BILGE PUMP SYSTEMS

Part II

ELECTRICAL CONSIDERATIONS, SWITCHES & MONITORING

STORY AND PHOTOGRAPHY BY STEVE D'ANTONIO

In the first installment of this two-part series, we investigated the various types of bilge pumps, flow rates and how they're affected by installation, and how to choose the right size pump for your boat. We now turn to the electrical details of pump installation, manual and automatic switches, and methods of monitoring bilge pumps.

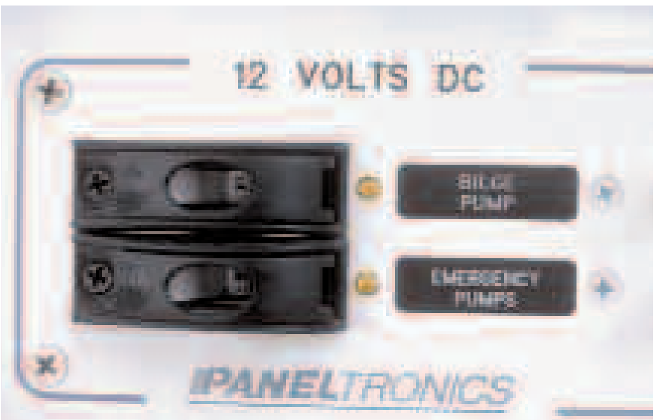
The design and execution of a bilge pump's electrical power supply are of undeniable importance. Electrical faults and flaws offer the greatest opportunity for a bilge pump installation to go awry. Some of these problems raise their heads even before a pump has been removed from its box.

Consider this: In the same way that bilge pumps are rated for capacity at "open flow"—with no resistance—they also are rated at "design voltage," or 113 percent of nominal voltage. This means the outputs of 12- and 24-volt pumps are rated at 13.6 and 27.2 volts, respectively. In turn, this means that unless a charge source is present, the output of the pump will be less than its maximum rated flow.

Nearly all pump manufacturers follow this protocol; thus, the comparisons are like. But it's important to apply this degradation when you're trying to determine a pump's overall capacity. As an example, let's look at a 2,000gph pump that's operating at 13.6 volts and at open flow or zero "static head" (the height to which water must be raised from the bilge to reach the discharge point). This pump's capacity would be 2,000gph. However, when the voltage is reduced to 12, which may very well be the case if several pumps are running and the engine or generator isn't running (or cannot run), the output drops to 1,700gph. Now, inject a dose of reality into the equation by adding 6.5 feet of head, and the output drops almost by half to 1,160gph, and that's without "dynamic head"—resistance imparted by hose turns, pipefittings, and valves—figured into the calculation.

WIRE: SIZING IT UP

If electrical faults are the most common source of bilge pump failure, using the incorrect wire size and fuse/circuit breaker value is the most common error committed within the electrical arena. Voltage drop—the phenomenon that occurs as electricity experiences resistance when traveling through wires—can have a significant impact on pump operation. In essence, even if 13.6 volts is available at the battery (the pump's source of power), if a significant voltage drop exists, it's possible that the pump will receive something less than this. And there will be a consequent decrease in flow.



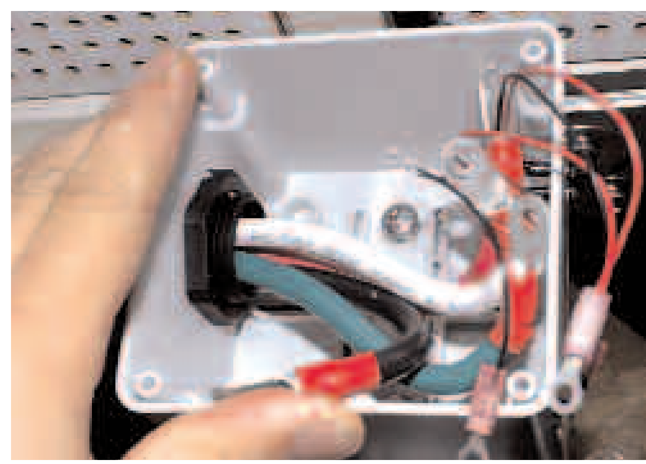
It's important that bilge pumps be installed in such a way that they cannot be inadvertently shut off. Having a protected or covered circuit breaker is one option, or a fuse can be used. The latter choice is not as convenient to service and requires that spares be kept on hand.

