. Some of the holes, though, will serve as vents for the kerfs—half the equation for water movement through the kerf system.* ***Center top—****These stainless steel mounting flanges, manufactured by Bighead, are equipped with perforated bases for adhesive bonding to composites. With the proper high-viscosity, fast-setting adhesive, installation is often place-and-forget, with no clamping or fixturing required.* ***Center bottom—****Every wiring-harness hanger location on this sailboat had integrally infused foundation blocks of solid core material. The fastener and pilot hole were correctly sized to penetrate the foundation only, and not the hull's inner skin.* ***Right—****Fresh out of its blister pack, this #10 self-tapper had contaminants—thread-rolling and cutting lubricants—on the threads (the black bands on the cloth, corresponding to the threads, came off on the cloth with a wipe). These contaminants can compromise the bond between fastener and sealant.*

and joinerwork; others, for pipes, ducts, wiring harnesses, headliners, and upholstery. Murphy's Law proved true once again: not all the fasteners went into core blocks; enough of them penetrated the kerf system to let kerf water drain through the inner skin into multiple interior living spaces and belowdeck compartments. Surprisingly, some leakage also was occurring around the gland nuts on the interiors of a number of through-hulls—a strong indication that the core had not been closed out at those locations.

How can air leakage be prevented at fastener penetrations in a cored panel's inner skin? First, a dab of some sort of sealant on the fastener's threads would be helpful—at least for as many years as the sealant survives in its bilge, engineroom, or cabintop environment. How about self-tappers with some sort of hot-melt adhesive or two-part epoxy on the threads? The adhesive gets activated by the friction and heat the fasteners generate when installed. Hot-melt-treated nails and staples are common in home construction, so why not something similar for boatbuilding?

Even better, don't penetrate the inner skin at all. Adhesively bonded pads for securing hardware and lightweight mechanical and electrical equipment, and fast-acting two-part adhesives to go with them, are already available. Some pads accept tie wraps, while others are configured with studs or tapped tubes to accept bolts or machine screws and act as small-equipment foundations. So far, though, I have seen only a few small- to medium-size cored boats built with this innovative technique, where everything from insulation to wiring harnesses and air-conditioning ducting was hung from bonded-in-place fasteners on the inner skin and bulkheads. Gluing is more expensive and time-consuming than screwing, but will result in a cored panel with a long service life.

There's another approach worth considering, especially if the components are to be infused. It's relatively simple to add small local taper-edged pads of plain core, covered with one or two small laminate patches of compliant reinforcement, in way of harness- and systems-attachment points. The pads are then

Scuppers and drains should be treated the same way as cored-panel penetrations below the waterline. This scupper tube was laminate-taped on the inside, but only puttied and painted on the outside. After five years in service, it was surrounded by a wide margin of wet and rotted core.

co-infused with the laminate. As long as the correct-length pilot drill and self-tapper are run into the pad, the primary structural inner skin and core of the panel will not be penetrated. Of course, it's possible that someone will use a drill depth-stop setting or self-tapper that's too long. Nevertheless, it's a technique that can work well in certain projects.

I have written before on the topic of dirty fasteners, but it bears repeating here: the world's greatest caulks, sealants, and bedding compounds cannot be expected to seal effectively to dirty fasteners or substrates. In my experience, most "new" fasteners are actually quite dirty, and usually dirty with exactly what you don't want on a bondline surface—hydrocarbons, in the form of thread-rolling and -cutting lubricants applied during fastener manufacture.

To test this for yourself, all you need is a new fastener and a clean paper towel with a bit of solvent on it—alcohol will do just fine. Spin the new screw a few turns in the damp section of the paper towel, and then take a look. Any color change or crud you see on the paper towel, if left on the fastener, will compromise the effectiveness and longevity of whatever product you select as a thread sealer.

