2000-#1

DIY boat owner — the MARINE MAINTENANCE MAGAZINE

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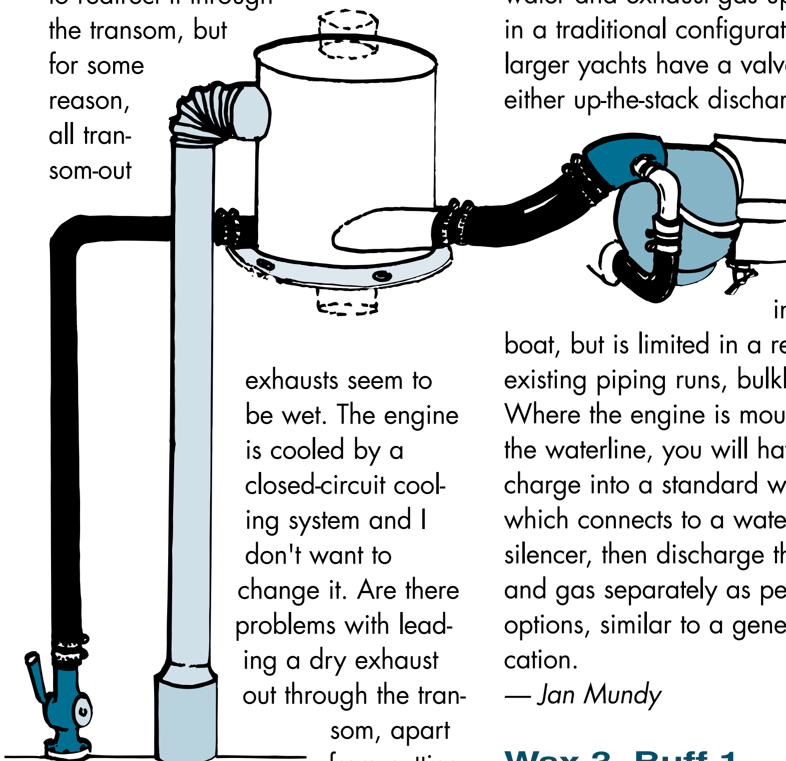
Talkback Q+A

Exhaust Rework

Q: I have just acquired a converted trawler with a dry exhaust vented up and out through the roof. I would like to redirect it through the transom, but for some reason, all transom-out exhausts seem to be wet. The engine is cooled by a closed-circuit cooling system and I don't want to change it. Are there problems with leading a dry exhaust out through the transom, apart from putting in a gooseneck and lots of sound-noise insulation?
Jack Creswick, Melbourne, Australia



A: The advantage of a dry exhaust system is that it eliminates problems related to engine-cooling water or seawater backing up into exhaust manifolds. According to the experts at Soundown, from the water injection elbow on the engine, you would attach the exhaust hose to an axial waterdrop silencer. This silencer separates the engine-cooling water and cooled exhaust gases and discharges them separately. You have three discharge options: discharge the water out the bottom of the boat via a below-waterline thru-hull and route the exhaust gases to an above-waterline thru-hull on the transom; or recombine the water and discharge as a traditional wet exhaust; or use the boat's existing stack and send the water and exhaust gas up the stack in a traditional configuration. Some larger yachts have a valve to select either up-the-stack discharge or thru-transom. This system is easily designed into a new boat, but is limited in a rebuilt due to existing piping runs, bulkheads, etc. Where the engine is mounted below the waterline, you will have to discharge into a standard waterlift which connects to a waterdrop silencer, then discharge the water and gas separately as per the above options, similar to a generator application.
— *Jan Mundy*

Wax 3, Buff 1

Q: I am looking for recommendations on restoring my boat's fiberglass. I have tried a few restorers and waxes but they don't last.
Ron McMillan, "Mary-Mac" Ottawa, Ont.

A: Unfortunately, once the polishing starts it never ends. The longest lasting shine is the one on a factory-new boat. After gelcoat has been buffed, it requires constant attention to keep that showroom look. It's possible the products you've been using don't last because of application intervals. It's not unusual to wax a boat two or three times a season in northern climates, more often in southern areas. You should only have to buff once a season, usually before launching in the spring. 3M makes a great fiberglass buffing compound that I highly recommend. Others are Meguiars or AquaBuff. Follow up with a brand-name wax formulated for fiberglass.
— *Wayne Redditt*

Freshwater Flush

Q: My S2 9.2A sailboat has a portable self-contained head and I intend replacing same with a Raritan or Par. I already have a holding tank. Can I flush the new head from my freshwater system? If so, should I tap into the line before or after the pump?
Brian Lee, St. Catharines, Ont.

A: Forget trying to use your potable water system to supply freshwater to your toilet unless you plan to disconnect it from your sink faucets. This approach is unsanitary because most marine toilets, other than Sealand Vacuflush units, share a common pump, piston and valve body for both sewage and flush water. Other than some dinky flapper valves there is nothing to prevent nasty pathogens from swimming back upstream to your drinking water while the system is idle. If you don't want to install a thru-hull it may be practical to tee into an overboard sink drain below the waterline as a source of flush water. However, to prevent siphoning back into the boat be ready to install an anti-siphon vented loop in the flush waterline between the bowl and the head pump. — *Nick Bailey*

Plug-Witted

Q:: I just bought my first boat, a 15-footer with a 15hp outboard and have a dumb question. Does the drain plug insert from inside the boat or outside?
Johnny Nixon, Vinton, Ohio

A: It's better to ask then be sunk. You'd be surprised at the number of boats that sink every year because someone forgot the plug or didn't know. Install the plug from the outside and screw in tight. Apply some waterproof grease to the rubber housing so it removes easily after every haulout. Replace plug when threads or housing wears, and carry at least two spares.
— Jan Mundy

What's Missing?

Q: We purchased a 1976 7.2m (24') SeaRay Weekender last summer and the 255hp MerCruiser starts and runs fine for an hour or so, then starts missing, first at higher rpms, later even at 1,000 to 1,500, while we limp home at 10 mph. Anything faster and the engine occasionally backfires through the carb. Symptoms also appear when we run the engine for 20 minutes, shut it down for a lunch stop, then restart to come home. We have changed plugs, coil, primary wire from ignition to coil, complete carb overhaul, water filter separator, points and condenser, and added Bardol to the oil and gas tanks. When we bought the boat it had an upscale distributor in it, new plug wires, platinum plugs, and a new coil, as if the previous owner had also been chasing this demon.
Hugh Enns, Blind Bay, B.C.

A: It only takes three things to make an engine work properly: fuel, spark and compression. One of these three is giving you difficulty. A good mechanical diagnosis is the first step. Do a compression test to establish that the mechanical part of the engine is working correctly. Compression or mechanical problems don't tend to be intermittent, so the fault is likely voltage related or fuel. Attach a vacuum gauge to the inlet fuel supply line — the value should not be above 5cm (2") of vacuum. An engine that misfires through the carburetor indicates that it's lean on fuel, overadvanced timing or overheating caused by sticking intake valves. A weak voltage or ignition system where all fuel doesn't get burned probably also causes backfiring. Your engine's breaker-point ignition must have 8 to 10 volts at the coil with the engine running. Make sure the coil is an external resistor-type coil. Did you replace the supply wire with a regular wire or a resistor wire? Your engine's alternator puts out 14 volts. The resistor wire steps this down to 10 volts at the coil. If the coil receives more voltage, it overheats and burns out points. If it's only receiving 6 volts, the coil won't overheat, it just performs poorly. If after all your diagnosing, your engine still runs poorly, I suggest you take it to a certified marine mechanic. TIP: When diagnosing engine trouble, if you install new components with no effect, return the original components, otherwise you can't source the cause of the problem.
— Steve Auger, Mercury Marine

Better to Cover Than Go Bare

Q: I just purchased a '97 Four Winns that has never seen bottom paint and plan to keep it in a marina on the Delaware River. Are there any alternatives to bottom paint? I have been told my only other option is to haul out every two weeks and pressure wash it.
David Buddendorff, Croydon, Penn.

A: Since gelcoat is porous, you need to apply some type of "sealer." Fouling tends to fill the pores of the gelcoat, making cleaning difficult, even with an acid cleaner (i.e. MaryKate On/Off), and yellows the hull. You could apply a clear bottom wax, followed by frequent power washings. We have tried various waxes specially formulated for underwater applications (i.e. Easy On, Super Slick) but have not yet found one that eliminates fouling and doesn't require either weekly cleaning or cleaning with an acid wash if left for longer periods before cleaning. Test areas include the Hudson River (brackish water) and freshwater. Unless you get an endorsement from your local marine store or a fellow boater, I don't recommend using a bottom wax. There are epoxy coatings available (i.e. VC Underwater Epoxy) but these don't have any antifouling properties and the boat would need hauling every week or two for cleaning, a task made easier with products containing Teflon. Unfortunately, there aren't other viable solutions that work that we are aware of.
— Jan Mundy

Prep for Barrier Coat

Q: My boat's bottom paint is thick due to yearly renewal. This spring I would like to sand the bottom and apply a barrier coat, then reapply new anti-fouling paint. Must all the old finish be removed?
Chuck Bentley, Rensselaer, N.Y.

A: To apply a barrier coat all of the old antifouling must be removed. There are various methods to do this: have the boat sand- or baking-soda blasted; have it power peeled (i.e. The Peeler); apply a chemical peel such as Peel Away; grind (not recommended); or sand heavily with 60-grit paper to make the antifouling more porous, then apply a paint remover (i.e. Interstrip 299E). After the paint has been removed sand the bottom with 80-grit paper, and then wipe down with fiberglass solvent wash (i.e. Interlux 202). Apply your barrier coat according to the manufacturer's instructions, then apply the anti-fouling paint.
— Jan Mundy

Heads Up

Q: I'm in the process of restoring a '79 Montego 19. Recently I saw some sailboats with pop-up companionway tops, adding about 25.4cm (10") of headroom. It looks like a good idea. Any suggestions for making a

new fiberglass top? Also, do you recommend using a router or Dremel tool with a spiral bit, rather than a saw, to cut the glass?
D. Leary, Quantico, Virginia

A: If you intend to remove the existing cabin top and make a new one that hinges upward, I would have to recommend against that. The cabin top is a very important structural part of the boat and this sort of change may create dangerous conditions of weakness in the structure. The companionway hatch could be made to pivot upwards, instead of sliding in the rails, to allow standing headroom under the hatch. It's useful at dockside, but probably not so solid while underway. For cutting fiberglass, a router with a down spiral bit works fine. You would be at it a long time with a Dremel tool, as they are simply not powerful enough for cutting fiberglass. Make sure that there are no embedded hardware parts before using the router.
— *Wayne Reddití*

Gelcoat Streaking

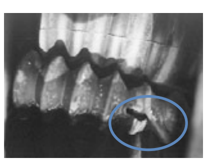
Q:: 10.2m (34') Silverton has some yellowish streaks while other parts are either white or off-white. Are there products to restore the hull to an all-white color?
Kevin Gallagher, "Millie," Belmont Harbor, Chicago, Ill.

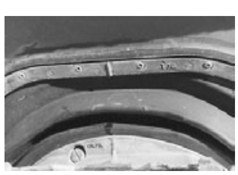
A: Your hull likely has what is known as alkaline streaking. Someone, at sometime, used an alkaline cleaner (i.e. Fantastik, Castrol Super Clean) which was allowed to dry. The cleaner attacking the gelcoat causes the streaking. Some alkaline cleaners have great cleaning power but must be rinsed thoroughly and never allowed to dry. There is no cure, aside from painting.
— *Jan Mundy*

Tech Tips ✓

STAKES FOR STRAKES: Lowes (a large building supply chain in the U.S.) sells 19mm- (3/4"-) square tomato stakes made of teak or other weather-resistant look-alike wood. After two years of garden use, the wood shows no signs of decay and has a silvery gray surface with a golden hue underneath. Perfect for small cockpit grates, eyebrows (if scarfed together) and lots of other small projects, or laminate some together for bigger jobs. A bundle costs about US$4.
Brian Gilbert, "Atricilla," Charleston, S.C.

A COSTLY MEAL: We're not sure why, but some muskrats enjoy a tasty meal of rubber. A pinhole morsel in a shift cable bellow can sink a boat in hours. Raise the outdrive out of the water and turn to starboard to help to repel and prevent accidental sinking. OMC drives built before 1985 have a rubber-type transom gasket, an especially easy dinner target. For these engines, OMC makes a rodent guard, a big chunk of plastic with the center cut out for the outdrive.





Warren Mills, owner Gannon Narrows Marina, Peterborough, Ont.

E-COMMUNICATIONS: When you need to stay in touch while cruising, buy a Sharp TM-120 (US$119), a new portable pocket computer with an acoustic coupler. Dial a toll-free number to send and receive e-mails and faxes from any phone, wired or wireless. No need to carry a laptop, acquire an Internet server or seek out libraries or Internet cafés. Long distance charges apply only when calling from outside the U.S.
David Burns, aboard "Kari II," via e-mail.

FILTERING FUEL AT THE PUMP: Marina fuel tanks are often a source of water and dirt. Instead of pumping fuel directly into the tank, pump it into a large funnel fitted with a fine screen in the bottom and inserted into the fuel intake hose.

PARTS ORGANIZERS: Use inexpensive plastic drawer organizers, preferably with see-through lids, for stashing fasteners, nav gear and a myriad of small parts accumulated onboard. Available in a variety of sizes and shapes, some fit snugly under deckheads or shelves. For units with opaque tops, instant glue a sample onto each drawer for easy identification.

FILTER GUARD: Some engines have the oil filter located behind the fan belt. Should the belt loosen, it could hole the filter. In order to prevent this, slip a hose clamp around the filter where the belt lines up with the filter.

EMERGENCY VENT PLUGS: Most boats are fitted with deck vents but few of these are sealed. Under extreme conditions, boarding seas could wash away the vents, leaving 7.6cm (3") or larger holes in the deck. Constructed similar to tapered seacock plugs, fashion them from cedar or pine, beginning with a diameter that is slightly larger than the maximum opening of the vent and with an overall length of about 30.5cm (12"). For construction details, see DIY 1995-#1 issue, page 21.

REST PEACEFULLY: To quiet noisy internal mast halyards, cables and wires, slide lengths of foam insulation, the kind used for wrapping pipes, up the mast.

GLUE ADVICE: No boatbuilder should be without Gorilla Glue (Lutz File and Tool, Cincinnati, Ohio). It foams up and crystallizes in place, making for a super-strong bond, even when joints aren't perfect.
Doug Barnard, "Fiesta Bimbo," Agoura, Calif.

MARKING SCOPE: To estimate how much anchor line to let out, insert pieces of polyester cord or tape through the line at your normal anchoring lengths. Laying the anchor line along the deck from bow to stern and back gives an accurate measure of total length.
Wayne Rezendes, "Makai," Honolulu, Hawaii

Tech Tips welcomes contributions from readers. If you have a boat-tested tip you'd like to share, send complete information along with your name, boat name and home port to: **DIY Tech Tips**
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Or E-mail to
info@diy-boat.com.

ShopTalk

SAND BY THE NUMBERS

Follow these tips to properly prepare wood and fiberglass surfaces for painting or varnishing.

By Wayne Redditt

Virtually every surface finishing job begins with surface preparation. For simple tasks such as waxing, a good cleaning may be all that's required. For painting or varnishing though, more thorough preparation is always in order.

Almost all paint or varnish (film) applications demand abrading of the surface prior to applying the film. There are many types of abrasives (sandpaper is a bit of a misnomer) and plenty of methods of using them.

Abrasive particle size is designated by number. A low number indicates a coarser material that is more aggressive and leaves deeper, wider scratches. This system applies to most abrasives. (Specialized systems using micron designations have the reverse numbering of common abrasives.) For most purposes, I use 80 (coarsest), 120, 240, and 320 (finest), normally garnet for everyday use, Adalox for sanding epoxy resin.

When removing old paint down to the substrate, don't start with abrasives. Use only heat guns, chemical strippers and scrapers when removing paint that is flaking off or has large open splits that soon will flake off. Don't remove solid-adhering paint — it has a great bond to what is underneath, so why start from scratch.

Surface prep on boats usually involves four categories: a bare wood surface; a wood surface that has paint adhering to it; a bare gelcoat surface; and a painted fiberglass surface.

When hand-finishing a bare wood surface, start with 80 grit on a sanding block to remove any high spots. Anything coarser than this will probably remove more material than desired. If you are flattening (fairing) a surface, sand at an angle to the grain to remove the material quicker. Sand out the cross scratches with 120 grit, moving the block in the grain direction of the wood. Don't sand past 120 grit for woods like mahogany, teak, oak or ash. When power-sanding with an orbital or double-action orbital sander, you have less concern about the grain direction, although it's not advisable to move an orbital rapidly across the grain as it will scratch deeply. Hand sanding is actually more aggressive than power sanding; power sanders leave a shallower scratch mark than similar grit done by hand.