Here's a real-world example from a boat I recently inspected. The vessel's 12-volt pump was located in the engine room, about 25 feet from the power source, the electrical panel. (Let's assume, arguendo, that the wire run also was 25 feet, although it's likely it was closer to 35 feet, taking into account routing issues.) Electrical resistance calculations must factor in the round-trip distance, so now we have 50 feet of wire. Determining the voltage drop requires nothing more than consulting a voltage-drop table, which can be found in ABYC's *Standards & Technical Information Reports for Small Craft* or any number of marine electrical books.

Before proceeding, I'll point out that when installing a bilge pump, you should aim for a voltage drop of less than 10 percent, and preferably around 3 percent. I recommend a 3 percent drop for all motor installations, and bilge pumps are motors. Motors are inductive loads, which means that as the voltage drops, the amperage goes up; this causes fuses and circuit breakers to trip or, worse, wires to overheat. Additionally, when motors run at lower than ideal voltage, they tend to heat up, which shortens their lives.

Back to our calculations. According to the voltage-drop table, a 50-foot run at 12 volts and 15 amps requires a pair of no. 6 wires to achieve a 3 percent voltage drop. (As an indication of size, the outside diameter of a no. 6 wire, measured over the insulation, is 0.33 inch, or roughly the diameter of a pencil.) This size wire is large and is rarely seen in bilge pump installations, although it would provide the highest pump performance. For a 10 percent voltage drop (13.6 volts would reach the pump as 12.24 volts), you would need a no. 10 wire, which has an outside diameter of 0.194 inch.

In fact, the wire that was used in the bilge pump installation on the boat I inspected was no. 14, which has an outside diameter of just 0.141 inch, slightly greater than the diameter of a wire coat hanger. This no doubt accounted for substantially reduced voltage—roughly a 20 percent drop, or 10.88 volts available at the pump—in addition to reduced pump output. It probably also caused the pump to run hot. Whether it caused nuisance tripping of the fuse is unknown, but I suspect it did. (Voltage-drop calculations, by the way, should not be confused with ampacity calculations, whereby the wire size, insulation temperature rating, and routing of the cable determine its ability to safely carry a specified amperage.)



Of all the factors that affect the efficiency of a bilge pump's operation, wire size or gauge is perhaps the most important. Undersized wires can seriously diminish a pump's capacity while giving no outward sign of a problem. Ideally, bilge pump wiring should present *no more* than a 3 percent voltage drop.

As you can see, voltage and wire size play a major role in bilge pump performance. But there's another important electrical factor that enters into our discussion: the locked rotor. When a pump, or any electric motor, first starts, it draws considerably more current than when it's running in what's known as a steady state. This is called "inrush" or "start-up load." Bilge pumps experience this, and it's one of the reasons that the fuse or circuit breaker value is specified as larger than the constant load of the pump. If a smaller fuse were used that only took into account the pump's steady-state running load, it's likely that it would trip frequently at start up.

What happens, though, if the pump becomes jammed or clogged with debris? Then, the pump is in a state of suspended inrush or start up, and the current draw remains high indefinitely. This is yet another reason that wire should be sized conservatively; it should be fully capable of supplying (because of its low resistance) full locked-rotor current, which in turn will trip the breaker or blow the fuse. If the wire is undersized, it's unlikely that enough amperage will reach the pump to cause the fuse or breaker to trip. Instead, the pump might overheat and catch fire in the event of a locked rotor. Pumps that comply with current ABYC standards must include a means by which power to the pump is shut off in the event that they experience overheating, regardless of the cause. Conversely, under normal conditions, in order to meet the same ABYC guidelines, bilge pumps must be capable of running continuously at their design voltage for 24 hours.

