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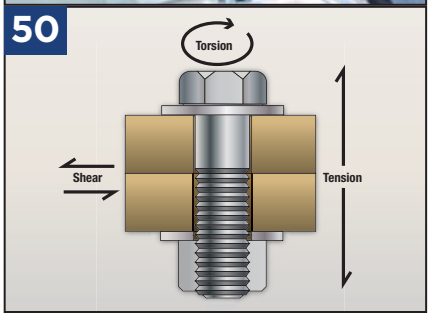

HOME

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UPDATED

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A guide to expanding, upgrading, surveying and troublshooting your boat's AC and DC electrical system. All articles follow ABYC Standards.

UPDATED

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The complete guide to painting and refinishing hulls, topsides and decks with marine coatings.

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How to prepare your boat for spring launch and winter storage. Includes lay-up checklists, maintenance and lubrication guides, engine servicing, haulout guidelines, easy-to-build storage covers and more.

UPDATED

Marine Equipment Installations

Here's how to choose, install and operate equipment for your boat including: air conditioning and heating systems, audio systems, bow thrusters, davits, lightning protection, propane systems, refrigeration, windlasses and more.

UPDATED

Fiberglass Boat Repair

How to survey, repair and prevent cosmetic and structural damage in fiberglass hulls, decks and transoms. Includes the step-by-step repair of minor cracks and gouges, large holes, water-soaked decks, delaminated hulls and proper installation of hardware.

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DIY BOAT OWNER
THE MARINE MAINTENANCE MAGAZINE

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Currents

Edited by Jan Mundy

Big Changes at DIY

DIY subscribers will note some changes with this issue. The big news is that DIY Boat Owner magazine is now part of the Boat Owners Association of The United States, better known throughout the recreational boating community simply as BoatU.S.

Headquartered just outside of Washington, D.C. in Alexandria, VA, BoatU.S. is an association of 670,000 boat owners and a worldwide consumer services organization with a 40-year history of providing many unique and invaluable services for boat owners. Having founded this magazine 11 years ago on the belief that much of the pleasure in boating is directly related to your involvement with and responsibility for your boat's safe operation, condition and maintenance, we came to the realization that it was time to ensure that this publication survive for the next generation of boat owners.

We are certain that our long held vision to inspire, challenge and empower readers with the value and satisfaction of maintaining, servicing, repairing and restoring their boats will fit right in at BoatU.S. where members are treated with a level of customer service that is legendary in the marine industry.

Of course, change is never without a few small adjustments. And so, with this issue, gone are the drilled holes, a time and labor-intensive task (expense) loathed by our printer. If you are a DIY reader who likes to keep every issue in a binder, the good news is that inexpensive plastic sleeves are available that will do the job better. For the price of a Big Mac you can purchase these three-hole punched plastic edge strip magazine holders for ring binders at Amazon.com in a package of 12 — enough for three years worth of DIY Magazine (just type in, "magazine strips"). These handy strips allow you to easily slip your issues into a three-ring binder and best of all, the magazine pages are much easier to turn than the old-fashioned way of sticking a three-hole punched magazine into an inflexible three-ringed metal binder.

We've also redesigned our logo to reflect a more modern design and we're planning a few more changes in the months ahead to make the magazine more reader friendly.

However, while you may notice a few changes in style, we can assure you that the guts of DIY Boat Owner will remain the same for years as we continue producing this magazine with our new colleagues who have long been responsible for producing "BoatU.S. Magazine," the largest circulation boating publication in the world.

Even so, our commitment to you remains the same. Every facet of DIY magazine will continue to focus on being a primary source for repair and service technology for amateurs as well as professionals. As our readers know, DIY is not a magazine of opinions nor is it a one-way editorial stream. Rather, the information contained within these pages is based on accepted marine industry practices and ABYC standards and readers can interact with the editorial team via Ask the Experts ("Ask the Experts" column) or submit boat-tested tips ("Tech Tips" column) or nifty projects ("DIY Projects" column).

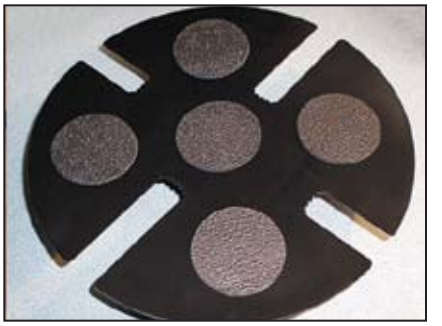
In short, we urge you to continue on this journey with us and to share what we offer with your friends. We are confident that this change is for the best.

— DIY founders Jan Mundy and Steve Kalman

Do it like a Pro

For many years, DIY's editor has conducted boat maintenance seminars at various boat shows. "Four Steps to a Shiny Hull" (it's actually five steps) is one of more popular topics and, over the years, DIY has helped countless boat owners restore their oxidized fiberglass hulls using professional techniques. It's not unusual for attendees to visit DIY's booth at later boat shows and present photos and discuss their success stories. DIY reader Wayne Brown of Kemptville, Ontario, emailed us his reaction: "I'm the guy you coached over the phone through the gelcoat restoration techniques you demonstrated at the boat show last year. Just wanted to let you know, I finally completed the work on our 1989 Cadorette 280 that has a powder blue accent stripe and it looks amazing! It's everything you promised. Thanks very much for your skill and patience."

A Firm Grip



Inexpensive and reusable bottom cap prevents sliding action of wooden supports on slippery decks.

Shrinkwrap is one of the most effective means to protect boats from the ravages of weather during storage periods and is relatively easy to apply. (For step-by-step installation instructions refer to the article in DIY 2003-#3 issue.) One drawback is the 2x4 wooden uprights used to support shrinkwrap covers. These can (and do) slide on decks and fall over, allowing water, snow and ice to pool in the cover. Since shrinkwrap supports up to 258lb per sq. ft., pooling can be hazardous, possibly damaging the cover and the boat.

Dr. Shrink's (www.dr-shrink.com) new Non-Skid Bottom Caps (US$1.98), solve this problem. Reusable caps slip over the base of a 2x4 and are constructed exactly as the company's End Caps, which fit on top of support poles to prevent poking through the wrap, except these Bottom Caps have non-marring, non-skid pads on the underside that offer friction and stability to keep uprights in place.

Fuel for Thought

"How does rising fuel prices affect your boating activities?" was the question recently asked on DIY's online poll. Of the four choices listed, 44.7% selected that fuel prices had no affect with responses indicating the same usage as last year; 21.6% reduced their boating by 50%, 18.9% opted for more anchoring and less cruising and 14.7% reduced their boating time by 25%. To enter DIY's current poll log onto www.diy-boat.com.

Of Tee Handles and Oil Damped Gauges

In the article titled "Diesel Fuel System Modifications" in DIY 2005-#4 issue, the author, Alan Donn, states, "the Racor gadget that integrates the compound gauge into the cover's tee handle isn't recommended because it can't be isolated in the event of a physical wipeout." In the system he discusses in the article, does he not recommend using this tee handle gauge or this type of gauge in any case? My single engine boat has the engine serviced by a dual Racor 75500MAX2 with a built-in gauge and a generator serviced by a Racor 500MA2, which doesn't have a gauge in the system. I want to add a gauge to replace the stock tee handle to monitor the filter in order to determine the best replacement time. Does he recommend the tee handle replacement gauge in my situation? Also, are my Racor gauges oil-damped as he recommends?
Paul Weakley via email

Alan Donn replies: The gauge available from Racor is built as an integral part of the cover closure tee handle assembly. One of the sources that I researched as I was writing the article pointed out that in the event of a physical impact that broke the gauge or tore the pipe threads adrift from the connection, there was no way to isolate the gauge and restore fuel tight integrity to the system. This seemed like good worst case design thinking so I passed the observation on in my article and put gauges in the system using a tee connection with an isolation root valve (shown in the photos) so that the gauges could be isolated if necessary. The Racor approach is just to tap the closure handle for 1/4" pipe thread and to add the gauge. You could probably use the Racor accessory as a starting point and add a close nipple and valve between the closure and the valve, but then you get into issues of overhead clearance and a lot of junk attached to the closure handle, which is not a very elegant solution. The ideal system, of course, is to have a differential pressure gauge that measures the pressure drop across the filter and provides inlet and outlet pressure sensing taps with isolation valves and sensing lines to the gauges. Unfortunately, this arrangement increases the system complexity beyond reason. Observation of the normal running pressure at the filter outlet (it will probably run at a slight vacuum, hence the need for a duplex gauge) should be an easy part of the safe management of your power plant's fuel filtration. Also, periodic observation of the filter outlet pressure (increasing vacuum) should give ample warning of the need to change the filter element. You do need some indication of filter outlet pressure and an oil-damped compound pressure/vacuum gauge with 2-1/2" face, fed through 1/4 ips needle valve, is perfect for the job.

To determine whether Racor gauges are oil-damped, just look at them. To achieve the damping effect, the gauge body is filled with a viscous medium, usually mineral oil or glycerin. The presence or absence of the damping fluid is pretty obvious. My experience with undamped gauges (a little cheaper) is that the action of the engine injection pumps precipitates pressure pulsations throughout the system that cause the undamped gauges to be in a constant state of agitation. Though still possible to eyeball an average reading, it was obvious that the undamped pulsations would soon cause fatigue failure of the bourdon tube sensing elements of the gauges. Engineering knowledge is always expensive to acquire; the undamped gauges are now serving as chart weights.

Corrected Silicone

In the DIY 2005-#4 issue article on recaulking cabin windows, you suggest using Dow Corning 759 glazing silicone to do the job. I have tried to get that product without success.
Jacques Charest via email

DIY replies: This is our error. The popular glazing silicone is Dow Corning 795 not 759.

DIY BOAT OWNER
THE MARINE MAINTENANCE MAGAZINE

DIY Boat Owner™
The Marine Maintenance Magazine™
2006-#3

P.O. Box 22473
Alexandria, VA 22304

Publisher: Michael G. Sciulla
Executive Editor: Elaine Dickinson
Editor: Jan Mundy
Associate Publisher: Steve Kalman
Technical Editor: Patricia Kearns
Circulation: Susan Clark
Designer & Illustrator: Joe VanVeenen
Cover: Photo by Jim Discher.
Contributors: Steve Auger, Nick Bailey, Susan Canfield, Tracy Croll, Jim Grant, Lee Mairs, Roger Marshall, John Payne

DIY Boat Owner™ and **The Marine Maintenance Magazine™** are registered trademarks. DIY Boat Owner is published quarterly. ISSN 1201-5598

Director of Advertising: Steve Kalman
888/658-BOAT (2628)
Advertising Email: stevek@diy-boat.com

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Subscription Inquiries:
Call 888/658-BOAT (2628) weekdays 8am to 6pm EST or log onto DIY ONLINE @ www.diy-boat.com

Subscription Rates:

1 year (4 issues)	$25
Canadian residents	add $5
Foreign residents	add $25
Payable in U.S. Funds only	
EZINE (web version) 1 year	$15

Periodicals postage paid at Alexandria, VA, and additional mailing offices. POSTMASTER: Send change of address to DIY Boat Owner, P.O. Box 22473, Alexandria, VA 22304.

PRINTED IN USA

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Drain Plug Quiz

Most small runabouts have a drain plug. Some are threaded into a socket, others are the common rubber expandable type. When preparing our cartopper to launch for a family outing I was chastised by my sister for placing the drain plug on the wrong side. "It always goes on the inside," I was told. "How else do you drain out the water when underway?" Trying to be humble, I retorted: "It only makes sense to have the plug inserted from the outside so that hydraulic pressure helps hold it in place. No one would dare pull the plug while underway to drain water!" My righteousness soon faded as I realized that I didn't truly know the proper placement of a drain plug. I needed to dig deeper into this matter so I checked my position with DIY's standards keeper, Pat Kearns.

Plug location depends on hull type and location. There ain't no law!

My first surprise: There are no absolutes about drain plug position and neither the USCG nor any other legislative body takes a position on the subject of the "ins or outs" of plug insertion. A plug can be inserted or removed from the inside or the outside of the transom, of course, depending on access to the drain fitting. The USCG and American Boat & Yacht Council (ABYC) both do require that all boats with expandable type drain plugs have flotation foam so they don't actually sink, drain plug or not. My second surprise: ABYC H-27 standard references the use of drain plugs but not their placement. The standard stresses the need for a watertight attachment to the hull and that the fitting be "constructed to prevent the plug body from loosening when the plug is inserted or loosened for draining" and that "expandable type plugs shall be adjusted and designed to prevent inadvertent disassembly."

Plug openings are always below the waterline. If you remove a plug when underway to dewater boarding seas (or leaks), the boat automatically self-bails as long as it's moving through the water. This is common procedure with small sailboats and RIBs that don't have a true bilge. On a runabout there's the added risk of not fully seating the plug when reinserting. The pressure of water slapping against a hull from the outside could push in a loose plug (inserted from the inside of the boat) and the boat could be flooded. Surprise number 3: There are no U.S. requirements for recreational boaters to have pumps or any other kind of "dewatering" device such as a bailer. Nope. It's true. Really, it is. On the other hand, boaters in neighboring Canadian waters must carry a bailing device or a bilge pump, a requirement that varies depending on the size of the boat. Bailers can be had off the shelf in a marine supply store or made by cutting off the spout top of a plastic jug. In any case, bailing a small boat of accumulated water is far less risky or complicated than pulling the plug.

Of course, this discussion is irrelevant for larger boats that typically have drain plugs that thread into a fitting and tightened with a wrench. So, what's the right or wrong of inserting the drain plug? You tell me. If you have a runabout with a below-the waterline drain plug, send me your experience via an email to tech@diy-boat.com

— Jan Mundy

Outboard 100 Years Young

By the early 20th century, rowing (or paddling) and sail were still the primary means of propelling a boat. Cameron Waterman, a Michigan lawyer, was the first inventor to successfully market a portable gasoline engine to propel rowboats and sold the first 15 Waterman Porto outboards in 1906. Ole Evinrude joined the competition to develop small boat engines in 1909 and his 62lb (28kg), 2 hp single cylinder engine sold for US$62. A year later, Evinrude sold 1,000 engines and outboard power was off and running.

— ABYC

Off-Season Pump Prep

It seems that, with every fall winterizing ritual, we forget to prepare some component for the impending cold weather storage. Last year, we failed to service the Flojet 2840 washdown pump. Residual water in the pump froze and cracked the housing and switch. Pumps aren't cheap and fortunately, pump manufacturers offer replacement parts kits for all components. This repair required the purchase of an upper housing assembly kit and a new long-life 40 psi pressure switch. The entire job, including remounting the pump, took about an hour.

Using a 5/16" socket, loosen the four hex bolts holding the upper housing assembly. As I was also replacing the pressure switch, it wasn't necessary to first remove it from the old housing. Remove port clips and lift off the old housing. Ferrules (rubber cones) fit tightly around each bolt and make if difficult to separate the upper from the lower housing. Insert the bolts in the new upper housing and reattach to the lower housing. Be sure the ferrules are properly seated in the housing, cone side first. I found it was easier to thread the bolts through the housing and ferrules and then snug down each bolt before fully tightening all. Be sure port clips are on the top side. Use a Phillips screwdriver to attach the two screws that hold the pressure switch to the upper housing. Wire one of the red (positive) wires to the existing pump red wire and the other red wire and black (ground) connect to the boat wiring. Snap on the protective cover and it's done.

(top) Running plumbing anti-freeze through this washdown pump would have prevented the upper housing and switch from freezing and cracking, a condition that wasn't evident until the first use the following spring (bottom).

Repairing freeze damage to this washdown pump required about 60 minutes and a few hand tools, a replacement switch and upper housing assembly kit available from the manufacturer.

Included in the upper housing kit are replacement check valves, ferrules, hex bolts, sealing discs and port clips not required for this repair but good to keep in your spares kit.

Threading bolts through the housing and rubber ferrules made reassembly easier.

New upper housing assembly and pressure switch installed on pump.

Wire ends are stripped in preparation for remounting pump.

Pump reinstalled. Note heatshrink tubing over wiring connectors used to prevent corrosion and electrical shorts.

DIY's Product Info Winners

Need more product information? Just use DIY's product information request at www.diy-boat.com and you're automatically entered to win one of three Sta-Bil Fuel Stabilizer.

The three winner's in DIY's Product Information Card Giveaway from DIY 2005-#4 issue who received a 3M Marine Mildew Stain Remover are: Gerald Farmer, Sebasco Estates, Maine; Brian Strong, Annandale, Virginia; and Vincent Sutton, St. Catherines, Ontario.

When you need information from marine manufacturers, log onto DIY's website at www.diy-boat.com and click on "Marine Product Info." This automatically enters you into this issue's draw for Sta-Bil Fuel Stabilizer.

Knowing Overboard Maneuvers

Going overboard is every recreational boater's worst nightmare. In 2004 alone, nearly 200 lives were lost to falls overboard. However, if someone does go over the side, a crew that knows the most effective rescue methods and has the right retrieval gear will improve the chances of making a quick rescue.

At the Crew Overboard Rescue Symposium, held August 9 to 12, 2005 on San Francisco Bay, 115 volunteers conducted almost 400 tests of 40 types of rescue gear and many maneuvers. Testing was done on 15 sailboats and powerboats of nearly every type (including multihulls) in conditions that ranged from flat seas to 35-knot gales. Using volunteer "victims" who went into the water, testers addressed the challenges boaters experience in a recovery, such as the best way to make contact with the victim, methods for bringing a victim back on deck, ways to rescue an unconscious victim and whether swim platforms help or hinder a rescue.

A free copy of the final report, authored by nautical journalist John Rousmaniere and a member of the event's organizing committee, is available for download at www.BoatUS.com/Foundation. It includes information keyed to different types of power and sailboats involved in a recovery. Also included is a lessons learned section with comments from symposium organizers. The symposium was co-sponsored by the BoatU.S. Foundation, West Marine and the Modern Sailing Academy, a Sausalito, California, sailing school.

Sacha

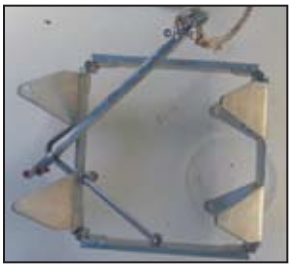
Neat Boating Stuff

DIY looks at some nifty products you might find at bargain prices at fall boat shows.

Edited by Jan Mundy

Hooked on the Box Anchor

You're not supposed to toss or heave the anchor into the water, rather you gently lower it into the water, though there will come a time when every boater needs to drop the hook fast. This is one anchor that you can hurl and it takes hold every time immediately on impact in almost any bottom. DIY first tested this anchor last fall and now, after a full season of use, we attest it's the best anchor for all-purpose anchoring on protected waters (e.g., inland lakes, streams, etc.). The ground-busting Box Anchor from Slide Anchor (www.slideanchor.com) is different from conventional anchors. It's big and boxy but it folds flat for storage, comes in a durable oversize vinyl storage case and is simple to use. Just unfold it and lock the spring-loaded stabilizing arm. There is no top or bottom to this anchor. The angled flukes bite into the bottom to wedge the anchor in place and also scoop mud, rocks and grass into the "box" to add to its holding power. Traditional anchors typically require an anchor line to water depth ratio (scope) of 5:1 to 8:1, depending on conditions. The Box Anchor needs only a 2:1 scope and has set instantly with as little as 10' (3m) of anchor rode in a water depth of 6' (1.8m).



Built tough of galvanized steel and stainless construction, the angled "jaws" bite instantly into most bottoms no matter how the anchor lands.

The Box Anchor folds flat for compact storage in the supplied heavy-duty vinyl carrying case.

We like how the Box Anchor sets quickly and holds fast in weeds but don't like the cleanup on retrieval.

For reassurance when anchoring, even with this anchor, we always reverse the engine until the rode is taut and then play out the standard scope before securing the rode. You also don't need a chain leader with this anchor, unless you want to compensate for ground swell. Should the anchor slip due to wind or current changes, it resets at once. Even a vertical pull directly above the anchor won't cause it to pull out. To retrieve, pull the rode in the opposite direction and the anchor comes out as easily as it set. Available in four sizes for boats up to 40' (12m), prices range from US$109.95 to US$229.95. You'll truly appreciate the on-the-spot setting and holding power of the Box Anchor when anchoring in strong winds or in a crowded anchorage or as happened to us, when the engine dies in the harbor and you need to stop quickly.

Effective PVC Cleaner

From the folks that offer Ultimate Sole (www.ultimatesole.com) comes Ultimate Red Cleaner (22oz/650ml for US$14.95), a one-step cleaner for inflatable boats, fenders, lifelines, power cords and other PVC gear that always seem to attract dirt and grease. Just spray on, let sit for a few minutes, scrub lightly and hose off. It's a very effective product as these photos demonstrate. Protect skin and eyes when using and don't splash on eyeglasses as this product will remove coatings and destroy lenses.

Exceptionally "greasy" 20-year-old PVC cowl that I had intended to replace.

Spray on, let sit for a few minutes, wipe off with a soft cloth and rinse.

Like new vent after a single application.

Never Lose Keys with a Key FD

An flotation device (FD) for your keys!

If you've had that sinking feeling watching your keys sink to Davey Jones' Locker, you'll appreciate why Key Buoy key ring from Davis Instruments (www.davisnet.com) was awarded an Innovation Award at this year's annual marine accessory trade show (MAATS). If keys fall into the water, this flotation device pops open and an air tube automatically inflates within 30 seconds, carrying the keys to the surface. The 14" (355mm) long air tube is a bright orange color and maintains buoyancy for about 40 minutes. Key Buoy lifts keys or lightweight tools weighing up to 4.2oz (119g). For one-time use only, this device is inexpensive insurance (just US$6.99) against a more weighty loss.

Water Pump Controller

ITT Jabsco took the brain from its variable speed drive water pressure pump and packaged it in the Smooth-Flow, giving boaters an affordable way to upgrade older water pressure systems.

If you are waiting for your boat's existing water pressure pump to fail before upgrading to a new variable-speed pump that automatically adjusts to water pressure and water temperature without an accumulator, your wait is over. ITT Jabsco Smooth-Flow water pump controller is an

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• TIP •

Boat Shield

To provide a protective barrier from UV rays, dirt, salt and other harmful environmental elements during the off-season, thoroughly clean your boat with a non-wax removing marine cleaner. Follow with Interlux Teflon Sealer thinly applied to the gelcoat above the waterline and smooth (not the skid-resistant areas) areas on the deck and cockpit and painted surfaces. Coat all metal parts and plastics as well. Teflon Sealer is different from any other product on the market. Unlike waxes that provide short-term gloss and protection and require extra elbow grease to apply and buff, this revolutionary product chemically cures to a hard, slick, non-stick surface that seals and protects. Best of all, it applies easily with a soft cloth and buffs with little effort. When applied over a wax, it more than doubles the life of the wax. DIY tested this product last spring when I applied one coat of Teflon Sealer over Interlux Teflon Marine Wax. One application completely filled the gelcoat pores and gave a baby bottom smooth finish that continues to repel dirt and grime five months later. Be sure to reapply in the spring after washing and waxing for all-season protection.
— Jan Mundy

affordable fix (US$99 compared to US$279 for a variable speed pump). This device converts most 12- or 24-volt water pressure pumps, operating between 30 and 65 psi and rated at 3 to 12 amps, into a sensor-controlled intelligent system. By maintaining the water pressure (e.g. 40 psi), it provides a smooth and pulsation-free water flow and also eliminates the loud plumbing "hammering" and on-off cycling, which results in hot and cold surges (and cursing during a shower). Easily retrofitted, Smooth-Flow comes with all hoses and fittings and installs inline on the discharge side of the pump in about 45 minutes.

Ventilate, Don't Suffocate

Boat covers offer protection from Mother Nature but, with little air circulation, musty foul odors and mildew build up. Invented by Mike Pontones, a boater looking for a solution to hours of spring-cleaning, the Bilge Wizard (www.bilgewizard.com) ventilates a boat's bilge at the lowest source — the transom drain plug. No tools or drilling are required for installation. A fan unit inserts into a 1/2" (12mm) drain plug hole and is powered by a 5-watt solar panel (AC adapter is optional). The fan apparently exhausts air and vapors at a rate of 2,000 cubic feet per hour. Besides exhausting foul air, Bilge Wizard (US$179.99) also safely eliminates concentrations of potentially dangerous fuel vapors. The brushless fan eliminates possible fuel sparks and the nylon housing prevents static electricity build-up, which could ignite fuel vapors.

Solar powered bilge ventilator eliminates the foul stuff from lack of air circulation that collects in a covered boat.

ASK THE EXPERTS

Helpline info@diy-boat.com

Gauge Exchange

Q: I plan to replace the original engine gauges on the flying bridge of my 1988 Mainship Nantucket with either Faria Chesapeake or Teleflex Driftwood gauges. The engines are 454 cu. in. 350-hp gas engines. Will these new gauges work with the existing sending units? I also want to replace the fuel gauge that has a switch to toggle between two gauges so I can see both tank levels in one glance. Is this feasible with a simple rewiring of the switch out of the circuit and direct wire to each individual gauge or do I need to stay with the current setup?
John Haverstock, Slidell, Louisiana

A: Almost all marine gauges operate on the same principal. They are gauged to read signals from 0 through 120-ohm analog senders. These senders read on a continuity to ground ohms scale. For example, a water temperature gauge reads a very low temperature when the sender has an ohms value near 120. This gauge reads hotter as the sender reacts to the coolant temperature of the engine and the resistance of the sender starts to drop towards 0 ohms. This also applies to fuel, water pressure and oil pressure gauges. You can likely replace your existing gauges with modern units without changing the senders. (Note: tachometers must be set to the correct number of cylinders to read correctly.) As for installing dual fuel gauges, remove the switch and run a dedicated signal wire from each fuel sender to the "S" terminal on each separate gauge. The correct color of a fuel sender wire is pink. Dual station boats require special senders designed to supply accurate information to dual station gauge set-ups.
— Steve Auger

Help for Flush Odors

Q: We recently purchased a like-new 2001 Doral 360 with just 20 hours on the engine. The previous owners never left the dock and we have reason to believe they never used the VacuFlush toilet system. We've noticed very strong head odors outside the boat after each flush (no smell inside the head compartment). We've added the "blue stuff" in the system to alleviate the smell but so far to no avail.
Wayne Brown, Kemptville, Ontario

A: The toilet system was probably used at some point and the holding tank has been sitting with waste in it. The decay of this effluent has caused the holding tank to have an anaerobic condition, which causes a strong smell in the tank. When you use the VacuFlush toilet a large amount of malodorous air is pushed out through the vent fitting on the hull. Either of two methods can fix the problem. Have the holding tank cleaned out to remove solids that may have solidified on the bottom. Then install a holding tank vent filter that removes any odors from exiting the vent. If you don't want to clean out the tank, install the vent filter and continue to use holding tank chemicals and they may break down the solids over time. Adding a vent filter solves the immediate problem. Before you purchase a new filter follow the vent hose from the tank to the hull to see if there is one already in the line. If this is the case it may just need the cartridge replaced.
— Mike Starito, Northeast Sanitation (www.northeastsanitation.com)

Vetus No-Smell filters contain an odor-absorbing material and mount in-line in the waste holding tank vent hose.

