Plumbing the Depths

Electric bilge pump systems debunked and done right.

Text and photographs by Steve D'Antonio

Above—*A standard 2,000-gph (7,571-lph) centrifugal electric bilge pump and its float switch pulled from the bilge for repairs. As this image illustrates, access to pumps for service is critically important. The most significant thing for a builder or repairer to keep in mind is that even in the best possible situation, this pump is unlikely to actually remove 2,000 gallons of water from the bilge in one hour.*

In my 25 years in the marine industry I've frequently encountered misconceptions about bilge pumps and their capacity to operate as damage-control devices. Many people believe that a bilge pump labeled "2000" can be relied on to pump 2,000 gallons (7,571 liters) of water per hour from a leaking boat. Nothing could be further from the truth. The majority of bilge pump systems are hamstrung by design and installation faults that diminish a pump's output by as much as 75%, so even under ideal circumstances it is incapable of keeping up with an inrush of seawater from a minor hull breach, much less catastrophic flooding.

Below is an excerpt from a letter from a client whose boat was nearly lost because of a small leak caused by a failed ⅜″ (9.5mm) stuffing-box injection hose, and the bilge pump's inability to keep up with this comparatively miniscule ingress of seawater:

The sound of the engine changed slightly, which made me glance at the instruments. The tachometer needle rested at the zero mark, and the voltmeter showed about 11 volts. I slowed to an idle, handed the helm to a shipmate, and went below to check the engine. When I opened the compartment it was as humid and foggy as a London street, and a faint smell of burning electrical components permeated the air. There was obviously a leak. I could see that water had risen to the level of the engine's crankshaft pulley and flywheel and was being slung everywhere, including onto the alternator, apparently killing its charge capability and the tachometer output along with it. I suppose it's a good thing the tach died; otherwise I

Ganged centrifugal pumps are an option for high-volume pumping. Often called crash pumps, these units are designed to deal with catastrophic flooding. Install multiple lower-volume pumps in multiple bilge compartments to meet the typical pumping-capacity demands on most boats.

wouldn't have known about the leak and the bilge pump's failure to keep up with it.... I made it to the dock and a haulout. How do I prevent this from happening again, and why didn't my bilge pump work properly, and why didn't my high-water alarm alert me to the impending emergency?

Many boats are seriously under-pumped, and the industry should take steps to improve flawed systems while designing new ones that take maximum advantage of each pump's rated capacity.

Although standard bilge-pump installations are commonly thought of as the first line of defense against catastrophic flooding, most are designed for only incidental water removal—rain, the occasional wave over the gunwale, extremely small leaks—and no more than this should be expected of them. If a boat owner wants more, you must be prepared to explain the difference between incidental and catastrophic water removal, and to design and install either system effectively.

The Mathematics of Flooding

Consider these sobering figures from the 2000 edition of the *U.S. Navy Salvor's Handbook.* A 1″ hole 1′ (25mm, 305mm) below the waterline will admit 1,200 gph (4,542 lph) or more than 5 *tons* of water; a 3″ 76mm) hole 1′ below the waterline will admit 10,620 gph (4,201 lph); a 1″ hole 3′ (914mm) below the waterline will admit 2,040 gph (7,722 lph); and a 3″ hole 3′ below the waterline will admit 18,360 gph (69,500 lph).

To run different scenarios for any size hole at any depth below the waterline, the formula is:

$$Q = CA\sqrt{H}$$

where:
Q = flow rate
C = 8 to measure flow in cu ft; 3,600 to measure flow rate in gph
A = hole area in sq ft (or any fraction thereof)
H = the depth of the center of the hole below the surface.

It's clear that even with the best pump installations, which virtually never exist aboard any boat, most electric bilge pumps would have trouble keeping pace with flooding from even the smallest hole.

Pump Options

Electric bilge pumps fall into three basic categories: rubber impeller, diaphragm, and centrifugal. The *rubber-impeller pump*—the same type, albeit electrically rather than mechanically driven, employed to supply raw water to an engine or generator—is self-priming but otherwise has few positive attributes as a bilge pump. Its problem is that it doesn't cope well with running dry for more than a minute or two. American Boat & Yacht Council (ABYC) standards require bilge pumps to withstand dry running for seven hours without creating a fire hazard. Note that this requirement applies to the electric portion of the pump, so while it's possible an impeller pump could run dry for this long without catching fire, after just a few minutes it won't be of much use as a pump.