OTHER ELECTRICAL CONCERNS

Further wiring considerations include connections, terminations, wire routing, fuses, and circuit breakers. As even the most inexperienced boat owner knows, water (particularly sea water) and electricity do not mix very well. Bilge pump installations are no exception to this rule, and because of the important role they play in the life of your boat, there's virtually no margin for error.

Most submersible pumps are available with wire leads that are long enough—usually about 6 feet—to accommodate connections being made well above maximum bilgewater levels. (Carefully check the specs of a submersible pump regarding this option before buying.) Ideally, connections should be made well above bilgewater levels and should not have to rely on waterproofing. A tinned copper terminal strip installed 4 or 5 feet above the bilge and then coated with corrosion inhibitor means low-resistance connections are secure yet accessible for inspection and testing.

If such an arrangement simply isn't feasible, then connections must be made as watertight as possible. Regardless of location, conductors should be coated with a conductant paste, such as Thomas & Betts Kopr-Shield, prior to installing crimp connectors. Connections should be made using high quality resin-loaded heat-

Debris is a bilge pump's worst enemy. This strainer, installed aboard a new vessel, has become impacted with "new-build debris," rendering the bilge pump it serves useless. The watch phrase for pump-savvy cruisers is: keep your bilges clean and free of all debris, no matter how small or seemingly insignificant.

shrink tubing, the kind that oozes sticky material when heated. Be certain the resin completely encapsulates the wiring as it exits the heat-shrink tubing ends. Secure these connections as far above bilgewater as possible. Remember: Water is the universal solvent. Given enough time, it will leak through any "waterproof" seal.

Secure wiring leading from the pump in such a way that it does not bridge any "air gaps"; that is, it should not pass through open space between the pump and a bulkhead or stringer. Instead, wiring should be continuously supported and secured at least every 18 inches using wire ties or P-clips. If the wiring passes over moving machinery, such as shafts or belts, use metallic securing clips, rather than plastic clips.

Appropriately sourcing power for bilge pumps can mean the difference between having a dry bilge and finding your boat sunk at the bottom of its slip. My preference is to supply bilge pumps with their power

Bilge pump electrical components—float switches, manual switches, wiring, and so forth—must be capable of handling the loads imparted on them by the bilge pump under all operating conditions. This float switch was not defective; it was simply underrated for the pump's ampere draw.

independent of both the vessel's house battery switch and the distribution panel's main circuit breaker. Wired in this manner, the boat can be left with the pumps operational but nearly all DC circuits de-energized, which is the safest approach for fire prevention. This is often accomplished either by supplying the bilge pump fuses or circuit breakers with a dedicated power supply from the house battery bank (sometimes in the form of a subpanel) or by establishing a separate, always-energized bus at the distribution panel from which bilge pumps are powered. Either way, all relevant ABYC guidelines regarding over-current protection must be followed; i.e., every conductor must be protected by an appropriately sized fuse or circuit breaker.

Where over-current protection is concerned, some prefer fuses, rather than circuit breakers, for bilge pump protection, believing that a breaker is too easy to inadvertently turn off. Because of their ease of use and "resetability," I still prefer breakers, provided they are equipped with locks. (Purpose-made locks are available from most marine electrical panel manufacturers and circuit breaker suppliers.) The fuse or circuit breaker should be sized in accordance with the pump manufacturer's guidelines. Of course, it also must protect the wire being used to supply the pump, but if the wire is rated for no more than a 10 percent voltage drop and the pump manufacturer's specified fuse/breaker is used, then this will almost certainly be the case.

SWITCHES

Even the most powerful bilge pump will be of little use if it can't be reliably turned on and off, both automatically and manually. Manual switches should be conveniently located at the helm or electrical panel. They must be of the highest quality and also should be rugged and reliable. Avoid spring-loaded momentary "on" switches for manual pump activation. If your automatic float switch fails while your boat is flooding, the last thing you want is for you or a crew member to be stuck holding this switch in the "on" position. Instead, go with a positive on-off switch, and wire the automatic portion of the pump circuit so that it is *always* energized via the pump's fuse or (lock-equipped) circuit breaker. This makes it unlikely that you'll forget to leave the pump in automatic mode.