Alwgrip Vs. Imron

Q: My 24' (7.3m) Maine boat is dark green and the finish is nicked and scratched. I want to have it refinished by a professional and I'm getting information that Imron is a better bet than Awlgrip as scratches can be touched up or even buffed out. What do the pros say? Any other comparisons I should know about?
Bob Goldson, Milton, Massachusetts

A: Both Imron and Awlgrip can be touched up and repaired by an experienced professional. There are, however, significant differences between these two linear polyurethane (LPU) paints. These particular brand names also happen to be the best-known examples of the two main classes of LPU coatings: the acrylic polyurethanes (Imron, Awlcraft 2000, Interspray 800, PPG Concept, Sikkens Yachtcryl) and the polyester polyurethanes (Awlgrip, Interspray 900, Sterling, etc.) Both acrylic and polyester LPU coatings produce a beautiful wet-look shine. The chief difference is that the polyester version yields a harder, more weather- and UV-resistant finish so boats stays glossy longer with Awlgrip than with Imron. Many smaller shops recommend the acrylic LPU because it's a lot easier to work with, especially if they don't have a dedicated paint booth. An acrylic LPU dries faster and, because it's a softer paint, it's easier to perform the after-the-fact buffing required to force a temporary gloss onto a mediocre spray job full of dust and dull areas. Awlgrip, on the other hand is quite unforgiving and it's a lot harder to get good results in marginal painting conditions. In our yard, we use Awlgrip for major work in our paint booth where conditions are ideal and use acrylic urethanes for smaller jobs (boot stripes, transoms) in our main shop and at our service docks where bugs and dust are a factor. Both types can be repaired by spraying a patch or brush touch-up and then wet sanding and buffing to blend it with the surrounding finish. Special blending additives help. One of the biggest problems in repair work is color matching and our experience is that an Awlgrip hull color stays stable and fade-free longer than an acrylic. This means it's

more easily matched years later with a stock color fresh out of the can. Because of the extra hardness of the coating, the Awlgrip repair is a bit more difficult to buff and blend but not dramatically so for an experienced technician.
— Nick Bailey

Diagnose Engine Miss

Q: The twin 305 V-8 engines in my 29' (8.8m) Chris-Craft run great but after 20 minutes or so at cruising speed, the starboard engine starts hesitating. Wires, cap, rotor, module, plugs, fuel pump and fuel lines have all been replaced and the carburetor checked, too. Any ideas? The engine doesn't hesitate until it warms up.
Mike Lennon, Stuart, Florida

A: Electrical or mechanical problems are the two possible causes of an engine miss at operating temperature. Check for correct ignition timing. Your engine has a maximum timing of 30° btdc at 4,000 rpm. Also, check for too low voltage at the coil. When tested with a multimeter, voltage should read a minimum of 14.5 volts for electronic ignition, 10.0 volts for a point ignition systems. A low reading means a new ignition resistor wire is needed. Other electrical causes include: a bad alternator, key switch or circuit breaker, incorrect spark plugs, cracked coil, distributor cap or rotor, too much resistance in spark plug leads, or a shorting tachometer. To test the tach, remove the gray tach wire from the negative side of the ignition coil and run the engine. Mechanical causes include: a crankcase over-filled with engine oil or use of automotive engine oil (replace oil with correct amount of marine engine oil); defective fuel system anti-siphon valve or damaged fuel supply system (test by running engine on a remote outboard fuel tank); too high, over 150F (65.5C), engine operating temperature checked at several locations on the block using a laser pyrometer; low compression or excessive cylinder leakage beyond specs (no less than 110lb (50kg) compression and no more than 20% cylinder leakage); and lastly, a restricted exhaust as seen in collapsed hoses and broken water shutters blocking off the exhaust.
— Steve Auger

Short Circuiting AC

Q: My sailboat's Cruisair reverse cycle air-conditioning system runs 12 hours or so before ice builds up on the condenser and the system starts putting out warm air. It's then shut down, left to thaw for several hours, turned on and runs cold again. Is this caused by a faulty installation? The air intake and exhaust grills are mounted about 4" (101mm) apart.
Alain Solari, Ottawa, Ontario

A: The problem you're experiencing is caused by either dirty screens in the air intake ducts, which reduces air flow or, if these are clean, it's a problem with the original installation. The air supply needs to be as hot as possible; the hotter the better the condenser operates. With the grills being so close together, the system is drawing in cold air and not enough hot air. This results in reduced heat transfer out of the coils so they get cold and form ice. Relocating the exhaust air ducts should resolve this air short-circuiting problem.
— Jan Mundy

ASK THE EXPERTS

Helpline info@diy-boat.com

Why Not Tar

Q: I'm doing some blister repair on my boat, applying Interprotect 2000, and want to finish using VC17m antifouling. Can I apply this paint directly over the Interprotect or do I need to prime using VCTar?
Marc Faubert, Gatineau, Quebec

A: Jim Seidel of Interlux replies: Interprotect has a very fine orange peel finish that is undetectable when overcoated by antifoulings, most of which are applied at about 50 microns dry film thickness (DFT) per coat. VC17m, however, goes on at about 8 microns per coat so it doesn't cover the orange peel, you don't get as smooth a surface and you don't get the advantage of the Teflon. You can apply VCTar over Interprotect 2000E but, in thin films, it may blister between the VCTar and the Interprotect. I usually recommend applying enough Interprotect 2000E to a thickness of 10 mils DFT and then apply one additional coat. Let the final coat cure overnight then sand with 220 to 320 wet or dry paper to smooth the finish and apply the VC17m.

A Case for Black Oil

Q: The oil in my 20-year-old Yanmar 20MF is always black. I change oil, start the engine, check the oil and it's black. Should I be concerned?
Scott Wagner, Elgin, Illinois

A: Your engine suffers from the same ailment as all marine engines. When changing engine oil you, like all boaters, draw out the oil through the dipstick using a suction pump of some kind. Depending on the quality of the pump you likely only suck out up to 60% of the "dirty" oil. The remainder stays in the oil pan. Your engine holds .5 gallon (2L) of oil. How much oil are you drawing out and how much are you putting back? A good pump will remove about 51oz (1.5L) of oil. That leaves 17oz (500ml) of dirty oil in the engine. Of course, this assumes that you always bring the engine up to operating temperature before changing oil. As long as hot, thick, dirty oil stays in the

Black oil identifies the residue remaining from out-the-dipstick oil changes.

engine, the minute you start the engine, this oil circulates, mixes with the clean (new) oil and you again have black oil. The only means to remove all dirty oil is through the drain plug and access to that is rare on most boats. These plugs are just too low in the engine sump to position a collection container underneath or to connect a hose that will drain the oil pan completely without risking spillage.
— Jan Mundy

Servicing Fuel Lines

Q: I have a 20-year-old Carver 28 with twin 220 Crusaders and I'm in the process of replacing the fuel lines and valves. I'm not sure where to place the anti-siphon valves. The configuration is two tanks, twin engines and two three-way valves so either engine can run from either tank or both tanks and both engines from one tank. My problem is that the gas line drains after a day or two and it takes forever to get the engines started; no problems if I restart the same day. Also, is it okay to use Teflon tape or PTFE paste to seal the threaded ends? Is it normal practice to use two hose clamps per connection or is one okay? Is the anti-siphon valve spring loaded, depending on the suction of the fuel pump to open the fuel line? Could debris in the fuel tank prevent the valve from seating, allowing siphoning? Do you think the existence of an anti-siphon or lack thereof would cause hard starting? Is the problem in the fuel pump and/or carb or the 3-way fuel tank selection valve?
Bruce Bittenbender, Malvern, Pennsylvania

A: Original fuel system components on a boat of this age should be ready for replacement so congratulations on your proactive maintenance program. Leaks in the fuel supply system cause hard starting as the fuel supply system runs under vacuum. Too many restrictions in the fuel supply cause vapor lock and lack of power at speed. I suggest that, in addition to new tank selector valves and anti-siphon valves, you install new fuel tank pickups with debris filtering screens. Ensure that new flexible fuel lines are USCG approved (marked as USCG Type A-1 or SAE J1527, which is the test standard relied upon by the Coast Guard) and are the required minimum of 3/8" (9mm) inside diameter (ID), though 1/2" (12mm) ID hoses are even better. I double-clamp all flexible fuel line connections though this is not required by any code or standard with exceptions to the connections for the fuel tank fill hose and hose used in the engine exhaust system. Mechanical anti-siphon valves are usually installed into the fuel tank pickup fitting, if they are required at all. There are, by design, other ways to meet this requirement, such as keeping all parts of fuel distribution and return lines above the level of the tank top from the tank to the carburetor inlet or its equivalent, (e.g., throttle body, port fuel injection or a location where fuel leakage cannot enter the boat when the boat is in its static floating position). Mechanical anti-siphon valves have a ball seated with a light spring that opens the valve when it's under the vacuum created by the engine's fuel pump. The valve can leak if obstructed or worn out. Electronic anti-siphon valves are better but more

All gasoline-carrying hoses used in marine fuel systems must, by law, meet U. S. Coast Guard (USCG) requirements. Besides the USCG type marking (type A or B), SAE or UL rating, labeling on gasoline hoses also includes: classification of resistance to fire ("A," fire resistant; "B," no fire test required); and fuel permeation, either "1" which is the requirement for minimum permeation for gasoline distribution and return lines, or "2," a less-stringent requirement commonly used for gasoline fuel fill and vent hoses because these hoses do not normally hold fuel continuously.

expensive. Never use Teflon tape on any fuel system fittings; instead, use a non-fuel soluble sealant, such as Gasolia, available from marine repair shops.
— Steve Auger

Humming Chatter

Q: I installed a Cobra MRF75 VHF radio and it has a consistent low hum coming from the speaker and microphone whether the antenna is attached or not. The hum is louder when engaging the trim tabs. I have two batteries, one for starting the outboard and one dedicated to the accessories, which include the trim tabs and VHF, and is recharged by the outboard. So far, I have installed a filter very close to the radio and connected the unit directly to the battery with an in-line fuse using 10-gauge wire but the humming continues.
Jerry Perry, Ahousat, British Columbia

A: The cause is, as you have already established, a power related one. If the noise stops when the outboard motor is not running, I presume that the motor is the source. Be certain that the VHF power cable runs well away from other electrical wires and cables. Also engine control loom cables should be run well away from other cables to preclude any induced interference. This also applies to the trim tab supply cables. The filter should eliminate the noise but is not. You may need to look at a much higher specification filter, such as those from Newmar. The noise may also be coming from the outboard charging circuit, rather than the outboard ignition system. In some cases, this may be due to a charging rectifier in the outboard being faulty, however, you don't mention charging problems.
— John Payne

Who to Call for AC Help

Q: I have a 1998 Pursuit 3400 with a Marine Air Systems Vector Series Passport II. The unit lost its charge and the only local service rep is backed up over three months. I need to troubleshoot and fix this myself.
Jim Dubrowsky, Hampton Bays, New York

A: If your AC unit has lost its charge, you have no choice but to get a service tech licensed to handle Freon refrigerant. The environmental laws in effect throughout most of the civilized world make it illegal to deliberately allow the release of this ozone depleting material so you can't just shoot some gas in on a DIY basis and hope for the best. The tech will need to: vacuum out your system; pressure test it to find the leak; repair the leak (probably replace the drier unit) and, only after all leaks are fixed, can the correct amount of refrigerant be reintroduced into the system. The good news is that this procedure does not necessarily require a Marine Air dealer. Any good HVAC shop with service techs on the road should be able to handle the job. The unit specific information (gas pressures, etc.) is available from Marine Air's service department or by downloading a service manual from www.marineair.com/manuals.
— Nick Bailey

Plastic Prejudice

Not just any plastic can withstand the rigors of constant immersion in salt water, regular contact with harsh chemicals, vibration and UV attack. Do you know what you're buying?

By Patricia Kearns

The following is quoted from a key scene occurring early in the film, "The Graduate."

Mr. McGuire (to Benjamin): "I want to say one word to you. Just one word."

Benjamin: "Yes, sir."

Mr. McGuire: "Are you listening?"

Benjamin: "Yes, I am."

Mr. McGuire: "Plastics."

With hindsight, we see just how prophetic these words were in 1967. Facsimiles of almost anything that can be fabricated of wood or metal and even cotton and wool, can now be made from plastic in some form. That evolution has brought plastics into boats, marine accessories, equipment, attire and even charts.

It's taken generations of engineering wizardry, a great deal of it fueled by the NASA space exploration program, to bring the generic plastic to its current state of utility. Along the way, we've seen considerable resistance to the use of plastic in boats, where previously only wood or metal would do. The fact is that the plastic materials of today are rocket science and the formulas and physics of plastic have been tested and proven in outer space applications. This doesn't that mean that all things plastic are suitable for space age applications. With plastics, performance is directly proportional to cost. Let's find out why.

Plastic's Status

Plastic prejudice is not hard to understand. Early plastic products often were cheap and flimsy and there was a prevailing perception that if a product was plastic and made elsewhere, it was junk. Fortunately, this synthetic material was being studied in earnest in the chemistry lab by physicists for its strength properties and observed in practical applications. Promoters of the future of plastic, manufacturers like Cargill, Corning, Dow and Dupont were persistent and optimistic. Now, there is a plastic with the performance characteristics to meet almost any need in virtually every product. Stuff is made of plastic, wrapped in plastic, paid for with plastic, carried home in plastic and, eventually, dumped into a plastic recycling bin to begin life again as something plastic.

Plastic, in all its forms, starts its life as a derivative of another product of critical means in our lives. Synthetic generic plastic begins with fossil fuel. From there, initially as a resin, the molecular structure can be chemically and dynamically engineered to be everything it can be and even the extent of that is still unknown. Plastic developers can impart the desired properties of hardness, durability, elasticity and resistance to heat, cold and acids, along with any color or shape and combinations of all or a few of these performance and appearance characteristics into virtually any plastic product.

Enter fiber-reinforced plastic (a.k.a. fiberglass, fiberglass-reinforced resin or glass-reinforced plastic) and you have the fiberglass boat. Actually, what we really mean is the mostly fiberglass boat because even the "fiberglass" is often further engineered and into a structure that comes to be known as a laminate and that laminate can embed wood or other materials, even other kinds of plastic, to further reinforce the structure. That kind of plastic is what legendary yacht designer Nathaniel Herreshoff referred to as "frozen snot," an ultimate among the pejorative descriptions of plastic.

The perfect example of a failed plastic thru-hull fitting (note the crack). It will eventually break off at the inside nut causing the bilge pump discharge to flow back into the bilge.

Chalky residue indicates UV attack and breakdown of inferior plastic thru-hull.

A dictionary of plastics includes, to name a few examples: acrylic, Bakelite, Cellophane, Celluloid, Lucite, melamine, phenolic, Plexiglas, polyacrylic, polycarbonate, polyethylene, polyolefin, polypropylene, polystyrene, polyurethane, resin and vinyl. As boaters, we're familiar with many of these names, as we've seen them as ingredients on labels of products we've used for a long time. Where plastic has met with prejudice in its applications in boats has been when the material or the performance specification for a material has been misunderstood. The most common areas where plastic has been accepted without reservation are adhesives and other maintenance compounds, carpet and upholstery, cabin and deck liners, electronics, flotation, furniture, hatches and windshields, molded interior modules, et al. The areas that bring trepidation and

Don't disregard the obvious warning label attached to this plastic fitting.

irrational fear to boaters have been plastic thru-hull fittings and valves, pipe and pipe fittings (including PVC), fuel tanks, filters and fittings, propellers and other components of a boat that, when they fail, they fail big-time and failures can be catastrophic.

Simply Marine

In much the same way as metals are alloyed (metals mixed with metals in prescribed proportions) to meet the needs for strength, corrosion resistance, hardness, malleability, etc., plastics can be formulated and engineered for special applications. Using the right plastic is the key to success in fabrication and application.

Let's blow plastic's bad rap as a material for thru-hull fittings right now. Common plastics found in hardware and building supply outlets are not intended for use as boat fittings. The dynamic and atmospheric exposures inherent in boats are entirely different and more demanding than those of a building on land. Requirements for boats are found in ABYC standard H-27. It's a common misconception that plastic thru-hull fittings are not permitted below the waterline. Wrong! If the material and design meets H-27, which reads as follows, it's acceptable. "All plastic fittings shall meet the following minimum physical properties: a minimum tensile strength greater than 10,900 psi (75 mPa), when tested to ASTM D638; and a flexural modulus greater than 500,000 psi (3,480 mPa), when tested to ASTM D790; and shall contain ultraviolet light inhibitors." This requirement applies only to dry, molded samples of a natural color. Colorants or other additives can change the physical property values. All fittings that meet the requirements may be marked "ABYC H-27."

Safeguards

The trick is to know if the material does, indeed, comply. Marelon is a brand name held by Forespar for a plastic that is a formulation of glass-reinforced Dupont zytel. Marelon fittings meet the materials' requirement of ABYC H-27. Other than Marelon fittings, any plastic that can be verified (tested by an independent laboratory such as UL) as compling with the H-27 standard can be used above and below the waterline. Look for the marking or check with the manufacturer. Just because something is sold in a chandlery does not make it good for you. Don't accept assurances of store staff that anything else complies. If you chose to accept such an attestation, get the clerk to put his/her opinion in writing and keep it for the day that fitting fails. Then you'll know where to point your legal eagle's finger.

As for other areas of plumbing systems, there are no restrictions on the use of plastic. There are cautions when using PVC. Sections of flexible piping (hose) should be integrated with PVC to mitigate the effects of vibration. One exception to this generality is engine exhaust piping. ABYC P-1 has a table of materials approved for use in exhaust piping. If, at some point, a plastic can be certified to comply with P-1's material standard, you could use it.

Another area of plastic hysteria is gasoline and diesel fuel systems. Once again, we turn to language in the ABYC standards. In this case, ABYC H-24 (Gasoline Fuel Systems) and H-33 (Diesel Fuel Systems) are the references of biblical proportions. H-24 reads as follows: "All individual components of the fuel system, as installed in the boat, shall be capable of withstanding a 2-1/2 minute exposure to free burning fuel (N-Heptane) without leakage as required by Title 33 CFR, Section 183590, and as required for individual components in H-24." There are additional requirements for portable and permanently installed plastic fuel tanks but, if a tank has been tested for compliance and is certified to comply, that plastic is suitable for use on a boat. Beware, though, of willy-nilly selections of plastic lines, fittings, connectors and tanks. You must be extra careful to ensure that what you buy or accept as suitable plastic is, in fact, in compliance with the standard.

Plastic's Worth

Is price the principle dictator of quality? A Marelon thru-hull fitting likely cost twice as much as its common plastic counterpart. The best sanitation hose is worth every inch of its extra cost since the effort required to replace hose that carries sewage is the same, whether you use cheap or expensive hose. Just as important to quality issues is the relationship between a plastic component's chemical formulation and its intended use. "Good" might be okay for plastic fittings connecting a potable water system but "best" (i.e. Marelon or its equivalent) is the only choice for non-metal thru-hull fittings, valves, holding tanks, cleats and other criticial components where a failure could cost heavily in repairs to your boat or jeopardize life and limb.

The sticking point for most of us is how to know what you need to know. Non-compliance by new boat manufacturers is relatively rare. The problems occur when you or your mechanic are replacing original equipment. What is readily available at auto parts suppliers is not likely to have been tested to the marine standard and is not "just as good." One way to cover yourself when giving a work order to a professional is to specify complying parts for the job and require that the compliance proof is available to you. Another way to reach the comfort level is to deal with ABYC certified technicians who are committed to doing their work by the book. Otherwise, it's up to you to make sure you are getting the real McCoy. It's worth the effort. The consequences could be hazardous to your boating health and welfare.

About the author: Patricia Kearns is DIY's technical editor.

Racer's Polish: For a super slick finish over Interlux Fiberglass Bottomkote, Pettit Vivid or other epoxy-type antifouling without compromising the antifouling qualities, apply Mequires Diamond Cut M85 using a wool pad on a buffer operated at 1,750 rpm for an effect similar to applying a finishing glaze.
Bob Jimenez, Costa Mesa, California

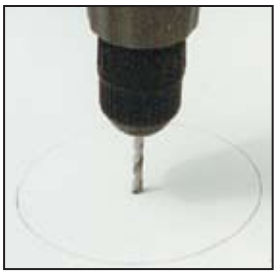
Towel Rack: To secure towels or clothing to rails or boat top frames, either for drying or to create shade, purchase molded PVC clips sold at specialty garden centers to attach cloth or plastic row covers to tube frames. Just 4" (101mm) in length, these clips won't brake, will never rust and fit most smaller tube sizes.

Line Organizer: Dying rope isn't an option as some fibers have a coating that prevents a dye from adhering, so when you want to color-code anchor or dock lines, or sheets, use Maxijacket from Yale Cordage, a water-based urethane that's easy to apply and recoat when needed and is available in many colors from riggers.

Power of Two: Use a double-grip winch handle to give a less-beefy crew some extra muscle power to crank winches.

Bird Hang Up: To deter birds from resting on a sailboat or trawler mast spreaders, run monofilament fishing line from the spreader end to the mast at about a 45° angle.

Measure Twice, Drill Once: When using a Forstner bit to drill a critical dimension 1" (25mm) hole through my boat's transom, the bit dropped slightly in the void between the laminates, causing the inner cut hole to be off center, which then had to be filled with plenty of sealant.



Using experience as my guide, when drilling into an area of thickness it's best practice to drill a small pilot hole first.
David Bakody, Certa Cito, Dartmouth, NS

Lacking a Mermaid: Should a sterndrive's raw-water intake ports become clogged with algae, seagrass and other obstructions, clean with a boat hook, deckwash brush or a paddle. Be sure to inspect and clean ports after each use.

Turnbuckle Lube: To prevent turnbuckles with stainless-steel screws in stainless bodies from "welding" together, routinely apply a grease or dry lubricant containing molybdenum disulfide. Use it carefully as it tends to blacken hands and sails. For turnbuckles made of dissimilar metals, for example a stainless screw in a bronze body, Lanicote, a Teflon lube or any good waterproof grease is adequate.

Cooler Blanket: To improve the efficiency of a top opening icebox, make an insulation blanket. Purchase window shade insulation, available at fabric stores, slightly larger than your boat's icebox opening, sew to it a piece of plastic tarp and drape it over the foodstuff.

To the Last Drop: Any submersible style bilge pump will suck air and lose its prime as soon as the water level gets down to the top of the slotted intake openings, which extend upwards anywhere from 0.5" to 2" (12mm to 52mm) from the bottom of the pump in the pump housing. To reduce the leftover water for a nearly dry bilge, install a secondary pump that has the pickup oriented face down close to the bilge floor, such as the Whale Super Sub, or a diaphragm style (washdown) pump (e.g. Jabsco 31610-0092) that self primes as well as happily pumps a mix of water and air, mounted remotely from the bilge with a low profile strum box as the water pick-up.
Nick Bailey, "Looney Tunes," Toronto, Ontario

Great Stuff: When you need to seal interior "air" holes or insulate wires where they pass through bulkheads squirt spray foam into the area. Available at hardware suppliers, use it with caution for it expands greatly as it dries so a little goes a long way.
Jim Discher, Long Beach, California

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PRO SERIES

Workshop in a Can

Epoxy, polyester and vinylester are the common resins used by do-it-yourself boat repairers. Knowing when and where and why of each type is key to the how to of a successful repair.

By Nick Bailey

One of the big differences between a professional fiberglass technician and an eager amateur doing a DIY repair is a day-to-day familiarity with the materials. An experienced amateur might do some glasswork once or twice a year but is more likely to have several years pass between projects. Between those episodes things are forgotten. I was reminded of this one recent Saturday morning while repairing the hull/deck joint on one of the family Lasers. It was a hot day and having what I thought was a thorough familiarity with epoxy resin, I selected a slow hardener and then confidently proceeded to mix up a batch of bonding putty using resin, chopped glass and silica filler. The 5' (1.5m) joint was wedged open and clamps were nearby and ready. I knew I would have to work fast to fill the repair in one shot and set the clamps before the epoxy began to harden.

Guessing that pot life should be about 20 minutes, I had plenty of time. I had forgotten that pot-life is a theoretical concept. After five minutes of fussing around mixing up the perfect batch I troweled the mix into the gap. I had filled about 2' (609mm) of the repair when I suddenly noticed the putty I was working with was getting stiff. I looked down and was shocked to see smoke rising from the mixing bucket. There was a classic runaway exothermic reaction underway not only in the bucket but also in my head as foul odors and foul language filled the air and I began to frantically dig the now unclampable hot filler out of the gap before it hardened completely.

Any well-equipped chandlery will have a whole section devoted to epoxy.

In retrospect I had made some embarrassing rookie mistakes. A small amount of fast hardener left in the pump may have accelerated the reaction but I can't escape the fact that the batch was too large on a day that was too hot in a container the wrong shape made of the wrong material (a cardboard bucket). A metal paint tray would have acted as a heat sink and also allowed me to spread out the mix in a thin layer for better heat transfer. This little incident also served to remind me that it's a good thing that I work in the front office at Bristol Marine and not on the shop floor. I had also forgotten that a continuous production epoxy job requires an assistant to constantly mix small batches of epoxy just before they are needed, something that Wendy, my wife and usual assistant, now alerted to the ruckus in the drive-

Nick Bailey

The Gougeon brothers, originators of the West System brand, pioneered providing the retail consumer with detailed instructions and all accessories and spares for DIY repairs.

way, was quick to echo: "Why are you trying to do that by yourself? Don't you remember that I am the epoxy queen?"

I'm often asked which resin is best and my answer is, "It all depends." It depends on the kind of job, the size of job, the boat's original construction material and style of construction, budget, weight versus strength and the final finish required (i.e., paint versus gelcoat). Regardless of the technical differences, often the most important question to ask yourself when choosing which resin to use for your DIY glass repair may be: "With which one do I have the most experience?" When in doubt, stick with what you know. It may not guarantee you avoid mistakes like mine above but it helps to be at least part way up the learning curve.

Epoxy Vs the Esters

Epoxy is king. [DIY's editor refers to epoxy as the "Eighth Wonder of the World."] Of all the available resins, epoxy is the most water resistant, has the highest strength and the best adhesive characteristics. This is why it's the material of choice for high-end fiber-reinforced plastic (FRP) composite structures ranging from racing cars to boats to military aircraft where the ultimate in performance is required and

cost is no object. Its low vapor pressure (100% solids, no solvents) makes it ideal for advanced vacuum bag and infusion lay-up techniques. Epoxy also has many advantages for DIY work as well. It's relatively simple to work with for routine glass repairs and lay-up and is an excellent waterproof base resin for filling and fairing putties. When it comes to gluing and bonding wood components, it's the only choice. With the appropriate additives, it can also used as a water barrier coating for preventing osmosis.

To serve the DIY market, the main epoxy suppliers, such as Interlux (Epiglass), MAS Epoxies, System Three and West System, have done an excellent job of marketing epoxy systems to the boating public by providing convenient retail packaging and comprehensive instructions. Any decent chandlery stocks the resins and hardeners together with the hand pumps and accessories needed to simplify measuring the precise ratios of resin to hardener that every epoxy application requires.