Tools of the trade.

If your project requires painting over bare gelcoat, use a fiberglass gelcoat cleaner prior to sanding. This will remove all traces of mold-release agents, waxes and other surface contaminants that won't be removed by sanding. Sanding the surface without removing these compounds will surely result in poor paint adhesion later. Read the can labels before proceeding and sand only to the grit recommended.

Treatment for wood or fiberglass surfaces that have paint adhering well is similar. The object is to lightly abrade the paint surface to provide mechanical as well as chemical adhesion from the new paint. The idea of mechanical adhesion is derived from the belief that the liquid film flows into the tiny scratches created from sanding and locks in tightly upon drying. This means that you don't want to create a shiny or burnished surface when sanding. Consequently, you must use the coarsest grit that will adequately be covered by the new film. Some professionals never sand with anything finer than 240 grit before

Easy paper changes, 3M Hookit sanding pad and discs use a hook-and-loop attachment system and are available in most any grit.

painting. It depends on the "hide" that the paint system will deliver. Always consult instructions on the can's label or contact the supplier. If it specifies 320 grit, then that's as light as you should go.

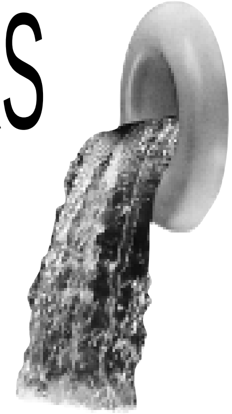
Newer abrasion systems incorporate special ingredients on the paper's surface to help shed dust. These non-loading type abrasive papers mean that dust won't clog up your paper after the first stroke. Wet sanding with wet-dry paper is still a viable alternative to the no-clog types.

Immediately prior to painting, use a tack rag to remove all dust. Dust will ruin all of the hard work you went through to create the "tooth" on the surface and the film won't stick. Completely unfold the tack rag, bundle it up into a loose ball, then lightly dust the surfaces to be painted. Turn the rag over often. Don't press the tack rag hard onto the surface, it may transfer contaminants that will cause paint failure later.

Used specially for detailed finishing, 3M flexible sanding sponges in five grits from medium to microfine can be used either wet or dry.

About the author: Wayne Redditt teaches boatbuilding, repair and restoration at Georgian College's Marine Technology-Recreation course in Orillia, Ont.

KEEPING DRY BELOW DECKS



Is your boat's existing bilge pump system adequate? Here's the lowdown on pump types, flow rates, installation options and other information you need to evaluate and plan an upgrade.

By Nick Bailey

Despite the fact that most boats are fitted with one or more bilge pumps, sinkings are common nonetheless. I'm always amazed how many boats are only a corroded fuse or dead battery away from sinking. Even more amazing is the blind faith boat owners have in what is often a very fragile and inadequate pump system. Many pumps are hard pressed to keep a boat afloat at the dock, let alone in the event of an emergency underway. A properly installed and maintained bilge pump system is your second line of defense against sinking, behind a watertight hull, and so deserves your earnest attention and resources.

Types of Pumps

Most bilge pumps are either centrifugal (submersible) or positive displacement (non-submersible) type. Both types can run dry for sustained periods without damage, unlike a flexible impeller pump which overheats and comes apart almost immediately if run dry.

Centrifugal pumps (common submersible pump) have a curved solid impeller designed to sling water entering from the center axis of the pump housing into an outlet pipe mounted tangential to the housing. A centrifugal pump moves water by momentum alone and as no suction is created it won't self prime. Many have a detachable base plate, fastened by screws in the bilge and the pump motor assembly snaps or twist locks into the base plate. Slots incorporated in the motor or base plate housing serve as a debris screen to keep the impeller from fouling. A discharge hose leads to a thru-hull above the waterline. It's a very simple plumbing installation in concept but one that is subject to a variety of problems — connecting a discharge hose often cuts actual pump performance down to half (or less) of rated capacity (see "Pump Performance").

Positive displacement pumps use a reciprocating flexible diaphragm or piston to force water out of the pump on the down stroke and suck water into the pump on the upstroke. The pump inlet and outlet have a one way flapper or duckbill valve to ensure that fluid can only go in the desired direction on each stroke. Due to the suction created, pumps are self priming and often mounted remote from the bilge with only intake hose and bilge strainer, a useful feature for boats with a bilge sump too narrow or inaccessible to fit a submersible pump, or in shallow bilges where bilge water level must be kept to a minimum.

The weakness of diaphragm pumps is their limited capacity. Even electric diaphragm pumps don't get much above 1,200 gallons per hour (gph), a capacity otherwise expressed as 20 gallons per minute (gpm). This is due to the inefficiency of their one-gush-at-a-time reciprocating action. Most manually actuated bilge pumps are the diaphragm type (i.e. Edson, Bosworth, Henderson, Whale) with rated capacities from 5 to 30 gpm. As all diaphragm pumps are easily crippled by debris lodging in one-way valves, a bilge pick-up strainer or in-line filter must always be installed.

Pump Performance

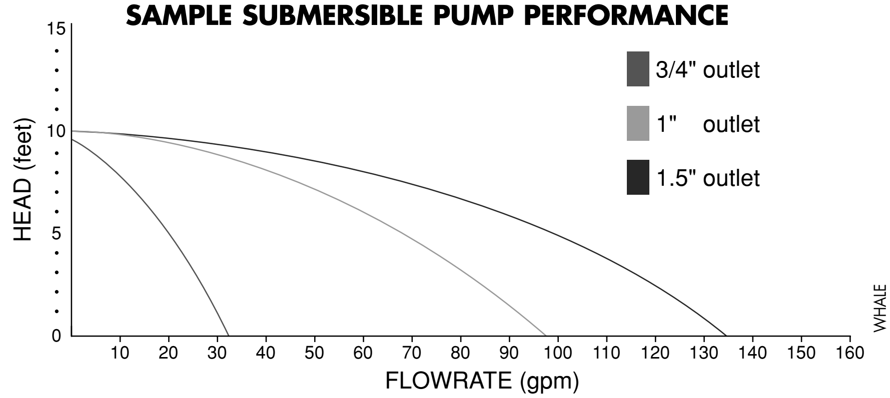
For all pumps, manufacturers provide the rated capacity and flow rate data. Nominal ratings are based on "open flow" conditions; for example, the pump is operating in a bucket with no hose attached. This nominal "maximum flow" rating does not even remotely indicate how a pump will perform in a typical installation.

The hydraulic head pressure the pump must overcome to push water through the hose and up to the discharge thru-hull governs realistic pump performance. Two factors contribute to head pressure: static head — vertical distance from the pump to the discharge thru-hull — and dynamic head, which is the total frictional resistance within the discharge plumbing, usually expressed as an equivalent to feet of static head. Adding static head to the dynamic head gives the total head pressure (also expressed in feet) that the pump must overcome. Pump manufacturers usually provide information regarding the maximum allowable head height and a graph of flow versus head height (**Figure 1**).

Another important capacity factor is whether full voltage is available to power the pump. Open flow rating is usually based on pump performance with a 13.6-volt DC power supply. (This represents the voltage available while the engine is running and alternator is charging.) In actual usage, this voltage is rarely available at the pump. The engine may not be running, wiring may be too small in gauge for the length of run, there may be corroded connections or the batteries may not be fully charged. All these conspire to reduce available voltage and the pump's actual performance. It's possible to theoretically calculate what flow rate can be expected in a given installation, but as a rule of thumb assume a 50% reduction in flow rate for a normal installation, and even worse for an installation with high head pressure. Since submersible bilge pumps won't lift water beyond a 1.8m to 3m (6' to 10') head, it's important to check the pump's performance specifications in relation to the requirements of your particular installation.

Figure 1

SAMPLE SUBMERSIBLE PUMP PERFORMANCE



How Big a Bilge Pump?

There are no mandatory pump size requirements for pleasure craft from the U.S. Coast Guard or even any recommendations from the American Boat and Yacht Council (ABYC). The American Bureau of Shipping (ABS) recommends that vessels under 19.5m (65') be equipped with a 24 gpm and a 12 gpm pump totaling 36 gpm (or 2,160 gph). If we assume this recommendation is for actual pump performance, then this spec calls for a pumping capacity of 5,000 gph or larger, depending on how restrictive the installation.

Without detailed small craft recommendations your pump choice largely depends on whether you view it as a convenience to dewater the bilge from minor leaks or as a major safety system designed to keep the boat afloat in the event of a critical failure such as a broken thru-hull or ruptured shaft log. According to a graph (**Figure 2**) adapted from the "Navy Salvor's Handbook" by Nigel Calder and published in Professional Boat Builder No. 57, a 25mm (1") hole 30cm (1') below waterline lets in 1,200 gph, a flow rate which looks manageable. A 50mm (2") hole at the same depth floods at the rate of 79 gpm or 4,760 gph, a situation equivalent to the failure of a large thru-hull and a flow rate that exceeds the rated capacity of any bilge pump.

The largest popular submersible pumps on the market range from 4,000 to 8,000 rated gph and require 5cm or 7.6cm (2" or 3") discharge hoses. Assuming the typical 50% of rated performance, even the 8,000-gph unit won't keep up with a 5cm (2") hole. Nonetheless, if a system is to be considered adequate for anything other than routine dewatering, it should be able to cope with the most likely failure, if not the very worst case emergency.

System Planning

Before upgrading an existing pump system, it's necessary to evaluate

Figure 2 - FLOODING RATES (gpm)

Depth of Hole	Diameter of Hull Opening						
	1"	1.5"	2"	2.5"	3"	3.5"	4"	6"
1'	20	44	79	123	177	241	314	707
2'	28	62	111	174	250	340	444	1,000
3'	34	77	136	213	306	417	544	1,124
4'	39	88	157	245	353	481	628	1,414
5'	44	99	176	274	395	538	702	1,581
6'	48	108	192	301	433	589	770	1,731

your boat's layout. The first question is whether the boat is divided into separate compartments that, if not watertight, can at least retain water up to a damaging level. Each separate compartment should have its own bilge pump sized to handle the likely source of leak in that compartment (see "Pump by the Numbers" on page 16).

A 7.5m (25') cabin cruiser, for example, typically has the engine compartment separated from the cabin by a watertight bulkhead. In the cabin, there may be a 12mm (1/2") head intake and two 25mm (1") sink drains. A single 2,500 gph should be adequate to handle one broken thru-hull assuming two won't break simultaneously. In the engine compartment the most common worst case scenario is a ruptured water intake or exhaust hose also equivalent to a 25mm (1") flow rate of 1,200 gph, so a second 2,500 gph unit should suffice, provided the exhaust outlet stays above water.

A smaller open or cuddy cabin 23-footer is at risk of being swamped in a big sea, or even in a heavy rain. Although cockpits are self draining, a lot of water still gets in through engine hatch covers and need the largest possible pumps to handle the flow.

If your boat doesn't have separate compartments or large limber holes draining into a common bilge, two pumps on separate circuits should still be considered the minimum to provide back up in case a pump fails or clogs. At least one of the pumps should be of high capacity to deal with a worst case leak.

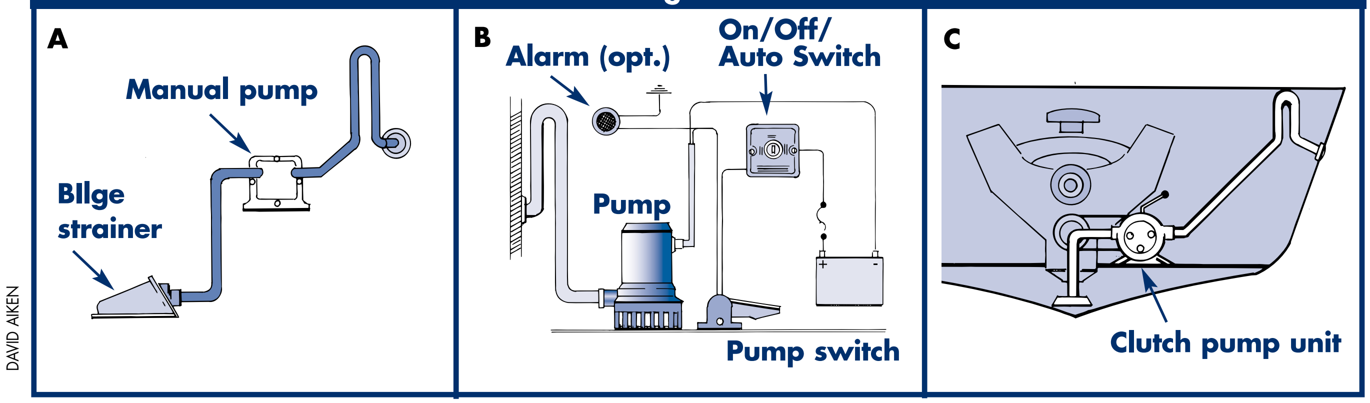
Sailboats often have a very narrow or shallow bilge that cannot accommodate a larger submersible

TIPS: WATER-PROOF WARE

When you have a very wet boat and need to keep connections dry and corrosion free, use a watertight plastic container and terminal strip. A similar concept to the watertight fuse box described in "DIY Projects," 1999-#1 issue, put the terminal strip loose in the box, pull wires through a single hole punched in the bottom, attach ring connectors to wires and connect them to the terminal strip, mount the box to any convenient nearby vertical surface and snap on the lid. Make sure the hole in the box faces down so rising or dripping water can't get in.

— Jan Mundy

Figure 3



TYPICAL PUMP INSTALLATIONS

A: Manual diaphragm pump (i.e. Edson) with inline strainer keeps debris from clogging the pump.

B: Submersible bilge pump with separate float switch, on-off-manual switch and optional red light (and/or audible alarm) operation indicator.

C: High-capacity engine-driven clutch pump has manual on-off lever (or electric) and includes bilge strainer.

pump. A small submersible electric pump or typical standard-equipped manual diaphragm bilge pump, although fine for routine dewatering, is not adequate for emergency use. Any boat that is configured in a way that prevents the installation of a properly sized electric pump is a good candidate for a standby emergency-only bilge pump system (see below).

Larger boats have more equipment, more and larger thru-hulls that tend to be situated deeper in the water. This increased depth increases hydraulic head pressure behind a leak and resulting rate of flooding.

Emergency-Only Pumps

For small boats, an Edson self-contained, portable pump kit fits in a cockpit locker and is quick-to-assemble when needed. A viable strategy for an effective emergency-only pump for larger boats would be a standby high-capacity, engine-driven pump (pricey) or a large submersible electric pump (more affordable upgrade) mounted in the lowest available space in, or near, the bilge.

Rubber-impeller style engine-driven pumps from Jabsco are capable of self priming and are engaged by either a level-actuated manual clutch or by a remote switch actuated electric clutch (**Figure 3, C**). The largest version has a rating of 5,000 gph at full speed (2,200 rpm) and a conservative capacity rating at 3m (10') of head. Intended for higher horsepower engines (30 plus), engine-driven units obviously require you to become aware of the leak before the engine drowns, so some kind of high-water alarm would be useful (i.e. Bilge Sentry, Ultra Pumpswitch Senior). Like any impeller pump, if the engine-driven pump runs dry it will quickly smoke the rubber impeller, but by then you have presumably stopped the leak. If you want to get fancy on electric clutch versions, install a vacuum-sensing switch that detects when the pump sucks air and disengages the clutch.