Perhaps the most critical aspect of a switch is its ampacity. A bilge pump switch must be capable of contending with the pump's steady-state ampere draw, as well as its locked-rotor ampere draw. Under no circumstances should the switch's ampacity be less than the over-current protection serving the circuit.

Automatic switches, which live in the bilge attached to or next to the pump, clearly play a critical role in the reliable operation of your bilge pump system. If you visit your local chandlery or page through a parts catalog, you will encounter a wide variety of automatic bilge pump switches, and it seems that new models are introduced each year. Attempting to cover in this article even a portion of those that are available would be difficult, indeed. I will, however, share with you some wisdom about float switches that I've garnered from 20 years of working in the marine industry.

When looking at automatic switches, begin by checking out the warranty. Two years is a minimum; five is my preference. While every switch was "new" or "just introduced" at some point in its life, when it comes to this critical component, I'd much rather go with "tried and true" or "proven." Visit *PMM*'s chat rooms and other cruiser forums to find out what other boaters have to say about the model of switch you are considering. While these reviews and comments must often be taken with a grain of salt, a preponderance of approving or disapproving votes can be telling.

My preference in automatic float switches is for the potted reed variety. An example is the Ultra Bilge Pumpswitch manufactured by Ultra Safety Systems (www.tef-gel.com) of Mangonia Park, Florida. I've used hundreds of these switches over the years, and they've proven to be exceptionally reliable. Warranties for these switches range from five years to lifetime. Among other options and features, they offer extended "hysteresis" (also called "differential"), the vertical distance between the levels at which the switch activates and deactivates the pump. An extended hysteresis can negate the need for a check valve where long discharge lines and small bilge wells cause frequent short cycling of the pump. (With this arrangement, the pump will continue to run for a period of time after the water has been pumped clear of the bilge, removing as much of it as possible in the process.) The only real weakness of the potted-reed-type switch is that an oil-fouled bilge might deposit emulsified oil inside the switch cylinder, which can prevent the cylinder from rising or falling. For those who keep their bilges free of oil, this isn't a concern.

Like a manual switch, a float switch must be capable of carrying the steady-state load and the locked-rotor load of the pump. If, for instance, the pump manufacturer calls for a 15-amp fuse, the float switch must be rated to carry this load continuously. Float switches should always be wired into the positive side of the pump's circuit. If the switch is wired into the negative leg, the inside of the pump will remain positively energized at all times. The smallest breakdown in insulation or carbon arcing inside the pump housing could cause this current to leak through the pump's shaft and into the bilgewater and immersed metals such as seacocks or shaft logs, which will almost certainly result in stray current corrosion of this hardware.

One additional comment on automatic bilge pump switches is warranted. For many years, the most common switch looked vaguely like a hinged paddle. Inside the switch was a small drop of mercury. As the paddle floated upward, the mercury, which is electrically conductive, would roll back into a set of contacts, activating the pump. This system worked exceptionally well. The point of failure usually was the wire attached to the float; after a few thousand cycles, the insulation broke down, the conductors corroded, and the pump stopped working (and the vessel may have experienced stray current corrosion as a result of the exposed, energized conductor).

Because of the environmental hazard presented by mercury, these switches are no longer manufactured. But thousands were sold, and many no doubt are still in use. If you have one, beware of the mercury content. If the switch paddle is crushed or shattered, the mercury could

Top: Even properly installed crimp connectors are not up to the harsh, corrosion-inducing conditions found in most bilges. These connections are far from waterproof and, when lightly tugged, they may separate, as the ones shown here did. Above: A typical bilge pump and float switch installation accompanied by a high-water alarm float switch. High-water alarms should be installed so that the crew is alerted to *any* abnormal accumulation of water, rather than emergency flooding alone.

