ShopTalk

Vacuum Bagging Basics

Vacuum bagging small fiberglass panels provides a higher strength-to-weight ratio compared to hand layup and produces a good finish on both sides. It's the ideal method to fabricate anchor lockers, hatches, tables and other small panels.

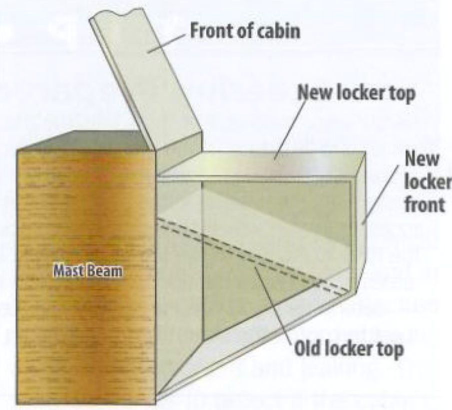
Story and photos by
Diane Selkirk and Evan Gatehouse

The anchor and fender lockers on "Ceilydh," a Wood's Meander 40' (12m) catamaran built in 1987, had begun to rot. Assembled from a combination of painted and fiberglass -coated plywood, the light construction and poor drainage had proven to be inadequate for the heavy use required of an anchor locker. Additionally, the size of the lockers made them too small for our ground tackle. So, rather than just rebuilding them from better materials, we decided to completely redesign the lockers for multi-purpose use.

The new lockers were designed to be bigger and have better drainage. Located in the middle of the boat, these lockers are in the optimal location for heavy objects. Catamarans are more sensitive than monohulls to excess weight in the ends of the boat, so we decided to use some of the increased space for a new diesel fuel tank. During the design process, we also realized the lockers could double as comfortable foredeck seating and we incorporated this idea into the design.

Using our design drawings, we prefabricated the locker panels. Prefabricating the panels allowed much of the work to be done in a controlled environment off the boat and meant that the build time in the boatyard was reduced. Although this was a relatively small project, all the panels were vacuum bagged. The bottoms of the lockers are subject to wave impacts and the extra strength of a vacuum bagged, cored panel are benefits.

When deciding if vacuum bagging is suitable for a project, consider the following pros. Vacuum bagging is the best way to securely bond the core of a fiberglass sandwich to the skins. It provides an excellent strength to weight ratio because of the higher glass-to-resin ratio and produces a good finish on both sides of the panel. As for the negatives associated with vacuum bagging, small parts are time consuming to fabricate due to the extra work involved in vacuum bagging. It's also more expensive than a standard hand layup because of the additional cost of vacuum equipment and supplies. The technique carries risk of partial failure if you don't get your vacuum bag in place before the resin begins to gel or if you have a vacuum bag leak that you cannot find. All the cons aside, this method was the best solution for our anchor lockers.



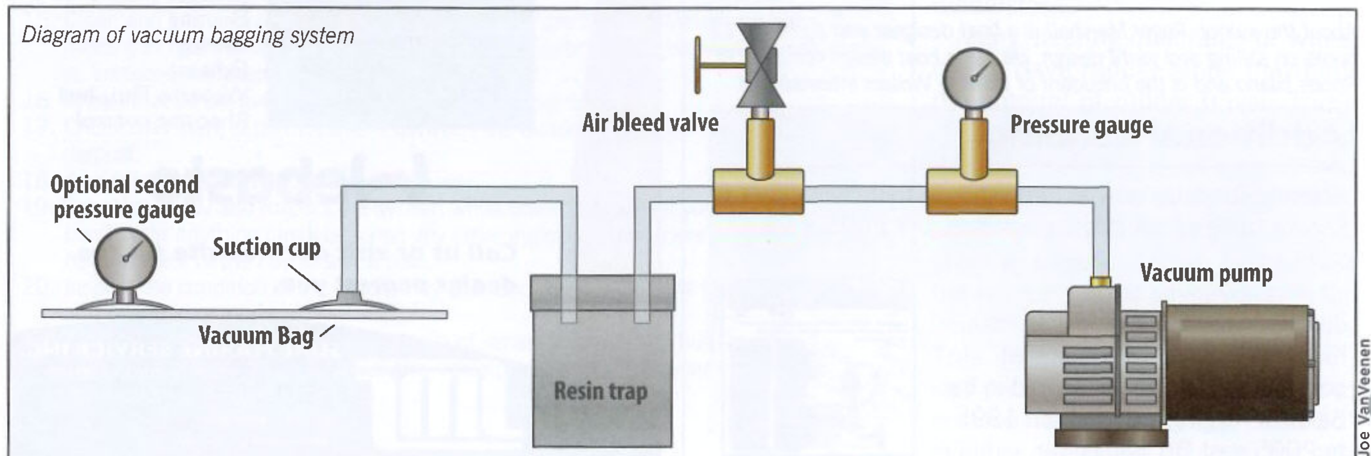
Anchor locker cross-section diagram compares old to new locker volumes.