Installation Guidelines

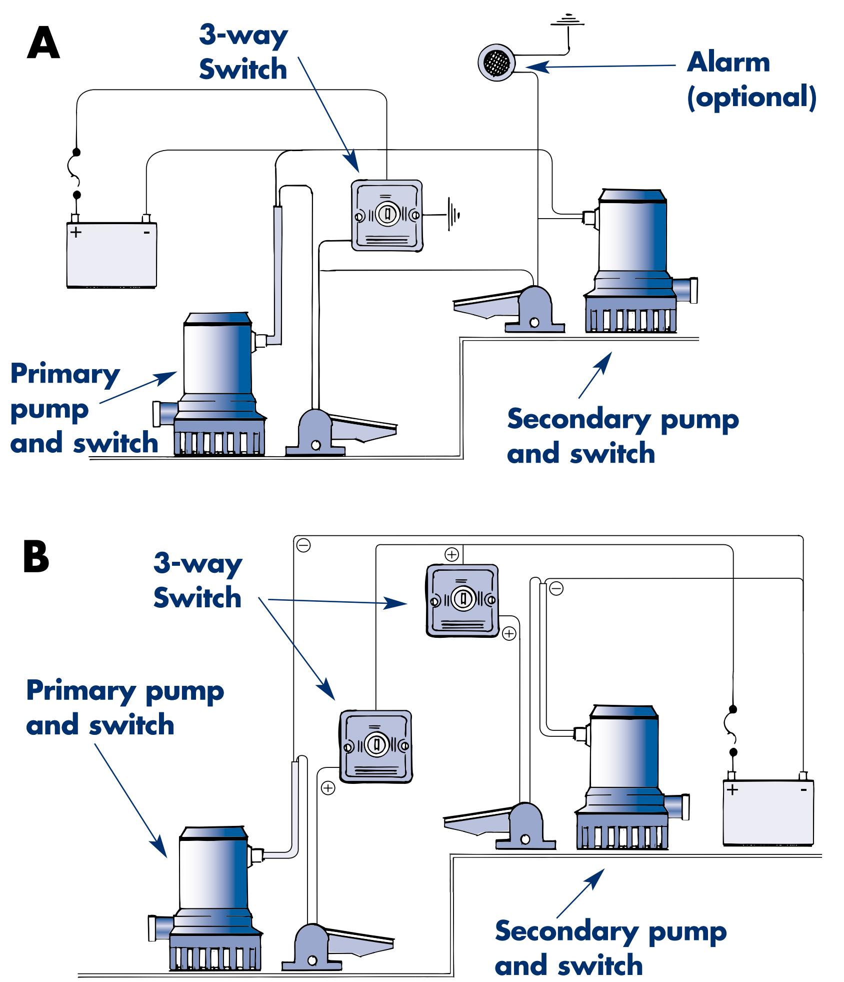
Manual bilge pumps (i.e. Edson) are robust, simple devices and seldom fail. Electric bilge pumps are also robust and simple but reliability is another matter entirely. When an electric bilge pump fails, it's rarely the fault of the pump but more likely to be a result of poor installation or maintenance: faulty wiring, a clogged pump inlet, and a stuck or broken float switch. (See page 22 for complete installation details).

Positioning: A submersible pump must be firmly fastened in the deepest part of the bilge. If access to the ideal spot is difficult, or you are reluctant to drive screws into the hull, mount the pump on an aluminum L-shaped bracket and fasten this to anything convenient and solid, like a stringer or rib. If you are planning to mount two pumps, it makes sense to have one larger than the other and mounted higher up (**Figure 4**). The smaller pump (lower power consumption) would be your every day pump and the larger reserve, back-up pump used when the other fails, or the rate of flooding exceeds the smaller unit's capacity.

With planing powerboats, the lowest point while underway may be different from the lowest point at rest. You may want a pump at each location, particularly if there are separate compartments.

Figure 4

PRIMARY AND BACKUP PUMP INSTALLATIONS



A: Both pumps on same circuit; B: Backup pump on separate circuit.

PUMP BY THE NUMBERS

Owner of Galleon Jewelers and avid sportsfisherman, Captain Richard Provenzano may be considered somewhat eccentric when it comes to staying afloat. Moored in Sebastian, Fla., his 11m (36') Hatteras has weathered numerous hurricanes, floods and the like which he largely attributes to having seven pumps onboard. Starting at the bow are two in the forward stateroom, one 1,200 gph unit in the bilge and one 800 gph high-water pump mounted 15cm (6") higher that attaches to the drain sump from the shower. "When I'm shy on fuel, the boat's bow heavy in the slip," says Provenzano, "and if the lower pump fails, the boat won't fill with water." Mounted in the engine compartment are two 2,000-gph pumps under each engine. In the bilge below the companionway beside the Racor filters is a Lovett pump. "This one is the main pump." Another two 1,500 gph pumps reside in the stern bilge. This gives a total pumping capacity of about 11,000 gph. "It's a lot of pumps, but leaks happen."

— *Jan Mundy*

SYSTEM COMPONENTS

Plumbing: Most hose sold for bilge pump use is light plastic corrugated stuff [Ed: Specs, standards and recommended options for marine hose appears in DIY 2000-#2 issue.] Corrugations have the advantage of making the hose flexible enough to turn tight corners without kinking, but they also contribute a significant amount of resistance to water flow adding to the dynamic head pressure the pump must overcome. Each bend, elbow and hose length itself contributes to resistance. So, to minimize adverse head pressure the hose route should theoretically be as short as possible, rise as little as possible, have few bends and have no corrugations. The discharge thru-hull must also be a safe distance above the waterline to avoid back siphoning.

Back Siphoning and Check Valves: Some systems may have the bilge pump discharge installed below the waterline with a check valve to prevent back siphoning. If you do this, your boat will sink — it's not a matter of if, just when. Every check valve eventually gets a bit of debris lodged in the flapper and when it no longer seals the boat sinks.

Sailboats have particular difficulty finding a good above waterline location for the discharge simply because when heeled over in a stiff breeze the waterline on the leeward side may be up on deck somewhere. Conversely, an outlet on the windward side may now be 3.6m (12') straight up from the pump (**Figure 5**). On one tack the pump wants to back siphon and sink the boat, on the other tack the head pressure is so great it may not pump any water at all. There are three solutions: reef sails to reduce heel; lead the discharge hose to the center of the tran-

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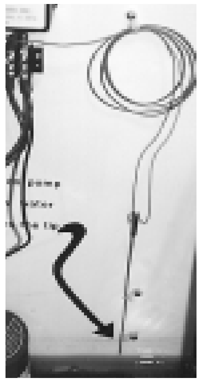

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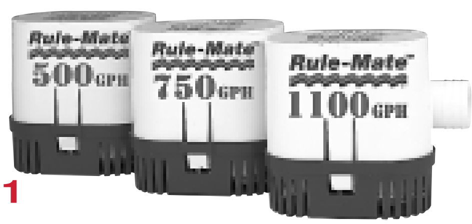

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1.Unlike submersible pumps that continuously cycle on and off, Rule Mate pumps have an integral float switch that turns the pump on only when water level rises. 2. Conventional float switch. 3. A high-water alarm triggered by an electrode provides early warning to irregular bilge water levels. 4. Ultra Pumpswitch has an non-jamming enclosed float and magnetic switch; Senior model features a high-water alarm 5. A "smart" bilge switch, the Bilge Buddy shuts off the pump switch when it senses petroleum products in the bilge; 6. Compact and quickly assembled when needed, Edson one gallon-one stroke portable pump kit includes carrying board and quick-connect couplings. 7. A manual override switch or a three-position on off auto switch lets you manually pump out the dregs and override a stuck float switch.

TIPS PUMP CYCLE METER

About 10 years ago, Rockland, Mass., marine surveyor David McKie installed a bilge pump "minutemeter" on his boat. Developed by a local inventor, the analog meter mounted inline with the float switch and registered pump-operating time in minutes, similar to an engine hourmeter. Recording meter readings before leaving the boat and upon returning gave McKie an accurate audit of pump run-time. We're not aware of any off-the-shelf products available, but if you're handy with electronics, it's a simple device to make.
— Jan Mundy

NOT ALL CLAMPS ARE EQUAL

Hose clamps vary greatly in quality and construction. What you may think is an "all-stainless" clamp could sink your boat.

By Jan Mundy

Replacing a failed submersible pump in one of our 6.6m (22') test boats prompted an investigation into hose clamps.

You'll note in the photo (below) the badly corroded clamps connecting hoses to below-waterline thru-hulls not equipped with seacocks. Like most boaters, we hadn't examined the clamps until the need arose. Besides saltwater (this is a freshwater-used boat), cleaners and chemicals in bilge water can and do accelerate corrosion of isome metals. Clamp failure in the bilge can sink a boat; clamp failure on a fuel line can be fatal.

Close inspection of five brands, four obtained from marine stores and one removed from our test boat, netted surprising results. Many clamps sold are not all 100% corrosion-proof stainless-steel construction. Stamped on every clamp screw was "All Stainless," yet the clamps in our test boat had badly rusted screws and corroded bands underneath the screw housings.

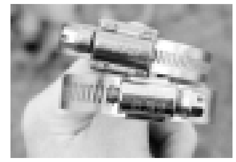
Although clamps may be labeled all-stainless, there are different grades of stainless; clamps are commonly made of 304, 316 or 400. Series 302, 304 and 305 stainless, commonly referred to as 18-8, are non-magnetic, but freely succumb to crevice corrosion. More expensive is non-magnetic 316, a lower carbon, higher nickel and chrome content stainless which makes it more corrosion resistance. Type 400 stainless is magnetic and corrodes rapidly in the marine environment.

Two hose clamps (left and center) with magnetic, potentially corrosive screw pins and housings stamped "All-Stainless" purchased from a local marine store, and clamp (right) removed from test boat. Perforated bands encourage crevice corrosion and are prone to cracking.

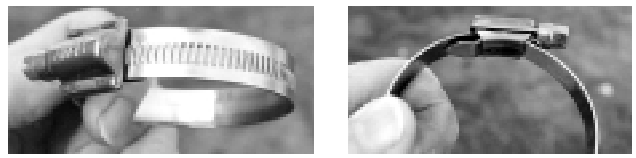
Our magnetic test found three clamps with magnetic screws and housings, which means they are highly corrosive. Two clamps, AWAB and Ideal All 316 SS held no attraction.

Our tests prove that boaters once again must be aware of what they're buying, and when it comes to purchasing clamps, look for either AWAB or equivalent "All 316 Stainless" clamps. You'll pay more, but it's unlikely you'll have to replace them. When in doubt, carry a big magnet.

Lastly, contrary to popular belief, tighter is not better. Use the manufacturers recommended tightening torque, typically 45 to 55 inch-pounds, or secure as tight as possible with a screwdriver. Using a ratchet or socket wrench overtightens clamps and damages hoses.



Only two of five "all-stainless" clamps passed the magnet test: AWAB and Ideal All 316 SS.



Details of a premium hose clamp: all-316 non-metallic, non-corrosive stainless; solid non-perforated band prevents metal fatigue and breakage, and uniform clamping force; stamped band threads on outside offer high clamping force; smooth band inside with no perforations and rolled edges prevent hose damage; pin housing designed to maintain circular shape.

BILGE PUMP SENTINEL

Easy to add to an existing system, this simple alarm sounds every time the bilge pump cycles.

By Paul Shard

This may be the most important upgrade you add to your boat — an alarm that sounds when your automatic bilge pump cycles. Water flow from a leaking stuffing box or parted hose-clamp can quickly overcome a pump, a plight that can continue undetected, as the boat sinks lower in the water. Numerous cases have been reported of boaters opening the hatch, stepping down into the cabin into a foot of water. With hundreds of gallons sloshing in the bilge, it becomes very difficult to find the source of the leak.

The solution is to install an audible bilge alarm. Any water in the bilge is detected immediately. The alarm should be audible both in the cabin and on deck, even when the engine's running (alternatively, consider more than one alarm). If you already have an electric pump with a separate float switch, an alarm is added easily. If you don't have an automatic pump with float switch, it may be a good time to install one.

To connect an alarm to an existing bilge pump switch, purchase a 12-volt DC alarm from a marine or electronics supply store. Models with indicator light and buzzer are usually mounted in a panel. Buzzer-only units can be mounted anywhere within hearing range. A location near the bilge pump switch simplifies wiring. Wire the alarm's hot (positive) lead to the terminal on the back of the bilge switch that manually turns on the pump (**Figure 3, B**). This terminal also has power to it when the float switch turns on the pump. Connect the other wire to a negative bus bar. Now test the system: switch the bilge pump to manual or lift the float switch to activate the pump. Every time the float switch turns on the pump, the alarm also sounds.

Some boats have "intelligent" bilge pumps with integral float switch in the same housing. Some models (Rule Mate) are wired with a manual override. If not so equipped, the easiest option is to add a separate float switch and alarm. Mount the float switch above the existing automatic switch so the alarm sounds when water rises above normal. One alternative, if you have room in the bilge, is to install a smaller second pump with an alarm (as described above) but mounted lower in the bilge. Now this pump sounds the alarm when it detects water; the original pump becomes a backup.

Boat motion may occasionally activate the switch then turn on the pump and alarm, though no water is actually pumped overboard. On a rough day, this gets annoying. Commonly caused by a poorly designed float switch or improper mounting, raise the switch slightly higher than the pump. If this doesn't resolve the problem, consider a switch with a larger vertical distance between the trigger points, such as the Ultra Pumpswitch, Groco Bilge Pump Control Kit or other ones that compensate for backflow without activating the switch.

Installed on our 37-footer, "Two-Step," this alarm system has been problem-free for 10 years and 35,000 miles of international cruising. On four occasions it alerted us to potentially dangerous problems. One time the dripless shaft seal had jammed with debris when we put the motor in gear and water was pouring in. It was easy to fix since the water level was still very low in the bilge and I could see the spray leaking out the seal. Occasionally the alarm activates in the middle of the night, usually after a heavy rain. Personally I don't mind hearing it cycle on for a few seconds, then go off again. It's when it comes on and stays on I take action. Altogether, it's the cheapest stay-afloat insurance we have on board.

About the author: Paul Shard and his wife and business partner, Sheryl, are the authors of "Sail Away! A Guide to Outfitting and Provisioning for Cruising" published by Pelagic Press. You can follow their adventures at www.searoom.com.

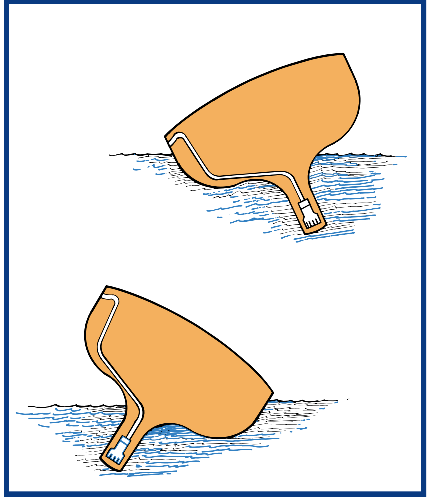
TIPS

LOSS COVERAGE

If your boat should sink are you insured? A loss due to "unknown" causes will likely be covered by the insurance company. Should a survey prove that the sinking was due to lack of maintenance or negligence, it's possible your claim might not be covered. Check your policy now for "exclusions" ere you need to file a claim.

— Jan Mundy

Figure 5



DAVID AIKEN

Static head varies in sailboats when heeled and siphoning potential varies depending on the tack.

(Continued from page 18)

som, if you have access; lead the hose up to the deck head and install a siphon break or riser loop. Hopefully, the hose is now above the heeled waterline and the extra head pressure on the other tack won't cripple the pump. Never install check valves for the reasons mentioned above.

Powerboat manufacturers often install the bilge pump outlet a few inches above the waterline to avoid annoying sounds of water splashing. Beware of crowded cockpit parties where excessive weight can submerge thru-hulls. To avoid a back siphon, the discharge hose should be routed through a riser loop. Riser height is a compromise between avoiding a back siphon and decreasing pump performance. A 46cm (18") riser ought to be about right.

If you hate the thought of drilling another hole in the hull for a thru-hull, it's possible to tee the discharge into existing above-waterline outlets (i.e. cockpit scuppers or sink drains) as long as the hose rises high above the waterline and includes a riser loop. If in doubt, do not attempt.

Finally, make sure all hoses can't kink, are well supported and are all double clamped with non-corrosive clamps (see "Not all Clamps are Equal" on page 19).

Batteries: Most submersible pumps draw about 6 amps of 12-volt DC current for every 1,500 gph of capacity. If your boat has a 90-amp battery at 80% charge (which is optimistic) you could theoretically run a 3,000 gph pump (or two 1,500-gph units) for three hours before you use up half the available juice. The other half of the battery's charge will be available at lower and lower voltages, so pumping efficiency will fall off rapidly.

If you have the motor running or plugged into shorepower with the battery charger going, battery capacity is not a problem. If you are adrift with a disabled engine and taking on water, a good bilge pump system doesn't mean much if your batteries can't supply the needed power until rescued. There are only two kinds of marine batteries; cranking batteries or deep cycle batteries, which cost two to three times as much but last five times as long. Don't skimp on batteries if you want your pumps to keep your boat afloat in an emergency.

Wiring: Bilge pumps are probably the only electrical item that should remain powered even when the main switch is turned off. Wire directly to the battery terminal or more neatly to the battery connection post(s) on the back of the main switch.

Pump performance suffers a lot from small voltage drops due to line losses, so when specifying wire sizes, ABYC 3% voltage loss tables should be used (refer to "Wiring Handbook," DIY 1998-#4 issue). For example: a pump draws 15 amps and you need 9m (30') of conductor to power it, the tables specify 8 gauge AWG wire to keep voltage losses within 3%.

Making durable connections to the float switch and pump is always

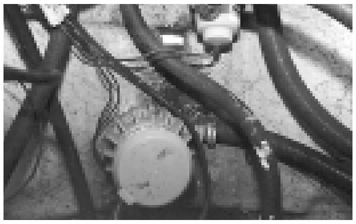
BILGE PUMP REPLACEMENT

By Jan Mundy

Boatbuilders often mount bilge pumps in inaccessible areas deep in the bilge, usually before the deck is in place, unmindful of replacement or servicing. Particularly in small powerboats, replacement demands crawling through a small hatch, often working blind. (Use a mirror for a rearview look if you're adept at working backwards.)