Epoxy Pros and Cons

With all of these good things, what are the negatives? Epoxy is much more expensive than polyester and vinylester resins, prohibitively so on large repairs. It can be harder to sand and is difficult to finish with polyester gelcoat. (Polyester gelcoat will not adhere to epoxy without special intermediary tie coats). It's common, when finishing an epoxy repair on a gelcoated boat, to find touch-up paint that is an acceptable match to the surrounding gelcoat. That can be harder than it sounds so, to avoid leaving behind conspicuous repair patches, the usual option is to refinish the entire deck or hull with a polyurethane paint, particularly if a large repair has been done.

There are occasionally subtle engineering issues when doing epoxy repairs on polyester boats. In some cases, an epoxy hull laminate repair (i.e. patching a large hole) can be significantly stiffer than the surrounding original laminate. This stiff spot can sometimes lead to stress cracking as load is transferred to the surrounding flexible laminate. There is also a tendency in DIY repairs to believe the epoxy resin alone can achieve miracles. Except for the very smallest repairs, any laminate repairs require fiber with the resin. A blob of extra tough epoxy filler is no substitute for a glass laminate patch.

Last but not least, despite the fact that epoxy does not have the pungent reek of other resins, the unmixed epoxy components are toxic, carcinogenic and, after sustained exposure, can lead to sensitization and severe allergic reactions. Use a respirator, wear goggles and full protective clothing when working with epoxy.

Jan Mundy

Dispensing pumps measure the correct ratio of resin to hardener to ensure a proper mix.

Working with Epoxy 101

Mixing epoxy resin in a precise ratio with matching hardener starts the chemical transformation from liquid goo to tough solid. Over the course of this transformation, the resin remains liquid and workable for a period of time (referred to as working time) before it initially gels into soft solid and then later cures to a rock hard plastic of great strength (and stubborn attitude). Good management of the time available to work with liquid resin is one of the most important things to master when working with epoxy. The amount of working time available can vary greatly and depends on two primary factors: the reactivity of the hardener used and the temperature of the epoxy.

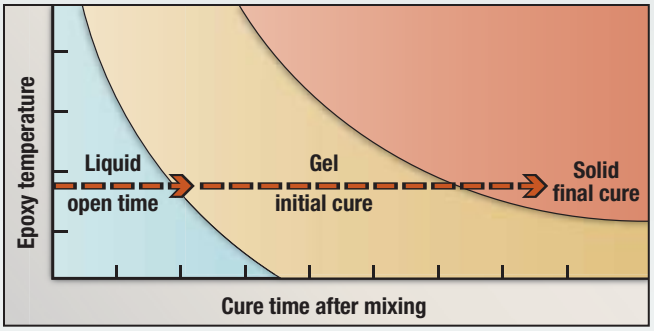
Most epoxy systems provide a variety of hardeners that react at different speeds to allow work in different ambient temperatures. At a given temperature, a slow hardener reacts less aggressively and yields a longer working time than a fast hardener. Depending on the hardener you choose, the same reaction and cure cycle takes place but at different rates. The usual method of defining hardener speed is pot life, a lab measurement based on mixing up a standard amount of epoxy in a standard container at a standard temperature, usually 100 grams at 72F (22C). Pot life, due to exothermic heat build-up, is much shorter than actual working time where the resin is usually applied to the job as a thin layer and has more surface area to allow cooling. In reality, when working with a batch of more than 100 grams on a hot summer day, the lab defined pot life is far too optimistic. My adventures show just how short "real world" pot life can prove to be. This is due to the other primary factor governing working time; namely, temperature.

Two factors govern the temperature of epoxy: ambient temperature, which includes the temperature of the epoxy resin prior to mixing; temperature of the general work environment and temperature of the work surface. The second is exothermic heat generated in the resin by the cure reaction itself.

• TIP •

Detachable Gloves

When working with fiberglass, put on two to three pairs of disposable gloves. Latex gloves work best and are cheap (about US$10 for a box of 100 at Home Depot; even cheaper in bulk at a warehouse club) as long as they are the correct size for your hands. When the first set of gloves gets too sticky or full of fiberglass strands (especially when working with mat), peel them off and you've got a fresh pair ready to go. If you're allergic to latex, wear a pair of thin cotton gloves underneath to avoid direct contact with your skin or wear nitrile (more expensive than latex but well worth the cost of avoiding the allergen) or vinyl gloves (although these don't fit as well and disintegrate with acetone). If no other gloves are available, wear rubber gloves with a fabric liner available at grocery or hardware stores. To clean them, dip the gloves, while wearing them, in acetone a couple of times and then wipe with a paper towel. The acetone dissolves the epoxy.
— *Sandra Turney*



Joe VanVeenen/West System

This graph from the "West System User Manual & Product Guide" shows the general relationship between the cure time of epoxy and temperature. As it cures, mixed epoxy passes from a liquid state, through a gel state, to a solid state. Cure time is shorter when epoxy is warmer and longer when epoxy is cooler. This time-to-temperature relationship holds for all resins discussed in this article.

Speed of the cure reaction varies directly with ambient temperature. Cooler temperatures slow the reaction and create longer working and overall cure times. Every epoxy has a lower temperature limit below which the reaction stops. This is usually around 50F (10C) but can be near 32F (0C) for some specialized types. Practically speaking, there is also an upper limit where the cure proceeds too quickly to do any useful work.

The amount the resin temperature increases during cure due to the reaction itself is dictated by the volume of the batch versus the surface area available to shed heat. The surface area amount available to shed exothermic heat is dictated by the size and shape of the mixing container. The risk of a runaway exothermic reaction is a mixing pot issue. Once resin is spread out onto the work surface, the additional surface area should provide enough cooling to prevent exothermic mishaps (like mine above). When working with epoxy in high ambient temperatures use a slow hardener, keep batch size to a minimum, use the largest possible mixing bucket or finish mixing in a wide shallow container (a paint tray is ideal). Keep the mix out of the hot sun and work quickly.

Jan Mundy

Organizing all materials and tools before mixing helps to maximize your working time. Note the foil-covered paint tray for easy mix and dispose without cleanup.

Low temperatures present different problems. Obviously, a fast hardener is called for but one must still beware. Exotherm in the mixing bucket can overheat cold epoxy very quickly. If you are working close to the minimum temperature, apply additional heat to the work area or the repair with heaters or lamps. I find 500-watt portable quartz work lights make an excellent heat substitute. Do not allow the repair to drop

below the temperature minimum for the epoxy you are working with at any point throughout the duration of the full cure cycle. The cure process will stop dead and warming things up again cannot restart a partial epoxy cure interrupted by low temperature. The other low temperature bugbear of epoxy is amine blush. This is a waxy contaminant that forms on the surface of curing epoxy. High humidity and slow cure times are almost guaranteed to produce it. Blush is a nuisance because it's a contaminant that prevents adhesion of any coatings or additional epoxy applied on top of it. A good scrub with soap and water can remove it. Do not sand it off as that just works the blush permanently into the surface.

Once new epoxy is fully cured, to ensure the good adhesion of any additional overcoats, it must be prep sanded with 80-grit paper. However, it's possible (provided there is no amine blush present) to apply overcoats, without prep sanding, to the new epoxy during the "green" coating window. As cure speed varies with temperature, so does this time window. It's the time between the stage where epoxy has gelled and is just tack-free and the point where it's fully cured. Use the fingernail scratch test to determine if the surface is ready for green coating stage. If the new epoxy is not tacky but is still soft enough to scratch with your fingernail, it can be overcoated without sanding.

'Ester Pros and Cons

Ortho or Iso or Dicyclopentadien (DCPD) polyester resin varieties are all similar to work with and rely on mixing in a small amount (between 1% and 5%) of catalyst, usually methylethyl ketone peroxide (MEKP), to react and form a durable, reasonably waterproof solid. The large majority of fiberglass boats are built with polyester resin. The same goes for the majority of professional fiberglass boat repairs (except osmosis repairs). It's less popular for DIY repair work for a few simple reasons.

Up until recently most of the polyester fiberglass repair kits available have been pretty basic and came straight from the automotive section of the local hardware store carrying with them the stigma of low tech. More useful polyester kits are becoming available at chandleries but the best sources for polyester and other resins, as well as any other materials needed, are usually specialist shops catering to boat builders such as Jamestown Distributing and Noah's, to name just two. Epoxy is much more cleverly marketed. It's touted, with some justification, as far superior and more versatile than lowly polyester. The epoxy kits include comprehensive repair instructions and all manner of accessories and additives are available.

Nick Bailey

The automotive department fiberglass repair kit has traditionally dominated the retail market for polyester resin.

Polyester is perceived as more difficult to work with than epoxy. It isn't really but here are a couple of tricky things to beware of and some examples of how the pros deal with them. If improperly catalyzed, polyester resin either catches fire (the exothermic reaction is even stronger than epoxy; see recommendations for epoxy above) or doesn't kick off at all. This tendency towards catalyzing errors by the inexperienced is probably due to the inconvenience of measuring the small amounts of catalyst required for most DIY repairs. The typical polyester repair kit gives you a tiny squeeze tube of catalyst and expects you to count the drips. ("Uh oh, I was supposed to put in 30 drips but I lost count.") The usual epoxy kit with pre-measured pumps is definitely user-friendlier. Things are different for the glass pros. To prepare the quantity of catalyst required, they use a convenient 17oz (500ml) plastic squeeze bottle with an integral graduated measure.

MEKP catalyst is available as a standard 9% or a diluted 5% solution. If working with the standard solution MEKP, a professional varies the catalyst to resin ratio, between 1% to 3%, depending on the temperature and job type. This flexible ratio allows the cure rate of the resin to be custom tailored. A "hot" (3% or more) ratio is used where a fast cure is required (working overhead or in cold weather) and less catalyst is used when a longer working time is needed or in hot temperatures. This requires a lot of experience to predict the results but at least the same catalyst can be used, unlike epoxy where different hardeners are required due to the fact the resin-to-hardener mix ratio can't be varied without ruining the quality of the resin. This ability to customize a "hot" mix makes polyester a little easier to work with than most epoxies in cold weather. MEKP contains lots of free oxygen making it a notorious fire starter

Comparison Shopping

	Epoxy	Vinylester	Polyester
Adhesion	Excellent	Good	Good
Shear Strength	Excellent	Good	Good
Water Absorption Resistance	Excellent	Good	Fair
Chemical Resistance	Excellent	Good	Fair
Fatigue Resistance	Excellent	Good	Fair
Cost	2.5	1.25	1.0

Notes

1. Never use polyester or vinylester to adhere wood components.
2. Polyester and vinylester are hardened by the introduction of a catalyst, usually at a ratio of 1% to 3%.
3. Mixing two agents, resin and hardener, hardens epoxy, usually at ratios between 1:1 and 5:1.
4. Vinylester has no compatibility problems with polyester.
5. Epoxy hardeners have toxicity problems. Use with caution.
6. Some cured epoxy resins tend to blush on the cured surface and must be removed with soap and water before overcoating.
7. All boat resins are formulated for room temperature cures but cure times may vary considerably by altering the chemistry of the hardener or changing the catalyst ratio. Read the instructions carefully.

and as toxic as strong bleach. Don't get it on your skin, eyes or clothing. To avoid spontaneous combustion, be careful not to spill MEKP on anything wood, paper or cloth.

Then there is the problem of air-drying polyester. It's a fact that standard polyester resin, although cured hard, remains tacky (and soluble to acetone) forever unless it's kept from contact with the air for the last stage of its cure cycle. This is a good thing in that it allows additional glass and resin to chemically bond without prep sanding (similar to green coating additional epoxy layers). Application instructions in the polyester kit tell you to cover the final layer of glass (or polyester gelcoat) with an airtight plastic wrap to ensure a full cure. You won't see a pro doing that. Instead, they add a small amount of a special waxy additive (known as Air Dry) to the resin or gelcoat that forms the outer layer. This addition rises to the surface and seals the resin away from the air to promote a full, tack-free cure. Another method of final sealing is to apply a layer of liquid PVA (polyvinyl alcohol) onto the last layer. This dries to form a green plastic coating that can be washed off with water later.

Polyester is much easier to sand than epoxy and is far less expensive. It may stink of styrene but it's actually less toxic than liquid epoxy. It's also completely compatible with polyester gelcoat. This simplifies finishing with a color-matched gelcoat, a technique that may present a real challenge to the less experienced DIY repairer. Painting, however, is still an option with polyester. Nonetheless, for routine repairs on production fiberglass boats, particularly above the waterline, polyester is the best choice. Polyester is never used as a barrier coat, adhesive glue or to bond hardware and is not recommended as a wood coating.

All the working characteristics of polyester are much the same for vinylester. The two can almost be used

An old master's top-secret gelcoat tint collection.

Nick Bailey

Regardless of the resin you use, it is useless without the addition of cloth.

interchangeably. Although vinylester is a bit tougher mechanically than polyester, the biggest single difference is that vinylester is more water resistant. For repairs and filling/fairing below the waterline, vinylester is ideal as it's easily mixed, has the easy sanding characteristics of polyester and a water resistance approaching that of epoxy. Retail availability is limited to the 3M Marine line of premium vinylester fillers and resin (e.g. 3M Marine Premium Filler).

Advice for the DIYer

Remember to include the fiberglass in a fiberglass repair. All the resins above can be used to create robust glass laminates, patches, tabbing and secondary bonds but resin is too brittle and has no useful strength on its own without fiber reinforcement. The only exception is epoxy when used in a well-clamped glue joint. For purposes of filling and fairing, they can all serve as a base for DIY fillers and putty by mixing in colloidal silica and/or microspheres. Be sure to add the powdered fillers after the resin is well mixed with hardener or catalyst. Always follow the instructions provided and, if you are unfamiliar with the product, start small and do a test job or two to get your feet wet (but not with resin). With care and preparation you can avoid a situation where your resin or your hair is on fire.

System Three

Ideal for the DIYer, the SilverTip series of epoxy products from System Three are conveniently premixed with the appropriate fillers for bonding, fairing, filleting and gluing. Mixing is no longer a science. Just mix the two components and pour.

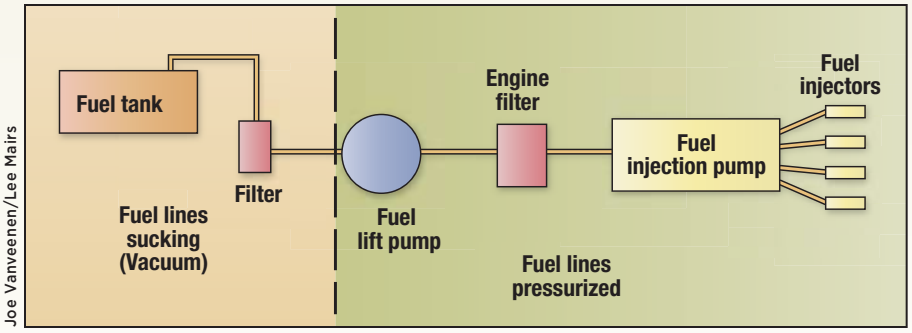
About the author: Nick Bailey is DIY Magazine's repair specialist and has spent 26 years in the boat repair business. He is the service manager at Bristol Marine in Mississauga, Ontario.

DIESEL

Bleeding Basics

Once you understand the generic step-by-step process for bleeding air from a diesel engine fuel system, you'll better understand the correct approach to purging air from a fuel system after changing fuel filters or when the fuel system is cranky.

By Lee Mairs



Joe Vanveenen/Lee Mairs

Figure 1 Typical Marine Diesel Engine Fuel System

A routine task that strikes the fear in the hearts of novice mechanics is bleeding a diesel engine fuel system. Each engine has its personality and the secret to a fearless approach to "bleeding," the vernacular for purging the fuel delivery system of air, is to know thy engine. Your engine type might have an electric lift pump, a cam operated lift pump, one fuel-injection pump or a fuel-injection pump for each cylinder. Sorting this out requires a little background knowledge of the theory of diesel fuel delivery.

Figure 1 shows a generic diagram of a typical marine diesel engine fuel system. The lift pump sucks fuel from the tank through the pickup tube, fuel lines and through the primary water separating fuel filter. Fuel is then pushed through the engine-mounted OEM fuel filter and on to the engine's fuel injection pump(s). The injection pump pressurizes the fuel to about 3,000 psi (this varies among engines), pushing the fuel through the injector pipes to the fuel injectors at the appropriate moment. Highly pressurized fuel causes the pintle to lift from the nozzle in the injector and a fine mist of fuel enters the cylinder combustion chamber, mixes with the compressed air and explodes into energy for the power stroke.

If there is any air in the fuel lines, the fuel injection pump pressurizes air instead of fuel preventing an atomized mist from entering the cylinder. The engine staggers its warnings of trouble and finally stalls. The silence is deafening. The only option is to bleed (purge) the air from the engine fuel supply lines. The only thing you want in those lines is clean diesel fuel.

Small diesel engines are built primarily for use in industrial and agricultural applications, such as powering road signs, running a generator on a North Sea oil platform, propelling a heavy street sweeper or plowing ground in a farmer's field. In most cases, where the fuel tank is mounted over the engine, gravity is sufficient to feed fuel from the tank to the engine and no engine-driven fuel lift pump is required. Marine engines are rarely installed to take advantage of this simple fluid dynamic. Because their installed position, relative to the fuel supply, does not enable a gravity feed the fuel must be pumped or sucked upward to the engine via an external and/or remote fuel pump.

Some diesel engines (notably those whose close kin are found in automobiles) are self-bleeding. If you have a large Detroit diesel, the mechanic will

Patricia Kearns

It's hot work for Daniel Mattos, a SAMS accredited marine engine surveyor, who is engaged with a 25-year-old pair of GM453 diesels onboard a Hatteras LRC.

use what is called a Caterpillar pump to bleed its air bound fuel system. There is a 1/4" pipe thread plug in the side of the injection pump where the Caterpillar pump is installed to pump fuel from the tank to purge trapped air from the fuel system. If you plan to buy the pump and add this arrow to your self-sufficiency quiver, I strongly recommend getting "down and dirty" with your mechanic to watch him do it. It's not a job for amateurs.

The only sticking point about explaining bleeding small engines is the seemingly endless possibilities for engine installations, fuel system design and components and idiosyncrasies, not the least of which is access. There are so many different combinations and configurations to consider that I can only describe the bleeding process in generic terms. Even if you are comfortable with my explanations, hiring your mechanic for an hour or so to have him walk you through the process in a one-on-one tutoring exercise is money well spent, largely because, when the air hits the lines, he'll likely not be handy for coaching in situ. Make notes and be prepared to mark or label the various bleed screws and other points on the engine so that you can easily find them when your time comes — it's not an "if," it's a "when." Finally, write up the details of the process and post them handy to the engine or in your maintenance log. The stubbiest pencil always beats your memory!

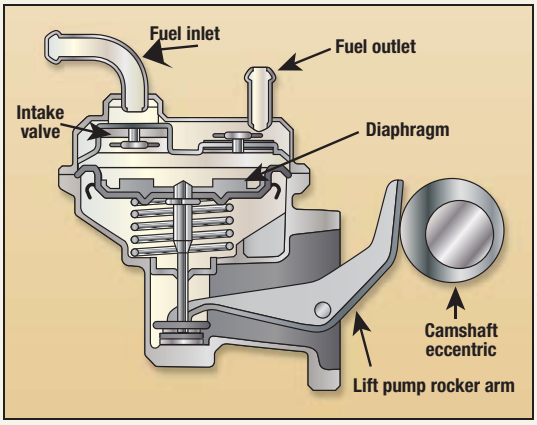
Fuel Primer

Proceeding from left to right in **Figure 1**, the fuel tank, primary filter and the lines connecting them to the lift pump are in a vacuum state relative to the outside world. I refer to this as the suction

side. A pinhole fuel line or connection leak often will not reveal itself as a drip. Instead, every time the lift pump tries to suck fuel out of the tank, air is sucked into the system through these imperceptible leaks since air is lighter and easier to suck then diesel fuel. Fuel line integrity is very important to keep things running as desired.

If you suspect an air leak, it's your job to find it and fix it. It may be a simple tightening of a fitting or the fix might call for new lines or connections. Fuel lines do not last forever, even if they are made of copper. Flexible fuel lines should be checked annually for abrasion, chafe points and permeation. Copper and other metal lines are subject to corrosion. Also, governments continue to order changes in fuel "recipes" in the efforts to minimize air pollution. These changes can have a negative impact on your fuel system. Routinely check you fuel lines for evidence of damage but remember that being proactive with replacements is far more economical that waiting for a failure.

The upstream side of the fuel lift pump (between it and the fuel injection pump as shown in **Figure 1**) is under pressure. Fuel line leaks are revealed by the presence of fuel, which has seeped out of the lines or at connections, on the engine and its component surfaces. If you see fuel on your engine or in your bilge, you must track and repair the source of the leak. Fuel in the bilge is not only a fire hazard, it mixes with bilgewater to create a foul odor. Begin by systematically searching for the leak. Start at the lift pump outlet and proceed towards the fuel injection pump. Carefully wipe each fitting and the hose with a clean paper towel, checking often to see if fuel appears. Even the smell of diesel oil can indicate a leak that you can't see. Remember, leaking fuel can travel a long way on engine surfaces before it drops into the bilge or to a place where you can readily see it. You will probably find the leak at a fuel fitting. Many of these fittings are sealed with copper crush washers. Keep a handful of various sized crush washers available. In an emergency, you can clip the tail off a round copper wire connector and use the copper circle to serve as a crush washer long enough to get you home.



Joe Vanveenen/Lee Mairs

Figure 2 Mechanical Lift Pump

Metal fuel lines running from the injection pump to each individual injector are steel, not copper, since the fuel is now pressurized to over 2,500 psi as it leaves the fuel injection pump. Also, note that, even though the shape differs, each of these injector lines is the same length as all the others. This is to ensure that the fuel pressure is the same for each injector. If any one of these lines is damaged, you must tell the parts supplier exactly which injector line it is so that the replacement fits exactly.

The Bleeding Process

It's impossible to write a detailed, step-by-step, process for bleeding air from every kind of engine but that doesn't relieve you of the responsibility to know how to bleed your engine when it needs it. Regardless of engine configuration, the first step is to open the fuel valve at the tank.

Lets start with the assumption that your engine has a mechanically operated lift pump (**Figure 2**). This pump works up and down on a cam, sucking fuel through the inlet valve and pushing out through the outlet valve. There is a small lever on the pump that allows you to operate that pump manually. Otherwise, the eccentric camshaft works the rocker up and down in your stead. You should be able to feel or hear the fuel squirting out the fuel pump. It's possible that the lift pump rocker arm may have stopped while resting the lobe of the camshaft eccentric. If so, you can pump until your fingers bleed yet not get any flow. If you think this is happening, simply turn the engine over a little bit until the rocker arm is not resting on the cam lobe.

Now, run your hand along the fuel outlet line until you come to the engine-mounted fuel filter. If the manufacturer used a small cartridge fuel filter, continue on tracing the fuel line until you come to the injection pump. Carefully consult your engine owner's manual. Most engine-mounted, canister style fuel filters and all fuel injection pumps have a bleed screw. Study your manual until you are sure that you can find the correct screw. Once you are certain, crack the bleed screw open a turn or two. At this point, you can probably better appreciate having your mechanic available for a bit of experienced handholding during a first time engine bleeding.

Now, manually operate the mechanical lift pump lever until fuel begins to seep out the open bleed screw. You will see a frothy, bubbly mess that soon turns into clean fuel flow. As soon as this occurs, tighten the bleed screw the two turns. If you have just changed fuel filters, this pumping process may take awhile. Have faith. Be patient.

You have now purged all the air from between the fuel tank and the engine-mounted fuel filter canister. You bleed any remaining air up to the fuel injection pump by similarly opening the bleed


Patricia Kearns

Cummins OSC series 500-hp six-cylinder shows injection pump (see arrow) with fuel lines to a fuel rail that feeds fuel to the individual injectors that act independently. On smaller engines, the injector lines run directly from the pump to the cylinders.

Patricia Kearns

Bleeding a Yanmar 6YA-STE: (1) Loosen the priming pump knob then push it to feed fuel to the engine fuel filter; (2) Loosen bolt on top of fuel filter to release fuel until no air bubbles escape, then tighten bolt; (1) Push down and tighten priming pump knob.

screw, manually pumping the fuel lift pump and then closing the bleed screw after clean fuel appears. If you have solid fuel flow to the injection pump, most engines will start at this time; however, there are always a few recalcitrant machines out there that will require you to bleed air out of the injector pipes also. Crack open the fuel pipe nut slightly at the injector and crank the engine. Again, as soon as fuel appears tighten the nut and, if necessary, proceed to the next pipe. The engine should begin to cough its way back to life.

If your engine has an electrically powered fuel pump, the process is much the same except you don't have to operate the lift pump lever with your finger. The click-click-click of the fuel pump pushes the fuel thorough the system until air bleeds out at the bleed point. Continue up the line towards the injection pump, opening and closing the bleed screws once fuel, free of air bubbles, appears.

Preventative Measures

It shouldn't take you long to master the correct bleeding technique for your specific engine once you understand the generic process and have invested in some time with your mechanic. The best thing you can do for your engine to avoid the bleeding process is to make absolutely sure that you never run the engine out of fuel. Insure that the lineup of feed fuel lines and return fuel lines is correct. I once incorrectly set the fuel manifold valves after a major refueling so that I was drawing fuel from the port tank and returning unused fuel to the starboard tank. The excess fuel quickly overflowed the full tank. Luckily, the odor of diesel fuel in the aft starboard stateroom alerted me to the emerging problem.

Be very careful to check the valve lineup if you elect to change primary fuel filters while underway. It only takes a minute or so to examine the lineup or, better yet, have some one else check it for you. It could take hours to get that big engine bled on a Sunday evening when a mechanic is scarce.

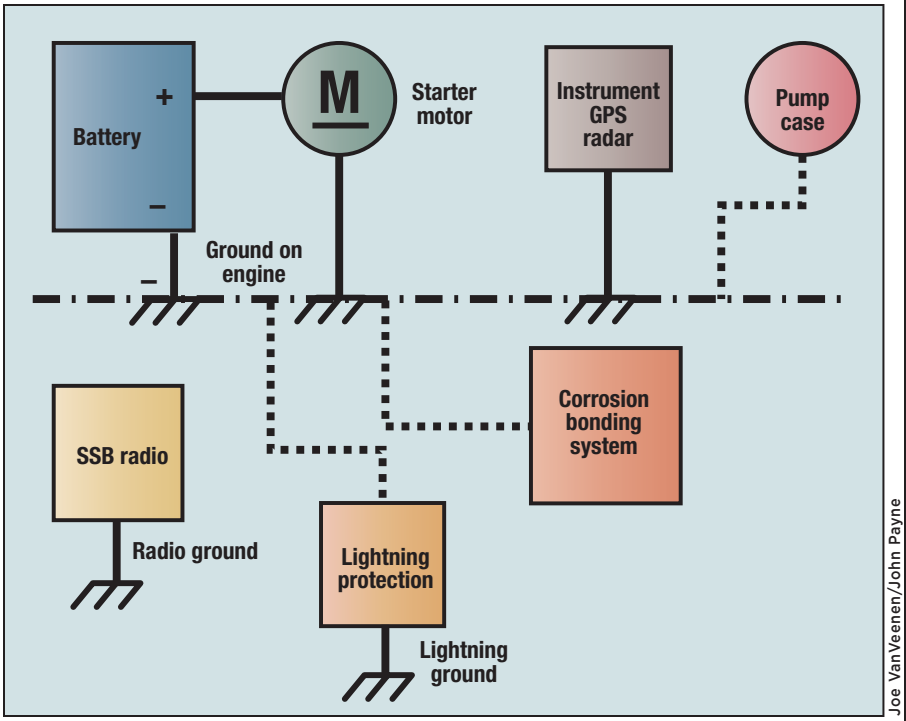
About the author: Lee Mairs is a graduate engineer and a retired Navy commander. His company, Security Marine Services, conducts seminars on a variety of boating topics. Lee holds a USCG 100-ton ocean operator's license for both sail and power.