Despite their rubber components, *diaphragm pumps*, are much more resilient. The most familiar variety comprises an exposed crankshaft and connecting rod actuating a flexible diaphragm. The reciprocating motion of the diaphragm, coupled with two built-in check valves, creates suction, making the pump self-priming. The

***Top**—A sturdy diaphragm pump is self-priming and nonsubmersible but has limited capacity.*
***Bottom**—Rubber-impeller pumps and diaphragm pumps are susceptible to clogging with debris from the bilge. The solution is an in-line strainer, shown here, between the bilge pickup and the pump.*

drawback with diaphragm bilge pumps is their pitifully small capacity. The largest diaphragm pump in a marine supply catalog on my bookshelf will pump a mere 600 gph (2,271 lph), and it costs over $500.

Neither the impeller nor diaphragm pump is submersible; both must be installed well above bilgewater level, or any other water accumulation or exposure. In addition, both types are prone to debris-induced clogging or failure. When applied for bilge dewatering, both pumps must be equipped with an in-line strainer or screen, which if clogged, will diminish or stop flow altogether. If debris makes its way to the pumps, it's likely to have the same effect. I've seen diaphragm pumps fail as a result of ingesting a single fingernail clipping.

Centrifugal pumps are by far the most familiar and effective for bilgewater removal. They operate by spinning a rigid impeller in a chamber, drawing water into its center, and slinging it out the sides, where it is then channeled into a hose. This type of pump is submersible. Indeed, because it won't pump air, it won't work *unless* its base is submerged, and its intake will still suck air unless it is at least half an inch (13mm) below the water level, or deeper for more-powerful pumps. Being submerged raises the importance of the pump's watertight integrity, especially where electrical wires enter the pump housing.

Centrifugal pumps can be further delineated into small and large varieties. Because most of these pumps with a rated capacity less than approximately 1,000 gph (3,785 lph) are smaller, their impellers are slightly closer to the bottom of the bilge. The practical effect is that these smaller pumps are typically capable of drawing water to a lower level than the larger pumps. The smaller pumps can't move bilgewater as quickly, but in *most* cases that's not the issue. Keeping the bilge as dry as possible reduces odors and corrosion, so less water sloshing around is always desirable. But you don't necessarily have to sacrifice overall pumping capacity for a drier bilge. Many systems include a small "drying" pump as well as a larger high-capacity pump triggered only when the small pump can't keep up with the demand or if it fails.

For many boats shorter than 65′ (19.8m) the submersible centrifugal pump represents the highest-capacity, most-reliable, and most-efficient method of removing bilgewater, and offers the most pumping capacity for the dollar. A 2,000-gph pump costs about $100.

Efficiency

Regardless of the type of pump, a variety of factors influence its efficiency. Note that for the sake of consistency and comparability, most bilge pump manufacturers rate and brand their pumps in what's known as open-flow capacity. That means the pump's volumetric rating is in a condition with no hose and with no lift to discharge. Most provide additional pumping capacities based on so-called heads (more on this term later) of 3.3′ and 6.7′ (1m and 2m). The difference, however, may not be clear to those simply seeking the highest-"rated" capacity pump. It's important to realize that a pump whose advertised 2,000-gph capacity, which would theoretically keep pace with flooding from that 1″ hole 3′ below the waterline, will probably fail to keep the boat afloat.

To make matters worse, inefficiencies must also be factored in. *Static head*, or the highest point to which the water must be raised in the hose run between the bilge and the discharge, is among the most significant. Note that in many installations the pump's outlet hose rises *above* the discharge, either by necessity or by default.

Taking a common pump with open-flow rating of 2,000 gph as an example, if the distance between the pump and the highest point in the hose run is 3.5′ (1.1m), the pump's revised flow is just 1,620 gph (6,132 lph), a 20% decrease in capacity. If the head is increased to 6.7′ (2m), the pump's output drops to 1,300 gph (4,921 lph), and neither calculation includes resistance imparted by hose length or turns, flow rate, pipe fittings, and valves, collectively referred to as *dynamic head*. Add them to the static head and it's not unusual to find the output reduced by half or, in some cases, almost completely.

For all submersible centrifugal pumps, there's a maximum head against which they'll pump. Exceed it and they simply no longer work. Insidiously, this often won't happen until the voltage drops slightly, and under these conditions the pump will run and sound as if it's pumping. It won't trip a circuit breaker or blow a fuse but will simply spin without removing any water. I've seen such undersized pumps on several boats, some of them *fresh from the factory*. Just because a pump installation is new, or installed on a new boat, don't assume it's correct.

Calculating dynamic head is a bit more challenging than its static counterpart. A Google search of "total dynamic head" yields a variety of resources for determining head losses caused by pipe/hose friction, fittings, valves, et cetera. To the best of my knowledge, there is no single source to

Left—*A classic centrifugal bilge pump is fully submersible, tolerant of some debris, and can move a significant volume of water.* ***Above***—*A low-profile, lower-volume centrifugal pump is a good option to serve as a so-called drying pump that keeps the bilge as dry as possible.*

Hard turns—such as this 90° angle coupled to a plumbing reducer in the discharge hose—and check valve friction are components of the accumulated dynamic head; these should be added to the static head (the maximum height the water must be pumped to) to calculate the size of pump required to effectively remove water from a bilge.

refer to for these calculations based on typical materials and equipment in small-boat applications.