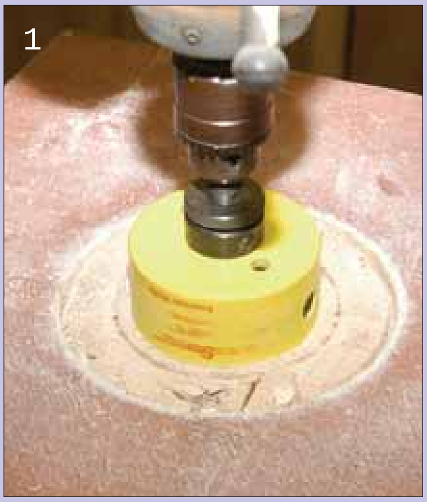
Methods for Closing Out the Core

I recently visited the North Yard of Pilot's Point Marina; in Westbrook, Connecticut, where I spoke to Brian Lenahan, head of composites and carpentry, about his shop's methods for making penetrations in cored panels, on new construction as well as retrofits.

• *Backfilling.* Lenahan and I agreed that backfilling the cut edge of a cored panel can be a very effective way to close out the core. We also agreed that most backfilling efforts fall far short of optimum. In visiting Lenahan's shop in Building 2 at the North Yard, I had noticed a wide vari-

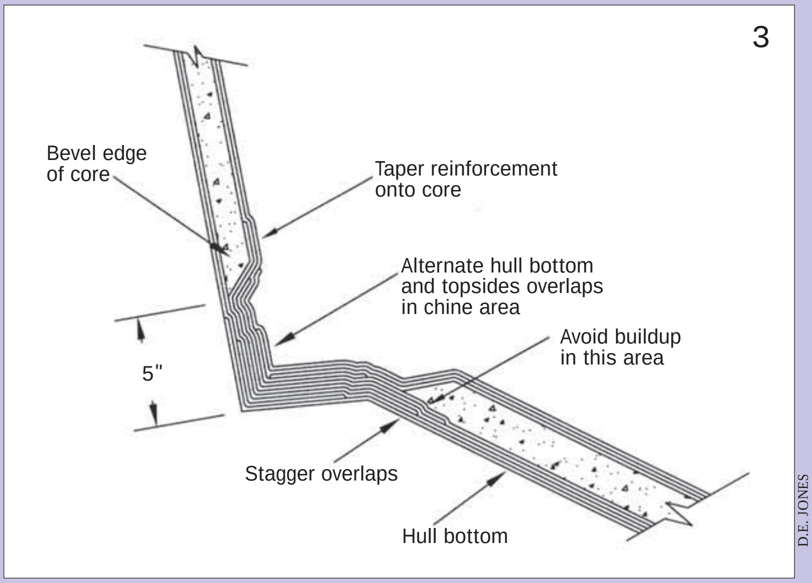
Of the region undergoing core replacement, three sides have outer-laminate overhangs that trap 3" to 6" (76mm to 152mm) of core. The laminates were left in place so the repair's scarf zones would not run around the transom corner, destroy the molded-in cove stripe, or enter the solid-laminate region at the hull centerline.

The numbered images here and on the next page illustrate the sequence of steps involved in closing out the core at a through-hull penetration by bringing the skins together. Brian Lenahan, head of composites and carpentry at Brewer Pilots Point Marina (Westbrook, Connecticut), demonstrates each step.



ety of hand and power tools that he and his colleagues were using to reef out dead wood and foam core materials from sandwich panels being repaired or retrofitted.

"Please," Lenahan asked me, "don't photograph those. They're pretty dangerous. But, they do get the job done for us. Excavating core is a time-consuming pain in the neck, especially when we're relaminating a part or a hull and have to leave wide margins of bad core with laminate still on it, so that the scarf zones connecting old boat with our repairs fall