ELECTRICAL

Getting Grounded on Grounds

Electrical grounds play an important role with respect to equipment function and performance.

By John Payne



Joe VanVeenen/John Payne

In a normal boat circuit wiring configuration, various DC grounds connect to a common ground, usually the engine via a negative connection from the battery to the engine block.

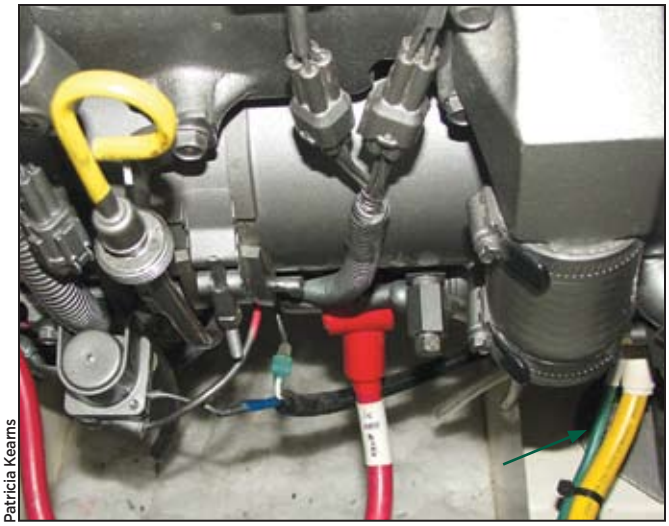
The term "DC ground" appears relatively simple but behind that simple phrase stands a range of more complex electrical and electronic equipment and installation issues. To begin, it's crucial to define the meaning of "ground" as it differs considerably between equipment, systems and functions and, in many cases, the term ground is improperly used.

What is a ground? The simple definition is that a ground is a direct electrical connection to the mass of the earth (the ground or "earth ground") or a large mass of conductive material and a connection to a specific location in an electrical or electronic circuit and that eventually leads to an earth ground point. The term ground may also apply to an indirect connection that connects to ground through the effects of capacitance. Having an effective grounding system reduces the effects of interference, may reduce the risk of damage from lightning and grounds any electrostatic charges that may build up that could otherwise damage components. In simple terms, a ground drains away any electrical charges to a grounding point where those charges can do no harm. When any point is connected to an effective ground, that same point will tend to remain at a constant and stable voltage level, no matter what might occur within the rest of the circuit. The earth itself is able to harmlessly absorb and dissipate virtually an unlimited quantity of electrical charge.

Why is grounding so important? The electrical ground provides the reference voltage level, often called zero potential or ground potential. It's against this reference value that all other voltages within a system are measured. In a shorepower connection situation, an earth ground traditionally comprises one or more conductive metal rods driven into the ground. There are other factors such as soil resistivity, soil moisture, etc., that, in theory, could affect the efficiency of the ground effect but, when properly designed, the ground is very effective. On a boat, seawater is the path to ground. When this ground interfaces with seawater, it must be non-corrosive and sufficiently large enough to dissipate any current that might flow in its search for ground. Typically, this interface with seawater is a metal keel, a metal hull or other metal originating in or on the boat and is connected to the common electrical ground point onboard. There is no absolute earth ground for boats in fresh or saltwater. If the overall mass of the boat is large enough, that same mass can simulate an earth ground in many applications.

Ground Modes

The DC negative in the average DC circuit is not strictly a ground. It is a current carrying conductor that carries the same current that flows in the positive conductor. In a normal boat circuit wiring configuration, it's bonded (connected) to a grounded point, usually the mass of the engine, and that is via a negative connection from the battery to the engine (engine negative terminal). The engine is also connected to an immersed item, such as the prop shaft or metal hull, although, in some cases, this may not be as efficient, as shaft couplings and engine mounts tend to insulate, thereby interrupting the conductivity. This negative connection to the engine negative terminal is used to polarize the system and doesn't actually carry current. Effectively, this means that you are holding the negative at ground or zero potential.



Patricia Kearns

DC ground conductor (green wire) attached to the engine. The yellow wire is the DC negative conductor (not a ground).

The lightning ground is effectively a safety ground. It only carries current in the relatively rare but, nonetheless, unfortunate event of a lightning strike. The primary purpose is to effectively shunt the strike energy to ground and dissipate it. It's not a functional part of any other electrical system although the conductors may also serve as bonding conductors for corrosion control. Some lightning grounds connect to the keel that, if metal, acts both as a ground mass and also as the interface to seawater. In some cases, the ground connection is made to a sintered bronze radio ground plate. I actually prefer a crow's foot arrangement that has three ground plates connected rather than a single unit to dissipate strike energy, as one plate cannot adequately do so. Where a lightning protection system is installed it must be done in compliance with accepted practices. ABYC E-4, the standard for lightning protection systems in boats, notes that a grounding strip "approximately 1" (25mm) wide and 12' (3.7m) long has nearly six times the amount of edge area exposed to the water, which, compared to the ground plates, will improve the dissipation of charges." [Ed: For complete details on installing a lightning protection system refer to DIY 2002-#1 issue.] In addition, all metal items, such as tanks, within 6' (1.8m) of the down conductor are also bonded to the lightning ground to prevent side strike activity as the energy seeks to divert and escape at the various bends in ground conductors. In fact, most ground plate makers do not recommend that ground plates (appropriate for radio grounds) be used for this function. If the energy does not quickly dissipate via a lightning ground system, either ashore or afloat, the voltage at and around the ground point can rise. I will cover this aspect in the bonding description.

Whilst commonly called a ground, the radio frequency (RF) ground is actually an integral part of the antenna system on single side band and ham radios and this is sometimes termed the counterpoise. The ground only carries RF energy and is not a current carrying conductor. This ground is always a broad copper strap as it's part of a high-frequency antenna system and the skin effect is important for proper function. In many cases, a ground is a suitably

sized copper plate inside the hull and this is grounded to the outside seawater through what is called capacitive coupling, so an actual external ground is unnecessary. The instrument ground is also known as the chassis ground or common ground and most communication equipment, GPS and radar sets have them. This ground also is a point that has zero voltage and is the reference point for all other circuit voltages, both positive and negative. All voltages within the equipment are measured with respect to this ground. Chassis grounds are always connected to the main earth ground on the boat. One other ground that can occur with instruments is that of cable screen drain wires. They should never be grounded at both ends and you should follow manufacturer's instructions.

The equipment ground is found on many DC motors and is bonded to the main ground point. This holds the metal casings of motors at ground potential and also assist in reducing interference. Bonding cables should be run back to the common ground point.

The cathodic protection system ground is more accurately described as an equal or equi-potential bonding conductor, as it bonds all underwater items to be protected to the sacrificial anodes and holds them all at the same potential. The process is not one of grounding anything.

This article primarily considers DC grounds but we should not forget the AC ground. Under normal circuit operating conditions, it carries no voltage or current; in fact, it should always be zero and not even leakage currents should flow. The primary purpose is that under fault conditions it will carry fault current to ground and hold all connected metal to ground potential, ensure operation of protective equipment and protect against electric shock from exposed metal parts. In most boat installations it also connects to the main boat ground point.

Common Grounds

What is a common ground on a boat? On shore, this is easy because it's the earth itself. On a metal boat, the general mass of the hull acts as the ground plane and directly interfaces with the seawater. By default, all grounds are to the hull itself and so all are held at an equal potential. With a fiberglass or wood boat, the whole issue of common grounds becomes somewhat controversial and harder to understand. This is also further complicated when we bring AC safety grounds into the mix. As we have seen, each ground has a different function and this should always be considered. Many recommendations call for all of these separate grounds be tied together or bonded, creating a similar scenario as you would find on a metal boat. This has a lot of merit; for example, bonding the polarizing ground point for the battery negative to the instrument and equipment grounds that are also supplied. By default, a battery circuit polarizing ground connects to the engine along with AC grounds and instrument grounds so that true isolation is impossible. Underwater items being protected find paths back through shaft couplings and careful consideration must be given to these systems and how they might interact and cause corrosion. This is the perfect place to bring the purpose and safety aspects of a galvanic isolator (or an isolation transformer) on scene. [Ed: ABYC A-28 is the standard for galvanic isolators on boats. For details on the use and installation of a galvanic isolator refer to DIY 2004-#4 issue.] The galvanic isolator is an important safety device for boats equipped with AC and DC systems. In the case of lightning protection, the purpose is to hold all circuits at an equal potential, as large voltages can be induced into other circuits. Again, this has a great deal of merit and is recommended by many.

Another reason given for bonding all parts is that of ground loops. A ground loop is the condition where all electrical grounds are intentionally not maintained at the same electrical potential, that is zero volts. Current is only able to flow between two points that have a difference of voltage or potential. One of the more undesirable effects of circulating ground currents is that it can generate electrical noise. In a boat, ground loops are relatively uncommon and most issues revolve around chassis grounds on electronic equipment. Some of my radio buddies also prefer no connection of the RF ground, preferring a separate ground plate or internal ground and that is an approach I would also prefer.

Practical Considerations

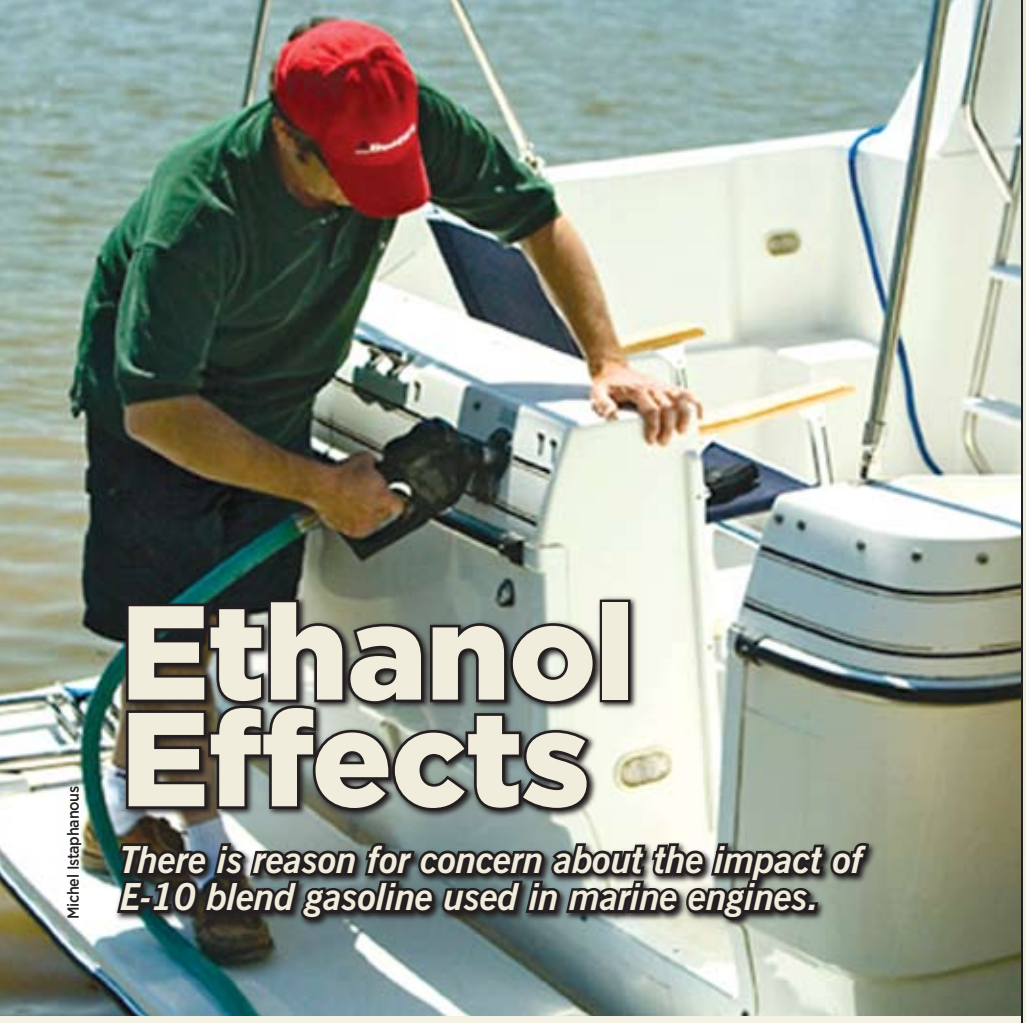
An installation of various DC grounds and other connections must provide a low resistance path (in AC systems we call this low impedance) as well as avoid the creation of circulating ground currents or ground loops, as they are best known. A low-resistance grounding path consists of three main elements: the grounding conductors must be of the correct size or cross sectional area; the conductor lengths must be short enough so as not to introduce any voltage drops; and the connections must be clean and tight to avoid introducing high resistance into the circuit. When grounding static discharges, these have relatively high frequencies and charges tend to travel along the surface of a conductor or wire in a mode often called the skin effect. Stranded copper wire is always used as it has more surface area. In addition to its distaste for high frequencies, it does not like traveling around sharp bends so always work within a minimum bend radii. The same caution applies to lightning conductors as well.

When running any grounding conductors, always run them separately from normal current carrying conductors. Terminations must be clean and tight. It's often preferable to have a connection bar to connect each ground to this point. If one connection comes loose, you don't lose all of them. Make sure you connect a grounding conductor to any equipment that has a ground terminal, otherwise performance will be affected, causing electrical interference and/or noise.

About the author: John Payne, DIY's electrical consultant, is author of "The Marine Electrical and Electronics Bible" and "Motorboat Electrical and Electronics Manual," (Sheridan House).

Additional Reading

Lightning Prevention	2005-#3
Testing Bonding Systems	2003-#2



Michel Istaphanous

Ethanol Effects

There is reason for concern about the impact of E-10 blend gasoline used in marine engines.

By Jan Mundy

There's increased concern among boaters about using reformulated fuels in their marine engines. And rightly so! Today's "gasoline" combines petroleum, oxygenates such as grain alcohol (ethanol) or ethers (MTBE), and detergent (called dispersants). Such oxygenates improve octane quality and reduce carbon dioxide emissions.

Many areas have recently banned the use of MTBE, replacing it with ethanol blends produced by the fermentation of primarily corn in the North America (sugar cane elsewhere) and limited to a maximum of 10% by volume. Referred to as E-10 (10% ethanol, 90% unleaded gasoline), this fuel is designed primarily for low emission automobile engines. It's not designed in consideration of the fuel needs of marine engines.

On the plus side, ethanol is a cleaner burning fuel than gasoline, which contributes to better air and water quality. It contributes about 3% of the overall octane rating, resulting in moderate increases in horsepower and torque but apparrently yielding slightly lower mileage. Albeit, marine engine manufacturers allow the use of ethanol fuel in their products, ethanol has some negative characteristics as well and it impacts marine fuel systems in multiple ways. Unlike automotive fuel tanks, boat tanks are vented to the air. Ethanol is hygroscopic, meaning it attracts water, as much as 100% of its weight in water. Moisture in the air drawn through the vent is absorbed into the tank, especially at high temperatures. When excessive moisture is absorbed, the ethanol and water separate from the fuel and settle on the tank bottom. The upshot of running this blend through a marine engine causes metal fuel system components to corrode; deterioration of certain rubber and plastic parts, not utilized in automobile engines, aggravating permeation and fuel leaks; accelerating wear damage to bearings, cams, pistons and piston rings; starting difficulties and low-speed stalling; fuel permeation through flexible fuel lines and vapor lock or fuel starvation. Ethanol fuels have a lower Reid (the common method for measuring vapor pressure) vapor pressure than gasoline. This means they function best in cold climates, which hardly describes the operating environment of most marine engines. If you increase either the percentage of grain alcohol, the temperature of the fuel (no higher than 110F/43C) or lower the pressure of the fuel sys-

Add a fuel stabilizer with every fill up and before storing your boat longer than a few weeks to counter the damaging effects of E-10.

Engine Off-Season Prep

If you're running your boat on ethanol-blended gasoline, prepare your boat's fuel system for long-term storage by either emptying the tank or filling the tank. In either situation, always add a fuel stabilizer.
To winterize the engine, add a small amount of two-stroke motor oil to a small remote tank with a quart of new premium fuel and stabilizer. (For complete engine winterizing details, refer to DIY's MRT Series "DIY Mechanic" CD-ROM.) This is particularly important with four-stroke engines as they have very small fuel jets that clog easily. If the carburetor on your engine has a drain that you can access, drain the carburetor before storage.

tem you increase the potential for an engine vapor lock condition.

There are other problems with E-10 fuel. The cleansing effect of ethanol acts like a solvent, cleaning dirty fuel tanks and other fuel system components. This is good for tanks, bad for marine fuel systems. Rust and other contaminants that have built up over the years are loosened and mixed with the fuel flowing to the engines, plugging fuel filters and interfering with reliable engine operation. Owners of Bertram, Boston Whaler, Chris-Craft, Hatteras and other boats with fiberglass fuel tanks may find their fuel tanks reacting with ethanol in a very dangerous and expensive way. BoatU.S. Marine Insurance reports that ethanol is dissolving the resins in some older fiberglass tanks. Resins form a gluey black residue that sticks to valves, clogs intake manifolds and bends pushrods. The fuel filters don't always trap this black sludge and it passes through along with the fuel carrying it. If your engine experiences rough running, hard starting or stalling, check for black sludge in the carburetor. Don't run your engine. Tank replacement is the only fix. Tank deterioration that was originally attributed to tanks manufactured prior to 1991 now appears in tanks made more recently. In some extreme cases, dissolving of the resins can cause perforation of tank bottoms and resultant fuel leaks (see "Anatomy of a Fiberglass Gas Tank" on this page). The bottom line? If your boat has a fiberglass tank and your fuel source is ethanol, replace the tank before the alcohol destroys it. Additionally, engines running on this fuel require special off-season storage care.

The settling of ethanol and water in fuel tanks is referred to as phase separation and can happen once water reaches as little as .5% by volume. Beyond two weeks in a boat's vented tank, ethanol beings to separate and this ethanol/water phase is drawn into the fuel delivery system. The longer this fuel mixture is stored, the more it deteriorates, which contributes to the gumming up of carburetors and fuel injectors. Since E-10 provides some of the fuel's octane rating, the octane level drops as it separates. This can cause engine pinging and knock, loss of power and reduced fuel economy. To protect fuel tanks and engines, experts recommend adding fuel stabilizer to the tank year round. MDR's E-ZORB, Sta-Bil, StarBrite Star Tron and other brands disperse and emulsify water and ethanol back into the fuel, allowing both to burn safely through the engine. Dewatering the fuel effectively prevents phase separation and octane loss. Some stabilizers claim even to breakdown the dissolved tank sludge into minute

Anatomy of a Fiberglass Gas Tank

(top left) Close up of damaged fiberglass fuel tank (right) after using 10% ethanol for just four months. This tank was made by Pate Plastics and installed four years ago under the center console seat on a Boston Whaler 17' (5m) Montauk. Fuel was slowly seeping out onto the deck where it became obvious to the owner that something was amiss. (bottom left) The other side of the same tank had not yet been penetrated (paint was chipped away to check for damage). A big sticker on the tank stated: "Do not use for alcohol."

The engine had been missing at high speed and finally wouldn't start at all. The engine-mounted fuel filter was removed and set on a bench to dry out for a few days. This photo shows about 20% of the residue that fell from the filter when tapped on clean white paper. Note the different "stuff" in the filter, mostly bits of fiberglass stained by gasoline along with other contaminants. Clearly the clogged filter caused the engine to be starved for fuel.

Replacement 7.5 gallon (28L) plastic (not fiberglass) tank and new fuel fittings. Not shown is a canister water separator 22-micron fuel filter installed on the transom, which is now used in addition to the filter mounted on the engine.

— Lee Mairs

CONTENTS/ PREVIOUS/ NEXT/

Engine Safeguards

Follow the recommendations below to keep your engine operational when running on ethanol-blended gasoline.

- Use alcohol-free fuel whenever possible.
- Frequently inspect fuel system components, especially plastic parts such as hoses, seals and gaskets, and replace if any of these are suspect of deterioration or leakage. Install a water separating fuel filter if your boat is not now equipped with one.
- Don't mix MTBE and ethanol fuel. When adding fuel with ethanol for the first time, ensure that the tank is completely free of water. Best practice, though seldom practical, is to start with a completely empty, dry tank.
- Add a fuel stabilizer to the fuel all year long.
- Add an OEM-approved fuel injector cleaner.
- Install a fuel vapor detector/alarm in case of a leak.
- Regularly inspect and change the fuel filters. Carry spare fuel filters so changes are handy if filter plugging becomes a problem.
- Routinely inspect the tank for the presence of water. If you suspect the fuel has separated, dispose of the tank contents (use a fuel recovery service), clean the tank and refill with fresh fuel.
- During the boating season, when not using the engine, keep the fuel tank full to prevent water accumulation.
- Listen for engine knocking or rough running, signs that the fuel you are using has separated.

particles that pass through filters and are burned away. With every refueling and when preparing your fuel system for long-term storage, add stabilizer at the mix rate indicated on the product's label. (For the recommended engine storage procedures, see "Engine Off-Season Prep" on page 29).

E-10 is here to stay and unfortunately, so are the side effects for boat owners. Some marine engines and fuel systems will operate seamlessly on ethanol, many will develop problems. DIY recommends that you consult your engine manufacturer for fuel system recommendations, routinely monitor your boat's fuel system and read "Engine Safeguards" (across) for tips on maintaining a healthy fuel delivery system.

About the author: Jan Mundy is co-founder and editor of DIY Boat Owner magazine.

Picture Perfect

Original radar arch. Note positioning of equipment. As part of the refit, the author relocated all gear to improve aesthetics and performance.

With today's satellite dish technology you can enjoy high definition picture quality and hundreds of channels while underway or on the hook. Here's what you need to know to install a satellite TV system.

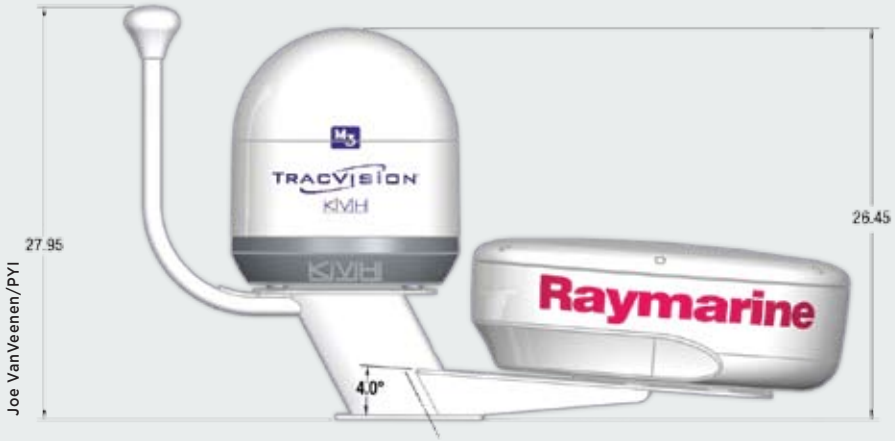
Story by Jim Discher, Photos by John Discher

Someone once explained "critical mass" to me as the last snowflake that lands on the mountainside just before the avalanche. On a number of fronts, technology has reached such a "critical mass." It's everywhere in our personal and professional lives and boating is no exception. Over the past 18 months I have spent countless weekends restoring "Bearboat," my 1989 12M Trojan Express Cruiser. Finally I arrived at that fun, albeit expensive part of my punch list, updating my navigation and communication systems.

If you are in the market for a new TV antenna, answering the following questions might help you narrow your options. How many televisions do you have on board and will you watch different channels simultaneously? How important is picture quality? Do you want access to cable channels or is network TV adequate? Do you want access to television while cruising? All those answers notwithstanding, what is your budget for onboard television entertainment?

If you don't stray from the dock, a basic set of rabbit ears from Radio Shack may be just fine. To kick it up a notch, I have friends who just added another receiver box to their home system for an additional $5 a month and installed a satellite dish on the dock. A nice option if TV viewing and cruising is not the combination you seek. For under $200, check out the Shakespeare Seawatch 2025 and 2030. These models are omni-directional so you don't have to physically rotate them to improve your signal and they will keep you tuned in while away from the dock. The big advantage with these antennas is their low cost and simple installation. If a satellite dish is in the picture, don't forget your checkbook. At this point, you're pushing the budget envelope to over $4,000, plus installation. If your budget can tolerate this stretch, consider options from KVH, Raymarine and Sea Tel. For the most part, marine satellite TV systems have been installed by marine technicians and were never really considered appropriate DIY projects. That changed with the introduction of KVH's new TracVision M3 (www.kvh.com), the world's smallest marine satellite TV system and the first that KVH has promoted as a self-install, do-it-yourself product. I decided to install the new TracVision M3 based on several key factors.

Few boats in the 25' to 40' (7.6m to 12m) size range have satellite devices, mostly due to size and weight limitations. The M3 is designed specifically for such boats. It's lighter, weighing just 19lb (8.6kg) and smaller with a diameter of 14.5" (368mm) and height of 17.5" (444mm). It has a stabilization system that compensates for the more active motion of these size boats verses larger yachts



Seaview Dual Mount with custom modifications engineered by PYI to keep the profile as low as possible and shrink the total height from 35" to 27.95" (889mm to 709mm).

and delivers performance comparable to 18" (457mm) systems yet is 40% smaller. Moreover, KVH has really simplified the installation. The entire M3 system is comprised of only five components: antenna/radome, coaxial cable, 12-volt receiver for DIRECTV service, RF remote control and the necessary cables. A single coaxial cable runs from dome to receiver and transfers data to the antenna, sends satellite signals to the receiver and provides power to run the antenna. Other satellite devices can require up to three separate cables to accomplish these same tasks.

Planning

Every boat project has its challenges and this one was no exception. In the planning stage I struggled with issues affecting bridge clearance, structural support, aesthetics, mounting options and giving each component adequate line of site clearance.

Where we live in Long Beach, California, at a typical high tide, we need to negotiate a bridge with a clearance as low as 12' (3.6m). With the current equipment on the radar arch we could clear that and it was critical to not add any height, retaining our freedom to go cruising pretty much at will. That would mean mounting all components inside a vertical space of no more than 30" (508mm).

Going through a major electronics overhaul was a great time to improve the aesthetics of the original arch. Over the 17 year life of the arch there had been numerous components added; GPS, stern light, VHF antenna, TV antenna, cell phone antenna and radar scanner. The arch looked cluttered and, in my opinion, dated the boat.