Submersible bilge pumps typically run for nine years before failure and less for leaky boats where the pump regularly cycles or dry boats, where lack of use causes corrosion or grit, sand or salt build-up. Failure also occurs when water gets into the pump through wires or shaft seal — the pump fills with water then goes through several freeze-thaw cycles.

This was the case with a Mayfair pump in one of DIY's test boats when it failed to run after 10 years of normal use in freshwater. Replacement is an easy one-hour job, after removing the old unit, drying the bilge and sealing the original mounting holes.



1 If you're lucky, the original pump has a detachable base, so removing mounting screws is easy. The Mayfair unit didn't; removal meant dangling in a narrow stern locker, groping with hands, trying to locate three Phillips-head screws. For bilge work, an extra-long handled screwdriver comes in handy. Note the corroded hose clamps in the photo (above).

2 Since pumps rarely have the same footprint, the next step is to seal the original mounting holes with 3M Premium filler, 3M 4200 (I prefer the Fast Cure) 5200 or equivalent brand. Be sure holes are dry before filling. While you're down there, inspect the hull for other openings in the hull and properly seal. I found a few extra holes drilled by the manufacturer, none were sealed. (The very first item on your to-do list after purchasing a boat, either new or used, should be to rebed every piece of hardware, caulk voids, holes, etc.)

3 Placement of pump and switch is critical. Even when replacing, it's best to double-check the location. Position the pump base (strainer) so the nozzle aligns with the discharge hose and locking tabs line up with the pump body. The float switch should mount at least 6mm (1/4") above the

a problem in an area that is often wet, particularly in saltwater. Corrosion at these connections is the most common cause of pump failure. Corrosion increases electrical resistance, which in turn can cause a connection to overheat or break.

Bilge pump wires and connections must be watertight, preferably crimp-on connections with self-adhesive, heat-shrink terminals. No wire nuts (Marette plugs) or tape. Specialty UL-approved multi-strand Boat Cable (or BC) is available for bilge pumps (two or three color-coded conductors 18 to 14 AWG with water-resistant jacket). All connections should be above the maximum bilge water level or as high as possible, fastened securely and away from float switches, control cables, shafts, etc.

Fuses: Corroded fuses and fuse holders are the next most common reason pumps won't go when they ought to. Because of this weak link, some surveyors even disagree with ABYC recommendations that a fuse or breaker should protect this circuit, like all others. Submersible pumps can overheat and even melt but rarely catch fire. The big danger here is a short circuit in wiring to the pump causing a fire. To minimize that possibility and preserve circuit protection keep any in-line fuses out of the bilge and in the closest available location with quick access. Check and clean terminals often, and replace fuses every year regardless.

Automatic Pump Switches

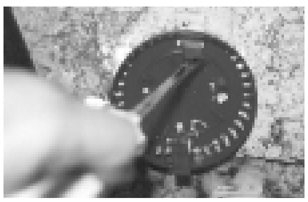
Generically known as float switches, there are many different kinds available. All of them can malfunction and frequently do, most likely from oily, hairy, slimy debris-filled sludge that inhabits most bilges. Switches become so badly fouled that they clog or stick. If stuck in down position, the boat might sink. If stuck in the up position, your pump runs on and on until it eventually burns out or flattens your battery — then the boat sinks.

The first step in keeping the float switch and pump alive is to keep your bilge clean and free of debris. Maybe it's time to add a drip pan under the engine [Ed: refer to DIY Projects, 1996-#4 for how to build one] or a separate graywater sump for the shower. Don't pump fuel — or oil-mixed bilge brew overboard. It pollutes and is illegal in many areas with fines up to US$5,000.

If the bilge sump is narrow and long enough to allow a few inches of water to surge back and forth it can beat relentlessly on an exposed float switch until the hinge or wires break. If your boat has this sort of layout you need a switch housed in a protective cover (which unfortunately can foul up) or install a cheap baffle to protect the switch. Installing the switch near a bulkhead with the hinge facing the surge will also help

strainer so it's not automatically running all the time. Rule pumps come with an adapter that connects the switch to the pump base and positions the switch at the proper height. Pumps are prewired and include fasteners; you'll need to supply sealant and heat-shrink connectors.

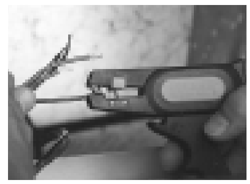
4 Carefully drill a pilot hole in the hull for the pump base, liberally caulk around the hole, then fasten base with supplied screws. Don't drill through! Never mount base directly on a



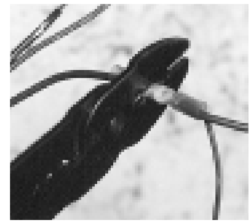
cored hull — a leaking fastener can quickly delaminate cores below the waterline. Instead, install a hardwood (teak or mahogany) backing block, then attach base to block.

5 Connect the hose, double clamp (if enough clearance on hose barb) and install the pump switch.

6 You have an option of wiring the pump for manual or automatic operation. Since this boat already had an automatic-manual pump control, we



stripped the lead ends, connected negative and positive ends to the original wires leading from the panel and battery, routing the wires high, just underneath the deckhead. Ends were crimped together using adhe-



sive-lined, heat-shrink connectors. If you don't have any, seal the connectors with sealant. Note: positive lead from bilge pumps should connect directly to the positive battery post so as not to accidentally disconnect with the master switch. Also, all pumps must be fused and with the proper size fuse or a pump may overheat and blow a circuit. The original pump installation included an in-line 6-amp fuse, the new Rule pump required a 9-amp fuse.

7 Not included but recommended is a protective float switch cover. For extra reliability, add a second switch mounted slightly higher. Better yet, add a second pump.

protect it. Wiring inside a switch not rated to carry the same amperage as the pump draws, will overheat, causing premature failure due to fatigue or corrosion.

In a sailboat the float switch must be on the same fore-aft axis as the pump, otherwise it won't operate in the same depth of water when the boat heels. This causes the pump to run dry on one tack, yet not trigger the pump when needed.

Although a switch will work installed on a pump's either positive or negative feed, don't install it on the negative side. This leaves the pump energized at all times. In saltwater there is a high risk of stray current leaks to ground. Any current leak from the pump will destroy it and possibly any metal thru-hull, which provides a path to ground. Proper bonding of thru-hulls will delay but may not prevent damage from stray current galvanic protection. [Ed: DC bonding systems and corrosion will be covered in upcoming issues.]

Make sure the float switch is set up to shut down the pump long before it begins to suck air, otherwise it will either never shut off reliably or water remaining in the hose will drain down and re-trigger the switch, setting up an endless cycle. You may need to choose a switch with a larger vertical distance between the trigger points for on and off (see "Bilge Pump Sentinel" on page 20).

Some panel switches have a provision to show an indicator light when the pump is activated; you may otherwise be unaware that the pump is working. Another useful gadget available is a cycle counter so you can gauge typical daily or weekly pump use and look for any sudden jumps in pump activity that may indicate a packing gland beginning to leak or a bad plank seam.

Another potentially useful accessory is a high-water alarm, such as a separate unit that's triggered by a secondary float switch or by the backup pump. If you are away, a high-water audio alarm or flashing light can also alert your dockside neighbors or marina staff that your boat is in trouble. [Ed: Consider upgrading to one of the newer, high-tech switches, such as the electronic "smart" Bilge Buddy or magnetic Ultra Pumpswitch. These self-contained, non-jamming switches cost as much as $100 more than a standard "cheap" float switch — buy the best you can afford.]

Conclusion

There is no fail-safe bilge pump system that will keep you afloat in all circumstances. It's important to understand the capabilities and limitations of your own system and never take it for granted, especially any automatic system. While underway, there is no substitute for regular manual checks of bilges as part of normal watch keeping. When at a mooring, no automatic system can ever substitute for weekly visits to your boat just to make sure it's afloat. ⚓

About the author: Nick Bailey is service manager of Bristol Marine in Mississauga, Ont., and an avid Thunderbird-class racer.

TIPS

EMERGENCY AUX PUMP

A raw-water cooled inboard engine is easily converted to double as an emergency bilge pump. Installation requires three valves, a couple tee fittings and hose connections. You'll find complete how-to instructions and configuration options in "Modifying Raw-water Cooling Systems," article in DIY 1997-#3 issue, now available in PDF format in DIY ONLINE at http://secure.the-wire.com/diy-boat/reprints.html.
— Jan Mundy

Rigging Sailboat

REPLACING OR SUPPLEMENTING KEEL BOLTS

Checking keel bolts should be part of a routine inspection. Here's how to identify problems and repair damaged keel bolts.

By Nick Bailey

Other than running aground, will you ever need to replace a keel bolt? If you keep your boat in freshwater, you aren't likely to have any problems for a very long time. Saltwater boats are another matter.

Consider these examples from Bristol Marine's service files: a 12-year-old racer-cruiser from a top-rated manufacturer was hauled out for some minor keel fairing. The owner also requested, as part of routine maintenance, that the keel bolts be tightened. Fifteen minutes into the job the technician returned and unceremoniously dropped a fractured 25mm- (1"-) diameter stainless steel stud on my desk. Under very gentle torque the bolt had snapped off deep inside the hull. Quick inspection confirmed that only 10% of the fracture face was freshly broken metal, the other 90% was badly corroded and had been for some time. A phone call to the owner confirmed that the boat had spent most of its life in saltwater.

On another occasion, a 15-year-old trailerable boat was in for replacement of the fractured original vermiculite and resin filler in the keel sump. Upon removing the old filler to expose the bolts, we discovered some of the supposedly stainless bolts were partly cut through due to corrosion, but only where buried in the cracked and soggy filler. The exposed portion still looked nice and shiny. The boat had recently arrived from a saltwater location.

What happened here? In both examples, a process known as crevice corrosion destroyed the stainless-steel keel bolts.

What Lurks Unseen

What makes crevice corrosion particularly nasty is that it only occurs in hidden and inaccessible locations, typically where keel bolts are buried in the hull. Small amounts of saltwater seep into contact with the bolts, stagnate and become de-oxygenated. Lack of oxygen in contact with metal bolts is where trouble begins. Stainless steel stays shiny and "stainless" under normal circumstances because it contains chromium which forms a tough protective oxide when exposed to air and well oxygenated water. Remove oxygen and the protective oxide coating breaks down, exposing metal to the water. Saltwater provides the electrolyte required to set up a miniature galvanic cell, either on the surface causing pitting corrosion or inside a microscopic crack or crevice, causing the dreaded crevice corrosion. As long as stainless steel remains wet or even damp, corrosion proceeds unchecked, eating away at the metal. Crevice corrosion is surprisingly common in older salt-water boats and tends to be worse in tropical waters due to lower oxygen content, higher salinity and the greater reactivity that warm temperatures provide.

Identifying Problems

Most keel fastening systems are designed with a conservative safety factor and you can get away with one broken bolt. Real trouble begins when the next bolt goes. Various famous ocean racers, "Drum," "Ville de Paris" and many others, no doubt, designed a little closer to the limit than your average family cruiser, have publicly demonstrated sailing without a keel. I don't recommend it.

There is no way to positively

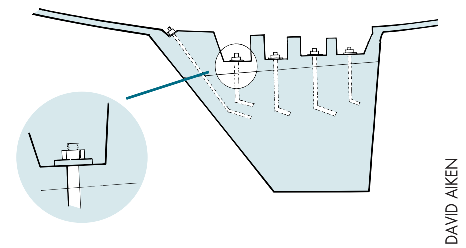


Figure 1

Integral studs cast into keel.

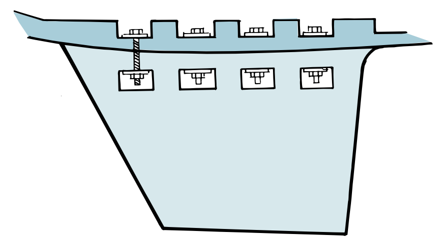


Figure 2

Easy access, windows cast or cut into keel and filled with fairing putty have nuts and washers at bottom end.

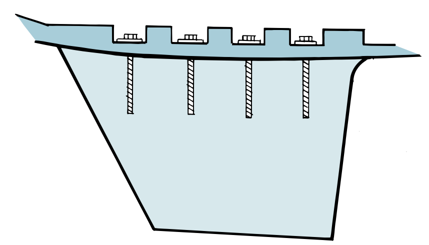


Figure 3

Holes drilled and tapped into keel for threaded bolts have nuts and oversize washers or backing plates (preferred) on the top end.

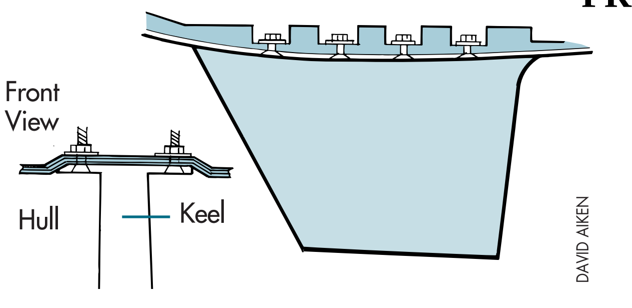


Figure 4

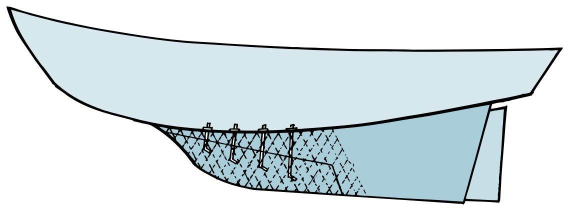


Figure 5

Full keel with external ballast converts to internal by adding a fiberglass laminate overlay.

identify bolt condition without either removing the keel or individual bolts. A broken or badly weakened bolt always becomes obvious when retorquing. It pops loose or turns indefinitely without tightening. Check with the manufacturer or your local yard to confirm the recommended maximum torque, but keep in mind that any 22mm (7/8") or larger diameter bolt requires tremendous leverage to the point where it's exceedingly difficult to over-torque.

Another place to watch is the keel-hull joint. Anything much larger than a hairline crack here can be a sign of trouble or at least may indicate it's time to tighten the bolts. This is best checked while the boat hangs in the slings. Once the boat is cradled and hull weight rests on the keel, any cracks tend to close up again. These signs may identify a broken bolt, but the only method to directly confirm if corrosion has begun an attack on the bolts is to expose them.

Repair Strategies

Bolt configuration and ballast type largely dictate how to fix bolts that are severed or deeply pitted by corrosion.

Keels with integral studs (**Figure 1**) are the worst case and the most common keel fastening method. The only practical option is to drop the keel (see "Dropping and Refitting a Keel" on page 28) and, if there is enough room in the keel sump, install a supplementary (or sister) bolt. This is done in one of two ways. Using an oxyacetylene torch, cut a window in the keel to access a nut (similar to **Figure 2**), then drill a hole down from above for a threaded rod or bolt. This method works best on lead keels. Alternatively, drill and tap the keel for a new sister fastener. This works best on cast iron. It may be possible to salvage the stud by threading on a heavy sleeve to bridge the damaged area and reinforce the bolt. This often requires excavating around the stud at the top of the keel to expose enough good threads to give any hope of success. It may also present difficulties refitting the keel due to the larger hole required in the hull. Most professional yards would do this sort of repair only on a "no guarantees" basis as the sleeve will not be as strong as the original bolt.

If you are faced with drilling or tapping large diameter holes, you will need to rent the appropriate power tools. However, the keel may need to be cradled and transported to a machine shop capable of handling large scale boring and cutting. Neither lead nor cast iron are easy materials to work with: lead jams and binds tools, cast iron is just very hard and brittle.

Keel bolt configurations as shown in **Figure 2**, **3** and **4** can theoretically be removed, inspected and replaced. Because this is done one at a time, it may be practical to do this without dropping the keel. Haul out and cradling are still recommended to minimize the chance of disturbing the keel-hull bond. Aggressively caulk new bolts with a polyurethane or polysulphide sealant on reinstallation. Boats with keel windows (**Figure 2**) or external flanges (**Figure 4**) have the bolt end hidden by fairing filler and may require lots of grinding and chiseling to expose the end. Broken bolts are more difficult to extract but can be knocked out of the external flange with a driving pin or, in the case of the window keel, driven down then cut off one piece at a time with a hacksaw. (Are we having fun yet?) An extractor tool designed for broken studs (i.e. Easyout) may also work with smaller bolts.

A broken tapped bolt (**Figure 3**) is very difficult to remove particularly in cast-iron keels. The bolt is likely seized into place by corrosion. You may have to drill it out and retap the hole. I envision some difficulty getting the drill press down the companionway so this one may also require keel removal and machine shop work as in keels with integral studs (**Figure 1**).

Typical top-end installation with backing plate and washer.