Layup Prep

We began the layup process by testing our procedures. Before any resin was wet out or the table was waxed, we stuck down some sealant tape and some foam core. We did a trial bagging operation to see where there were leaks and then learned how to fix them. Then, we did a second test run by laminating a non-essential piece. Vacuum bagging requires a bit of practice, so experimentation and test runs help ensure the outcome is successful.

For the lockers, we used a flat mold surface. We marked out the outline of each part on mold table with an indelible marker. Using this outline, we used an Olfa fabric rotary cutter to cut the fiberglass fabrics that formed the skins and then used a utility knife to cut the shape from the Corecell foam core. If the core is not predrilled, it must be punctured to allow air to escape from the outside reinforcing skin. We drilled holes every 3" (75mm) apart, about 1/16" (1mm) diameter.

Diagram of vacuum bagging system



Mold table with outline of a panel written on the table with indelible marker to act as a cutting template for fiberglass fabric and other vacuum bagging consumables.

Waxing the mold table with several coats of wax.

Typical laminate stack: (right to left) mold surface, inner fiberglass skin, foam core, outer skin, peel ply fabric, breather bleeder layer and clear vacuum bag.

While we prepared our supplies, we had a helper wax the mold table with a carnauba mold release wax. Five or six applications were required for the first part, one or two for further parts from the same table. Waxes need to harden for a few hours between coats so we allowed two days for this step.

We then used the following weight ratios and weighed out our fiberglass materials to determine the amount of resin needed for the correct fiber to resin ratios: mat 35% fiber to 65% resin; woven roving or woven cloth, 45% fiber to 55% resin; stitched uni-directional/biaxial type fabrics, 50% fiber to 50% resin and precoating balsa core, 0.5 oz/ft. sq. (150 g/sq. m) resin. Here are a few example calculations: 12oz of mat = 12oz x (0.65/0.35) = 22oz (624g) resin; 24oz of biaxial = 24oz x (0.50/0.50) = 24oz (680g) resin.

Bagging Technique

When we were ready to begin, we cut out the vacuum bag plastic, the peel ply and the breather/bleeder layer. The vacuum bag needs to be at least 12" (300mm) wider than the part on each edge. The other layers were cut to the size of the part. We applied a 1" (25mm) wide outline of masking tape to the mold surface, about 6" (150mm) away from marked outline of the part. This protected the area where the sealant tape will go from epoxy drips.

(top to bottom) Any excess bag material requires a pleat; To form a pleat in a vacuum bag apply a short amount of sealing tape to the perimeter tape, inside the pleat, then fold over the top of the short length of sealing tape; seal the bag against the short length of sealing tape, pinching it off at the top; seal the bag against the short length of sealing tape at the bottom corner; finished pleat.

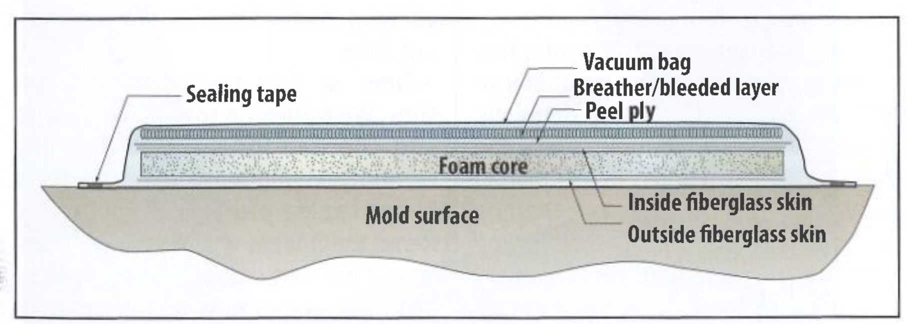


Diagram of laminate stack and vacuum bagging materials.