A web search found PYI (www.pyiinc.com), a supplier of PSS Shaft Seals and other engine components, Whitlock sailboat steering systems and stock and custom electronics mounts, based in Lynnwood, Washington. What really caught my attention was the Dual Mount, specifically designed to accommodate the new TracVision M3 and the 4kW Raymarine radar scanner that I had chosen. I had the opportunity to speak with Brian Gallagher, PYI's Seaview electronic mounting solutions product manager. Brian has an engineering background and was a tremendous resource on the subject of structural support considerations. He expressed concerns that installing a fully outfitted Dual Mount weighing 46lb (20.8kg) and adding 36" (914mm) of vertical rise would cause excess stress on the arch. Brian referred to similar applications where installers didn't like the movement of the arch while underway. He suggested I seriously consider single pole mounts for the M3 and scanner or what he called a single roll cage style mount for both. I really liked the look and efficient use of real estate that the stock Dual Mount provided but its height meant I didn't have the bridge

Removing old equipment left 43 holes to fill. Shown on the bimini is the new Seaview Dual Mount.

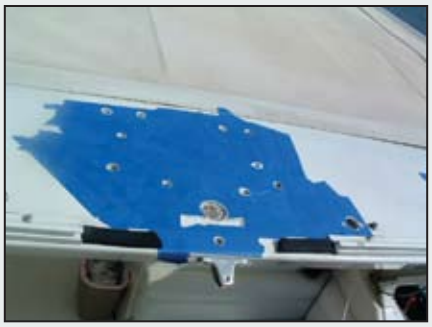
clearance. I gave Brian's comments careful consideration and decided to seek a second opinion.

The next stop was my local West Marine store where I had the pleasure of spending the better part of two hours with the electronics installation manager. We talked through the options, concerns and considerations. He assured me that he had done six PYI Dual Mount installations of radar arches with no complaints from customers or installers. Based on his experience, I decided to further pursue the Dual Mount option.

Another call into PYI landed me with PYI's creative designer Jason Rosenberg. Over a 10-day period, he

Marking the footprint of the new mount on arch top seemed like a good place to start this project.

Fiberglass mat epoxied to the underside of the arch sealed the holes and provided additional reinforcement.



After filling two-thirds full of epoxy resin, the perimeter of each hole was beveled using a Dremel then filled with 3M Marine Premium Filler.

produced several CAD drawings of a customized Dual Mount that would accommodate the radar scanner, GPS antenna and M3. Jason designed a dual mount shorter than the stock version with a lower center of gravity. He also added a 4° negative slope to the radar scanner mount to optimize scanner performance by keeping it more parallel to the surface of the water when cruising on plane. The final modification was an oversized backing plate, extending beyond the footprint of the top plate, to help distribute the weight and torque on the arch surface.

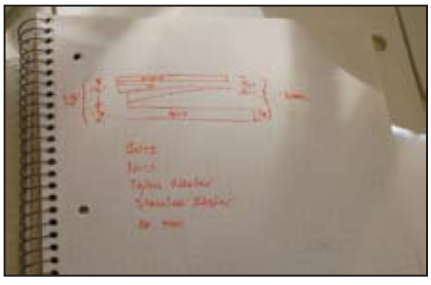
A Holey Task

It was finally time to remove the old equipment from the arch. I didn't anticipate that this task would turn the arch top into a Swiss cheese look alike. I decided to disassemble the radar arch first to expose all wiring and make for a cleaner install. This involved removing the two side vertical panels and then the one-piece underside. I planned to reposition all the equipment so I decided to fill all 43 holes. To provide additional reinforcement and seal the underside of the holes, I fiberglassed the bottom side of the arch. Working from the arch top, I taped around the holes and then used a syringe to fill each hole two thirds full of epoxy resin to protect the balsa core from water intrusion. Since gelcoat won't adhere to epoxy resin, I topped off each hole with 3M Marine Premium Filler. After it dried (about 30 minutes), I wet sanded and finished them off with gelcoat, which consumed two tubes of white Evercoat Scratch Patch. White paint finished the bottom of the arch. The result was a fresh look and a nice clean install.

Mounting Hitches

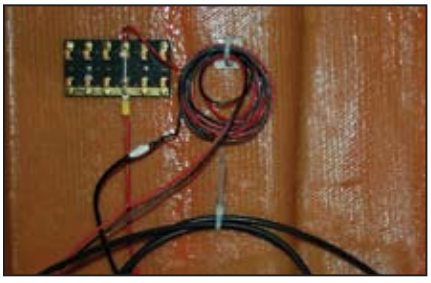
Finally, my attention turned to actually installing the new equipment. The West Marine rep warned me that the top of the arch was crowned, not flat. The Seaview mounting plate was, for the most part, flat. To achieve a flush fit with the arch surface, PYI came to the rescue and overnighted a pair of predrilled wedges made of StarBoard. My son, John, patiently shaped the two wedges with an orbital pad sander to achieve a flush fit between the arch surface and the mounting plate. I stacked the two wedges in position and applied a generous amount of 3M 4000UV sealant to all surfaces. As I bolted the wedges to the arch and backing plate, the sealant oozed out. I formed a smooth bead around the edges to level the excess sealant for a weatherproof seal. I left this to cure overnight. The next day I removed the bolts and the stacked wedges had become an integral part of the arch.

The KVH M3 installation guide is especially well done. It details 11 easy-to-follow steps with detailed photographs and illustrations. It may be the



(top) Dryfitting the Dual Mount made it obvious that you cannot mate a flat base to a curved arch using the supplied flat base. (bottom) The author's revised base assembly plan.

(top) Fitting predrilled StarBoard wedges. (middle) Drilling mounting holes in arch for the Dual Mount. (bottom) Taping edges before caulking saves on cleanup.



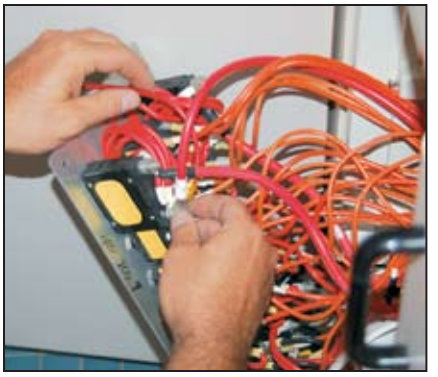
Wiring neatly placed inside locker behind the 12-volt receiver.

easiest to follow install guide I have ever used. For several reasons, it made more sense to install the TracVision system in reverse order, more or less. So the starting point for the installation was the electrical panel. The new 15 amp toggle switch fit nicely into a blank location on the electrical panel. Using electrician's "fish" tape, I ran a 10-gauge duplex cable from the starboard to the port side under the companionway steps and secured it every 18" (457mm). I decided to run the power source into a fuse block so we could have the added protection of a 6-amp fuse and access to power source for future components in that area.

Because the M3 comes with an RF remote, I was able to mount the receiver box discreetly on the back side of an access inside a hanging locker, conveniently located next to the television. I installed enough extra wiring and cable so the entire panel, with receiver intact could be pulled out for easy access in the future. After installing all wiring as specified in the install manual, we flipped the switch and held our breath. The receiver box lit up like a Christmas tree. Don't all of your installs work on the first try?

Running the coaxial cable required drilling a hole in the bulkhead. I routed the cable over the port fuel tank and secured it every 18" (457mm). After sealing the pass through hole in the bulkhead with silicone caulking, the excess cable was neatly coiled and secured on the port side vertical of the radar arch.

(top) Original locker frame was made slightly larger using a jigsaw and then the vinyl is stapled down. (middle) Receiver mounts to the hatch access panel. (bottom) Beside it is the TV installed by the previous owner. Plans are to eventually replace this unit with a ceiling mounted LCD TV that can be turned and viewed from anywhere and install a splitter for cockpit or dock viewing.



Wiring the dedicated toggle switch into the electrical panel.

It was time to mount the components (TracVision, scanner, GPS antenna) onto the radar arch. I ran all cables up through the hole in the arch and then through the Seaview Dual Mount. I had enough excess cable to connect each of the respective components on the deck. This was much easier and safer than wiring everything standing on a ladder. With the help of my wife, Kim, we hoisted the fully loaded mount up on the arch. I through bolted it to the backing plate on the underside of the arch. Everything was taped off and I applied 3M 4000UV sealant (recommended by PYI) around the base plate and at the point where cables pass through the mount to prevent water from entering the mount.

Sea Test

The only satellite provider the M3 will work with is DIRECTV. If you're already a DIRECTV subscriber at home, it costs US$4.99 a month to get service on your boat (same as adding a new TV to your home account). If you're not a DIRECTV subscriber, you need to sign up before you activate your M3. When you open the box that comes with the M3, you can't miss the colorful instruction sheet that directs you to call the number to activate your TracVision M3. Once your DIRECTV system is installed, you call KVH and they authorize your onboard 12-volt box as an addition to your home subscription.

Excess cables are neatly coiled and secured to the inside of the arch every 12" to 18" (304mm to 47mm). Note metal backing plate to give extra support for the mount.

M3 and scanner are attached to the Seaview mount before hoisting onto the arch.

GPS antenna now installed on the arm.

Author caulks around radar cable and GPS pole mount to prevent water intrusion inside the mount or arch. "We get some pretty wet rides on this boat when the seas kick up."

As I continued the process of installing everything in reverse order, I turned my attention to the business of switching my home satellite TV provider to DIRECTV. Fortunately, my condo was wired for a satellite system so I switched my provider to DIRECTV, added the KVH receiver as the fourth box on my system and it's included in my monthly bill. If you don't have or are not interested in installing satellite TV in your home, you will have to subscribe to the service solely for the KVH system. This could be a fairly significant increase in your monthly expense, depending on the package you select. In the future, I would suggest to the folks at KVH that they offer options to other satellite TV providers if possible. Dealing with the DIRECTV installation company was the most difficult and time consuming part of the process and I was working with DIRECTV corporate, not a dealer or agent. Out of frustration, I ended up calling the president of DIRECTV directly and finally got things moving in

the right direction and I ended up with a direct dial number to the manager of their installation department.

Now for the good news. Once the home system was up and running, I was anxious to get to the boat and fire up the M3. Everything was connected and all that was left was to activate the receiver. I flipped the switch on the electrical panel and absolutely nothing happened except a rush of disappointment. My thoughts went to the dark side, "I knew this all seemed to easy." A good friend who is an electrical engineer once told me, "When it comes to solving electrical problems, start with what you know." Following that sage advice, my first thought was to make sure the cables and wires on the back of the receiver were connected and at least passed a visual inspection. To my delight, I discovered there was an off/on switch that had been switched to the "off" position. What a sense of relief when I flipped it to the "on" position and all the indicator lights fired.

Almost immediately, a very space age, sci-fi whining noise came from the KVH dome and all the information I needed to get the activation process underway appeared on the TV screen, including a phone number to call for activation and serial numbers for the receiver, antenna and card. Knowing that I was going to use the system for the first time on a weekend, the week before my planned M3 startup I contacted KVH's airtime services manager who personally contacted the manager at the installation company to provide all the necessary information for activating the M3. Once I had the system working, I called DIRECTV's installation department in Denver with my information and before I hung up the phone, I was surfing through over 300 channels and the picture quality was great.

The only drawback at this point was a constant whirring noise that came from the M3 radome. On a smaller boat, this noise could be a bit intrusive. The next week I contacted Chris Watson, corporate communications manager of KVH Industries. Chris explained that "As for the whirring sound, if you're not underway, the system will perform what's known as a CONSCAN (conical scan) during which the antenna moves in small circles around the signal origin point (i.e., the satellite's position in the sky) to ensure it's always getting the optimal signal strength. In addition, as you move around the boat and its position changes; for example, you move to the starboard side and that side dips a bit due to your weight, the antenna automatically adjusts to compensate. As a result, it's usually in some sort of motion to compensate for even minor dynamic changes."

We decided to combine work and play to sea trial the system and take a cruise down to Newport Beach for some lunch at one of our favorite spots, The Cannery. I intentionally plotted a route that took us 5 nautical miles offshore in 2' to 4' (61cm to 122cm) seas with a mixed chop that made for a fairly bumpy ride and a good test for the M3's tracking system. Much to my delight, everything worked like a charm. The KVH consistently delivered a high quality picture and sound with only some minor snow on occasion. I'm also pleased to report that arch movement did not increased a bit. If anything, it seemed to be more stable and have less torque or movement than before.

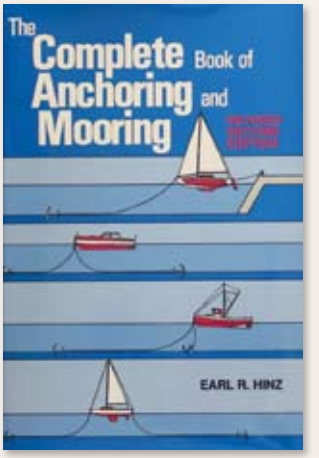
Job completed! The hailer is mounted on one side and the VHF on the other side.

Two last points worth mentioning. Everyone at KVH was very professional and responsive. While the installation guide was excellent, I mentioned two minor areas

•BOOK REVIEW•

The Complete Book of Anchoring and Mooring by Earl R. Hinz

330 pages, Hardcover
(Cornell Maritime Press
US$29.95)



Anchors, rodes, bow rollers, windlasses and crew skills are all factors to consider to ensure you anchor safely in all kinds of weather situations. Focusing on recreational and work boats in the 12' to 80' (3.65m to 24.3m) range and covering monohulls, multi-hulls, light displacement sailboats, cruisers, sportfishers, passagemakers and workboats, this book is written in three parts. The sections (The Technology of Ground Tackle, The Art of Anchoring and Permanent Moorings) aim to educate you and your crew to minimize potential problems during important anchoring maneuvers. Hinz shows boaters that, with the right equipment and technique, they can be more confident that their boats will stay put at anchor.

— Tracy Croll

CONTENTS/ PREVIOUS/ NEXT/

DIY Bill Of Materials

MATERIALS	COST (U.S. Dollars)
KVH TracVision M3	$4,995.00
PYI Seaview custom Dual Mount for KVH M3 and RayMarine 4kW radar scanner, including design and consulting	$1,300.00
6oz fiberglass mat	$16.99
West Systems epoxy resin with #105 hardener and #205 pumps	$58.00
Miscellaneous: acetone, mixing buckets, resin squeegees, latex gloves	$17.15
3M Marine Premium Filler	$29.29
Evercoat Scratch Patch (2)	$12.58
3M Marine 4000UV sealant	$10.49
2" (5cm) #2090M tape	$15.79
West Marine Sea Gloss paint	$29.99
Nuts, bolts, washers	$20.00
Radar cable (a casualty of the project, I inadvertently drilled through my new cable)	$220.00
20' (6m) 10 gauge duplex wire	$21.80
Plastic wire ties	$12.00
Toggle switch	$5.29
Fuse Block, AGC 6 circuit and fuses	$13.19
Electrical connectors	$10.00
12-Volt Doctor Handbook	$14.49
Total Materials	**$6,802.05**

Description	APPROXIMATE TIME (hours)
Preparation and research	5
Removal of all old navigation equipment and wiring	5
Arch Repairs	20
Mount and plates	3
Wiring (M3 only)	4
Receiver installation	2
DIRECTV installation	5
KVH activation	1
Total Hours	**45**
Install all other electronics (radar, GPS, VHF, Fluxgate compass, hailer) and associated wiring, etc.	50
Total Hours for Project	**95**

that weren't clear and Chris Watson passed them along to the technical publications manager for inclusion in the next printing.

Being a true DIYer, I look to the future and ask, what's next? As it relates to this project, I'm considering a complete audio-visual refit to include: upgrading to a LCD TV and perhaps positioning it on the ceiling in the middle of the salon with some sort of swivel mount that would allow viewing from almost anywhere below decks; add a splitter and two jacks so I can position a second TV in the cockpit area or on the dock when I have the boys over to watch the big game; connect the TV audio into the sound system to pick up XM Satelite Radio (included with DIRECTV); upgrade all six speakers, adding two to the underside of the arch, adding a amplifier and a sub woofer; upgrade my stereo to include CD and MP3 players and possibly relocate it or add a remote control at the helm station. Then there's TracNet 100, a complementary product to KVH's satellite TV systems that brings MSN TV Internet connectivity and simultaneously turns the boat into a moving Wi-Fi hot spot. So if you're in Long Beach or Catalina Island (in California) and want to watch the big game, stop by "BearBoat" for a cold brew.

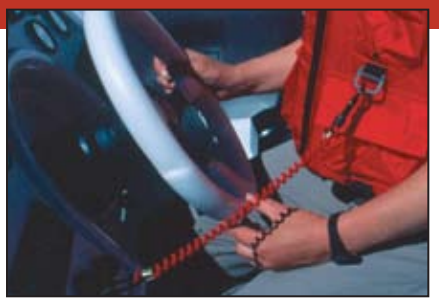
About the author: Since discovering boating just five years ago, Jim Discher has nearly completed his second boat refit, a 1989 Trojan 12 Meter Express Cruiser.

POWERBOAT RIGGING

Life Saving Switch

Install an engine "kill" switch to ensure that the engine shuts down if the driver is accidentally ejected from the boat.

By Steve Auger

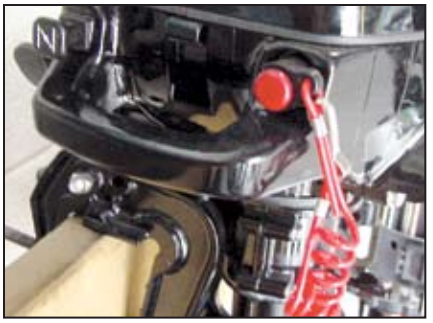


Too many sad stories of boating injuries or fatalities start with a fall overboard. Some of the saddest are those that involve a driverless boat with the engine at full throttle.

All single engine boats in a runaway situation, without someone at the controls, will continue to run in circles until they run out of fuel or collide with some immovable object. Under these conditions, the boat can return to the position where the driver was ejected, running into or over the person in the water.

In the mid-80s, in response to the growing number of accidents, many outboard engine and boat manufacturers responded by making the engine "kill" switch standard equipment on all tiller-steered outboard engines. A lanyard of coiled line or similar design connects to a switch that shuts down the engine if the lanyard is subjected to full tension. The other end of the lanyard clips to a wrist strap or other connection device worn by the boat operator. If, for any reason, that lanyard pulls taut, the tension activates the engine shutdown. The tension needed on the lanyard to activiate the shutdown can result from the driver stepping away from the helm, falling overboard or some event that results in unintentional abandonment of helm control. In the best outcome of this worst case scenario, the boat operator, wearing the lanyard and the recommended PFD, ends up being dunked but still able to get back to the dead-in-the-water boat. While the boating industry responded to the need, far too many boaters still fail to use this simple safety device.

In order to protect operators of larger boats, the lanyard device was designed to be connected on or near the remote helm console or engine control lever. For boats with twin engines or multiple control stations, a lanyard activating switch is mounted on the instrument



Steve Auger

Most tiller-steered outboards built since the mid-80s are equipped with a "kill" switch either on the engine front panel (left) or on the cowl (right).

Safety lanyard and engine shutdown control switch mounted near the helm station.

panel. These switches are available as part of a rigging kit on current products and are also available as a kit for retrofitting to engines not equipped with this highly desireable safety device. Quicksilver Lanyard Kit (part number 87-19674Q2; about US$75) fits most outboards diesel and gas inboards (including jet and sterndrives). It comes with complete instructions, including wiring schematics, that any confident DIYer can follow.

The flush or surface mounted stop switch assembly installs in a convenient location on the dash that's free of obstructions and within the lanyard's reach of the driver. On inboard or sterndrive engines, the three-wire switch is wired in series between the key switch and the engine or power wire (usually purple in color). With the switch in the run position, power is supplied as per normal to the engine's ignition system. Activating the lanyard switch (lanyard clip pulls the switch down to "off") opens the circuit to the ignition power supply, which in turn, shuts down the engine. In an outboard or two-stroke jet application the stop switch is wired in series between the switchbox (power pack) kill switch and ground. With the switch in the run position there is an open circuit between the switchbox and ground, allowing normal operation. Again, activating the lanyard under tension closes the circuit, grounds the switchbox output and shuts down the engine. To mount a stop switch on the flying bridge as well requires an extension harness kit (part 84-16866A2) that connects to the lower helm station. Multiple lanyards can be wired to the same stop switch terminals to protect passengers in applications such as high-performance boats and high-powered inflatables or any boat operating in heavy seas.

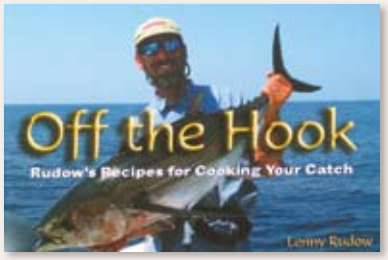
Steve Auger

(top) Lanyard stop switch kit consists of a dash-mounted stop switch assembly, 56" long (when stretched) lanyard and mounting hardware and is easily retrofitted to most engines. (bottom) Sample dash-mount installation.

To reduce the risk of injury when boating (especially when alone) wear a PFD and attach a safety lanyard. You'll dramatically reduce the potential for injury or worse and you'll set an excellent example for younger boaters that are eager to take the helm.

About the author: Marine mechanic and DIY's engine technical advisor, Steve Auger, has more than 35 years experience in marine retail and manufacturing, mostly with Mercury Marine.

•BOOK REVIEW•



Off the Hook by Lenny Rudow
230 pages, Hardcover (Tidewater Publishers US$19.95)

If you're like me and your relentless quest for the "big one" has you releasing most of your perch catch back to the water to give it a chance to grow into the "big one" for another angler, then the recipe for Grilled Perch Salad on page 178 may go some way to making your usual catch much more attractive and palatable. Lenny Rudow, fishing editor for Boating Magazine, extends his expertise about getting the fish to the boat to getting the fish to the plate so that it tastes better than anything you can buy at the fish market or as restaurant fare. While full of recipes that tantalize your taste buds for catfish, cobia, halibut, mackerel, mahi-mahi, sunfish, swordfish, trout, et al. The list goes on and Rudow's book takes you through the whole process, from proper chilling to filleting and cleaning methods for specific fish. Fire up the grill and have a fish party! — Tracy Croll

S. Canfield

Quick Connect

Installing a modern potable water plumbing system is, literally and figuratively, a snap once you've cleared the planning and purchasing hurdles. This guide will help you navigate the course of plumbing terms and product availability issues.

By Sue Canfield

In recent years, semi-rigid polyethylene (PE) tubing has become the preferred material for water systems in boats and elsewhere. Its physical properties of chemical resistance, flexibility and durability at temperature extremes make it an ideal material for piping in hot and cold potable water systems. If protected from direct exposure to sunlight, PE tubing will last as long or longer than other approved plumbing materials (**Figure 1**).

Semi-rigid PE tubing is sold in both straight lengths and coils. In the United States, nominal tubing sizes are not actual sizes. For example, PE tubing that is nominally 1/2" copper tubing size (CTS), has an inside diameter (ID) that is actually less than 1/2" and an outside diameter (OD) of 5/8". In Europe, PE tubing is sized according to its actual OD. The PE piping onboard most recreational boats is 1/2" CTS (5/8" OD) or 15mm OD.

Polyethylene is generally classified according to its density and molecular structure. Tubing used in potable water systems is most often linear low-density polyethylene (LLDPE) or cross-linked polyethylene (PEX). Look for the certification labels "ANSI/NSF 61" and/or "FDA approved" (see "ANSI/NSF 61" on next page).

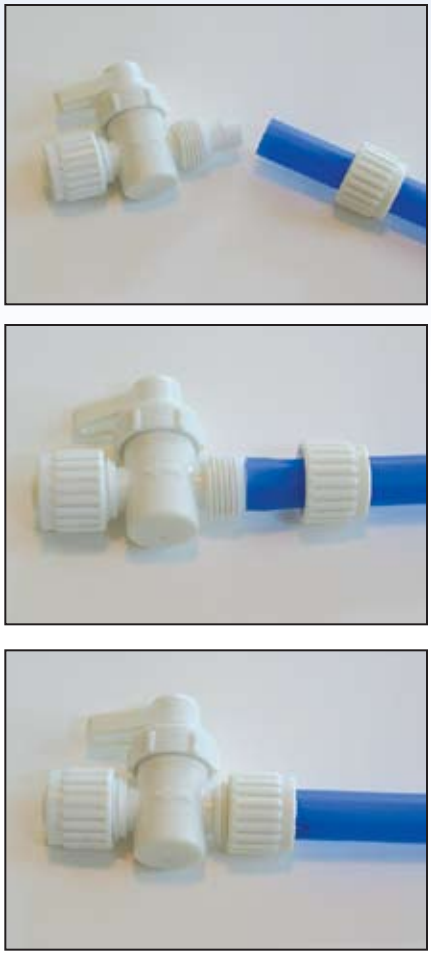
Translucent tubing will admit light and encourage algae growth; opaque tubing is preferable. Much of the PE tubing used in boats today is semi-translucent; red for hot water lines and blue for cold.

Sea Tech

Coiled polyethylene (PE) tubing.

Fitting Facts

Sections of PE tubing join together using mechanical fittings. Compression fittings have a threaded nut that unscrews and slides onto the tubing. The tubing is then forced over the fitting's flared barb until it butts against the shoulder of the fitting. Finally, the nut is threaded back onto the fitting and tightened. Quick-connect (push-in) fittings have a collet, a grip ring (or teeth) and a synthetic rubber O-ring seal (**Figure 2**). Tubing inserts into the fitting until it butts against an internal stop. It's held securely until disconnected by pushing the collet squarely against the face of the fitting. Slipping a collet (or lock) clip over the tubing between the collet flange and the body of the fitting prevents accidental release.



S. Canfield

Assembling a Flair-It compression fitting.

Figure 1: PE Tubing for Potable water Applications

Advantages

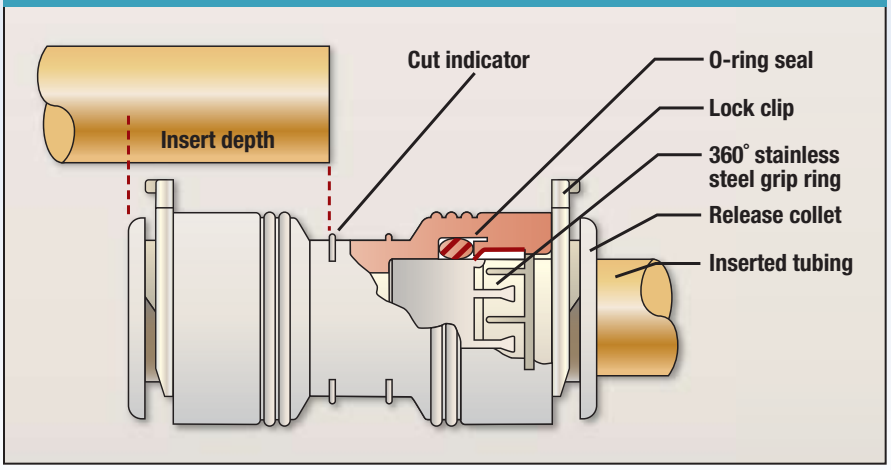
- Non-toxic; will not leach taste or odor.
- Can be used with hot or cold water.
- Flexible, lightweight and easy to install.
- More burst-resistant than other piping.
- Can be readily disconnected and reused.

Limitations

- Designed for indoor and buried applications only; do not expose to direct sunlight.
- Filtered or reflected light will not harm PE tubing.
- Performance rating: 100 psi (7 bar) at 180F (82C), 160 psi (11 bar) at 72F (22C).