For fiberglass boats with low-profile full keel configurations (**Figure 5**), it doesn't matter how the keel is fastened because the repair approach is completely different. It may be more practical to laminate several layers of fiberglass to encase the keel and bond it to what becomes, in essence, a new part of the hull. This converts the boat from external ballast to internal. Many traditional full-keel glass boats are built this way and neatly sidestep the whole keel bolt corrosion issue.

Laminate thickness of the new keel should match the original hull thickness and overlap at least a foot or two onto the existing hull. As is normal practice, make sure the hull surface receiving the overlapping laminates is ground to bare glass and is clean and dry. If you are unfamiliar with glass lay up procedures, hire a professional.

About the author: Nick Bailey is service manager of Bristol Marine in Mississauga, Ont.

DROPPING AND REFITTING A KEEL

Fin Keel dropped for rebedding.

1. Haul out and cradle. Put a jack under the keel to ease it down later or else use screw jacks on the cradle pads to raise the boat. For boats longer than 8.1m (27') or when the cradle is unsuitable, book a Travelift or crane. You may need to devise a way to separate the keel and hull.
2. Rent or borrow tools. You'll need extra deep sockets, a heavy drive bar, extra long lever arm (a pipe will do) and a long extension to reach into the bilge. You may also need a variety of wedges and a sledge hammer plus glass tools for grinding, filling, fairing etc. Professional yards rarely lend tools.
3. Undo keel nuts. Use a thread lubricant to help prevent stainless-on-stainless galling (binding and seizing).
4. If needed, grind away fillers or fiberglass to expose the keel-hull joint.
5. Lift the boat (or drop the keel) so that the full weight of the keel is suspended by 6mm (1/4") or so, then take a break.
6. If the keel doesn't drop on its own (most won't), carefully drive wedges in between the keel and the hull at the joint. Lift the keel or lower the hull and repeat until 5cm to 7.6cm (2" to 3") of bolts are exposed.
7. Inspect bolts carefully to assess any corrosion damage.
8. To remove the keel, install braces to support the keel in an upright position. Lift the boat, or lower the keel the rest of the way.
9. Proceed with the bolt repair or replacement as required.
10. Clean mating surfaces on keel and hull with a mini grinder.
11. Reposition keel under hull and mate bolts to holes in hull.
12. Apply thick bead of sealant around each bolt and hole only — don't cover mating surfaces with sealant as its flexibility makes the keel wiggle too much.
13. Mix up epoxy resin thickened with cabosil and chopped fiber to a thick paste. Apply liberally to top of keel.
14. Immediately join keel and hull together and torque into place using a staggered tightening pattern. Recradle if needed.
15. Before epoxy fully cures, remove excess that has squeezed out. Make sure air temps are warm enough for epoxy to cure, otherwise set up heat lamps.
16. Fill and fair the repair area, repaint and launch. Check for leaks. If it leaks, see Step 1. If not, go sailing in heavy air. Check again for leaks.

Electronics

ELECTRICAL TROUBLESHOOTING

A multimeter is the quintessential tool to detect DC and AC electrical faults and to measure voltage, current and resistance.

By Larry Douglas

There are few worse environments for electricity than a boat. Combine broad temperature ranges, vibration, moisture and salt spray and electrical problems are a common enigma for most boaters. When it happens, you need to be prepared with the knowledge and proper tools to solve the problem. Perhaps the most common and most important tool for electrical troubleshooting is the portable multimeter, also referred to as a voltmeter or VOM for an analog unit, or DMM for a digital one.

Multimeters come in many sizes, prices and types. All measure voltage, current and resistance; some models also measure inductance, frequency and/or capacitance. Though more costly, my preference is a digital unit. Those who have used analog multimeters (VOM) will find that the increased accuracy, repeatability and ruggedness of the modern DMM, although more expensive, makes them a better choice for marine use. A suitable DMM for boat use should measure common AC and DC voltages, DC current up to 10 amps and resistance from less than one ohm to over 10,000 ohms. It should display at least three full digits plus a leading "1" and be accurate to 1% or better. Some DMM units are auto ranging, which means once you select a function, the meter adjusts the decimal point based upon the measured value. This makes them slightly easier to use but adds to the price. You can spend less than US$20 or more than US$170 on a portable DMM and, as with most other tools, you get what you pay for. Pick a name-brand meter that gives you the features you like. If you choose a meter from the low end of the price scale, you might want to buy two. The second unit will come in handy when you drop the first one. Also purchase a spare set of leads with probes. They will probably wear out long before the meter needs replacement and a broken lead results in an erroneous reading or worse, fools you into thinking the power is off when it's not.

Measuring Basics

Everytime you turn on your multimeter, form the habit of moving the dial to the "X1 ohms" scale and touching the two probes together. The display should move from indicating an open circuit to nearly 0 ohms. This confirms that the meter and probes work and is an important safety check. Now select the appropriate measurement type (AC voltage, DC voltage, resistance) and the range, except auto ranging meters. The following information is not intended to replace the manual that accompanies your meter. Now place the red and black probes across (in parallel with) the circuit to make the voltage or resistance measurement.

Current (amps) measurements are not made in exactly the same

Always ensure selector switch is in the correct position and the red (hot or "+") and black ("COM" or "–") lead ends are in the proper input jacks before taking a measurement.

Check meter operation before every use: move the selector dial to the X1 ohms scale and touch the probe ends together. If you get a reading other than "0," the battery or fuse needs replacing or the leads or meter are defective.

Selector switch on "DC voltage" scale checks battery voltage (no loads).

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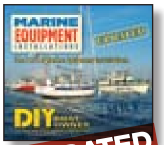
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Here's how to choose, install and operate equipment for your boat including: air conditioning and heating systems, audio systems, bow thrusters, davits, lightning protection, propane systems, refrigeration, windlasses and more.

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.

Nautical Necessities

From cleaning to fuel filtering to waterproofing charts, you'll find ideas and inspiration in this compilation of tips to do-it-yourself boat maintenance, repair and troubleshooting. Divided into 20 categories to make look up easy.

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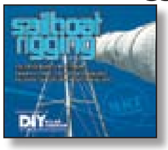

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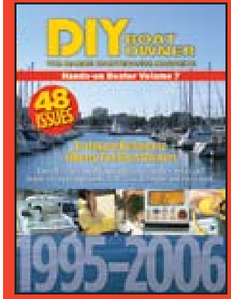

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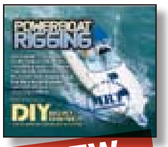
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way, as are voltage or resistance measurements. They require electrically inserting the DMM in series with one of the load wires. This usually requires relocating one or both probes into sockets on the DMM that are used only for current measurements. Form the habit of always returning the probes to the proper locations for voltage and resistance measurements immediately upon completing the current measurement. If you forget, you'll cause a short circuit the next time you use the DMM for a voltage measurement. Most digital meters have internal fusing and often a spare fuse for such an occurrence.

DMM checks loads or voltage drop on an existing circuit before adding accessories.

Top: Use the low-resistance scale to test a fuse. Left: To test equipment for resistance, disconnect the circuit (otherwise, you will measure the entire circuit), set selector switch to the proper resistance scale and connect test leads, red to the positive side. Defective equipment will have no resistance reading.

TIPS — MEASURING THE LINE

When troubleshooting electronic equipment, don't overlook the obvious. Connections on a boat eventually work loose. Fuse holders corrode. Batteries need constant attention. Any wire that moves will eventually fail and will do so at the worst time. Starting at one end of the circuit, use your meter to measure all components in the line. Often it's a minor problem that's easily fixed.

Problem Solving

Around 75% of the time you'll use your DMM for voltage checks, such as determining whether a battery is charged or your VHF radio is receiving DC power. The rest of the time you'll be checking fuses, lamps or wires for continuity using one of the resistance scales.

To trace a short circuit, disconnect the circuit, set the switch X1 ohms scale and place leads on a hot and ground side. Any value other than infinite ohms indicates a short, possibly frayed or worn wires. Also, use your DMM to check loads or voltage drop on an existing circuit before adding accessories, unless you opt to run new wires. Turn on all loads to obtain a correct current reading. Another common use for the current scale is to check DC bonding wires to prevent electrolysis problems. Leakage currents are often in the milliamp (0.1 to 0.001 amp) range. Most top-rated DMMs do an excellent job measuring this which lets you know that your zincs are working — or not!

Larry Douglas has 30-years experience as a technician, product developer, and a consultant in marine and industrial electronics systems and cruises the West Coast in a 12m (40') Tollycraft.

TROUBLESHOOTING TIPS

- Use properly sized wire. Just because a manufacturer provides #18 AWG leads doesn't mean you can add another .9m (3') of the same wire. Chances are that you'll be coming up short in the supply voltage.
- Purchase a good crimp tool and learn to use it correctly. Use the properly-sized marine-grade crimp terminals. Use proper circuit protection, whether fuses or circuit breakers. Be aware, though, neither will directly protect your electronic equipment. Circuit protection devices are solely intended to protect wiring.
- Periodically inspect your entire electrical system. Tighten all connections and check for corrosion.
- Carry a spare fuse kit. Fuses do fail on occasion, often having nothing to do with excessive current. Label them as to which device they go with.
- When replacing a blown fuse, replace it just once. If it fails again, immediately fix the problem before sacrificing another fuse. Don't substitute a larger one hoping that it will work long enough to get you home — in most cases it won't!
- Label all wiring. Use the existing color or number code (if any) that you have on the boat or create your own. It will save you time later.
- When all else fails, consult a professional. If you're uncertain that you've installed something properly, call a pro before you apply power. Once turned on, it may be too late to avoid an expensive mistake.

Maintenance

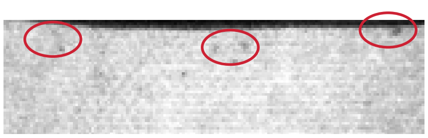
A COLLECTION OF USEFUL ADVICE, TIPS AND TRICKS

By Jan Mundy

MILDEW CONTROL: Clean, Exterminate, Ventilate

Boats and mildew go together like ducks and water. It attacks carpeting, drapes, cushions, lifejackets, clothing, plastics, gear stashed in sealed lockers — anything stored in a humid environment where mildew spores flourish and multiply.

In the many years of owning boats, I've found removing mildew stains with a mildew remover or bleach solution gives only temporary relief. Spores remain in an inactive phase, lingering in nooks and crannies, once again waiting for the return of humid conditions. Mildew seems nearly impossible to destroy; preventatives we've tested only work when applied every few months; if not, the first time a humid condition exists, spore colonies sprout again.



Every year, tell-tale black mildew stains reoccur after a four-month layup in an sealed boat. Even after cleaning, mildew spores continue to remain active in a damp environment.

Follow these three steps to vanquish the enemy. Scrub surface with a specially-formulated mildew remover, bleach solution diluted 10:1 (do a test spot in an non-critical area), TSP, vinegar or other cleaner of choice and a soft brush, scrub pad or household power carpet cleaner. Spray on, wait per the label instructions, or overnight if using bleach, then rinse thoroughly with freshwater, and let dry. Wear plastic gloves.

If you only clean, mildew likely will reestablish in a week or so in a closed boat. Use of chemical dehydrants help control moisture in small lockers, but usually won't keep the entire cabin dry. You could rent or buy an ozone generator, running it every few months when damp. A less-expensive, more compact and disposable alternative is Star brite's MDG Mildew Control Bags. Containing Aseptrol, a fungi growth inhibitor, it releases trace amounts of chlorine gas that's completely non-toxic to humans, pets, plants, fabrics or equipment. A box contains two foil packs and hangers (US$8). For best results, replace every three months. We'll let you know the effectiveness of this product after testing this season.

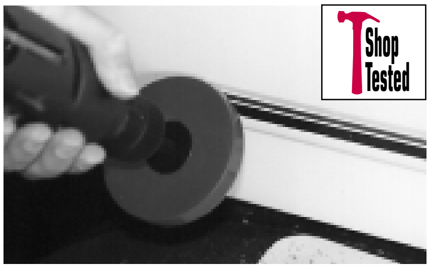
Vanquish the enemy with MDG Mildew Control Bags that release non-toxic chlorine gas smell to kill spores on contact.

Ventilation is vital to controlling dampness, mildew and musty odors. Install opening ports, cowl or mushroom vents in every compartment and at least two solar- or electric-powered vents (i.e. Vetus Fan12, US$62) on the cabin top, one exhaust, one intake, for a continuous supply of fresh air. If the boat is divided into staterooms, and if your budget allows, install a vent in each separate living area. Vents eliminate condensation build-up and associated moisture and odor problems. If space allows, a 110-volt household dehumidifier works wonders.

COLOR-MATCHED SEALANTS

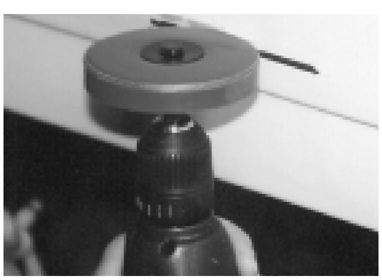
Star brite supplies most of the major boatbuilders with silicone sealants, some in custom colors. If you need to match your boat's gelcoat, call the company's customer service department toll-free (800/327-8583) and provide your boat's year, manufacturer and model. We're told the company has a good inventory of gelcoat-matched colors, especially for boats built in the last four years.

ERASE AWAY VINYL STRIPING



Removing vinyl striping, lettering or graphics using a heat gun and scraping with a putty knife followed by a solvent wipe to remove adhesive usually damages the surface finish. We have found a better method: Stripe Eliminator is a 9cm- (3-1/2"-) diameter, 3.8cm (1-1/2"-) thick disk "eraser" that strips away vinyl and adhesive residue in one pass. No discoloration, or damage to surfaces, no need to scrape; just wipe off rubber residue with a rag and the surface is ready for reapplication.

We tested this unique tool coupled to a portable drill to remove 10-year-old stripes on one of our test boats. Operating the drill at low speed, 800 to 1,200 rpm is recommended, we sampled a small area at the transom. With the drill running slowly, we "rubbed" the Eliminator over the stripes in an up-down motion, starting at the top edge and applying slight pressure. It "erased" stripes fast, removing triple stripes



If disk edge "erases" unevenly, reduce drill speed, and if it becomes lopsided, reverse disk in the arbor.

Maintenance

and all adhesive residue over a 91cm (3') area in less than five minutes. Except the faded surface under the vinyl, the hull is prepped for refinishing in one-easy power stroke.

With the correct drill speed, proper pressure and a little practice, this tool quickly removes vinyl without any friction, abrasion or heat build-up. Made of a flexible rubbery material, but harder than an eraser, if the disk wears evenly, reduce speed, and if needed, reverse the disk in the arbor. Contact Ferro Industries at 800/343-3776 or Fax: 810/792-6006. At the same time, buy the special half-circular pad to smooth vinyl for a professional finish. ⚓

POST LAUNCH TIPS

BRIGHTWORK Clean teak then coat with a premium finish, such as Cetol or Star brite Tropical. Follow steps outlined in "Teak 101," DIY 1999-#2 issue.

CANVAS Examine all canvas for broken or chafed stitching and seams. Do the drip test: pour a cup of water onto an indent in the canvas. If it instantly leaks through, apply a quality water repellant.

ELECTRONICS To check for electrical interference, turn on all electronics then switch on fluorescent lights. Some lights have noise suppression circuitry but may still cause interference in certain conditions. Moving the lights may be necessary.

ENGINE Warm up engine, then turn off. To check for leaks, place a finger under all hoses and connections. Inspect hoses and fuel lines for chafe. Put a wrench on every nut and bolt to make sure they are tight. Check engine zinc(s) and replace as needed. Examine all wiring connections for corrosion and all wire leads for support.

FLOOD TEST When properly installed and sized, cockpit scuppers should empty a water-filled cockpit in about two minutes or less. To check your boat, cork the scuppers, fill the cockpit with water to the top of the cockpit lockers or to deck level, then pull the plugs. Time the discharge rate. When empty, check the lockers for leaks and reseal if needed.

HATCHES Check hatch gaskets and replace if brittle or cracked. Inspect hinges, support and latch for corrosion. Check companionway sliders.

HOSES Check hoses for chafe and add chafing strips at contact points — wrap slit spare hose around primary hose.

LIGHTS Remove all bulbs and check sockets for rust. Insert new ones with a dab of petroleum jelly on bulb end.

STANCHIONS Tighten all screws and examine all ends, gate hooks and wire for cracks (use a magnifying glass), wear and corrosion. Plastic coated stainless-steel wire will corrode under the plastic and should be replaced with non-coated wire.

TANKS Look for corrosion in steel and aluminum tanks around fuel pickup, fuel gauge sending device, inspection hatch and welds. Read "The Weak Leak" on page 37.

UPHOLSTERY Check for wear, tear, broken seams. Move zippers, check for corrosion and add canvas lubricant to improve sliding action.