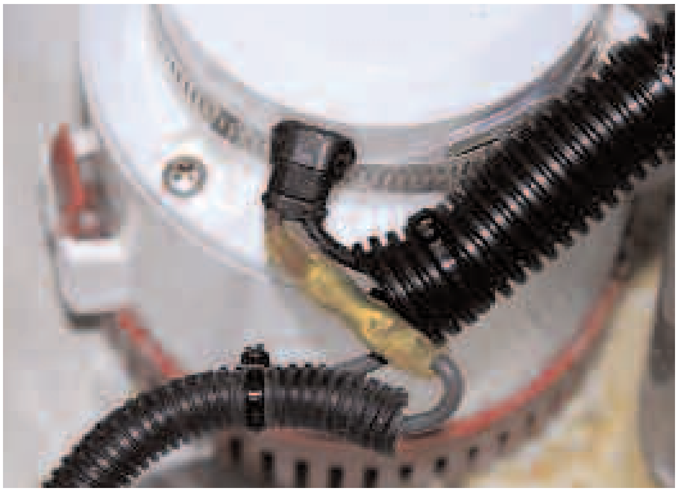
escape, which may present a health risk for those living or working aboard your boat. Also important is the risk that mercury presents to aluminum and steel vessels. When exposed to mercury, aluminum and steel corrode; mercury is a metal and acts as the cathode, while the steel or aluminum is the anode. Thus, if your steel or aluminum boat (particularly the latter) is equipped with a mercury-bearing float switch, consider replacing it with one that's friendlier to metal vessels. The redesigned switches are mercury free, and the wires no longer move with the paddle, negating the possibility of insulation breakdown.

ENUNCIATORS, ALARMS, AND COUNTERS

When a bilge pump runs, you want to know about it. This can be achieved in one of two ways. The first and most common method involves installing a pilot light that is readily visible from the helm. Whenever the bilge pump operates, regardless of whether it's been manually or automatically activated, the light will illuminate. With this arrangement, if a bilge pump runs in a manner that's out of the ordinary (for instance, if it cycles on every few minutes while you are under way, which means a raw-water hose may be leaking), you'll know it needs to be checked out. A pilot light enunciator is simple, inexpensive, and effective, and it's required if you want to comply with ABYC standards.

The other method of monitoring bilge pump activity is to use a counter. Bilge pump counters have been available for ages, and they range from the simple to the complex. (Many who own wood boats wouldn't dream of doing without a bilge pump counter.) The simplest variety is a mechanical digital counter. It looks something like a mechanical odometer that rolls up by one number every time the pump cycles on, and it's reset by pushing a small lever. If you reset the counter to zero when leaving the boat, when you return you'll know how many times the pump cycled. The only drawback to this approach is that the counter only tells you how many times the pump cycled, not how long each cycle lasted. If the pump ran continuously since you left the boat, the counter would still read "1." More sophisticated variations on this theme exist, and, not surprisingly, they involve digital electronic processors that can monitor multiple pumps, tell you how many times each pump ran and for how long, and more. In short, a counter is a worthwhile addition to any bilge pump system.

If your engine ran out of oil or if carbon monoxide was accumulating in your cabin, you'd want to know about it, right? That's why oil pressure alarms and CO detectors sound an impossible-to-ignore signal, alerting you to a pending catastrophe. Bilge alarms work in much the same way, and many people, including me, consider them to be as vital as bilge pumps themselves. Like bilge pump counters, bilge alarms range from the simple to the complex. In their simplest form, a bell or buzzer is connected to a float switch. When water rises high enough to trigger the switch, the alarm sounds. More sophisticated systems are capable of monitoring multiple bilge compartments. Some include their own power



Left: The height at which a bilge high-water alarm switch is installed can spell the difference between a disaster averted and the loss of a vessel. Alarm float switches should be installed just high enough to avoid nuisance alarms caused by normal accumulations of bilgewater—but *no higher.* Right: The importance of the integrity of a bilge pump's wiring connections cannot be overstated. All connections should be located well above normal and extreme accumulation of bilgewater (at least 18 inches above the former). If this cannot be accomplished, then connections must be truly waterproof. The installation shown here meets neither of these requirements.

supply, and some will call or text message you if bilgewater reaches a critical level. Such “extras” can be useful, but it’s important to get the basics of a bilge alarm right. After all, that alarm may be all that stands between you and catastrophic down flooding.