(top) A panel under vacuum. The red fabric is peel ply; the quilted white polyester breather/bleeder material is on top. (bottom) Another flat panel under vacuum. The excess resin is coming through the laminate stack and is being absorbed by the breather/bleeder material.

Common vacuum bag leaks are due to (top) bag not pressed against the sealing tape; (middle) leaks at top of pleat and (bottom) and a leak point at corner.

Next, we laid the outside skin against the mold table. While most people use a first layer of 3/4oz (225gm/m^2) mat against the mold to prevent print through of the reinforcing fabric layers, we used a thinner mat "surface veil" to minimize weight of the panels. Next, we added the primary reinforcing fiberglass, a stitched 20oz (666gm/m^2) triaxial E-glass. The triaxial fabric was wet out by pouring a large amount of mixed resin directly on to the fabric, which was spread out with a plastic squeegee. This was much faster than brushing or rolling with a roller.

We then precoated the core with resin, to seal the open pores. We did this well before placing it on the wet resin of the outside skin; otherwise the core could absorb excess resin from the lay-up and leave us with a resin starved fiberglass skin. When using polyester, an additional layer of mat is required before the core but, because we used epoxy, with its superior bonding ability, this was not required.

For these flat panels, we found it possible to laminate the outside skin, core and the inside skin in one operation. We used a resin with a long working time and ensured that the ambient temperature wasn't too hot. Alternatively, we could have vacuum bagged the outer (mold side) skin and core in one operation and used vacuum or hand layup for the inner skin, after the outside skin and core had cured.

The first layer against the core or inner fiberglass skin must be peel ply or perforated plastic film. We used peel ply because it was easier than punching a lot of holes in a plastic film. Then, we unrolled the breather/bleeder layer on top of the peel ply, putting an extra layer of this material where the vacuum hose would attach in the middle of the part. Parts larger than 30 sq.ft (3 sq.m.) require additional vacuum connections.

Next, we removed the protective masking tape around the perimeter of the part and unrolled a strip of mastic sealant tape onto the mold where the masking tape protected it. We placed the vacuum bag over the part. Starting at one corner we removed the backing paper from the sealant tape in short sections and stuck down the vacuum bag, pressing down the vacuum bag firmly onto the mastic tape and putting in pleats along the edge. Pleats are required with a polyethylene plastic bag because the flat plastic has to form a three-dimensional surface over the thicker part.

We made an "X" shaped incision in the middle of the bag about 1" long with a utility knife and affixed the vacuum suction cup with more sealant tape.

Now, we were ready to apply pressure. We turned on the vacuum pump and checked for leaks by listening carefully. While leaks almost always happen at the pleats, other places we found them were where a single fiberglass fiber was caught under the sealant tape, as well as at the vacuum suction point.

Starter Kit Makes Vacuum Bagging Easy

When used with a conventional air compressor, the West System 885 Vacuum Bagging Kit (US$181.30) contains everything needed to complete repairs or laminate projects up to 13 sq. ft. (1.2 sq.m). The kit includes a venturi vacuum generator, vacuum gauge, tubing, connectors and three vacuum cups, release fabric, breather fabric, vacuum bag film, sealant tape and an instructional booklet. The venturi generator develops more than 20 inches (mercury) of vacuum (10 psi) and has an operating range of 40 to 100 psi. Contact: West System at tel: 866/937-8797; web: www.westsystem.com.

We fixed all the leaks. Since we had a bigger vacuum pump, we could have ignored a small leak, but it was easier to try to get them all. Locating the vacuum pump outside the workspace can make it easier to find leaks because it will be quieter. Some vacuum pumps are oil lubricated and give off an oil mist. We used a hose connected to the exhaust port on the pump to vent the mist to the outside air.

Once all the leaks were found and fixed, we monitored the vacuum level, with 12" to 15" (0.4 to 0.5 bar) of Mercury about optimum. Too much vacuum sucks out excess resin from the part; too little is insufficient to create a good bond with the core. We adjusted the vacuum level using a tee connection to a bleed air valve. This allowed the pump to suck in a little extra air to reach the desired vacuum level. As the vacuum level increased, we often saw resin coming through the peel ply into the breather/bleeder layer in small spots. This was extra resin from the outside laminate coming through the holes in the core.