DIY MECHANIC

Attention to proper routine maintenance is the key to continued low-cost operation of your engine. The following pages will help you maintain, troubleshoot and repair the most common gasoline and diesel inboard and stern drive engine component failures; namely, cooling systems, starters, thermostats and fuel tanks, an item that is seeing more failures as boats age. Some work may require special tools and we suggest investing in the proper equipment if you plan to own the boat long and do the work yourself. If this is a one-time repair, you may opt to hire a trained mechanic to do the work. Whatever you decide, follow our recommendations, refer to your shop manual and follow all safety precautions. — Jan Mundy

THE WEAK LEAK

Leaking fuel tanks are becoming a common and serious problem in older boats. Here's the latest info on tank materials, step-by-step tank repair methods, replacement options and installation tips.

Story and photos by Nick Bailey

Unfortunately, metal fuel tanks — domestically, aluminum and stainless steel; iron in some trawlers and other boats built in the Far East — are unlikely to last the lifetime of your boat. Eventually they will leak. If you're lucky, you'll find a tiny pinhole leak first rather than have a welded seam on the tank bottom suddenly split open. Suddenly discovering you have a bilge full of fuel, particularly gasoline, is a true test of character. If you live to tell the tale, you're blessed. Such incidents are surprisingly common and becoming more so as boats age.

Rotting Metal

Even the best alloys designed for marine use can suffer from subtle corrosion damage over the long term and usually only occur in locations that are not obvious to casual inspection. Aluminum and stainless steel are normally protected from corrosion by a natural layer of shiny oxide on the surface. This layer instantly forms when in contact with air or oxygen dissolved in water. Problems occur in covered areas, such as under tie-down straps or where the tank bottom rests on stringers or flotation foam. If the tank is in contact with stale, immobile, oxygen-starved water, the lack of oxygen prevents the oxide layer from renewing itself and the protective coating erodes away exposing the metal. The presence of water, particularly saltwater, provides an electrolyte and a tiny galvanic cell is formed on the surface of the metal or in a tiny crack. The spontaneous electrical activity in the cell dissolves the metal and transfers metal ions from one grain to another of the same piece of metal. As long as it stays wet the tiny spot or crack from which the metallic ions are removed becomes a steadily growing pit or crevice, a process referred to as pitting corrosion and crevice corrosion. Welded seams in tanks are particularly susceptible to corrosion because the weld metal is a slightly different alloy than the surrounding plate, thus accelerating the galvanic reaction.

Some tanks fail from metal fatigue. The right angle welded seams where tank sides join the top or bottom are subject to mechanical stresses, particularly in tanks built of light gauge metal and fitted with skimpy internal baffles. In this case, the fuel sloshes back and forth unhindered and beats relentlessly on the tank walls, flexing seams and leading eventually to a split and the sudden release of fuel into the bilge.

Had boatbuilders originally installed tanks so they could easily be maintained or removed, it would not be necessary to remove the cockpit floor in this runabout; large cruisers often require removal of the cabin sole, aft cabin berth, or hole cut in the transom.

Crevice corrosion on the surface of these aluminum gasoline fuel tanks caused by poor installation.

Removing the Tank

The tank goes into the boat before the deck or the floor. In many smaller stern drives you have no choice but to cut open the floor to remove the tank. If you need to hire a professional yard, the cost of removal and installation can be in the thousands, high enough to constitute a write-off with an older boat.

Larger boats are often no easier. On one occasion, a nearly new 9.9m (33') cruiser suffered a bad fuel tank leak from a cracked seam. The long rectangular tank was removed and replaced through a hole cut in the transom, the hole then fiberglassed and painted. [Ed: Yard labor averages 150 hours in a twin tank reinstallation, at an estimated cost of US$14,000. Obviously, the most cost-effective time to replace tanks is when repowering, as discussed in DIY 1999-#4.]

If the tank cannot be maneuvered through the hatch, removing the engine may allow the necessary access. Alternatively, it may be possible to chop the tank (make sure it's purged of all fuel vapors) and passed though the hatch one piece at a time. The replacement tank is then downsized to fit through the hatch, or if concerned about losing fuel capacity, it may be practical to fit two or more small tanks in the same location as the original single tank.

When faced with major reconstruction, one solution may be to abandon the original tank in place and mount a new one elsewhere. This, however, often results in a smaller tank placed in a location (i.e. bow) that compromises trim or stability.

When removing the original tank pay close attention to the cause of the failure to avoid a repeat. If the tank, for example, was surrounded by soggy flotation foam, or sitting on a wet carpet pad, there should be no surprise that it corroded. You'll have to devise a method of keeping the new tank (if metal) dry and well supported.

Integral Tanks

Leaking integral or built-in tanks — not legal for gasoline, only for diesel — present other problems. Such tanks utilize the boat's hull or interior structure; the hull twisting and flexing, causing a cracked weld or separated fiberglass bond usually causes failure. If you can positively identify the exact source of the leak and have access, you can probably repair it successfully — a brief respite until it leaks again due to repeated flexing and twisting. If the leak is hidden or inaccessible, you are probably out of luck as repair may involve removing the boat's interior. It may be possible to fit a fuel bladder tank into the original space, though these tend to flop around, making it difficult to restrain them against chafe as well as keeping all connection fittings intact.

Repair Versus Replacement

Any tank with suspect seams or widespread corrosion should be replaced. If you can remove the tank in one piece is repair a viable option?

If the problem is a small leak, confirm the leak location. To do this, purge all fumes from the tank, plug the vent, fill and pick-up fittings and using a pressure tester, inflate the tank to 3 psi, the recommended minimum test pressure. Apply soap and water to the outside and check for bubbles. Providing the tank exterior is corrosion free, welding fixes a single pinhole leak but welded repairs are only practical where the metal gauge is relatively heavy. [Ed: Vapors from empty fuel tanks are extremely flammable. To prevent combustion when welding, one method is to displace the oxygen with carbon dioxide (several pounds of dry ice or a fire extinguisher), or an inert gas, such as argon.]

The end of the line: fuel tank replacement costs can be high enough to send a boat to the junkyard.

Another option is hire a contractor to apply an internal coating. This may stop minor leaks for a short term but it makes me nervous, especially with gasoline tanks. Check the supplier's warranty for marine service before proceeding.

New Tanks

Any new gasoline tank is required to be tested for compliance with U.S. Coast Guard (USCG) standards and labeled as such. These tests are also recommended by the American Boat and Yacht Council (ABYC) for diesel fuel tanks, but are voluntary.

ABYC recommends that aluminum tanks be fabricated of 5052, 5083 or 5086 alloy with a minimum sheet thickness of 2.29mm (.090") for gas and diesel. At this thickness an Underwriters Laboratories (UL) study done in 1994 postulates a theoretical service life of only 6-1/2 years in marine service. It's worth specifying the more commonly used 3mm (.125") sheet, which has a projected service life of 17.4 years. In general, the actual service life of any metal tank is dictated more by the characteristics of the installation (see "Installation Tips" on page 40). A corrosion-resistant paint applied to the tank exterior may help, but it's no guarantee against localized corrosion at a tiny scratch in the paint. Copper alloy (brass or bronze) fittings are not recommended for direct connection to aluminum tanks because they promote galvanic corrosion at the fitting. Stainless inserts or adapters are required as a barrier between the tank and typical brass fuel fitting.

Stainless tanks have a reputation for quality but in the past have been just as likely to corrode as aluminum, especially when using lower grade alloys such as 304 stainless. ABYC has recently amended its recommended materials for diesel fuel tanks to include 14-gauge (.0747"/1.90 mm) or heavier 316L or 317L alloy stainless steel for 75.7L (20 gal) tanks or larger. Smaller capacity cylindrical tanks are permitted to use lighter 22 gauge.

ABYC's new standard only recommends stainless when special provision is made to mount the tank to avoid crevice and pitting corrosion from entrapment of moisture. To assure air circulation to tank surfaces, ABYC advises supporting tanks on welded brackets of like material permanently bonded to the tank surface with impermeable non-hydroscopic adhesive.

There are also new stainless steels that have a 6% molybdenum content compared to the usual 2.5% or 3.5% found in 316 and 317 respectively. These new alloys, though more expensive, promise enhanced corrosion resistance.

Non-corrosive XLPE fuel tanks are a better choice but only available in stock sizes and shapes.

For diesel only, sheet steel, spec ASTM-A93 in 14-gauge, is a lower-cost alternative to stainless steel, but not as long-lived.

Fiberglass (FRP) can be an excellent tank material, but there are no builders of production tanks. Any FRP tank will need to be custom made and this makes USCG certification for gasoline impractical. A custom FRP diesel tank may be practical for a skilled amateur to build, provided he or she is familiar with glass lay ups.

Roto-molded, cross-linked polyethylene (XLPE) is the most common plastic tank material (not suitable for potable water).

It's immune to corrosion and can install in the lowest, wettest part of the bilge. Care must be taken to support the tank over as much of the length as possible to avoid chafe or mechanical damage. XLPE tanks permanently expand in all directions by about 2% within the first month or so after being in contact with gas or diesel so allowance must be made for this during installation. This characteristic also means an XLPE tank should not be foamed into place. XLPE tanks are strong but can be vulnerable at the connection point for fittings. Do not over-torque the threaded connectors or install a hose in such a way that it applies too much side load on the connector, and can crack the tank at the connection point.

COPING WITH A LEAK EMERGENCY

You've got a leaking fuel tank. If the fuel is gasoline, and is mostly in the bilge, the boat is a ticking time bomb so call the fire department. A fuel spill may prove to be a do-it-yourself job simply because many marinas or yards won't touch it due to employee safety and liability concerns.

Evacuate the area and close off the dock entrance. If connected to shorepower, shut off the breaker on the dock and disconnect the shorepower cord. Open all hatches to ventilate the boat and, if practical, push the boat by hand to an isolated dock. Turn off the master battery switch first and then make sure all electrical equipment is turned off at the distribution panel. Once the main cabin has been ventilated, you can turn on the main switch to operate the bilge blower. Do not use any fans, pumps or any other electrical equipment that is not certified as "explosion proof" or "ignition safe." Small amounts of gasoline will evaporate quickly especially in dry, breezy weather, but a big spill may need to be pumped out. A hand-pumped oil changer (i.e. Pela) or certified fuel-transfer pump will work. Do not, under any circumstances, use a shop wet/dry vacuum to slurp up fuel-contaminated bilge water. You risk an Earth Shattering Ka-boom (ESK) and the results aren't pretty. Use a solution containing fuel-eating microbes to clean up any residue.

Once the boat is ventilated and the chance of an ESK reduced, any remaining fuel in the tank should be debunked. If it's impractical to get a hose into the tank through the fuel fill, access can usually be gained by removing the fuel gauge sender mounting plate. If the boat has a second tank that is intact, you can transfer fuel from the leaker to the good tank. Otherwise, debunk it into fuel-certified jerry cans or drums for re-use or disposal by a toxic waste outfit.

Diesel fuel leaks are a huge nuisance but there is little risk of an ESK. After cleaning up the spill you are sure to have difficulty getting rid of the reek of diesel fuel. An odor-remover, such as Captain Phab Odor & Stain Remover, helps to mask the smell, unless of course, you like the fragrance.

— *Nick Bailey*

Properly installed, a polyethylene tank should last the life of your boat, and, in fact, the USCG recommends replacing any failed metal tank with one constructed of XLPE. The only drawback is that they are available in a limited number of stock shapes and sizes.

Installation Tips

The ideal location of the fuel tank from the standpoint of stability and trim is low in the boat on centerline. This is also usually the dampest location in the boat so care must be taken to keep any metal tank dry and exposed to air — no bilge water in contact with the bottom, no water pooling on the tank top, no having the flat tank bottom in contact with a flat mounting surface, no self-wicking material (carpet or foam) in contact with the tank, etc. ⚓

About the author: Nick Bailey is service manager of Bristol Marine in Mississauga, Ont.

NEXT PAGE CONTENTS

WATER COOLING SYSTEMS

Everything you need to know about raw-water and closed cooling systems — components, corrosion protection, pressure testing for leaks and blockages, and converting to a closed-cooling system.

Story by Robert Hess

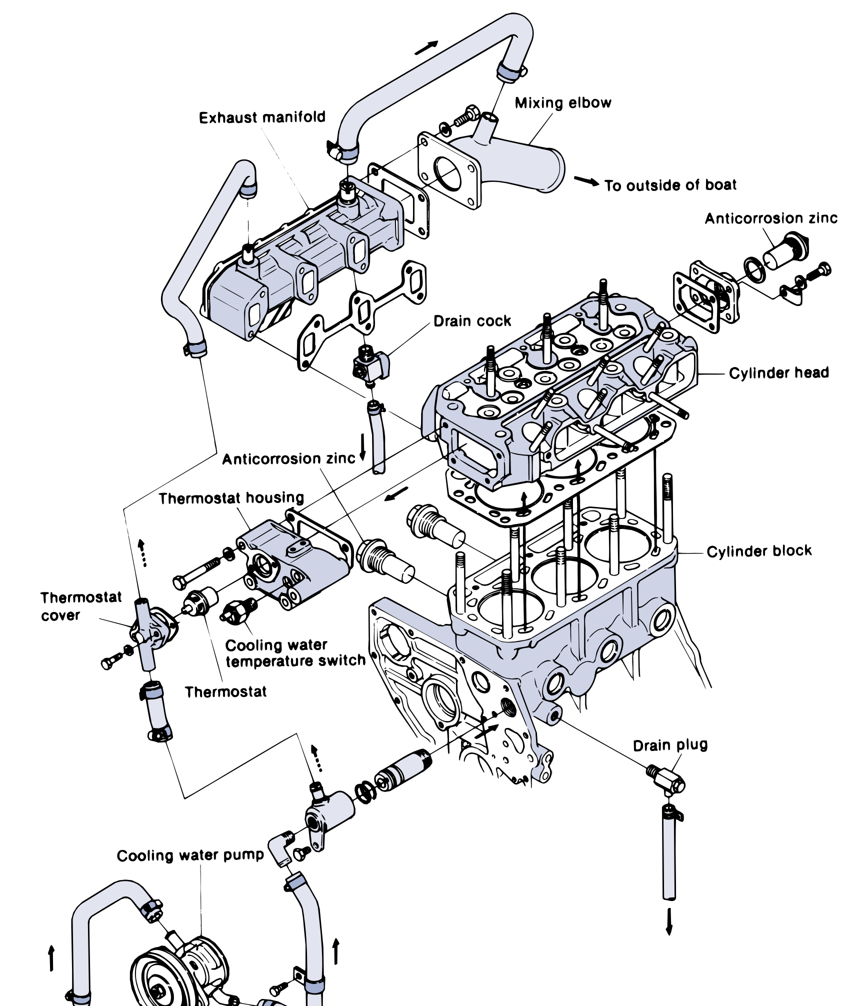
There are two types of marine cooling systems: open or raw-water, and closed. A cooling system that pumps water into the engine and circulates it through the hot engine water jackets before pumping it overboard along with the heat it collects is called an "open" or "raw-water" system (**Figure 1**). This system uses one pump, a raw-water pump, to bring the water into the boat and circulate it through the engine. Water drawn into the engine is usually first passed through a strainer before entering the pump to prevent blockage of the system by seaweed and debris. Quite often two raw-water strainers are used: an outboard grate covering the thru-hull water inlet (sometimes incorporating a forward facing scoop to force extra water into the intake); and an inboard strainer to prevent the ingestion of small particles which may damage the water pump or clog the cooling system and usually fitted with a removable basket to simplify cleaning. Some engine manufacturers specify that exterior scoops should not be fitted to the raw-water intake — when the boat is moving at top speed they force too much water into the cooling system, flooding water lock mufflers and backing water up into the engine through the exhaust manifold and exhaust valves.

Raw water circulated through

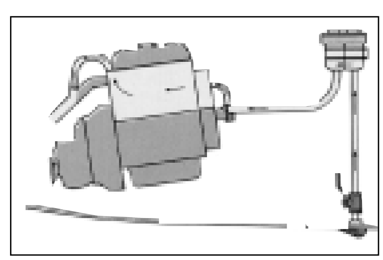
Figure 1

Details of a raw-water cooling system.