(facing page) 1/2" tees: Flair-It, Sea Tech (35 Series) and PEXtite. (above) 15mm tees: Whale, Sea Tech (Metric) and John Guest.

Figure 2: Quick-connect Cross-section



Joe VanVeenen/PEXtite

Fittings used with PE tubing are made of high performance thermoplastics, namely: acetal, PE, polypropylene (PP) or polysulfone (PSU). All four materials have very low water absorption rates and are chemically resistant. Acetal has the lowest impact strength and melting temperature. Polysulfone has the greatest strength and highest melting temperature. It's suitable for continuous use in temperatures up to 300F (149C). Polysulfone fittings were specifically developed to meet residential building codes in the U.S. and Canada. However, PSU is not resistant to certain volatile organic compounds (VOCs) and caustic chemicals, many of which may be found on boats. Manufacturers' catalogs advise that PSU fittings should not be exposed to "pipe dopes (liquid thread sealants), leak check compounds, bug sprays, lubricants, cleaners, paints, bleaches, acids, solder fluxes, plastic piping primers and cements, oxidizing agents, alkaline solutions, thinners, fuels, oil based caulk, hydrocarbons, spray foam or foaming agents. i.e., insulation." Nonetheless, if installed per ABYC guidelines (that is above the normal bilge water level) and maintained appropriately, PSU fittings should do well in the marine environment.

S. Canfield

Stem fitting manifold.

At first glance, the various fittings pictured in catalogs and their nomenclature can be a little intimidating (For clarification, refer to "Acronyms" on page 48). Connectors (a.k.a. couplings) are used to join tubing end-to-end; elbows and tees join tubing at right angles. Stem fittings (which may also be connectors, elbows or tees) have a straight stem (tube) in lieu of a quick-connect collet. This stem allows the stacking together of two or more fittings, such as to configure a manifold.

Special connectors (often called adapters) connect PE tubing to the various water fixtures found onboard a boat, including one or more water tanks, pressure pump, hand or foot pumps, water heater, faucets, showers, icemaker, etc. If you are modifying rather than replacing your water system, there are also connectors for joining PE tubing to flexible hose, rigid pipe and copper or polybutylene (PB) tubing. It makes little difference if you choose to install an imperial (inch) or metric system, so long as the adapters you need are available.

In the manufacturers' catalogs, you will also find shut-off valves, check (non-return) valves, end plugs and caps. Common accessories include mounting clips for securing the piping in your boat, collet clips to prevent accidental release and tubing cutters.

ANSI/NSF 61

The American National Standards Institute (ANSI) is a non-governmental organization that acts as administrator and coordinator for U.S. private sector voluntary standards-making bodies like NSF International, formerly the National Sanitation Foundation, and the American Boat & Yacht Council (ABYC). Plastic piping and fittings sold for use in potable water systems must comply with ANSI/NSF 61 and/or U.S. Food and Drug Administration (FDA) requirements. ABYC standard H-23, Installation of Potable Water Systems for Use on Boats, is the recreational marine industry's guide for system design, materials selection, installation and sanitization.

Planning Perfection

Before you start shopping for tubing and fittings, visit your boat and make a plan drawing of your existing water system. Then make a list of all the








(1) Sea Tech metric series coupling and elbow; (2) Whale 1/2" hose connector, (3) 1/2" BSP female and 1/2" NPT male adapters; (4) Flair-It three-way valve; (5) Whale foot pump with brass check valve and polypropylene fittings; (6) PEXtite 1/2" by 3/4" garden hose adapter; (7) Sea Tech connector (adapter) with cone seal. (8) John Guest twist and lock fitting with opaque barrier pipe and color-coded collet cover.

S. Canfield

Sample Plan Available Online

A comprehensive sample system drawing, plumbing plan and parts list for a 37' (11.2m) sailboat in pdf format is available by clicking here.

fixtures connected to the system. Don't forget the cockpit or transom shower, deck and/or engine room spigot and icemaker, if applicable, or toilet(s) with freshwater flushing. Do you want to make any changes in addition to replacing the piping? My boat was 24 years old when I finally replaced its water system, so I decided to install new foot and pressure pumps, as well as a new strainer, accumulator and inline water filter.

Do you want to install a conventional system or a manifold system? In a conventional system, fixtures are plumbed in series (**Figure 3**). In a manifold (or octopus) system (**Figure 4**), dedicated lines run from a manifold directly to each fixture. The manifold serves as the "main distribution panel" for the system. While manifold systems use more tubing than conventional systems, they use fewer fittings and so are often less expensive to install. Manifolds with valves allow you to turn off the water to one fixture (e.g., for repairs) while

S. Canfield

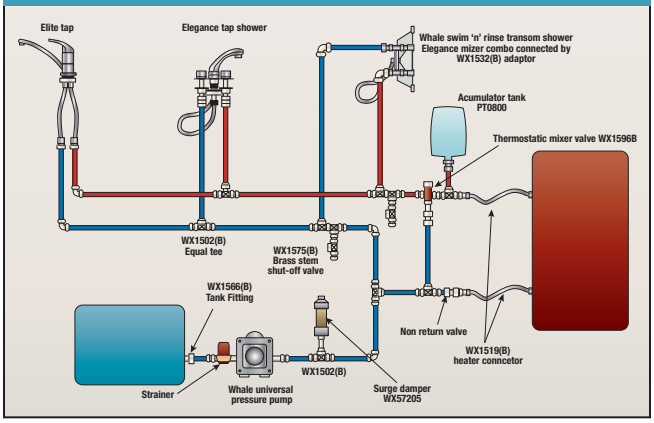
Red and blue tubing makes it easy to identify hot and cold water lines. Black plastic clips support the tubing and minimize stress on fittings due to the boat's movement.

the rest of the water system remains in service. As needed, modify your drawing to reflect any desired changes.

Now you're ready to put your plumbing plan together. You will need a notepad, tape measure and caliper. I started by mentally dividing my plan drawing into segments, then listed the fittings needed for each segment in the order in which I would install them, starting from the water tanks. Then I measured to determine how much tubing would be needed for each segment. Since PE tubing is quite flexible, you may discover that you need just a few tees and elbows in addition to adapters at each fixture. Use the recommended minimum radius bend table in **Figure 5** to help you decide where an elbow fitting may be required.

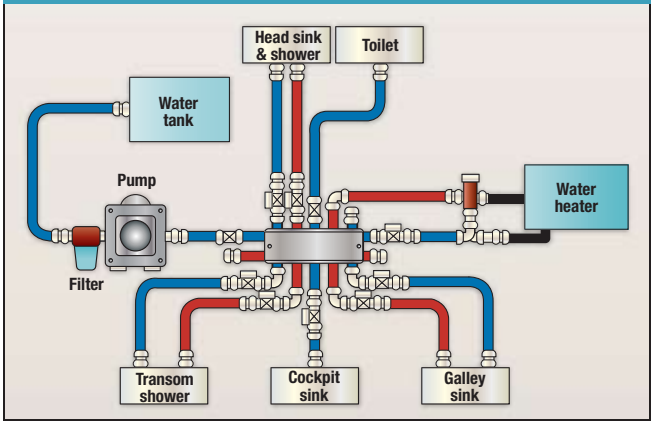
What type of connection does each fixture have? Hose barb or threaded connection? What size? Straight or

Figure 3: Whale Conventional System



Whale

Figure 4: Manifold System



Whale

Figure 5: Minimum Bend Radius (PEX-8)

Tubing Size	Bend Radius
3/8" CTS/12mm OD	4"/101mm
1/2" CTS/15mm OD	7"/178mm
3/4" CTS/22mm OD	9"/228mm

tapered threads? Male or female? Record all this information on your list of fixtures. If you plan to buy any new fixtures, check with the manufacturer to determine the type of connection. This information is often listed in catalogs and/or owners manuals that can be downloaded from manufacturer's websites.

Whale tubing cutter.

S. Canfield

Tubing cutlines provide visual confirmation that tubing is fully inserted.

Before leaving your boat, double-check your list of fittings, the amount of tubing needed for each segment and the connection type for each fixture. Next, review fitting manufacturers' catalogs, draw up a list of required parts (with part numbers) and get price quotes. See "Shopping Guide" on page 48 for suppliers' contacts.

Installation

Finally, after the many hours devoted to system planning, installation is straight forward and very rewarding. Assembling a new PE water system is like adult Tinker Toys. Here's a handy list of installation tips.

- Prior to installation, store your tubing and fittings indoors away from direct sunlight.
- Cut the tubing squarely using a tubing cutter, not a hacksaw.

Fitting Guide

Brand	Sizes	Color/Material/Type	Warranty
Flair-It	Inch	Ivory/Acetal/Compression	5 Years
John Guest	Metric	White/PE/Quick-connect	1 Year
PEXtite	Inch	Ivory/PSU/ Quick-connect	Lifetime
Sea Tech			10 Years
35 Series	Inch	White/PSU/Quick-connect	
24 Series	Inch	White/Acetal/Quick-connect	
Metric	Metric	Black/Acetal/Quick-connect	
Whale	Metric	White/PP/Quick-connect	10 Years

Sanitizing Guide

Follow these steps to sanitize a new potable water system before using. Remove, clean and replace the strainer at the water pressure pump. Remove the cartridge from the water filter, if installed. Unscrew aerators at faucets. Per the U.S. Public Health Service, use 0.13 oz (3.8ml) of common household bleach per gallon of water tank capacity. Add water to fill the tank(s). Open all faucets and showers. Allow water to run at each fixture until the odor of chlorine is detected. Allow the solution to sit in the tank and piping for 4 hours. The contact time may be reduced to one hour if the solution concentration is doubled (i.e., 0.26 oz (7.6ml) per gallon of water tank capacity). Drain the system completely. Flush with fresh water before refilling the tank. Replace the aerators and install a new filter cartridge.

S. Canfield

Use a hose with metal braided sheath to connect polyethylene tubing to a water heater. The Whale adapter shown here is 1/2" BSP female, threaded onto a 1/2" NPT male hose fitting with Teflon tape. The threaded adapter has an O-ring seal and need only be tightened by hand.

- If using quick-connect fittings, ensure the tubing is inserted fully to the raised indicator mark on the fitting. Some manufacturers also mark cutlines on their tubing as a visual guide.
- Tubing bends less than 10" (25mm) in diameter should be made cautiously to avoid kinks.
- PEX tubing will expand and contract with changing water temperature. Don't pull the tubing tight during installation; allow 1/8" (3mm) slack per foot (305mm) of installed tubing.
- To prevent undue stress (side load) on fittings, use clips to support horizontal tubing runs every 24" (610mm) or less, not the minimum of 30" to 36" (762mm to 914mm) as recommended by some manufacturers' catalogs.
- Support clips should not be closer than 3" (75mm) to fittings.
- Use plastic sleeves or grommets to protect tubing from abrasion where it passes through bulkheads, fiberglass moldings, etc.
- Use collet clips if desired to prevent accidental release of quick-connect fittings.
- Keep tubing away from sources of high heat; at least 12" (305mm) vertically or 6" (150mm) horizontally.
- Before connecting to a water heater, check the owner's manual to determine its temperature/pressure relief settings.

Hot water supplied to faucets and showers should be controlled between 110F and 140F (43C and 60C) by a thermostat and/or mixing valve. To minimize the number of fittings required, braided metal flex hoses can be used to connect PE tubing to a water heater.

- Ensure that the water supply to a freshwater flush toilet cannot siphon back into the potable water system. In a SeaLand Vacuflush toilet, for example, anti-siphon protection for the freshwater supply is integral to the unit's design. ABYC H-23.5.1 requires that "The potable water system shall be designed and installed so that the potable water is totally separated from any contact with water used for other purposes."
- Test the system after installation; check for leaks.
- Sanitize your boat's new water system before placing it in service. See "Sanitizing Guide" on page 47.

Winterization

Polyethylene piping is resistant to freeze damage but not freeze damage proof. Drain and winterize your boat's water system using compressed air or a potable (plumbing) anti-freeze solution. If water does freeze inside the tubing, it can be thawed using a hair dryer, warm wet rags or heat tape, provided care is taken not to overheat the tubing.

About the author: Sue Canfield is a marine surveyor in Annapolis, Maryland. She also teaches "Surveying Fiberglass Boats" at WoodenBoat School in Brooklin, Maine.

DIY Bill Of Materials

Summary of materials and costs in U.S. dollars, exclusive of taxes, to replace the potable water plumbing on the author's 37' (11.2m) sailboat.

Whale #	Item	Quantity	#/Package	Unit $	Total
WX1502	Equal tee	9	2	8.99	44.95
WX1503	Equal elbow	35	2	6.99	125.82
WX1504	Equal straight	4	2	7.99	15.98
WX1513	Adapter 1/2" NPT male	2	1	15.49	30.98
WX1514	Adapter 1/2" BSP male	2	1	3.02	6.04
WX1519	Flexible heater connector	2	1	12.20	24.40
WX1532	Adapter 1/2" BSP female	6	2	8.99	26.97
WX1544	Hose barb 15mm to 1/2"	1	1	5.99	5.99
WX1546	End cap	2	1	4.99	9.99
WX 1565	Tube mounting clip	60 clips	10	7.99	47.94
WX1574	Shut-off valve	4	1	14.48	57.92
WX1582	Check valve	2	1	5.88	11.76
WX7162	Tubing, blue	60'	1	.79	47.40
WX7164	Tubing, red	50'	1	.79	39.50
WX7951	Tubing cutter	1	1	32.99	32.99
Total for tubing, fittings & accessories					**$528.63**
FT1152	Telescoping faucet	1	1	17.99	17.99
GP0551	Foot pump LH	1	1	109.99	109.99
UF1215	Strainer/pump/accumulator	1	1	173.36	173.36
WF1530	In-line water filter	1	1	39.96	39.96
Total for fixtures					**$341.30**
Total for project					**$869.93**

Price quote: West Marine

Shopping Guide

There are currently five PE tubing/fitting manufacturers that market to the North American recreational marine industry. Each of the companies listed herein is more accustomed to working with boat builders than boat owners. Their products are often not readily available in local marine or hardware stores. Even online retailers rarely list a manufacturer's full line of fittings. With the increasing popularity of PE piping, however, that will eventually change. But for now, special orders through a distributor/retailer are likely to be the answer to your product availability questions. Review these manufacturers' catalogs and use the system plan available at www.diy-boat.com/diyweb/emailgraphics/systemplan.pdf as a guide. Develop one or more parts lists you can use to obtain price quotes. Shop and compare.

Flair-It fittings (Tel: 800/456-3726), manufactured by THC in Santiago, Chile, have been available since 1991. Standard Flair-It fittings are made of acetal. The newer Flair-It Plus fittings are PSU. All are compression fittings, so they take more time and effort to assemble/disassemble than do quick-connect fittings. On the other hand, they are less expensive than their quick-connect competitors. Flair-It fittings can be found in hardware stores (e.g., Ace, True Value and Do it Best), recreational vehicle (RV) centers and are also sold online. You can download product catalogs at www.flair-it.com. THC's three North American distributors share this website. At present, each distributor maintains its own web pages. Until they consolidate, check each distributor's pages to get the complete picture.

John Guest, the original developer and world's largest manufacturer of push-

Acronyms

BPT	British pipe thread
CPVC	Chlorinated polyvinyl chloride
CTS	Copper tube size (OD)
FPT	Female (internal) pipe thread (NPT)
LLDPE	Linear low-density polyethylene
MPT	Male (external) pipe thread (NPT)
NPS	Nominal pipe size (ID)
NPT	National (US) pipe thread (tapered)
OD	Outer diameter
PB	Polybutylene
PE	Polyethylene
PEX	Cross-linked polyethylene
PP	Polypropylene
PSU	Polysulfone
PVC	Polyvinyl chloride
NPS	Nominal pipe size (straight thread)
FGHT	Female garden hose thread

in (quick-connect) fittings, is based near London in the U.K. For a list of North American distributors, contact John Guest USA (800/945-4872). (In the 1990s, John Guest fittings were distributed by Whale.) Its marine plumbing catalog is found under "US Literature" at www.johnguest.com/litdown.asp. The company's twist and lock fittings are secured with an easy three-quarter turn; collet clips are not needed to prevent accidental release. In addition to LLDPE tubing, the catalog also lists opaque Speedfit barrier pipe. The "barrier" is bonded between the tubing's outer and inner layers. It prevents oxygen from penetrating the piping, thereby reducing the risk of corrosion in domestic hydronic heating systems. Speedfit barrier pipe is NSF 61 certified for potable water use; however, it's less flexible than LLDPE tubing.

PEXtite plumbing was introduced to the Canadian marine and RV markets in 2003 by ITT Industries (Flojet/Jabsco), based in Gloucester, Massachusetts (Tel: 978/281-0440). PEXtite polysulfone fittings and PEX tubing are available in 3/8" and 1/2" sizes. Special plug-in connectors fit Jabsco PAR-Max water pressure pumps, strainers, water entry regulators and accumulator tanks. Adapters, in both inch and metric sizes, are available to fit other fixtures and competitive brands. The fittings and tubing carry a limited lifetime warranty for as long as you own the boat in which they are installed. Look for the PEXtite catalog at www.jabsco.com. PEXtite will be introduced to the US market this fall.

Sea Tech was established in 1995 and later acquired by Watts Water Technologies. Based in Wilmington, North Carolina, Sea Tech (Tel: 888/500-0056) markets its products worldwide. It manufactures acetal fittings in 1/2" (24 Series), 15mm and 22mm sizes, and polysulphone fittings (35 Series) in sizes ranging from 3/8" to 1". Many of Sea Tech's connectors (adapters) utilize a swivel nut with NPS straight threads and a cone seal; the swivel nut can be threaded onto NPT, NPS, and BSP thread fittings and hand tightened. Sea Tech fittings are available from West Marine, Lowe's hardware and others. You'll find a list of distributors and its current catalog at www.seatechinc.com.

Whale products are made by Munster Simms Engineering, based in Bangor, Northern Ireland. A strong niche player, the company designs, manufactures and sells pumps, valves, faucets and plumbing for use in boats, RVs and other low voltage environments. Originally a distributor for John Guest, Whale developed and introduced its own quick-connect piping system in 1999. Whale fittings are easily recognized by their molded "ears" that prevent accidental release, negating the need for collet clips. Whale pumps, fixtures, tubing and fittings are inherently compatible and can be purchased through West Marine and Defender among others. Visit www.whalepumps.com for its marine catalog and a list of distributors. The U.S. distributor is based in Peabody, Massachusetts (Tel: 978/531-0021).

A Fastener Primer

Bolts and nuts on all marine engines are non-stainless steel graded fasteners. If you routinely mess with these fasteners, you need to know the grading codes, the proper use of washers, the why/why not of locknut use, how to get threaded fasteners tight and the causes of failure.

By Doug Cohen

A fellow I used to work with created and regularly presented a fastener seminar that ran for a full six hours. He would start the presentation by holding up a nut and bolt and say, "This is the most dangerous mechanical device ever created by man." He then used the next six hours to prove it. Most of us take fasteners for granted, especially nuts and bolts. Just insert and tighten. Right? Wrong. For example, you change or adjust the alternator and a bolt fails or you try to remove the exhaust elbow and a bolt fails. Do you know how to select a replacement bolt and install it correctly? To prevent failures when servicing or replacing fasteners, you should.

Every inch dimension bolt has a grade mark on its head, such as three radial lines, exactly 120° apart. This indicates a Society of Automotive Engineers (SAE) grade 5 hex head cap screw, the minimum grade of bolt commonly used in automotive applications, made of a medium carbon steel and heat treated (**Figure 1**). Each SAE grade represents different steel chemistry (alloy), heat-treating and resulting strength or performance characteristics. Grade 5 is typical of mounting bolts for alternators and other engine accessories. Bolts normally found at a local hardware store are usually SAE grade 2. These have no grading marks on the head and are made from steel that is not even as strong as some alloys of aluminum or even some species of wood.

Though you might be familiar with this marking system, you may not be familiar with the grade marking system used to identify hex nuts (**Figure 2**). Just as a chain is only as strong as its weakest link, always use the same grade of nut as the bolt you're using or you'll have unexpected failures. Unfortunately, it's not uncommon to have a fastener supplier provide grade 5 bolts, for example,

Figure 1 *Chart indicates the grade marking system for SAE and metric hex head cap screws.*

Grade Marking	Specification	Material	Normal Size, Diameter Inches /Metric	Proof Load PSI (MPa)	Tensile Strength Min. PSI (MPa)	Bolt Rockwell Hardness Min.	Bolt Rockwell Hardness Max.	Nut Rockwell Hardness Min.	Nut Rockwell Hardness Max.
	SAE J429 Grade 2	Low carbon steel	1/4 through 3/4 over 3/4 to 1-1/2	55,000 33,000	74,000 60,000	B80	B100	-	C32
5.8	ISO SAE J1199 Property Class 5.8	Low or medium carbon steel	Metric 5 through Metric 24	55,100 (380)	75,400 (520)	B82	B95	-	C32
	ASTM A449 Type 1 SAE J429 Grade 5	Medium carbon steel, quenched & tempered	1/4 through 1 over 1 to 1-1/2	85,000 74,000	120,000 105,000)	C25 C19	C34 C30	-- 	C32 C32
8.8	ISO/DIN SAE J1199 Property Class 8.8	Medium carbon steel, quenched & tempered	Metric 3 through Metric 16 Metric 17 through Metric 36	84,100 (580) 87,000 (600)	116,000 (800) 120,350 (830)	C20 C23	C30 C34	- -	C32 C32
	SAE J429 Grade 5.1 (SEMS)	Low or medium carbon steel, quenched & tempered with assembled washer	No. 6 through 5/8	85,000	120,000	C25	C40	-	-
9.8	ISO SAE J1199 Property Class 9.8	Medium carbon steel, quenched & tempered	Metric 1.6 through Metric 16	94,250 (650)	130,500 (900)	C27	C36	-	C32
	SAE J429 Grade 7	Medium carbon alloy steel, quenched & tempered, roll threaded after heat treatment	1/4 through 1-1/2	105,000	133,000	C28	C34	-	-
	ASTM A354 Grade BD Grade 8 SAE J429 Grade 8	Medium carbon alloy steel, quenched & tempered	1/4 through1-1/2	120,000	150,000	C33	C39	C24	C36
	SAE J429 Grade 8.2	Low carbon boron martensite steel, fully killed, fine grain, quenched & tempered	1/4 through 1	120,000	150,000	C35	C42	-	-
10.9	ISO SAE J1199 Property Class 10.9	Medium carbon alloy steel, quenched & tempered	Metric 6 through Metric 36	120,350 (830)	150,800 (1,040)	C33	C39	C26	C36
12.9	ISO Property Class 12.9	Medium carbon alloy steel, quenched & tempered	Metric 1.6 through Metric 36	140,650 (970)	176,900 (1,220)	C38	C44	C26	C36

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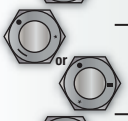
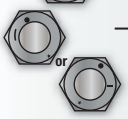
Figure 2 *SAE Grade Marking Hex Nuts*

Grade Marking	Spec Notes
 2	
 5	Old marking method
 5	New marking method
 8	Old marking method
 8	New marking method

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with grade 2 nuts, either out of ignorance or a desire to increase profit margins. This combination results in fastener failures that most consumers, even mechanics, almost never blame on the low strength, inappropriate hex nut.

The same is true of metric dimension fasteners, although the grade marking system consists of numbers raised on the hex head (**Figure 3**). Metric property class or grade 8.8 is approximately equal to inch dimension grade 5 and is the minimum you'll find on most engine applications. Again, there is a property class or grade marking system in use for hex nuts; however, on metric dimension hardware, it's a single number, such as 8. This would indicate a hex nut compatible with property class or grade 8.8 cap screws or bolts.

Double Washer Installation

Have you ever seen a flat washer that is bent or dished out? This is because the average hardware flat washer is a wrought washer, made of low carbon, dead soft scrap steel and is not strong enough for even grade 5. A flat washer's purpose is to provide a flat, smooth bearing surface against which to tighten the fastener and one should be placed under the head of the bolt as well as under the hex nut (**Figure 4**). A good installation utilizes an alloy steel, through hardened flat washer, capable of remaining perfectly flat and true, even under fastener loads. According to the testing done by the SAE in the '60s, lock washers not only do not work, they are dangerous and should not be used. The mechanics of the logic behind this are involved but lock washers actually disguise a loose fastener, allowing what is known as a fatigue failure to occur.

Torque Readings

A bolt is not capable of holding any load or securing any part or piece when it's at rest or relaxed. Just like a rubber band, a fastener only works when under tension, creating what is known as clamping force. It's critical to develop the correct amount of clamping force for the given grade, diameter and thread pitch of fastener. So, how do we know how much clamping force to generate? Many mechanics and DIYers

Figure 3
Metric Grade Marking Hex Nuts

Grade Marking	Property Class
	5
	8.8
	10.9
	12.9

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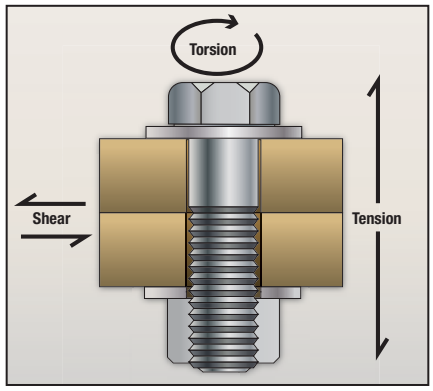
just plain guess, tightening until it feels right.

Engineers created torque charts and torque wrenches to allow everyone the opportunity and tools to obtain the proper tension. Always use a torque wrench on all graded fasteners and handle it properly: grip only the handle, pull slowly and steadily and, when it clicks, stop. When reading your torque chart (**Figure 5**), be aware of whether you are looking at "clean and dry" or "lubricated" torque values, as they are significantly different. If using the lubricated value, be sure to use the lubricant specified on the torque chart to which you are referring. Each specific brand or type of lubricant has a different lubricity factor or ability to provide lubrication, requiring a unique lubricate torque value for each. Each fastener, by grade, diameter and thread pitch, has its own strength and, therefore, it's own required clamping force and recommended installation torque.

Fastener Speak

Let's add a few fastener terms to our vocabulary. Tensile strength is defined as the amount of force it requires to literally rip a fastener into pieces. Many companies specify fasteners by tensile strength and many others buy fasteners by tensile strength; however, it is irrelevant. Yield strength is the amount of force it takes to permanently stretch a fastener, kind of like when you pull on a piece of taffy. At the point a fastener yields, it's destroyed and unsafe to use, although it's still in one piece. Yielding can be subtle and the deformation not readily visible. The best course of action with a used fastener is to hold it against a new, unused fastener, to compare the thread pitch and length. To provide a margin of safety, engineers established proof load, which by definition is the maximum safe load a fastener can support and is 80% of the yield value.



Joe VanVeenen

Figure 4
A fastener only holds when under tension, so it's critical to always install a washer under the head of the bolt as well as under the hex nut.