Much like a bilge pump system, the wiring for a bilge alarm must be virtually foolproof and failure-proof. All connections should be made well above the maximum bilgewater level or should be thoroughly waterproofed, and the switch, regardless of variety, should be well secured and protected from misplaced feet, gear, and tools. Placement of the switch is critical. I’ve been aboard vessels whose high-water alarm switch was more than a foot above the bilge pump’s switch, which led me to wonder, why bother with an alarm? My preference is for the bilge alarm switch to be installed as close as possible to the level of the conventional bilge pump float without triggering false alarms. If that means the high-water alarm switch is 2 inches above the conventional float switch, so be it. If your bilge pumps stop working or can’t keep up with a torrent, it’s best to know about it as quickly as possible.

A high-capacity bilge pump mated with a durable, reliable reed float switch installed in the bilge of an aluminum trawler. The wiring is well secured and chafe protected, and the pump rests on a small platform, reducing the likelihood of debris fouling.

The audible alarm that sounds when high water is encountered should be loud enough to be heard over any other operating equipment: engines, stereo, TV, and so on. And it should awaken even the soundest of sleepers. I’ve been asked by some vessel owners to install load hailer alarms on the weather decks so that if the bilge floods while the vessel is unattended, there’s a chance others will notice.

High-water alarms, as well as bilge pumps, should be tested after their initial installation and at least seasonally thereafter. If you’ve never tested these systems (even if your boat is new), you should do so right away. Testing does not mean lifting the float switch; it means filling the bilge with water until the bilge pump is activated and pumps water overboard. Testing the system in this manner achieves two ends. First, it gives you an indication of how well, or how poorly, your bilge pump system works. You’ll get a feel for how long it will take to pump out the bilge. (If you’re curious, place a bucket under the discharge, and determine how long it takes to fill up. Then, do the math to determine the pump’s actual capacity.) Second, it exercises the system and allows you to see for yourself that it works properly, pumping water or sounding an alarm as and when it should.

High-water alarms should be tested in a similar manner. Shut off the bilge pumps and fill the bilge with water until the alarm sounds. It should do so long before water approaches critical mechanical or electrical equipment. If you are unable to do this because water is in danger of reaching batteries, flywheels, inverters, etc., then the message is clear: the high-water alarm float switch is too high, and it needs to be lowered.

No bilge pump system is 100 percent effective or reliable. There’s always a way to make it fail. I recall one occasion of salvaging a cabin cruiser that had been partially flooded as a result of a leaking seawater strainer. After the water was pumped out, I inspected the bilge pump system, expecting to find it improperly installed or poorly maintained. In fact, it was a textbook installation; I could find nothing wrong with it until I noticed that a pencil had gotten stuck in the float switch, jamming it in the “off” position. Remember that bilge pumps are designed to contend with water—not trash, dirt, or hair. The problem of grossly contaminated bilges isn’t reserved for old vessels, either. The vast majority of new vessels I inspect possess bilges that are seriously contaminated with what I call new-boat detritus, such as fiberglass shards, wood chips, wire ties, crimp connectors, screws, and wire trimmings. All of these items ultimately conspire to clog bilge pumps.

Take care of your bilge pump system, and it will take care of you. Ensure that your pumps are installed according to the manufacturer’s recommendations and ABYC guidelines. Keep your bilge clean and inspect it regularly, and you’ll have little to worry about where this vital system is concerned.

Steve owns and operates Steve D’Antonio Marine Consulting (www.stevedmarineconsulting.com), providing consulting services to boat buyers, owners, and the marine industry.