***1.** Drill a ¼" (6mm) pilot hole through the sandwich panel. Then, holesaw the inner skin and core. For this step, switch to a smooth ¼" drill rod for the holesaw's arbor, or turn the arbor drill around in the holesaw, so the alignment hole in the panel's outer skin does not get chewed up by the drill's flutes. Using the largest holesaw required, cut the inner skin and pop the laminate disc off the core. Next, make a series of concentric holesaw cuts through the core, just to the outer skin, to make the core easier to remove. Do not drill the bore for t he fitting at this time. Only a ¼" (6mm) hole should penetrate the outer skin. Take care when cutting the core and levering out the pieces on thin-skinned panels. It may be safer to rout or grind away the core if the outer skin is delicate. **2.** The seacock flange shown here is approximately 4" (102mm) in diameter, so the solid-laminate disc should be a minimum of 5" (127mm) in diameter. Including the putty fillets for the 1" (25mm)-thick core, the largest holesaw required for this procedure measures about 7" (178mm) in diameter. **3.** Diagram of a cross-section through a chine showing inner and outer skins brought together to close out the core. Note fillet strips along core edges, tapered transitions, laminates overlapping onto core edges, and plenty of room to work. Stopping the core well away from the chine prevents core bridging, and also produces a thick, solid laminate in way of an area that often gets point-loaded by support stands and blocking.*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__4.__ Grind away any core material left behind on the inside surface of the outer skin. Avoid overheating the laminate, which could cause a color change or dimple in the exterior paint or gelcoat. __5.__ Special tools can make the filleting job much easier. This bevel-squeegee was made from ⅛" (3mm)-thick polyethylene sheet stock, but could just as easily have been razorknife-cut from a plastic putty spreader or piece of Formica. __6.__ Prime the core edge and laminate with catalyzed vinyl ester resin. Using a paint-stirring stick, pack the bevel region with a low-shrink, low-exotherm, BPO-catalyzed polyester-based filleting putty. (The author advises against making your own with laminating resin and MEKP catalyst or core-bonding putty.) Then, sweep the squeegee 360° around the hole, making a uniform putty bevel. __7.__ Remove both inner and outer pieces of masking tape immediately after the last sweep of the fillet squeegee, before the putty begins to gel. __8.__ In this sample, two layers of 1808 stitched bi-ax with mat were required to match the original laminate schedule. Lenahan cut two concentric discs, one approximately 4" larger in diameter than the other. He cut four darts in each disc, but offset them 50% to prevent any gaps in the laminate patch. He laid these plies down into the filleted recess largest ply first. __9.__ Lenahan inspects the completed closeout, after covering the wet laminates with six wedge-shaped strips of untreated peel-ply, followed by bubblebusting through the peel ply. He tapered out the repair laminates onto the original inner skin to reduce the amount of finish grinding needed. __10.__ The finished core closeout in cross-section, sanded to 320-grit and painted with clear nail polish. Note the neatly tapered overlaps and edges of the laminate patch, and how little filling and grinding will be required to complete the cosmetics of this panel penetration.

This three-bladed cutter's ball-bearing standoff collar can be switched from side to side, so that core can be reefed out of bore edges from one side only. It's important not to tilt the cutter too much, or it will dig into the laminate.

in the right places."

Lenahan pulled a three-bladed fly-cutter head (**above**) out of his tool cabinet and explained that he liked it for cutting away core material around through-hull bores holesawed through hulls and decks. "This one isn't too spooky to use. I can run this cutter on my high-speed router, cordless electric drill, laminate trimmer, or air-operated sanders and grinders. With the three chipper teeth, it jumps around a lot less than a two-blade flycutter. It removes about ⅜" (10mm) of core back from the hole's edge when the ball-bearing spacer bushing on the arbor hits the sidewall of the hole." Lenahan switches the ball bearing from one side of the cutter to the other to track the inside and outside skins of the panel, and noted that after the first pass with this cutter he then sometimes switches to a bigger one to remove about another ⅜" of core depth, creating a backfill zone approximately ¾" (19mm) deep.

When as much core as possible has been removed, Lenahan then switches to an angle grinder with a backing pad small enough in diameter to fit into the bore. He aggressively grinds both core bondline surfaces with a coarse abrasive disc. Both he and I had used the trick of selecting a flat metal disc for the grinder's backing plate, instead of a rubber one with only one flat side. We then put two sanding discs on it, one facing up, and one down, on either side of it. With this setup you can prep both surfaces inside the sandwich panel with access from only one side.

Before backfilling the cavity with a low-slump putty, Lenahan prefers to thoroughly wet the core material's edges and the faces of both laminates with neat catalyzed resin or epoxy resin and hardener to maximize sealing to the core surface. The putty is typically made from epoxy resin and slow hardener, thickened with Cab-O-Sil or glass microballoons, and troweled into place, with special effort devoted to forcing the putty into open kerfs. Both Lenahan and I had unhappy experiences with shop-made polyester or vinyl ester resin–based

A core closeout for a lightweight Marelon composite fitting and valve, built into a vacuum-bagged, wet-preg, cored hull. Note the concentric laminate patches and their offset darts.

putties that got too hot during exotherm and cracked or discolored the adjacent gelcoated surfaces. With the wide range of specialized polyester- and epoxy-based low-shrink and low-exotherm putties and catalyst/hardener systems available today, there's no reason for this problem to occur. We both like to mask around the hole before primer and putty application. If that's carefully done, no further sanding or grinding will be required before the fitting is installed.