Typical small horsepower diesel



COURTESY OF SELOC, CHILTON MARINE



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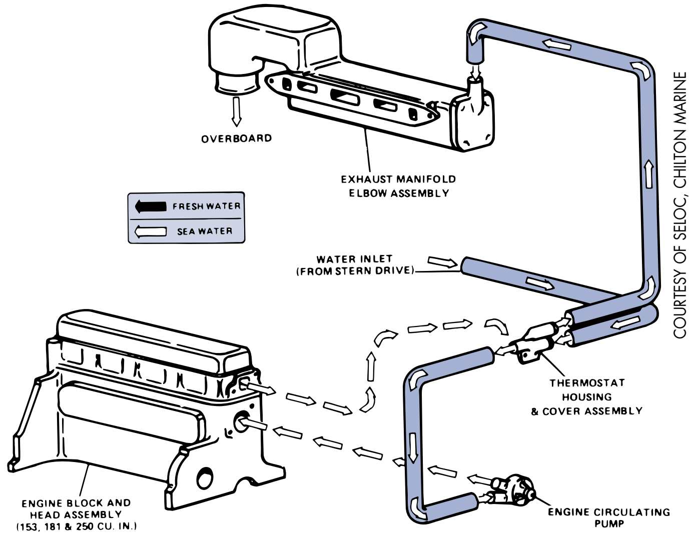


Standard raw-water cooled MerCruiser engine installation.

the engine rises in temperature as it absorbs engine heat. When it reaches a temperature of 71°C (160°F), it begins to precipitate out the salts and other minerals held in solution and deposits them in the cooling system. In the hottest part of the water jackets, such deposits build up scale and gradually restrict the flow of cooling water until the engine begins to overheat. Because the water jackets are intricate passages cast into the engine block and head, it's very difficult to remove these deposits. Engines operated in saltwater build up scale much faster due to the higher mineral concentration. In order to reduce scale formation in water jackets, raw-water cooling systems use thermostats to maintain water temperature as hot as possible but lower, approximately 65°C (150°F), than the 71°C (160°F) precipitation limit.

Engines run more efficiently at hotter temperatures. A hot coolant temperature allows the engine oil temperature to reach 100°C (212°F), at which point it boils off any water absorbed from condensation or produced by the engine and reached the oil pan as piston ring blowby. (Water in the oil forms acids that attack bearings.) Because engines use pure water or water-based solutions as coolant, the optimum engine operating temperature is about 87°C (190°F). This allows coolant temperatures to exceed the thermostat temperature by about 10°C (20°F) in very hot weather or very heavy loads without the coolant boiling. (Engine components are machined so they have the correct clearances when operating at an optimum temperature.)

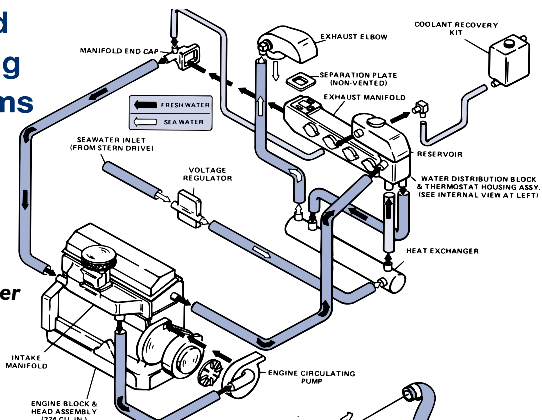
Closed Cooling

In order for engines to run at optimum temperature (87°C/190°F) but prevent precipitation of minerals in water jackets, many cooling systems incorporate a heat exchanger (**Figure 2**). This assembly circulates raw water through one section, called the raw-water side, and at the same time circulates a separate liquid used as an engine coolant through the other section, called the fresh-water side or engine coolant side. Heat collected by the engine coolant can be exchanged to the raw-water side without the two liquids actually coming in contact. Water containing the heat transferred from the engine coolant is then discharged as it does in a conventional raw-water system. Known as a closed-cooling system it uses two pumps: a raw- or sea-water pump, and a coolant pump to circulate coolant through the engine and heat exchanger.

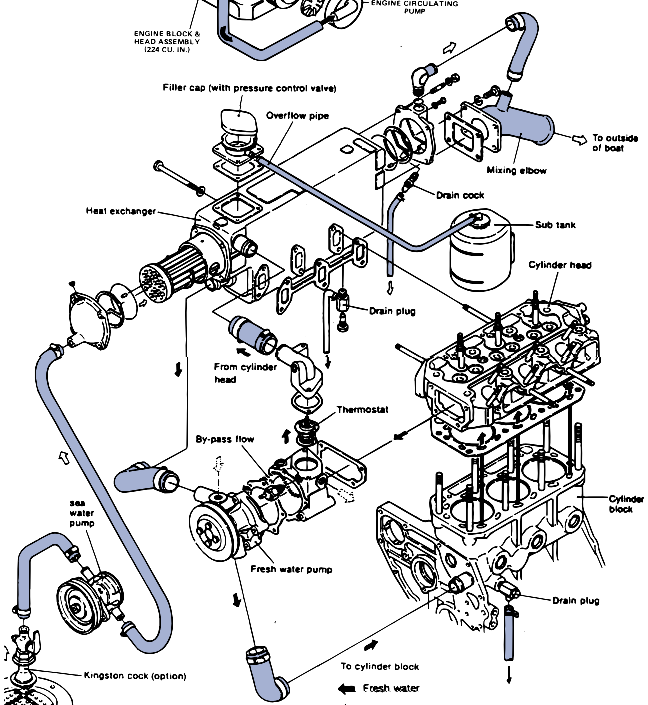
Since raw water is only circulated through the heat exchanger and never touches the engine, scale is created only in the raw-water side of the heat exchanger, where it's easily removed through inspection panels. The fitting of a heat exchanger allows the standard thermostat used with raw-water systems to be replaced with an 87°C (190°F) unit.

Figure 2

Closed Cooling Systems



MerCruiser 470.

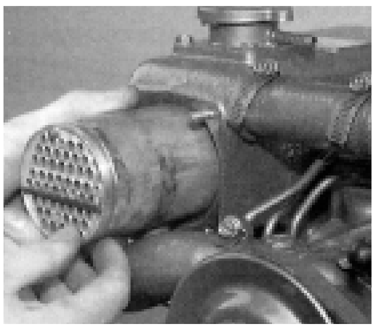


Typical diesel inboard.

COURTESY OF SELOC, CHILTON MARINE

Heat Exchanger

Most marine heat exchanger cores are the shell and tube type, which consists of a bundle of copper tubes encased in a shell so that the liquid "freshwater" to be cooled flows through the tubes while the cooling "raw water" enters the shell and flows around the tubes. The separated liquids transfer heat from one to another without actually being in contact. In some designs this process is reversed and the raw water flows through the tubes and the freshwater flows through the shell.



COURTESY OF SELOC, CHILTON MARINE

Heat exchanger located inside header tank.

Coolant used in the heat exchanger's engine coolant side is automotive antifreeze-coolant solution in normally a 50:50 mixture. This solution improves heat transfer, reduces foaming, prevents cooling system metal corrosion, lubricates the water pump and inhibits the formation of mineral scale in the cooling system. It also protects against freezing down to approximately –23°C (–40°F) and raises the boiling point to approximately 104°C (220°F).

Maintenance is easy: use an antifreeze hydrometer to check the freezing point of the antifreeze, and drain and replace the coolant about every three years.

Header Tank

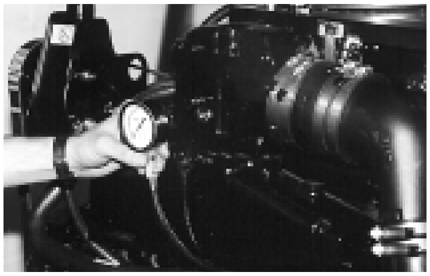
The freshwater side of the heat exchanger system includes a header tank. Usually incorporated into an extra section of the heat exchanger assembly or the exhaust manifold water jacket, it's a storage tank for extra coolant to allow for coolant loss, coolant expansion and contraction. Where space is a problem it's mounted separately from the heat exchanger and connected by hoses. To prevent air locks, remote header tanks are always mounted at the highest point of the system.

The header tank is usually fitted with an automotive-style radiator cap. This allows the system to be filled, the level checked, and the system sealed so it can self-pressurize itself when coolant expands due to heat build up. The cap incorporates a spring-loaded pressure release valve to prevent pressure from exceeding 7 pounds per square inch (psi), though some systems use a cap with a higher-pressure setting (15 psi). Pressurizing the system raises the boiling point of the coolant and prevents coolant vapor loss.

TIPS

MEASURING COOLANT LEVELS

Your pre-start check before starting the engine should include a check of the heat exchanger coolant level. To do this, remove the header tank cap. If only a stub hose is fitted, the "cold" coolant level in the header tank is always an inch or two below the level of the cap — after the expanding hot coolant is forced out of the stub hose it's replaced with air when the cooling coolant contracts. On a heat exchanger fitted with a stub hose, the expansion of the coolant as the engine warms up forces coolant out the stub hose. Therefore, there is no point in continually topping up the coolant in the header tank when the engine is cold, since the level will expand to fill the system to the top when the coolant is hot. Unless, there are leaks in the system, which is also a good reason for checking the level. Never remove the header tank cap when the engine is running or when hot.



If you suspect a leak in the engine coolant side of the heat exchanger, pressure test the system with an automotive radiator pressure tester connected to the header tank cap neck.

Managing Overflow

The header tank cap neck includes a hose fitting connected to a short overflow hose called a stub hose. This hose leads overflowing coolant either to the side of the engine so it can drip into the bilge, or to a hose connected to the bottom of a separate small tank, called an overflow, expansion or catch tank mounted in an accessible location near the engine. [Ed: Refit kits are available for many engines not equipped with catch tanks.] The cap incorporates a vacuum release valve: when the engine is shut off and coolant is contracting as it cools down, the vacuum created by the contracting coolant can be eliminated by allowing air to flow into the header tank through the stub hose, or by sucking coolant back into the header tank from the catch tank, which is usually made of clear plastic so it's easy to check the coolant level.

Corrosion Protection

In both open and closed cooling systems, raw water is in contact with other metal parts, such as a thru-hull valve, water pumps, engine, shaft or propeller, so a sacrificial zinc anode(s) is often fitted in the raw-water side of the system, either in the engine, the heat exchanger, or in a raw-water hose with the zinc wired to the engine and heat exchanger ground.

Sacrificial anodes should be checked monthly by removing them and comparing them in size to a new one. Replace when they are 25% of the size of a new zinc. Always carry spares, since stray electrical currents in some marinas can cause rapid depletion and make frequent changes necessary.

Detecting Leaks

To locate leaks in the engine coolant side of the heat exchanger system, pressurize the heat exchanger with an automotive radiator pressure tester connected to the header tank cap neck. Inspect the system carefully to determine the source of the leak.

To seal the raw-water side of the system and pressurize it for leak testing, squeeze together a section of the raw-water hose just before the exhaust water-injection elbow with Vice Grips (clamp these over spare hose or two pieces of curved wood to prevent hose damage). Fabricate an adapter to allow an automotive radiator pressure tester to connect to the hose at the raw-water intake after removing it from the thru-hull seacock. Never pressurize the system more than the rating of the correct radiator cap (i.e. 7 psi or 15 psi), since it's possible to over-pressurize the system and rupture the header tank or damage water-pump seals.

TIPS HEFTY FINES FOR COOLANT SPILLS

Closed cooling systems require a coolant recovery tank, a.k.a. expansion or catch tank, to prevent toxic antifreeze that is expelled by the cooling system from discharging into the bilge and pumped overboard. The fine for dumping contaminants into waterways is US$5,000, not to mention the potential environmental damage.

Overheating Test

Engine overheating can be caused by a lack of cooling water flow in either open or closed systems. Lack of flow is caused either by a restriction in the intake or outlet side of the water (or coolant) pump, or a damaged pump.

A pressure gauge installed at the pump outlet in either a fresh-water or raw-water system can determine whether the system pressure is too high, indicating a blockage in the system after the pump (i.e. blocked mixing elbow), or too low, indicating a restriction in the pump intake or a damaged pump (usually the impeller).

Raw-to-Fresh Conversion

Converting from an open to a closed system by installing a heat exchanger and 87°C (190°F) thermostat also involves installing a second pump for the engine coolant, and adding coolant. Plumb the raw-water side of the new closed system from the raw-water seacock to the raw-water strainer, to the raw-water pump, to the raw-water side of the heat exchanger, and finally to the exhaust water-injection elbow (see **Figure 2**). Plumb the engine coolant side of the system from the engine coolant side of the heat exchanger to the engine coolant pump, to the engine water jackets and exhaust manifold, and then back to the engine coolant side of the heat exchanger. Kits are available for most engines complete with all components that make this a half-day job. It's recommended you eliminate all engine scale build-up before converting. ⚓

About the author: Robert Hess operates Atomic Four Engine Service in Vancouver, B.C.

TROUBLESHOOTING STARTING SYSTEMS

Engine won't start? This step-by-step diagnostic guide will get your engine running again.

By Robert Hess

Problems with starter motors and solenoids account for most engine no-starts. All engines must be rotated long enough to go through one or more intake-compression-firing strokes, thus drawing fuel into the combustion chamber, compressing it, igniting and starting. Diesel motors only start very quickly when fitted with glow plugs; otherwise, they need to rotate quickly several times to generate enough heat to start.

Most marine engines are conveniently equipped with an intermittent-duty electric starter motor, except small horsepower outboard engines, fitted with a small driving gear that drives a large crankshaft-mounted ring gear (usually incorporated on the circumference of the flywheel). A typical starter gear to flywheel ring gear ratio of approximately 12:1 turns the starter motor at a speed of approximately 2,400 rpm, while turning the ring gear at about 200 rpm, the minimum rpm required to start most engines.

Because diesel engines need to be rotated faster than gasoline engines to start — diesels have approximately three times the compression ratio — they are fitted with more powerful starters. Many diesels have an automatic decompression system (some have manually operated decompression levers). This holds exhaust valves off their seats during starting, allowing the starter to rotate the engine up to starting speed without having to overcome cylinder compression. Once the engine turns fast enough to start, the decompression system fully closes the exhaust valves and the combined momentum of the flywheel plus the starter motor overcomes cylinder compression,

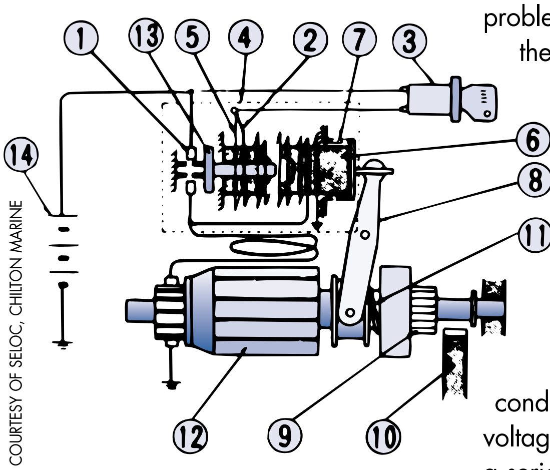
and the engine starts. Diesel engines usually need to be rotated at approximately 400 rpm to start, or 200 rpm when fitted with glow plugs. These plugs improve ignition by heating the combustion chamber when the engine is cold which aids in starting and warm-up.

Design

Starter drive gear on most modern marine engines is usually a positive engagement Bendix type, which uses a gear with an internal helix thread on the end of the starter drive shaft. A solenoid assembly (a.k.a. magnetic switch) mounted on the starter acts as a heavy-duty switch to power the starter motor. It also incorporates a lever system that positively engages the starter gear with the ring gear. When activated, the solenoid forces the starter gear out against the ring gear, the gears begin to mesh and then a split second later begin to rotate the starter. Rotation direction of the starter drive gear and the angle of the internal helix thread causes the starter drive gear to move further out and fully engage the ring gear as it begins to rotate the engine. When the engine starts and begins to rotate faster than the starter, the ring gear then drives the starter drive gear, rotating it in the opposite direction on the internal helix. When the operator releases the start button, the gear quickly rotates down the starter drive gear to the rest position.

Voltage Check

Designed to operate in short bursts of 10 seconds with a cool-down period between each burst, starter motors demand hundreds of "cranking" amps. If the cranking battery is not fully charged, or there is any resis-



Exploded view of starting motor circuit. 1. Stationary contact 2. Series coil 3. Ignition switch 4. Solenoid 5. Shunt coil 6. Plunger 7. Return spring 8. Shift lever 9. Drive pinion 10. Ring gear 11. Pinion sleeve spring 12. Armature 13. Movable contactor 14. Battery

tance in the starter cables or connections, the resultant voltage drop restricts the current and prevents the motor from rotating the engine fast enough for it to start. Low voltage at the solenoid sometimes causes either a single clunk sound as the solenoid pushes the Bendix gear against the ring gear, or just a rapid clicking sound as it tries to hold the contacts together against the contact spring.

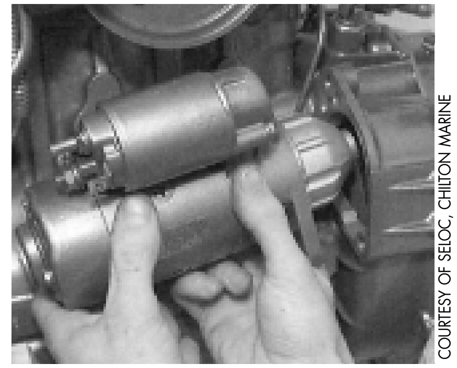
Some diesel engine starting problems are simply low voltage. The starter turns the engine over at what sounds like an acceptable speed, but it's not sufficient to allow the engine to develop enough heat to start, especially in colder-than-normal temperatures.