Figure 5 SAE Torques

Diameter	TPI	SAE Grade 5 Dry Threads	SAE Grade 5 Lubricated Threads	SAE Grade 8 Dry Threads	SAE Grade 8 Lubricated Threads
1/4"	20	9 † (108)	5 † (60)	12 † (144)	7 † (84)
	28	10 † (120)	6 † (72)	14 † (168)	9 † (108)
5/16"	18	17 † (205)	10 † (120)	25 † (300)	15 † (180)
	24	20 † (240)	12 † (144)	27 † (325)	17 † (205)
3/8"	16	31 † (370)	19 † (230)	44 † (540)	26 † (310)
	24	35 † (420)	21 † (250)	49 † (590)	30 † (360)
7/16"	14	50 † (600)	30 † (360)	70	42 † (505)
	20	56	33 † (395)	78	47 † (565)
1/2"	13	75	45 † (540)	107	64
	20	85	51 † (610)	120	72
9/16"	12	110	66	154	92
	18	120	72	171	102
5/8"	11	150	90	212	127
	18	170	100	240	144
3/4"	10	265	160	376	226
	16	300	180	420	252
7/8"	9	430	260	606	364
	14	475	285	668	400
1"	8	645	390	909	545
	14	720	435	995	597
1-1/8"	7	800	480	1288	773
	12	900	540	1444	866
1-1/4"	7	1120	670	1817	1090
	12	1240	745	2012	1207
1-3/8"	6	1470	880	2382	1430
	12	1670	1000	2712	1627
1-1/2"	6	1950	1170	3161	1897
	12	2200	1320	3557	2134

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Recommended assembly torques for SAE grade 5 and grade 8 hex head cap screws. All torque values shown are for turning the nut while holding the head of the bolt with a wrench. Torque values are calculated at 75% of proof load. Lubricated torque values are calculated based on applying a copper-based anti-seize compound to the threads before assembly. Inch pound torque value is listed in parenthesis.
+ Installation with an inch pound torque wrench is recommended.

Reasons for Failure

Torque charts typically provide clamping force equal to about 75% of the proof load value. For instance, a 3/8-16, grade 5 fastener has a tensile strength of 9,300lb (4,219kg) and a proof load value of 6,600lb (2,994kg). This means that applying a force over 9,300lb (4,219kg) to this fastener would first yield as the force increased past its yield point and then it would ultimately break in two. Engineers, however, would never specify this fastener for applications where forces of that magnitude would be likely.

So, if we tighten our 3/8-16 grade 5 fastener properly, using a torque wrench, we generate about 5,000lb (2,268kg) of clamping force or "tightness." Again, this is the expected result, because the application for this fastener actually applies lower forces in use.

For example, let's say that the expected load on a particular connection is 4,000lb (1,814kg) in use. If we don't use a torque wrench but hand tighten and generate, let's say, only 3,500lb (1,588kg) of clamping force, we have created a failure waiting to happen. Here's how. When the assembly is put into service and all forces are acting on it the 4,000lb (1,814kg) of working load is trying to pull our "engine" apart but it's only being held together by 3,500lb (1,588kg) of clamping force. The result is the fastener stretches to accommodate the excess load or force acting on it. Of course, on engines or most machines, the loads are not constant but cyclical, varying as parts move. Picture your alternator "jumping" around as the engine runs. The fastener then stretches and relaxes, rapidly, repeatedly, until a small crack forms that spreads across the diameter until the fastener fails.

View and print the full-size SAE and Metric torque charts by clicking here.

Have you ever used the universal repair material, you know, the coat hanger? You wanted just a small piece, didn't have your cutting pliers so you bent it back and forth 'till it broke. This is referred to as a fatigue failure and actually accounts for approximately 90% of fastener failures. Fatigue failures result when clamping force is less than the working loads on a connection and is caused by under-tightening, use of a lower grade hex nut, use of a wrought or soft flat washer or a compressible joint (gasket).

The other very common cause of fatigue failures is the reuse of the hex nut, specifically in the clean and dry installation mode, as the threads in the hex nut deflect and become permanently deformed upon installation. If you want to safely reuse hex nuts, install the assembly to the lubricated torque value on initial and subsequent installations. Fatigue failures generally occur in one of the following locations: under the head of the bolt, at the first thread on the shank or at the first thread between the nut and the bolt shank. Fatigue failures generally appear relatively smooth on the cross section of the fastener and are often mistaken for shear failures, which are very, very rare. Shear is defined as any force that tends to cut a fastener across its diameter into two or more pieces and occurs in less than 2% of fastener failures.

Let's go back to lubrication for a moment. If you use Loctite or another brand of thread locking compound, be aware that they act as a lubricant during installation. In fact, Loctite Blue (medium strength) reduces require installation torque by 26%. The oil from your skin is also sufficient lubrication to affect the clamping force obtained when installing a fastener, so your best protection is to intentionally lubricate all threaded fasteners with a quality anti-seize and use the lubricated torque chart installation values.

Another possibility is for you to over-tighten the innocent nut and bolt, yielding it on installation. Remember, this means that we have stretched it so far that it's permanently deformed, thinning out the cross section of the bolt (think of that taffy you pulled). Now what? First of all, since the stretched section is inside the connection, you won't see the damage. Secondly, you now have a bolt that is smaller and weaker than originally called for, likely resulting in the connection catastrophically failing when the engine or machine is under load.

Erroneous Locknuts

So, now you know how to get threaded fasteners tight, to use the correct hex nut for the grade of bolt, use a through-hardened flat washer and avoid lock washers and the connection comes loose! Now what?

First, let's check and be sure that the fastener didn't yield or permanently stretch by holding it against a new fastener of the same diameter and thread pitch. Okay that checks out. Now what?

View and print a chart of stainless-steel hex head and nut grade markings by clicking here.

Most people have seen nylon locknuts, referred to as ESNA nuts or Nylocks, a hex nut with a nylon ring crimped into the top, intended to perform as a locking device. This style locknut doesn't function well, as most are based on a grade 2 hex nut and, at best, the nylon ring is good for a one-time use. The nylon ring gets threads cut into it by the bolt passing through and it therefore has no locking ability or resistance to loosening from vibration.

There are several styles of locknuts available and most of the "locking" occurs simply by crushing the hex nut to create a tight friction fit. The problem with these various designs is that they are not predictable and repeatable; therefore, no torque charts can be created, leaving us guessing, "How tight is tight?" Additionally, most of these designs are not reusable, as both the threads of the nut and the bolt are damaged by the extreme friction and deformation.

The automotive-style steel prevailing torque nut is one example of an effective nut. In this design, the threads are deflected down, not in, at three points around the perimeter, creating a predictable, repeatable resistance to loosening. Such torque nuts are grade C, strong enough to be used effectively with even grade 8 bolts and reusable a minimum of five times without loss of prevailing on or off torque. You'll find this style on drive train and suspension components in automobiles.

Of Stainless Steel

The same basic principles apply to stainless steel fasteners but there are some significant differences. First of all, stainless steel is resistant to corrosion but it's not particularly strong. There are two common grades of stainless nuts and bolts, 18-8, also known as type 304 and type 316. Type 316 has slightly more strength than type 304 but neither is even as strong as Grade 5. Type 316 is more corrosion resistant than type 304. For stainless steel, the only style of locknut is the elastic or nylon stop nut because of a problem mostly unique to stainless, which is galling of the threads. Stainless steel is not very hard, albeit corrosion resistant, so the threads tend to gall or "weld" together.

The bottom line is that the proper grade, diameter, thread pitch and material of fastener, properly installed for the application, should never come out of the hole. It's not just about nuts and bolts!

About the author: Doug Cohen and his wife Fran sail a 1973 Gulfstar 41' (12.5m) center-cockpit ketch on Lake Champlain, New York, that they are patiently refurbishing. Doug is vice-president of J & D Supply Group, a fastener supplier who recently launched a web store for specialty boat maintenance parts and tools (www.jdsupply.com/sailwares/trilock.htm).

Additional Reading

How to Use a Torque Wrench	2003-#2

Sewing With Sailrite

Rail Protectors

Acrylic fabric covers are excellent sunburn protection for varnished handrails, toerails and other brightwork. These easy-to-make covers will keep sun, salt, ice and pollution from undoing your hard won finish.

Story and photos by Jim Grant

There is an easy way to fabricate attractive and durable covers for brightly varnished rails on your deck. Actually, the design that I'll describe is just one of many that could be employed, so feel free to deviate from my instructions as your creativity dictates.

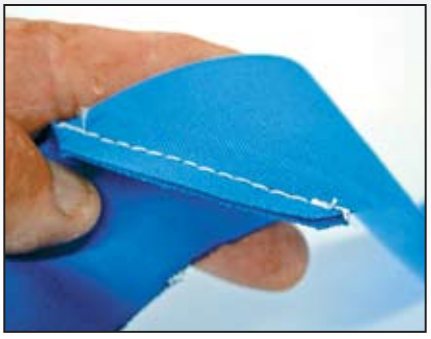
Since thread is always subject to ultraviolet deterioration well before a modern "canvas" cover cloth, cover durability is achieved by keeping all but decorative stitches hidden from the sun. All seams in this project employ a semi-flat felled seam that utilizes a straight stitch hidden under the cover fabric. Double-walled skirts along the vertical sides of each cover replace hemmed, finished edges that are normally created by sewing a fold of fabric in place with an exposed row of stitches. Using brass chain as weights inside sleeves keeps the covers in place but weight alone cannot be relied upon in strong winds so we also utilize mechanical fastenings. These mechanical fastenings, however, cannot mar the appearance of the covered rails nor interfere with free movement around the deck. Where possible, use snaps or Velcro secured under the rail's handhold openings. When that is not possible, your own ingenuity for a suitable method of securing the covers will rule.

Measuring and Cutting

Measure the length, along the sides only, height and width of the rail to be covered. Cut three rectangles of cover fabric: two side rectangles of exactly the same size having a width twice the height plus 1/2" (12mm) for seam allowance (1/4"/6mm at each end) and the length equal to the measured length again adding 1/2" (12mm) for seam allowance; and one top rectangle with a width equal to the width of the rail plus 1/2" (12mm) for seam allowance and a length equal to the actual length plus three or four times the height of the rail (to cover the rail end). The ends of the two side rectangles will be trimmed later to match the curve of the rail at its two ends. Cut the material with shears, although a hot knife (a soldering iron or gun also works) seals the edges of synthetic fabrics and makes raveling unlikely.

Two side rectangles and top rectangle cut for a handrail cover.

If more than one length of fabric is required to cover the rail, join the two lengths by laying them right sides together at a 90° angle. Run a row of straight stitches at a 45° angle over the two layers. Trim all but 1/2" (12mm) or so of the excess fabric from beyond the row of stitches and then fold the two lengths of material out; they should lie in a straight line. This junction method distributes the seam allowance "bump" along the length of the joined pieces.

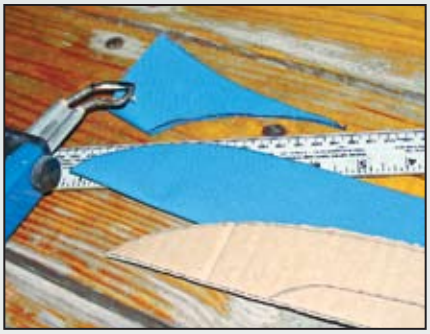


(top) Joining two lengths of material together to minimize the bulge. (bottom) The finished fabric joint.

Side Rectangle Preparation

Fold and carefully crease the two side rectangles down their center and along their length. (Tip: use scissor ends held flat to do this.) If the fabric has an obvious right and wrong side (most cover fabrics do not), fold so the wrong surfaces are face to face. Now, trim the rectangle's ends to match the curve on the rail's ends. To guide in cutting these curves, I prefer to make a cardboard pattern of the rail's profile that also includes the handhold openings. Trim the fabric from the open side; the folded side is the longest side as this lies on deck when completed. Note that the side rectangles are 1/4" (6mm) wider than the height of the rail to provide for a seam allowance. Do not cut away the seam allowance at the ends.

Cut two lengths of brass chain a couple inches shorter than the length of the side rectangles. Use either a needle and twine or a glue gun to secure the chain in place at 6" or 7" (15cm or 18cm) intervals along the centerline crease in both side rectangles. This keeps the chain from

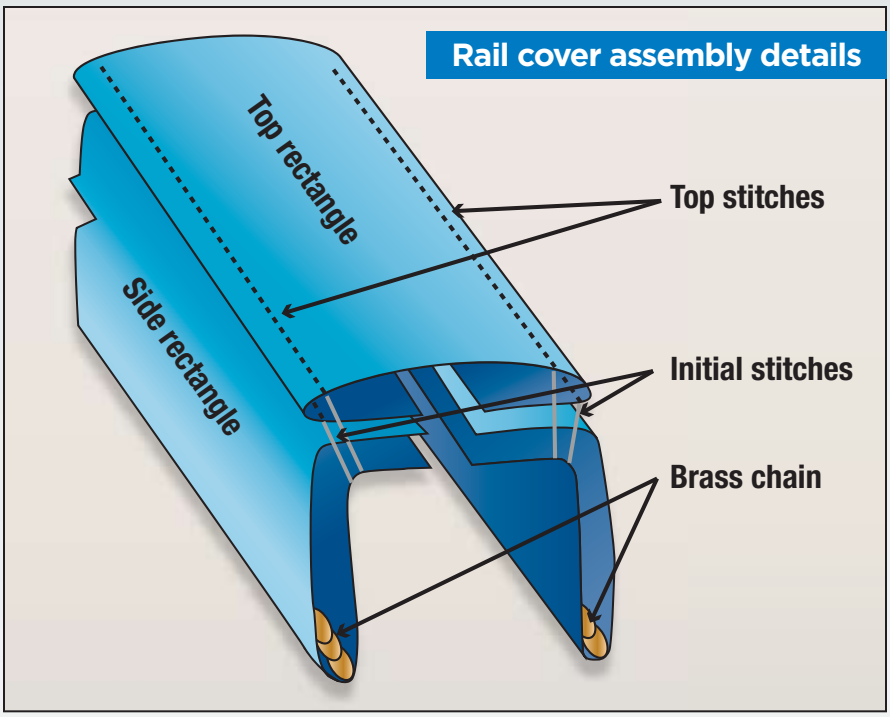


Fold fabric wrong sides together then form a crease down the center and using a cardboard pattern, mark and cut the curve of the rail ends.

Use a glue gun to attach the brass chain to each sidepiece.

sliding into one end of the cover and becoming hopelessly tangled. The chain is intentionally short to allow sewing the cover ends.

If using Velcro to secure the rail, now add the Velcro strips. Lay the folded side rectangles flat as shown in the photo below. I use chalk to mark "I" on the inner surface of each one and also mark "B" for bow on each one at the appropriate end. Using your cardboard pattern, mark the location of the handholds, which identifies where to sew the Velcro tabs. These tabs should be about 3" (7.6cm) long and placed in the center of each handhold. Sew Velcro loop along one side rectangle and the hook along the other. Sew them only on the inner panel (the "I" side) of each side rectangle so the stitches don't show on the outside of the finished cover.



Two folded side rectangles with Velcro tabs in place.

Sew the second side rectangle to the top rectangle.

Completed cover secured to handrail with Velcro. The top stitch is a nice looking detail.

Assembly

Lay out the side rectangles so the "I" surface is down (the outside surface will be facing up). Place the top rectangle so its outside (right) side is against one side panel. Line up all edges. Sew these pieces together with a row of straight stitches just 1/4" (6mm) inside the raw edges. Now sew the second side panel to this assembly. It too should be "I" side down. You may need to fold away the already attached side in order to position the top rectangle over the second side so all edges are flush. Sew a row of straight stitches

Drain holes with two types of locking pins demonstrated.

just 1/4" (6mm) inside the raw edges just as you did above.

Turn the assembly right side out. The stitches are hidden inside the cover where the sun cannot deteriorate them. Now sew a second row of top stitches along each seam as shown in the schematic above. This adds very little in the way of strength but it does make the cover look quite finished and attractive. Fold the excess material underneath at each end and sew with a short row of stitches. Trim away any excess.

Security Measures

If snap fasteners are preferred to Velcro, install now in the handhold opening of a rail. Place the cover over the rail and chalk mark the location of each desired snap.

Toerail cover mounted.

Remove the cover and install the fasteners. When making a toerail cover, it's often difficult to provide a secure attachment without placing snaps or Velcro where they are visible. I usually find that there are drilled openings that allow for deck drainage at intervals along these rails that can accommodate a locking pin to hold the cover in place. Place the cover over the rail and mark the location of each of these holes with chalk on the bottom of both side rectangles. Then remove the cover and install a small (00 or 0) spur grommet at each chalk mark. If the rail is a low one, as it is on my Lindenburg 22, use a locking pin to hold it in place. With taller rails, a stainless machine screw serves the same purpose.

About the author: Jim Grant founded Sailrite (www.sailrite.com) in 1972 to supply specialty marine fabrics, component hardware and tools, sewing kits and sewing machines for boaters to build or repair canvas and sails. Headquartered in Indiana, the company has satellite stores in Fort Lauderdale, Florida and Annapolis, Maryland.

Point and Shoot Helmsmanship

There's always the option of using the tried and true, familiar steering wheel for all maneuvers but once "on the stick" will be enough to convert even the most conservative helmsperson.

Story and photos by Pat Kearns

Always keep both hands on the wheel! This is a fundamental precept of driving a car and it's certainly a best practice for safe operation, along with keeping your eyes on the road. So, when approaching my first assignment as skipper of a Hinckley Picnic Boat with a joystick control, in addition to the traditional steering wheel, by JetStick (a.k.a. the "joystick"), the boat owner's direction to me to "keep your hands off the wheel" was totally counterintuitive to my ingrained orientation to traditional helmsmanship.

The first temptation to stray from the "stick" was the gorgeous teak steering wheel at the helm console of the boat. This solid wheel just plain felt so good when I wrapped my hands around its beefy ring but the cautionary words of the owner rang out loud and clear in my memory and I knew that, to please him and to advance my own willingness to embrace something new, I had to, literally, "get on the stick."

I was born too soon to be an ardent video gamer so the joystick experience is an alien one to me. Mastering close quarters maneuvering by joystick helmsmanship on somebody else's million dollar dreamboat is not a game for me but I knew that the boat's owner expected me to rise to the challenge and it took only about 60 seconds twirling the highly varnished knob to realize that this stick was aptly named "joy."

My classroom for this experiential learning leap was powered by a Yanmar inboard engine mated to a Hamilton Jet Drive. The JetStick helm control consists of a gorgeous varnished knob with a silk-like feel. This knob is about the size of the shift lever knob on a Porsche and sits atop a "stick" that emerges from

JetStick's joystick installs either (top left) on the control panel or (across) on a separate panel. Colored lights indicate operation mode: docking, power steer and normal.

a rubber boot and is surrounded by amber, red and green indicator lights for the respective operating modes. That's it! The rest is the joy of steering every which way you can, to and fro, side to side and along any horizontal plane you encounter on the water.

This control allowed me the deft touch to back the boat into a tight berth with the same steely composure of the captain of a 55' (16.7m) sportfisherman in my neighborhood whose technique of facing aft, with his hands on the shift levers behind him, while he proves his verve with a perfectly aligned landing between the pilings, gives me empathetic goose bumps. He never flinches. He is wicked cool!

Anything you can do with your hands on the wheel of the Hinckley can be done with the joystick and it will be done better and with more precision. Trusting it is the hardest hurdle to jump, especially when instinct drives you to grab the wheel when you first start fiddling with the stick and you haven't quite mastered the game with confidence. Just hold on to that stick for another minute and you'll be hooked.

There are three modes of operation: docking, power steer and normal, each with its own actuation button and indicator light. The most exciting of these, for me, is the docking mode. Here's where the thrill of the hunt for the perfectly executed arrival in the most impossible looking docking situation lives. In this mode, the boat's bow thruster and the JetStick control are coordinated to enable the boat to move sideways at the bow or the stern or even along the plane of the centerline. If the agitation of fear of the unknown sets in, just let go of the stick and the boat instantly stops dead in the water so that any errors of positioning can be recovered in the cool, calm of no headway (no matter what the throttle position is).

Push the "power steer" button on the control unit and the responses will be limited to forward and reverse. Throttle speed is controlled by the traditional and separate throttle lever. Twist the knob to port and the bow goes to port; knob to starboard and the bow responds. Too scary? Let go of the stick and the boat goes straight ahead.

Again, a comfort mode is built in for those times of techie overload. Push the "normal" button and grab the wheel and all bets are off at the stick control but I warn you, it won't take long before that stick starts its tantalizing, siren call and you succumb to the lure. More comfort comes with the knowledge that "normal" automatically comes into play if there is any electrical or electronic malfunction.

About the author: A marine surveyor and DIY's standards keeper, Pat skippers a Hinckley Picnic Boat and 62' (18.9m) Ferretti berthed in south Florida. It's a dirty job but....

PROJECTS

6

Indicates the degree of difficulty with 10 being the hardest and 1 being the easiest.

Freshwater Flush

A built-in valve set simplifies the flushing of a boat's engine, generator or HVAC for routine maintenance or winterizing.

If you keep your boat in a slip, it's very difficult to flush the mechanical systems with freshwater after use. The engines, sterndrives, generators and air conditioning (HVAC) system on boats operated in saltwater must be flushed regularly to avoid internal corrosion. The Mercruiser engine manual calls for a freshwater flush after each use, a challenging task if the boat is in a slip.

My 2002 Bayliner 2855 has a Bravo III sterndrive and Mercruiser 5.7L engine, a Kohler 5kW generator and HVAC system, all seawater cooled. Since I boat in Chesapeake Bay, I am concerned about the corrosive effects of brackish and saltwater on the mechanical systems and so decided to build an easy-to-use flush out system.

I built two different types of flush-out valve systems: one utilizes the existing thru-hulls for the generator and HVAC; the other for the sterndrive and engine. Necessary parts are readily available at well-stocked marine supply stores and professional plumbing supplies. For more difficult to find parts, log onto Fittings and Valves Unlimited on the web (www.fittingsandmore.com) or a commercial plumbing supply house.

HVAC and Generator Flushing

Since both my HVAC and generator already had bronze thru-hulls and shutoff valves, this plumbing project was rather simple. I built two identical single valve systems. They were then spliced into the existing hoses from the thru-hulls to the HVAC and generator. The diameter of the raw-water hose varies (mine was 3/4"), depending on the make and model of your boat so check closely to make sure the fittings are the correct size for your application.

Each single valve system consists of the following parts: two bronze tail pieces of the same diameter as the hose; one bronze tee of the same diameter as the hose; one bronze hex bushing for reducing from the tee to a 3/4" ball valve, if needed; one 3/4" bronze ball valve with bib connection (a standard male garden hose connector); one brass garden hose end cap (the only piece of brass in the entire system and it acts as an insurance policy on the bib connector to prevent any possible leaks); one tube of 3M Marine 4200 polyurethane adhesive/sealant (don't use 3M 5200 or you won't ever be able to disassemble the parts); and four stainless-steel hose clamps. Use only marine grade bronze or plastic ball valves. [Ed: for information on purchasing marine grade plastic fittings, refer to "Plastics Prejudice" on page 14.]

Components and assembled parts for genset and HVAC flushing device.

Make sure that all parts are full flow (full pipe diameter). Don't buy partial flow hardware since it may sharply reduce the water flow to the engine, generator or HVAC when flushing and cause overheating problems. Also, take the time to inspect the existing hoses for any signs of deterioration or aging and replace as needed.

Installation is straightforward. I spliced the new valve sets into the supply lines upstream of the inline seawater water filters. This allows for flushing the in-line filters. The valve sets were double clamped with SS clamps. In the case of the valve feeding the generator, I mounted it onto the bulkhead since the hose run was long and strain could be a wear factor.

To flush the generator, first attach a garden hose to the bib connection of the valve and turn on the water to about half strength. Don't open the ball valve at this time. After making sure that the raw-water thru-hull is open, start the generator, and then open the freshwater valve. The next step is to close the thru-hull. Run the generator for 10 minutes with fresh water, shut down the generator and quickly close the valve to shut off the fresh water. Winterizing is snap, since it's the same process using a bucket of anti-freeze as the source. Don't attempt to flush the generator when it isn't running. You could fill the exhaust passages with water, causing damage to the engine.

The process for flushing the HVAC is virtually the same. Open the thru-hull, start the system, open the freshwater valve, close the thru-hull and run for 10 minutes or so. As with the generator, winterization is simple.

If you have an inboard engine(s) fed via an existing thru-hull(s), you can plumb in this same type of valve set to allow for flushing and winterization.

Engine and Sterndrive Flushing

In the case of a sterndrive, there is no thru-hull. Instead, there is a direct raw water supply hose coming from the sterndrive. A more complicated three-way valve set allows for both independent sterndrive and engine flushing or winterization. The valve system consists of the following parts: two bronze tail pieces of the same diameter as the

Three-way valve set allows easy flushing and winterization of engines and sterndrive.

hose; one bronze tee, same diameter as the hose; one bronze hex bushing for reducing the tee to a 3/4" ball valve; two bronze ball valves to fit the hose; two bronze hex nipples, same diameter as the hose; one 3/4" bronze ball valve with bib connection and the same brass garden hose end cap, sealant and hose clamps as described above for the genset and HVAC flushing device.

Again, make sure that all valve parts are full flow. Also, take the time to check the condition of all engine hoses. Worn, damaged or old hoses could become a point of failure. Regular inspection of all mechanical systems should be a standard part of your maintenance routine.

To install, I rerouted the raw-water supply line from the sterndrive away from the engine and then spliced in the new valve set using doubled stainless-steel hose clamps. The valve set is rather bulky and heavy and must be securely attached to a bulkhead. If this heavy valve set is allowed to flog around in the engine compartment, it could come apart and flood the boat. Remember not to create any loops or crimps in the line that could reduce or impede water flow from the valve to the engine intake.

Attach a garden hose to the bib connector and turn on the water to about half strength. Don't open the freshwater ball valve at this time. With the raw-water supply open, start the engine and then open the ball valve from the fresh water supply. Now, close the ball valve leading to the raw-water from the sterndrive. Flush the engine for 10 minutes and shut down. Immediately turn off the freshwater ball valve. Turn off the freshwater supply and remove the garden hose. Cap the bib connector with the garden hose cap. Remember to normalize the system for use, so you don't forget when you're ready to run again. Remember that the system can also be used for sterndrive flush and it makes winterization very easy.

Precautionary Measures

Use bronze fittings, where possible. Never mix brass and bronze as they fail at different points upon the galvanic nobility scale. In the presence of an electrolyte like saltwater, the brass will be the first to corrode as sacrificial to the more noble bronze.

These valve sets can be dangerous to use. After flushing the engine or generator, you must normalize the valve set before starting the engine or generator. If you don't, you could cause them to overheat. Luckily with ball valves, you can tell at a glance if the valves are open for normal use.

— An avid DIYer and mechanical tinker, Robert Bryan is found most weekends cruising the Chesapeake Bay in a 28' (8.5m) cabin cruiser.

Steady on Course

8

With periodic cleaning, lubrication, sources for replacement parts and some luck you can expect an old model 5000 linear drive to provide years of dependable service.

Author holding his trusted 5000 linear drive autopilot.

One of the most dependable products on our boat is the old model 5000 linear drive. Produced from the early '80s for about 10 years, this device was supplied with autopilot displays bearing the brand names Autohelm, Nautech and Raytheon. Raytheon discontinued repair and parts support in the mid-90s, although it did provide conversion of the drive units to operate with later model course computers for a few more years. Raymarine's current linear drive is similar only in appearance to the old model 5000. It uses a different motor, has a gear reduction unit and a different drive belt but is fully supported with repairs and spares.