• *Bringing the skins together.* This method is also appropriate for new construction or retrofit. During new construction, the closed-out area is created by applying tapered edge strips of core material around the location's perimeter. Lenahan did not have a cored boat in his shop that needed a new through-hull. So, to illustrate closing out the core by bringing the inner and outer skins together, we used a balsa-cored test panel about one sq yd (0.8m^2) in size that I had in my shop. The panel's core was 1″ (25mm) thick, the skins about 5⁄32″ (4mm) thick. We did use a drill press, which wouldn't be practical for a retrofit, but if you substitute a handheld drill big enough to spin a

At Boston Boatworks, where vacuum-bagged wet-pregs are the standard, through-panel penetrations are closed out to a single skin with tapered edge strips of core and additional laminate patches. The inside surface is ground after application of interior finish to ensure a flat landing for the through-hull's gland nut.

holesaw, you can duplicate our procedures in the field.

Lenahan and I decided that we wanted at least ½″ (8mm) of solid laminate out beyond the perimeter of the seacock's flange for our demo installation of a bronze through-hull and direct-attached seacock valve.

Next, we masked off the panel to prevent putty smear-out onto the back of the outer skin and the inside skin's interior surfaces. This step takes extra time, but is worth the effort. Putty built into the solid laminate in way of the fitting obviously compromises the integrity and seal of the new laminate stack onto the original skin, and putty on the inside skin's bonding surface also degrades the strength of the secondary bond attaching the new laminates to the original laminates.

Making the two big sections of masking tape takes just a few minutes with a "knife compass," and is a great time-saver overall. It's especially nice when working inside an existing boat. Putty smeared on the closeout region can be removed by grinding, but what a mess that will make. Careful masking nearly eliminates the need for sanding.

Note the white disc at the center of the closeout in **photo 9** on **page xx**. Said Lenahan, "I have a good inventory of plastic discs of various sizes—cutouts from various projects made from polyethylene, Starboard, or Sintra material. I like to fit one that's slightly larger than the fitting's mounting flange into the closeout, and then squeeze it down into the wet laminate by using a through-bolt from the inside to the outside. Starboard is so slimy that we don't need release agents when using epoxy. With other materials, I'd use Mylar tape and wax, or some PVA. The disc guarantees a flat surface for the fitting's flange and sealant to register on. If you used a carriage bolt, with the head's flats registering into the outer skin [which will later be holesawed away], you could tighten this setup all by yourself, from only one side, and you wouldn't need to recruit someone from another project to help out."

• *Burying a piece of solid material.* If it seems like too much trouble to bring the skins together, or if you're not exactly sure of the precise locations of panel penetrations, laminate in an oversize hunk of solid core material in the area of the penetration. Plain foam cores of urethane, PVC, or SAN formulations are common in this application.

As illustrated by the preceding two photographs, page X and X, core closeouts made during original construction or during retrofit are nearly identical in appearance. When inspecting composites, I prefer a core closeout to a buried piece of solid material, which can be hard to identify without disassembly. If you do choose to laminate-in a solid piece, I suggest using a bevel-edged solid block slightly thicker than the surrounding core. It looks good, and is easy for an inspector to interpret.

Solid core inserts, core removal and backfilling, or bringing the skins together in way of cored-panel penetrations are reliable, time-proven methods for preventing water from reaching core materials. For fasteners that penetrate a cored part's inner skin, a dab of sealant on each carefully cleaned fastener that penetrates a part's inner skin is at the low end of the quality spectrum. I prefer dedicated, laminated-in fastener pads and rails, or adhesively bonded pads and foundations.

There's nothing particularly special about the materials or skills required to make high-strength, watertight holes in sandwich panels, just "a willingness to spend two to four times as much time on making a proper cored panel penetration as our competitors down the river," as Steve D'Antonio at Zimmerman Marine (Cardinal, Virginia) told me. "Most of the time," he added, "customers don't understand why making a radar mast or davit foundation is so expensive in our yard versus the competition. Modifying cored construction, when done the right way, takes longer. We wouldn't do it any other way."

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