After the part cured overnight or longer, we removed the vacuum bag, breather/bleeder layer and peeled off the peel ply. The peel ply layer would occasionally stick firmly to the part and required pulling on it quite hard to allow it to release. To release the part from the mold, we used thin wooden shims that we taped between the part and the mold. The parts would often release all at once with a loud sound.

When all locker pieces were completed they were transported to the boat. The old lockers had been cut away as part of a larger project and the boat was located on the hard.

Assembly

The anchor lockers run between the hulls and attach to the front face of the mast support beam. First, we attached two long panels that formed the bottom of the locker to the mast beam and sides of the hulls. We temporarily supported these panels in position with 2x4 props.

Installing new panels with 2x4 props holding them in position.

After grinding off old paint from the hulls and wiping down the surfaces to be fiberglassed, we filleted and taped the inside seams of the lockers to the hull and the mast beam with two or three layers of 12oz (340g) biaxial fiberglass tape. When the epoxy had cured, we removed the props and fiberglassed the external seams. Each fillet was formed with a mixture

Lockers under construction. (top) The vacuum bagged panels have been taped to the existing cabin structure and some fairing compound has been applied to the seam. (bottom) New locker panels and partitions fiberglassed in place.

of epoxy thickened with microballons and colloidal silica. We used a plastic squeegee cut into a 1/2" (12mm) radius as a tool to form the fillets into a smooth shape before applying the fiberglass.

Once the bottom panel was solidly glassed, we fiberglassed three internal, vertical dividers to the 13' (4m) long locker. This divided up the locker into spaces for the propane tanks, two separate anchor rodes and a fuel tank. The locker top forms the base of new forward seating.

New fuel tank being installed in locker.

About the authors: Evan Gatehouse is a naval architect and mechanical engineer, with extensive experience in composite boat design and boat mechanical systems. Diane Selkirk is a freelance writer and sailor with stories and photos published in a variety of magazines. Together they are completing a total rebuild on "Ceilydh," a Wood's Meander 40' (12m) catamaran.

Composite Materials at a Glance

Mat: A random collection of short glass fibers held together with a binder. Conforms well to tight curves and also provides a smooth resin rich surface for the outside skin of a molded part. Usually available in 3/4oz and 1.5 oz/ft^2 (225 gm/m^2 and 450 gm/m^2).

Cloth: Tightly woven fiberglass that is light and also drapes well. Often used as the last layer of a laminate. Available in weights from very light 1.5 oz/yard^2 (50 gm/m^2) to the more common 6 to 9 oz/yard^2 (200 to 300 gm/m^2).

Woven roving: More loosely woven heavy fiberglass to add strength and thickness to a layup.

Stitched fiberglass fabrics: Available in unidirectional, biaxial, triaxial and quadraxial construction. Layers are stitched together with thin threads. Since the fabric is not crimped by the weaving process, the resulting fabric is considerably stronger than plain woven fiberglass types. These fabrics are the best choice for boats where weight is important. Biaxial weaves are very effective for taping pieces together.

Kevlar/Aramid: Where impact resistance is important, Kevlar is often used. This golden colored fabric is very strong but is difficult to work with. It tends to float in resin due to its low density, requires special scissors to cut and, when sanded, it forms a fuzzy surface. It is also quite low in compressive strength compared to fiberglass and is expensive.

Carbon fiber/graphite: Where high strength and stiffness is important, carbon fiber can be an excellent choice. This black colored fabric can be worked similarly to fiberglass. Its primary drawback is high cost but small amounts can be integrated into a structure where strength is most important.

Core Choices:

- SAN foam (e.g. Corecell) is most costly but very tough and resistant to impact and easily worked with woodworking tools.
- PVC foam like Divinycell, Herex and Airex are often about 20% less costly than Corecell and still a good choice for most applications.
- Balsa, the cheapest option and a good choice where compressive strength is important but is also the heaviest option. Where hardware will be through bolted, builders should use higher density cores.

[Ed: DIY recommends installing hardware in cored laminates using the potting technique as outlined in DIY 2005-#2 issue.] Builders should not use styrofoam or polyurethane insulation foam because their shear strength is not sufficient.

Resin Options:

- Ortho/iso polyester resins are the commonest type of fiberglass resin available. Offering low cost and working ease, these are the best choice where material properties do not have to be high.
- Vinylester resins are a nice compromise between the low cost, low material strength of ortho/iso polyester resins and the high cost, high strength of epoxy resins. They have similar working properties to polyester resins.
- Epoxies have the highest costs but the best material strength. They are the best choice for bonding to already cured and properly prepped fiberglass parts and are the best choice for vacuum bagging where weight is critical. Epoxies are much stiffer and have a higher elongation to failure ratio, both qualities that make them a better choice for high strength and stiffness parts. They also offer very long working times.