While the starter is rotating the engine, a multimeter (see "Electrical Troubleshooting" on page 30) with the red (positive) probe connected to the starter positive terminal and the black (ground) probe to the metal body of the starter, should read at least 9.6 volts. If voltage drops below 9.6 volts, then check the battery cell condition with a hydrometer and ensure it's fully charged to 12 volts. Remove and clean the battery cable terminals and battery posts (a common source of many battery problems), then remove and clean the engine block ground cable terminals. Use your meter to check for a voltage drop between the starter and solenoid terminals, while a helper activates the starter.

If voltage checks verify that the battery is fully charged and battery and starter cables are in good condition and properly sized (no voltage drop), either the engine has a serious mechanical problem, which is preventing the starter from cranking it quickly (i.e. a partial bearing seizure), or the solenoid and/or starter needs repair.

Engine or Starter Failure?

If the engine is stiff, the starter and cables usually get very hot because they are drawing more current than intended. To verify that the engine turns freely and smoothly, you must eliminate engine compression. To do this on gas engines, disconnect the ignition coil leads (to prevent sparks)



To test the starter, remove from engine and connect it via booser cables directly to a fully charged battery.

and remove the spark plugs; remove glow plugs or fuel injectors from diesels, or disengage manual decompression lever. Place a socket wrench on the crankshaft and turn over the engine in the normal direction of rotation (check direction in owner's manual). Any noticeable stiffness or resistance may foretell of some internal engine damage; however, before making any assumptions, inspect engine-driven attachments such as water pumps, alternator, transmission, etc. Now rotate the engine via the starter. As it doesn't have to overcome engine compression, the starter should turn the engine at a higher than normal speed. If the engine turns freely when rotated by hand, but doesn't turn quickly with the starter, the starter likely needs repair.

Bench Test

To test the starter, first remove from engine and use a set of booster cables to connect it directly to a fully charged battery. A starter fitted with a positive mechanical solenoid should immediately move the Bendix gear out to the end of the starter shaft, and the shaft should begin to spin quickly. If the Bendix gear doesn't move to the end of the shaft or the shaft turns slowly, the solenoid and/or starter needs rebuilding, likely worn-out brushes and burnt windings. If the solenoid snaps the Bendix gear out to the end of the shaft, and the starter begins to spin quickly, it's probably okay. If the starter hasn't been serviced for several years, now may be a good time to have it cleaned and checked before reinstalling, just to make sure it's in good condition.

Note: When bench-testing a starter, as soon as it begins to turn quickly, immediately remove one of the battery cables and let it stop. Most starter motors are not meant to run without a load and are easily damaged when allowed to rotate faster than their designed limit. ⚓

About the author: Robert Hess operates Atomic Four Engine Service in Vancouver, B.C., and specializes in sales and rebuilding of Universal gas and diesel marine engines.

ENGINE TEMP CONTROL

A faulty thermostat causes an engine to overheat or to operate too cold, either condition resulting in costly damage. Here's how to test, remove and replace your engine's thermostat.

By Robert Hess

Early raw water-cooled marine engines had a gate or needle valve fitted in the block exit to act as an operator-adjusted manual temperature control valve. Later versions were fitted with a wax pellet thermostat, installed in the block coolant exit in place of the operator-controlled valve.

The introduction of the fiberglass or plastic waterlock muffler in the '70s, resulted in substituting a double-acting type thermostat. This device controls the direction of water flow: if the coolant in the block is cold the exit at the top of the block is closed to stop the flow of cooling water and force the block to heat up. At the same time the water is diverted through the bypass loop to cool the exhaust manifold and waterlock. Conversely, when the coolant in the block is too hot, the block exit is opened fully and the bypass is closed, so that the water is diverted through the block to the exhaust system.

Once the engine has reached the thermostat's rated temperature, it gradually assumes a partially open state of equilibrium based on the thermostat temperature rating, the initial coolant temperature, the engine load, throttle setting, and ambient temperature of the engine room.

Two-stage gas engine thermostat open at 62°C (145°F).

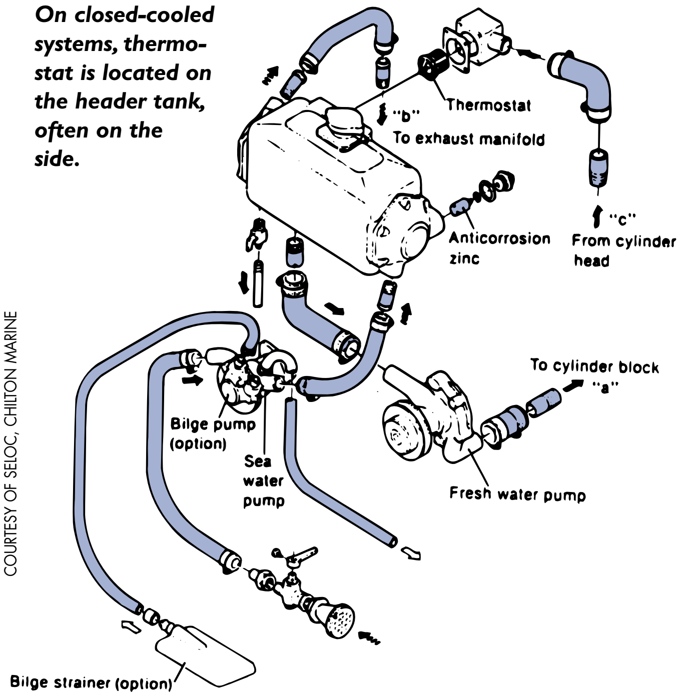
Optimum Temp Ratings

Raw-water cooled engines (especially those operated in saltwater) should be fitted with thermostats rated at 62°C to 65°C (145°F to 150°F) to avoid scale build up in the water jackets caused by temperatures over 71°C (160°F). Removing the thermostat so

TIPS COOL BUT DEADLY

Traditional ethylene glycol automotive antifreeze that fills an engine's heat exchanger is extremely appetizing to pets but fatally toxic. Never leave any in an open container, always drain engine coolant into a sealable container, and consider switching to a non-toxic propylene glycol (plumbing) coolant.

On closed-cooled systems, thermostat is located on the header tank, often on the side.



COURTESY OF SELOC, CHILTON MARINE

To remove, disconnect coolant hose, remove thermostat housing and lift thermostat.

Single-stage diesel engine thermostat showing coolant bypass hole.

the engine runs extremely cold is not recommended, since cold running greatly increases problems, such as valve guide and piston ring sticking, high fuel consumption and accelerated engine wear. Removing two-stage thermostats, such as those fitted to older Universal Atomic Four engines, can eventually cause head gasket failure and cylinder head cracking. Heat exchanger-equipped engines should be fitted with thermostats rated at 82°C to 87°C (180°F to 190°F) to take advantage of the exchanger's ability to cool the engine without circulating raw water through the water jackets.

Testing Tools

Since thermostats are mechanical devices that are constantly opening and closing all the while the engine is running, they gradually wear out and should be replaced regularly, roughly every 1,000 hours. A rebuilt engine should always be fitted with a new thermostat.

A sticking thermostat can cause erratic temperature fluctuation; but the most common thermostat failure is a total seizure, usually in a closed position that causes extreme overheating. To monitor thermostat operation, run the boat at moderate speed and load (do this at the dock) and attach a surface thermometer to the thermostat housing or cylinder head. Using the control panel water temperature gauge, a water temperature probe in the header tank of closed cooling systems or waterlock muffler of raw-water cooled systems, compare temperatures — the exterior temperature of the cylinder head metal is usually the same temperature as the engine coolant.

A cold engine should quick warm up to the operating temperature stamped on the thermostat. If warm-up takes a long time and the temperature rises only slightly suspect a thermostat stuck wide open. If warm-up takes a long time but the temperature finally gets close to normal, the thermostat may be stuck partially open. If the temperature goes up quickly and exceeds the temperature stamped on the thermostat, the thermostat may be seized closed. If the engine temperature is too hot, try removing the thermostat and running the engine to see if it suddenly runs cold, which may indicate the thermostat is sticking closed.

Many thermostats have the rated opening temperature stamped on the body. This temperature can be measured and the thermostat tested for erratic operation by placing the thermostat in a pot of water and heating it on a stove while monitoring the water temperature with a cooking thermometer. Once the thermostat has opened fully, test it for sticking: remove from the hot water and place it in cold water, where it should close quickly and completely.

Removal and Reinstallation

Remove thermostats for inspection or replacement only when the engine is cold to reduce the risk of burns. If the engine is equipped with a heat exchanger remove the header tank cap, then drain the engine coolant into a bucket so that the level in the engine is below the thermostat. Remove the thermostat housing or cover, and carefully remove the thermostat without damaging it. Check the housing against a straight edge to make sure it isn't warped; in the case of double-acting thermostats such as those fitted to Universal Atomic Four engines inspect the thermostat housing bypass boss for corrosion damage. Replace or repair as necessary.

Scrape the gasket and old gasket cement from both the block and thermostat housing, and install the thermostat with a new gasket or silicone gasket cement. (Loctite is recommended.) If the thermostat fits into a lip or depression, make sure it's installed properly to avoid cracking the housing when you tighten it down. Torque the housing fasteners to the specified torque using a torque wrench. (Refer to your owner's manual for proper procedures.)

COURTESY OF SELOC, CHILTON MARINE

Testing the thermostat: place in water-filled container and heat, then place in cold water. It should open then close quickly without sticking.

For a closed-cooled engine equipped with a heat exchanger, fill the header tank with 50:50 antifreeze-water solution, and if there is an air bleed valve on the thermostat housing or the top of the head open it to release any air trapped under the thermostat. Leave the heat exchanger cap off until the engine has warmed up and the level of coolant has stabilized, and then top up the level to make sure the header tank is full before replacing the cap. If the header tank overflow hose is connected to a catch tank, make sure it's about half full of coolant, and check it again after first-time run of the engine.

About the author: Robert Hess operates Atomic Four Engine Service in Vancouver, BC.

Powerboat Rigging

KEEL ARMOR

Protect your boat's keel with this ultra-tough bumper. Easily installed in less than one hour, just peel and stick — no holes to drill, no fasteners.

By Jan Mundy

Whether you're cruising in the shallows, landing on a beach or launching at a concrete ramp, Megaware KeelGuard (Tel: 800/292-9835) protects keels from abrasion, chafe, dents, rocks — whatever lurks below. Ideal for all wood, aluminum, fiberglass, plastic or rubber boats, it consists of an extremely durable and abrasion-resistant polycor composite band held permanently in place with 3M VHB (Very High Bond), a pressure-sensitive acrylic industrial adhesive. It bonds so well, the company offers a lifetime warranty.

Available in 13 colors, two widths and in lengths in 30cm (1') increments from 1.2m to 3.6m (4' to 12') to fit boats 9m (30') and longer. Kit prices range from US$100 for boats up to 4.8m (16') to US$235 for 30-footers and larger. No curing time is needed, so allow an hour for installation before launching.

For our 6.6m (22') test boat, we ordered the 2.1m (7') white kit in the larger width of 12.7cm (5") at a cost of US$156, which is a lot less expensive than major fiberglass surgery should we hit a submerged rock.

1 Clean keel area, remove any algae or dirt with an acid cleaner and antifouling paint.

2 Beginning at the forefoot, pencil mark the centerline and width, extending 6.3cm (2-1/2") out on either side. Continue measuring down the keel the length of the KeelGuard, adding an extra 5cm (2") at the end (aft) to allow for the curvature; otherwise, after laying down the material it may be necessary to cut off any excess or reprime any untreated keel surface.

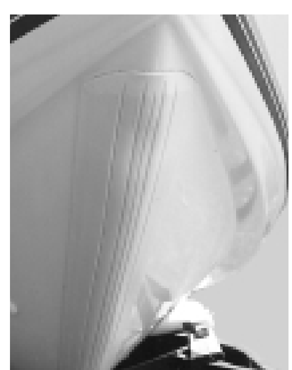
3 Mask along pencil marks with 3M Fine Line or 233 tape to prevent marring the gelcoat when sanding.

Tape also acts as an edge line for applying primer and attaching band.

4 Sand the surface hard to remove hull wax, pencil marks and other contaminates with 3M Scotch Brite pad (provided). Sight down the keel line — any glossy areas require additional sanding. Follow with a solvent cleaning.

5 To apply 3M primer, push foam applicator hard against the hull until foam is wet with glue. Draw applicator sideways over surface, applying a thin coat, extra along the edges. Primer is odorless and not messy, so gloves are not necessary. Wait five minutes for glue to cure. Unroll KeelGuard and lay flat in sun until supple, about five minutes in 32°C (90°F) temps.

6 Starting at the bow, pull back about a foot of the red plastic liner and align the band. Working from the center, one side at a time, pull back the tape and press on by hand or use the burnishing tool to remove all trapped air. Position carefully as the bond becomes permanent immediately upon contact. Continue working towards the stern and once completely attached, press entire surface down firmly with burnishing tool. Make sure all edges are down. Remove tape, wipe off any excess adhesive and go boating.



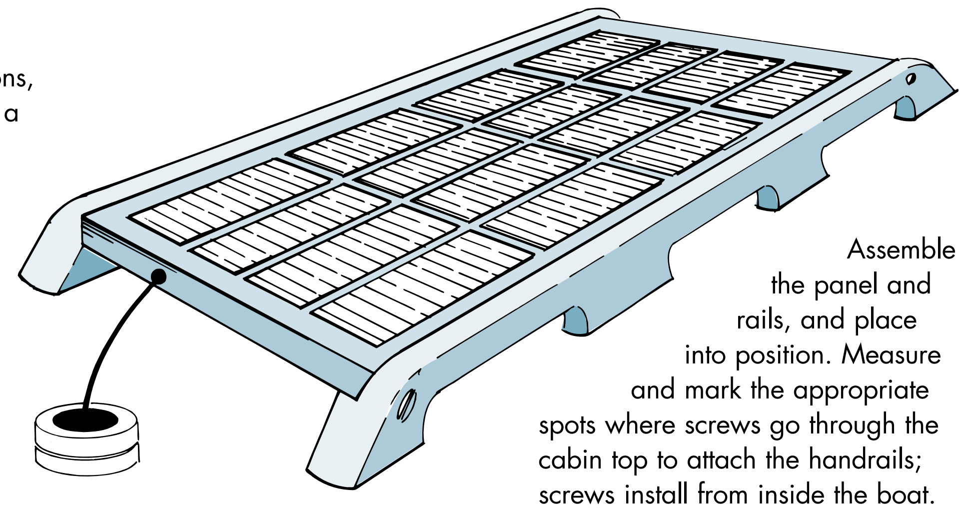
Good Boatkeeping

BUMPGUARD FOR SOLAR PANELS

Customized handrails add a decorative touch and protect solar panels from side impact.

By Zora and David Aiken

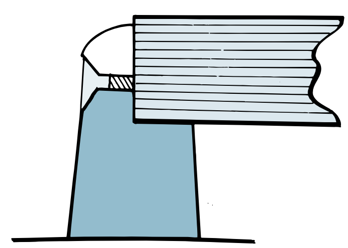
Solar panels are practical add-ons, but their installation can present a couple of problems. One is the very real in-your-way, toe-stubbing kind of problem. The other is one of perception: the black-glass squares are not particularly yachty looking, but you can hardly hide them. Recently, we saw a sailboat whose owner had managed to minimize both.



Buy a solar panel, then buy two teak handrails of the same length as the panel, or slightly longer. The ultimate placement of the panel will be a compromise: it must have sun exposure for the longest possible time each day without being directly underfoot in a high traffic area. In this case, the panel was positioned on the starboard side cabin top, far enough behind the mast so that sail handlers would not step on it.

Cut (or router) an L-shaped notch into the intended inner edge of each handrail. The size of the solar panel's frame will determine the finished depth of the cut. The panel mounts on top of the cut surface, flush with the uncut top portion of the rail, and is positioned so that screws pass through the rail's outer edge and into predrilled holes on the panel frame. Naturally, if the brand of panel you purchase uses a different mounting method, it can be adapted to this application.

Assemble the panel and rails, and place into position. Measure and mark the appropriate spots where screws go through the cabin top to attach the handrails; screws install from inside the boat. Drill pilot holes first to check for accuracy. Rails likely won't require strong backing plates that an actual grab rail needs, but depending on the type of overhead or headliner in your boat, such a plate makes a more secure attachment. Mount a watertight deck



connection to lead the panel's wiring harness through the cabin top to the battery.

About the authors: David and Zora Aiken are the authors of "Good Boatkeeping" and "Good Cruising" published by International Marine. The Aikens currently live aboard "Atelier," berthed in Grasonville, Maryland.