If you have the old model 5000 linear drive aboard your boat, periodic cleaning and lubrication will greatly prolong the life of the drive and thus postpone the dreaded day of purchasing a new one. Additionally, if your drive is broken, with a bit of luck you can restore it to operation. If you can obtain a used drive, even if broken, buy it and keep it for spare parts, as the

Figure 1

drive motor is no longer in production. Also, obtain a spare drive belt from Optibelt (part number 285-3M-A 05), a German company. Any good auto parts store can order one for you or you can find one yourself with a search on Google.

Begin by locking your helm and turning off the power to the autopilot as a safety precaution. Disconnect the power cables and control cable at the drive unit. Disconnect the drive from the rudderpost quadrant and the support bracket. Unlock the helm and turn the wheel from lock to lock a few times. If the helm is stiff, remedy the problem now.

Drive Disassembly

Using snap ring pliers, remove the bolt from the center of the drive housing (**Figure 1**). Slide the housing over the ram cover and set it aside for now. Remove the four bolts securing the back cover and set it aside, being very careful not to disturb the clutch brushes. Remove the drive belt. It just slips off the motor sheave. Take care when lifting the clutch brushes to clear the belt. The brush holders are easy to knock out of alignment and replacements might be difficult to find. It's a good idea to replace the drive belt, even if the old one looks to be serviceable. After all, it might be 20 years old or older.

Drive Motor Inspection

Rotate the drive motor by hand. If the bearings are noisy or feel dry, now is the time to replace them. Before disassembling the drive motor, clearly mark the two end plates and the motor barrel, so you'll surely reassemble the motor correctly. When disassembling the motor, take extreme care not to damage the two field magnets. They are ceramic permanent magnets and are quite brittle. Although held in place with clips, rather than with adhesive, don't remove them if at all possible. I'm

•BOOK REVIEW•

Boat Smart Chronicles

by Tom Rau
244 pages, Paperback
(Seaworthy Publications US$19.95)

Twenty-seven year Coast Guard veteran, Tom Rau, chronicles first hand accounts of boating emergencies spanning more than two decades. While specific to Lake Michigan, the book is applicable to boaters everywhere and helps to alert all who enjoy being on the water to the boat smart message. Rau deals with safety topics such as how to behave in congested waters, how to recognize and deal with seasonal dangers and he fills a gap in the needless ignorance and naivety that accounts for a high percentage of the 708 boating fatalities in the first four years of this century. While there will inevitably be a read, laugh and weep entertainment factor for readers, Boat Smart Chronicles sounds a serious call to novice and experienced boaters alike who think life jackets are "uncomfortable." Rau's intention is not to entertain but rather to silence the tragic saga of needless boating mishaps and mischief and their all-too-often fatal fallout. Even if you think you boat smart, the lessons in this book are bound to add some smarts to your boating experience.

— Tracy Croll

unable to locate a source of replacement motors or magnets, so if your motor is unserviceable, you need go no further.

Any competent electric motor shop can true the commutator, reseat the brushes and replace the two sealed ball bearings for a reasonable price. The bearings are commonly used in clothes driers, of all things, and are readily available. They are part numbers NMB 608Z (brush end bearing) and NMB RL-1438HH (drive end bearing.) Make sure to caution the repair shop about the brittle ceramic magnets. Inspect the motor power leads and replace them at this time if required, using only tinned marine grade wire.

Reassembly

Before reinstalling the drive motor, clean the bolt threads with acetone. Apply a couple of drops of blue Loctite to the threads and tighten securely. The two belt idler rollers are self-lubricating. Insure that they turn freely. If not, clean and reassemble. Clean the clutch slip rings with 1,200-grit wet or dry abrasive paper. A light touch is required here. Just brighten up the slip rings a bit, no more sanding than that. Closely examine the two clutch brushes and clean them carefully. Make sure that they pivot freely and that they are centered in the slip rings. Using your digital multimeter, take a resistance reading across the slip rings. You should measure around 100 ohms. Install the new drive belt at this time, again taking care not to disturb the brushes.

To install the end cover, first clean the bolt threads with acetone, apply a couple of drops of blue Loctite and tighten securely. The end cap should be installed with the mounting dogs in line with the ram, as shown in **Figure 1**.

Jackscrew Lubricating

Remove the tubular cover over the jackscrew by unscrewing it from the housing. Use a strap wrench or very heavily padded pliers, taking care not to distort the cover. The jackscrew is the recirculating ball type and it contains 51 tiny ball bearings. If you want to do a 100% perfect cleaning job, then by all means, disassemble the unit but do so over a large bucket as those tiny balls will go everywhere! Use an old toothbrush and clean diesel fuel (or a degreaser) to wash out the old grease and accumulated dirt. Use cotton swabs to get down in the grooves of the jackscrew. When it is clean to your satisfaction, lubricate with a light grease, such as Super Lube, or a white lithium grease, such as Lubriplate. (The black greases are fine lubricants but make a horrible mess.) Coat the ball bearings with grease as you insert them into the jackscrew; otherwise, they will simply run out the other end. Run the jackscrew in and out a few times to distribute the lubricant and to insure freedom of operation. Replace the tubular cover over the jackscrew and tighten securely. The motor end of the jackscrew is supported by a sealed ball bearing, which should last forever. Check it anyway and if noisy, replace it.

Reinstall the linear drive, connect the power and clutch leads and turn the helm lock to lock to insure freedom of operation. Power up the autopilot and ensure that the drive unit operates properly. If you have done your work correctly, your drive will provide many more years of faithful service.

Before beginning each voyage, turn your helm lock-to-lock to insure freedom of movement and to redistribute the grease along the jackscrew in the linear drive.

Raymarine supplies a ferrite on the power leads of their current model linear drive to suppress radio interference caused by arcing at the drive motor brushes. If you can hear noise on your single side band radio, caused by the linear drive, the addition of a ferrite or two on the power leads will help suppress this noise. These ferrites are available from Radio Shack or from a Raymarine dealer.

— Harry Hungate and his wife, Jane Lothrop, have cruised over 24,000 miles onboard "Cormorant," 1985 Corbin 39 cutter.

Working with Non-Skid StarBoard

Maintenance-free polymer with a slip-resistant finish offers more versatility.

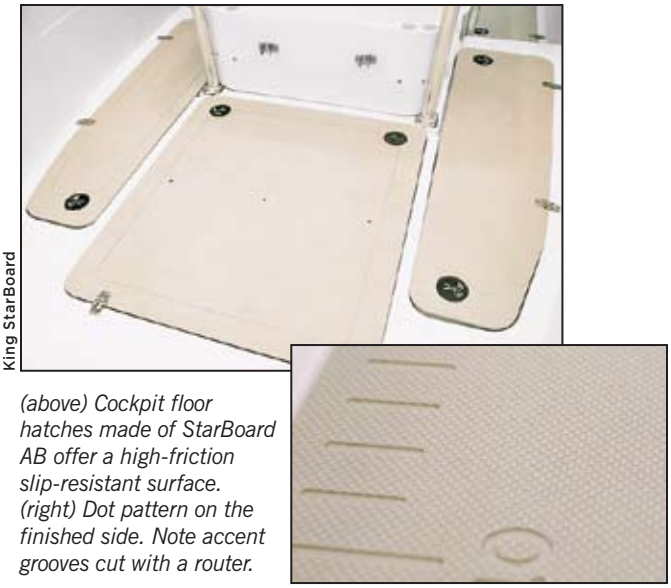
Remember the old days when any walking surface made from a polymer, such as StarBoard, had to be routed to create a skid-resistant surface? Not any more, thanks to King StarBoard AS, a polymer sheet that features a high-friction surface and either a dot or diamond slip-resistant pattern on the finished side.

Just like the original product, AB is easy to fabricate using standard woodworking tools. To replace rotted wood parts, simply remove the old part and use it to draw the pattern with a grease pencil (China marker) on the polymer sheet. Then cut it with a circular saw operating at 1,275 rpm, using a 50 to 70-tooth carbide blade. Use a router with a rollover bit to shape the edge and lightly sand the edges with a fine-grit sandpaper for a finished look.

Common applications for AB include hatches, swim platforms, boarding ramps, step treads for ladders and other steps, cockpit box lids, foot rests and engine room walking areas. The material is excellent for transom bait station lids. Be sure to provide adequate weight support for any area that could be used as a step. Plan and test your applications for safety. As a general rule, support pieces every 16" to 18" (406mm to 457mm) when using 3/4" (19mm) sheets, although more support may be necessary.

For users that are familiar with working with the original polymer, the AS version has two important differences. First, unlike the standard mat finish, the diamond pattern is directional (the long part of the diamond runs the long way of the full sheet). The dot pattern is not directional. Second, the edges produce tiny "fuzzies" during cutting with a saw or router. If these get too bad, try a different router bit. You can knock down these edges with a roundover bit, then finish them with fine sandpaper.

One of the best decorative techniques is to use a small router bit and a guide to create a simple groove accent at a consistent distance from the edge of the



King StarBoard

(above) Cockpit floor hatches made of StarBoard AB offer a high-friction slip-resistant surface. (right) Dot pattern on the finished side. Note accent grooves cut with a router.

finished part. Follow your router's instructions for attaching a rail that will keep the bit a consistent distance from the edge. There are many bits to choose from to give different looks. Carbide bits with two to four flutes are generally recommended; use your cutaways to experiment. Visit cabinetry websites for more ideas and use your imagination. A free, detailed guide to working with StarBoard is available to download at www.kingstarboard.com/CMS/Media/Docs/workingwith.pdf.

For advanced CNC router users who have the ability to design their own patterns, try routing a fish-measuring pattern in the surface of the material. This technique has also been used successfully for routing the boat's name or logo into the material. It's a good idea to practice on inexpensive wood or plywood before trying it on the polymer sheet.

Here are a few tips to keep in mind when working with polymer sheet products.

- Store the sheets flat and level, away from heat and staining products, such as teak oil.
- Don't mark the sheets with pen or pencil. Pen is hard to remove and pencil is nearly impossible.
- Don't route any solid polymer sheet thinner than 1/8" (3mm).
- Test applications for unforeseen complications, such as excessive weight concentration or expansion/contraction issues.
- Use standard fasteners with oversize holes. Drill pilot holes first, followed by an oversized hole to allow for expansion and contractions. Use press-in, threaded inserts where repetitive motion is expected, such as for hinges.
- Adhesives are not recommended for attaching components; however, polymer welding rods are available and have been used with some success.
- Save the cut offs for testing bits and to make plugs for screw holes using wood plug cutters.
- Silicone spray is often used to add shine or hide scratches in polymer surfaces but never use it on any walking surfaces.

— Rich Odato cruises Florida's Gulf Coast aboard his family's 36' (11m) Carver, "Kobayashi Maru," and fishes the local flats in his Boston Whaler Dauntless.

Maintaining An Even Keel

Stability determines a sailboat's heeling angle and handling characteristics in winds and waves. Though innate in each boat's design, some stability shortcomings are correctable by shifting ballast and weight.

By Roger Marshall

Hull stability is a key design factor for all boats and, when not correctly achieved, it's literally a "sink or swim" situation. It's the stability element of design that keeps the boat on its feet against the dynamics of wind, waves and loading. Sailboat stability is dependent on two things: waterline beam and the center of gravity of the ballast weight. Often, growing one factor reduces the other. For example, on a catamaran, the waterline beam is extremely wide and there is no ballast. For a 60' (18.2m) cat, beam might be as wide as 40' (12.1). This gives the cat a lot of initial stability but, when that stability is overpowered by waves or wind, the cat capsizes and is apparently more stable upside down than right side up. At the opposite end of the scale is a 12 meter racing sloop with 12' (3.6m) or less of beam on a 65' (19.8m) hull. The displacement on these boats is about 65,000lb (29,484kg), with nearly 70% of that in lead ballast. The boat heels to about 30° and usually won't heel much further, no matter how hard the wind blows.

A designer uses the hull righting moment to determine stability as compared to other boats. This number can be calculated or, on an existing boat, it can be found with an inclining test. Unfortunately, the righting moment isn't useful without figures from comparative data on other boats. It may be easier for a sailor to judge stability simply by the feel of the boat in a seaway. If your boat slows almost to a stop in a heavy sea or doesn't have the power to punch through waves in a head sea or you have to reef sooner than similar sized boats do when things breeze up, stability might be questionable. On the other hand, if you reef long after similar sized boats and your boat sits up like a church steeple in the worst of conditions, stability probably exceeds the need. Too much stability may also manifest as a jerky motion that can throw crewmembers off their feet. So, how do you know if your boat is stable enough? First of all, it's important to accept that proven designs speak for themselves and tampering with success is not encouraged. If stability is a concern, how do you increase or decrease it? Adding weight below the yacht's vertical center of gravity (VCG) increases stability. On most sailboats, the VCG is somewhere just above the waterline, so adding lead below the cabin sole almost always increases stability. However, be aware that increasing stability can cause other problems. The strength of many masts is based on the righting moment. Increasing the righting moment by adding lead can reduce the safety factors on your mast and lead to a failure. (Note that chainplates often have safety factors of two or three, but as you get higher in the rig, the hardware safety factor decreases.)

Adding "wings" or a torpedo bulb to the keel bottom is the simplest and lightest method for adding ballast and consequently increasing stability.

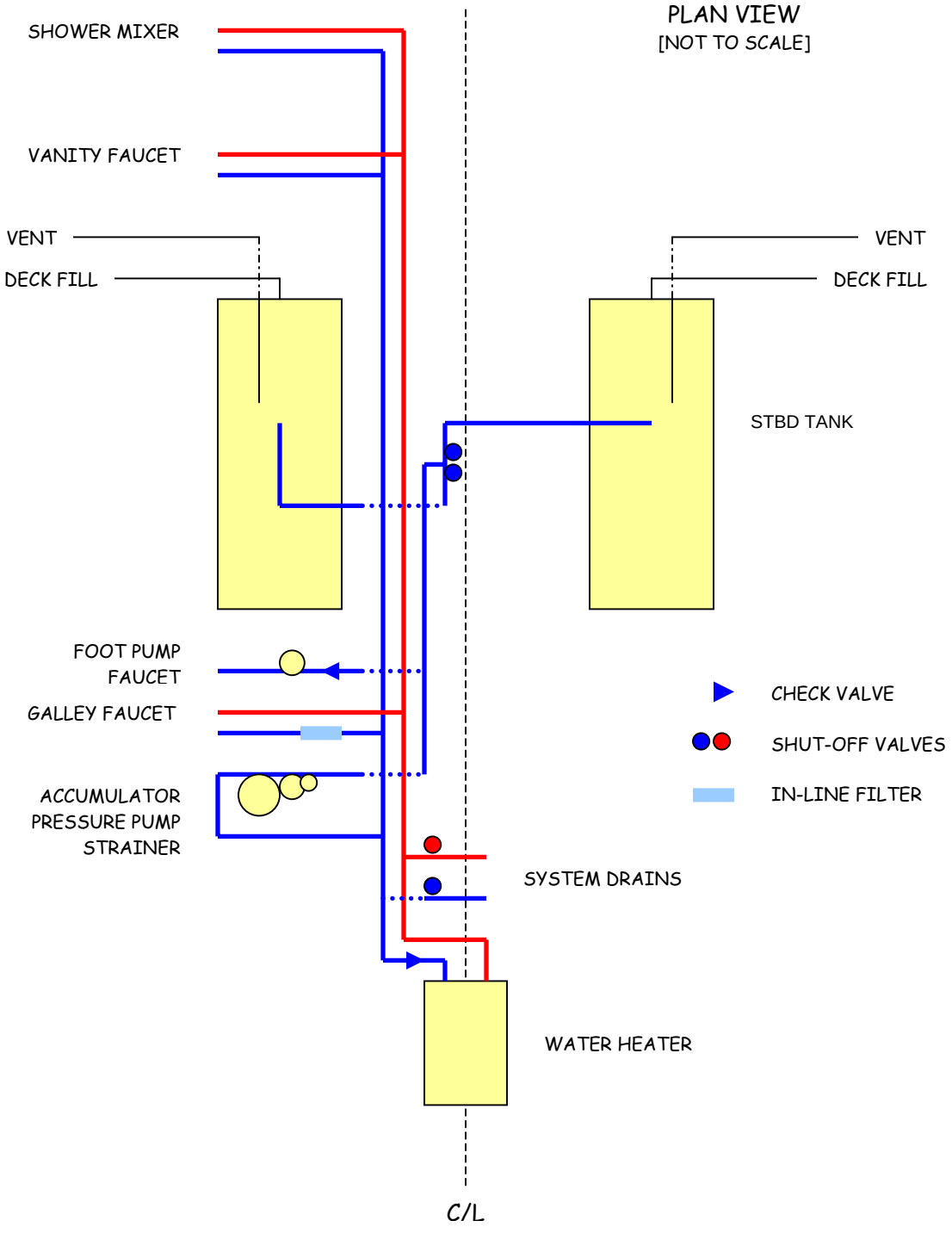
The lightest and best way to increase stability is to add lead on the bottom of the keel. This puts the lead the farthest distance from the VCG and also allows you to add the least amount of lead. On a conventional keel, you might want to make "shoes" that bolt onto the keel sides to give you a slight bulb. Of course, you can also redesign the keel to eliminate wetted surface, increase righting moment and make the boat go faster all in one step, but this is a more expensive option and could leave you with boat that is difficult to sell to someone expecting a stock edition.

If the boat has too much stability, the simplest way to reduce it is to add weight above the VCG. This may mean that you can carry your dinghy on deck or that an anchor is left on the bow instead of being stowed below. If you find that you have a ton or two of other gear stowed below, you can get rid of some of it, which will both lighten the boat and reduce stability slightly.

Stability, then, is a design ingredient that has to be just right or you'll be reefing early, sailing on your ear at an extreme heeling angle or struggling with the helm on windward courses. If the design recipe is too rich with stability, the boat will have a jerky motion and will stand up in heavy winds, which may lead to gear failures and torn sails.

About the author: Roger Marshall is a boat designer and author of 12 books on sailing and yacht design.

Potable Water System
37’ Sailboat



Plumbing Plan

Fixtures
Cold Water
Hot Water

Component	Quantity	Whale Part #
Water Tanks/Manifold		
Water Tanks		
Adapter ½" NPT male	2	WX1513
Equal elbow	8	WX1503
Shut-off valve	2	WX1574
Equal tee	1	WX1502
Tubing	19 ft	WX7162
Galley Foot Pump/Faucet		
Tubing	3 ft	WX7162
Equal tee	1	WX1502
Equal straight	1	WX 1504
Check valve	1	WX1582
Equal elbow	1	WX1503
Foot pump (left hand)	1	GP0551
Equal elbow	1	WX1503
Equal straight	1	WX 1504
15mm to ½" hose barb	1	WX1544
Telescoping faucet	1	FT1152
Strainer/Pump/Accumulator		
Tubing	8 ft	WX7162
Equal elbow	2	WX1503
Strainer/Pump/Accumulator	1	UF1215
Equal elbow	2	WX1503
Equal tee	1	WX1502
Galley Faucet		
Tubing	6 ft	WX7162
Equal tee	1	WX1502
Equal straight	1	WX1504
In-line water filter	1	WF1530
Equal elbow	2	WX1503
Adapter ½" BSP female	1	WX1532
Galley Faucet		

Vanity Faucet

Tubing	6 ft	WX7162
Equal tee	1	WX1502
Equal elbow	3	WX1503
Adapter ½" BSP female	1	WX1532
Vanity Faucet		

Shower

Tubing	4 ft	WX7162
Equal elbow	3	WX1503
Adapter ½" BSP female	1	WX1532
Shower		

System Drain – Cold Water

Tubing	3 ft	WX7162
Equal tee	1	WX1502
Shut-off valve	1	WX1574
End cap	1	WX1546

Water Heater

Tubing	5 ft	WX7162
Equal elbow	2	WX1503
Check valve	1	WX1582
Equal straight	1	WX1504
Adapter ½" BSP male	1	WX1514
Flex heater connector	1	WX1519
Water Heater		
Flex heater connector	1	WX1519
Adapter ½" BSP male	1	WX1514
Equal elbow	2	WX1503
Tubing	24 ft	WX7164

Galley Faucet

Tubing	6 ft	WX7164
Equal tee	1	WX1502
Equal elbow	3	WX1503
Adapter ½" BSP female	1	WX1532
Galley Faucet		

Vanity Faucet

Tubing	6 ft	WX7164
Equal tee	1	WX1502
Equal elbow	3	WX1503
Adapter ½" BSP female	1	WX1532
Vanity Faucet		

Shower

Tubing	4 ft	WX7164
Equal elbow	3	WX1503
Adapter ½" BSP female	1	WX1532
Shower		

System Drain – Hot Water

Tubing	3 ft	WX7164
Equal tee	1	WX1502
Shut-off valve	1	WX1574
End cap	1	WX1546

Tubing

Tubing, blue	60 ft	WX7162
Tubing, red	50 ft	WX7164
Tubing cutter	1	WX7951
Tube mounting clip	60	WX1565

Parts List

Whale #	Item	Quantity	Unit	Unit $	Extd $
WX1502	Equal tee	9	2	8.99	44.95
WX1503	Equal elbow	35	2	6.99	125.82
WX1504	Equal straight	4	2	7.99	15.98
WX1513	Adapter ½" NPT male	2	1	15.49	30.98
WX1514	Adapter ½" BSP male	2	1	3.02	6.04
WX1519	Flexible heater connector	2	1	12.20	24.40
WX1532	Adapter ½" BSP female	6	2	8.99	26.97
WX1544	Hose barb 15mm to ½"	1	1	5.99	5.99
WX1546	End cap	2	1	4.99	9.98
WX1565	Tube mounting clip	60 clips	10	7.99	47.94
WX1574	Shut-off valve	4	1	14.48	57.92
WX1582	Check valve	2	1	5.88	11.76
WX7162	Tubing, blue	60 ft	1	0.79	47.40
WX7164	Tubing, red	50 ft	1	0.79	39.50
WX7951	Tubing cutter	1	1	32.99	32.99
				Total for tubing, fittings & accessories	528.62

FT1152	Telescoping faucet	1	1	17.99	17.99
GP0551	Foot pump LH	1	1	109.99	109.99
UF1215	Strainer/pump/accumulator	1	1	173.36	173.36
WF1530	In-line water filter	1	1	39.96	39.96
				Total for fixtures	341.30

Total for project	869.92

Price quote: West Marine

SAE Torques

Diameter	TPI	SAE Grade 5		SAE Grade 8	
		Dry Threads	Lubricated Threads	Dry Threads	Lubricated Threads
1/4"	20	9 † *(108)*	5 † *(60)*	12 † *(144)*	7 † *(84)*
	28	10 † *(120)*	6 † *(72)*	14 † *(168)*	9 † *(108)*
5/16"	18	17 † *(205)*	10 † *(120)*	25 † *(300)*	15 † *(180)*
	24	20 † *(240)*	12 † *(144)*	27 † *(325)*	17 † *(205)*
3/8"	16	31 † *(370)*	19 † *(230)*	44 † *(540)*	26 † *(310)*
	24	35 † *(420)*	21 † *(250)*	49 † *(590)*	30 † *(360)*
7/16"	14	50 † *(600)*	30 † *(360)*	70	42 † *(505)*
	20	56	33 † *(395)*	78	47 † *(565)*
1/2"	13	75	45 † *(540)*	107	64
	20	85	51 † *(610)*	120	72
9/16"	12	110	66	154	92
	18	120	72	171	102
5/8"	11	150	90	212	127
	18	170	100	240	144
3/4"	10	265	160	376	226
	16	300	180	420	252
7/8"	9	430	260	606	364
	14	475	285	668	400
1"	8	645	390	909	545
	14	720	435	995	597
1-1/8"	7	800	480	1288	773
	12	900	540	1444	866
1-1/4"	7	1120	670	1817	1090
	12	1240	745	2012	1207
1-3/8"	6	1470	880	2382	1430
	12	1670	1000	2712	1627
1-1/2"	6	1950	1170	3161	1897
	12	2200	1320	3557	2134

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Recommended assembly torques for SAE grade 5 and grade 8 hex head cap screws. All torque values shown are for turning the nut while holding the head of the bolt with a wrench. Torque values are calculated at 75% of proof load. Lubricated torque values are calculated based on applying a copper-based anti-seize compound to the threads before assembly. Inch pound torque value is listed in parenthesis.
+ Installation with an inch pound torque wrench is recommended.

Metric Torques

Recommended assembly torques for metric hex head cap screws. All torque values shown are for turning the nut while holding the head of the bolt with a wrench. Torque values are calculated at 75% of proof load. Lubricated torque values are calculated based on applying a copper-based anti-seize compound to the threads before assembly.

Diameter	Property Class 8.8		Property Class 9.8		Property Class 10.9		Property Class 12.9	
	Dry Threads	Lubricated Threads	Dry Threads	Lubricated Threads	Dry Threads	Lubricated Threads	Dry Threads	Lubricated Threads
M4	27.5 †	17 †	30 †	18 †	38.5 †	24 †	53 †	32.5 †
M5	56.5 †	33.5 †	61 †	37 †	78 †	47 †	107 †	65 †
M6	95 †	57.5 †	103 †	61 †	132 †	79 †	180 †	109 †
M8	19	12	21	13	27	16	37	22
M10	39	23	42	25	53	32	73	44
M12	67	40	73	44	92	55	127	76
M14	107	64	116	69	148	89	203	122
M16	167	100	181	108	230	138	316	190
M20	325	195	352	211	449	269	617	370
M24	562	337	609	366	775	465	1066	640
M30	1117	670	1210	726	1540	924	2188	1271

Metric Grade Marking Hex Nuts

Grade Marking	Property Class
	5
	8.8
	10.9
	12.9

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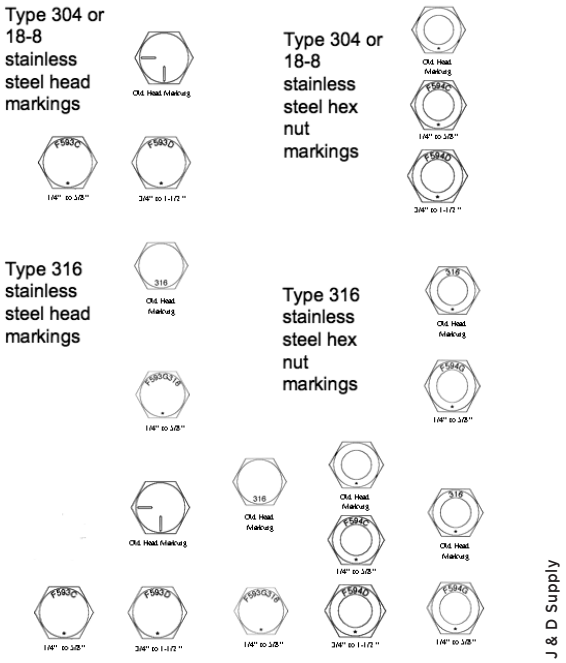
CONTENTS/

Stainless-steel hex head and nut marking

(clockwise, top left) type 304 or 18-8 head; type 316 head; type 304 or 18-8 nut; type 316 nut.



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