Showcase your Boat in Readers' Boats

You don't have to be a writer to have DIY's audience read about your boat. Just send us a complete description of your boat — point form is okay — along with photos. Include details of any repairs or upgrades and if available, provide a breakdown of materials, costs and labor. If published, you'll receive a DIY HANDS-ON BOATER 1995-2005 CD-ROM (value US$99.95/CDN$119.95).

(See page 64 for additional description.)

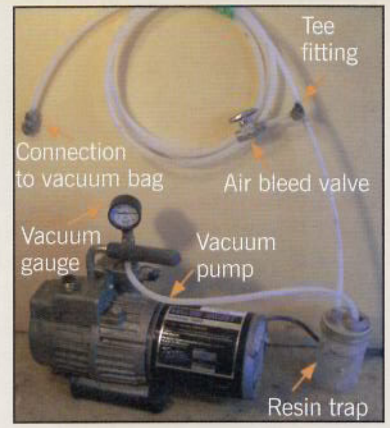
Email your boat information and photos to Jan Mundy at: ***tech@diy-boat.com***

Or Snail Mail to:

In the U.S.: DIY boat owner Magazine, P.O. Box 1072, Niagara Falls, NY 14304

In Canada: DIY boat owner Magazine, P.O. Box 118, Lindsay, ON K9V 4R8

DIY Materials List and Costs



Vacuum pump equipment.

- Central to the vacuum bagging process is the vacuum pump. The size of the laminate pieces and the amount of material being laid up will determine requirements. We were able to purchase a 6 CFM, 29" Hg, HVAC technician type used for $150 from eBay.
- Airtight mold surfaces need to be built in the shape of the pieces to be made. The mold surface can be Formica, melamine-covered particleboard, glass, smooth metal, etc. We purchased old, discounted sheets of Formica and glued them to a plywood substrate. We also used melamine-covered particle board and found that gave an acceptable surface finish with less expense and preparation. Cost: $22 for a 4' by 8' (1.2m by 2.4m) sheet of melamine-coated particleboard.
- We chose flat Corecell foam core because our parts were not curved. You can purchase predrilled core but the cost premium is often enough to make it worth doing yourself. Knife slit cores, used for curved parts, have air passages that allow air to escape as well and do not require drilling. Cost: 1/2" (12mm) thick Corecell core, 4' by 8' (1.2m by 2.4m) sheet for $125.
- Specialty mold release waxes are available from fiberglass supply houses. Car waxes can contain silicone, which will contaminate the surface and hinder future painting. Cost: $18.
- The vacuum bag is the final layer in a vacuum bagging operation and forms an airtight seal against the mold. We used rolls of 4-mil lightweight plastic sheeting that are available from hardware stores. Cost: $10 per roll.
- The breather/bleeder layer performs two functions: it absorbs excess resin that bleeds through the peel ply and it also doesn't compress fully so vacuum pressure is distributed evenly to all parts of the part. Common breather/bleeder layers used are bubble wrap and polyester batting quilting material. We used polyester batting because we have seen bubble wrap leaving small dimples in the finished part of other vacuum bagged projects. Cost: $2 per yard.
- Peel ply prevents the other layers from sticking to the part. We used sale priced Ripstop nylon from a fabric store. We used many different types and never found any release issues. Commercial peel ply is more costly and is essentially the same material, though it may be treated to release more readily. Cost: $1 to $2 per yard.
- We used stitched triaxial 20 oz (666 gm/m^2) E-glass from V2 Composites (web: www.v2composites.com), as we were also using it elsewhere on our boat project. However, it only sells whole rolls so other vendors should be consulted if you need smaller amounts. Cost: $8 per yard.
- We used Jeffco 1310-L6 resin and 3155 slow hardener. This had a working life of a few hours when mixed in one gallon (3.78L) batches and, with an ambient air temperature in the 60F (15.5C) range. It's only available in 5 gallon (19L) pails so you'll need to contact suppliers for slow or extra slow hardeners if using smaller quantities. Cost: $50 per gallon.

Note: Prices in Canadian funds. Divide by 1.10 to convert to U.S. dollars.