If you care to do the research and mathematics, all hose, pipe, 90° and 45° bends, sweeps, and valve-friction losses are simply converted to additional head, which can be added to static head and the total compared to pump output versus head graphs available from most pump manufacturers.

For a practical test of an existing system, you must determine the time required to pump a known quantity of water from a bilge. Do this by allowing the bilge pump to pump the bilge as dry as it can; turn the pump off; pour a known quantity of water, say, a few 5-gal (19 l) bucketfuls (or more, depending on the size and configuration of the bilge) into the bilge; turn the pump on; and time how long it takes the pump to remove the water. (Make note of the voltage available to the pump during this test as well.) Simple arithmetic will reveal the actual pump capacity in gph (or lph).

Carry out this analysis periodically to ensure pumps are working properly, ideally annually, especially for offshore vessels, and to identify any reduction in flow from test to test. Only one thing, the float switch circuit, is tested by lifting a float switch and confirming the pump turns on; it does not prove that a pump will evacuate water from a bilge.

Pump Size

As discussed earlier, even large pumps will have difficulty keeping up with catastrophic downflooding in a holed vessel. In a flooding emergency, the crew's primary mission is to stop the leak. A good bilge pump system may buy some time to accomplish this, but pumps are primarily for removing water once the flow has been halted, not for holding back the sea. Make sure every vessel's damage-control kit is well stocked and easily accessible, because hitting something may be unavoidable.

My rule of thumb calls for a bare minimum of 100-gph (379-lph) pump capacity for every 10′ (3m) of overall boat length, rounding up to the nearest 10. Therefore, a 38′ (11.6m) boat should have *at least* 4,000 gph (15,142 lph) of bilge-pumping capacity to contend with a normal accumulation of bilgewater, or a small leak, particularly if it's handicapped by excessive head or resistance, as so many installations are. *This figure should be doubled or even tripled* to prepare a boat operator to deal with a serious leak by giving the crew precious minutes to slow the flooding. I recently inspected a 45′ (13.7m) offshore passagemaking vessel equipped with just two 600-gph (2,271-lph) diaphragm pumps, a sobering revelation.

The number of bilge pumps is as important as their collective capacity. If, using the formula on page **xx**, you installed a single 4,000-gph (15,142-lph) pump in the bilge beneath the V-berth, you'd meet the requirement. However, if a 2″ (51mm) propeller shaft separated from the transmission coupling and went spinning out of the stuffing box as the vessel was backed into a slip, and the resulting hole was 3′ below the waterline, it would admit 136 gallons per minute (8,160 gph, or 515 lpm/30,900 lph). The pump could deal with only half the incoming water under perfect operating conditions, and its extreme forward location would offer additional challenges, as the leaking water would drag the stern down, and water flowing forward to the pump would likely be impeded by bulkheads, stringers, and small limber holes. The preferred distribution of pumping capacity would be for multiple pumps, say, two 2,000-gph (7,571 lph) models, with at least one in each compartment. Small "drying" pumps, if present, should be excluded from this calculation and treated as a reserve capacity.

I'm asked frequently about the option of employing the engine as an emergency bilge pump. Via an engineroom selector valve, this arrangement enables the engine's own raw-water pump to draw from a bilge pickup. Pumps on moderately sized marine diesel engines move a compelling 3,600 gph (13,627 lph) at "high" rpm. The logic is that the vessel has this pump moving a significant volume of water already, so why not use it to save the boat in the event of a down-flooding scenario? Here's why not:

In a flooding emergency the crew's best allies are a running engine (it may be moving the vessel closer to help or a beach) and a fully charged

Employing the engine's own raw-water pump as an alternative to a conventional bilge pump is a controversial practice. While the volume of water that can be removed from the bilge may be appreciable, the risks of impeller fouling and consequent engine failure are equally high.

Detritus in the bilge is one of the chief causes of bilge pump failure. While this pump is unlikely to burn out if the intake is fouled, it is quite possible that flow could be reduced to the point that the unit can no longer remove water from the boat.

battery bank, which is remaining charged thanks to the engine-driven alternator; this in turn enables the electric pumps to operate at full capacity. If the engine is allowed to draw water from the bilge and it loses prime, gets clogged from the inevitable flooding-induced debris, or sucks air, the rubber impeller will melt very quickly, and the exhaust system will overheat and possibly fail long before the engine-temperature alarm sounds. The only way to avoid this is to station a crew member in the engine compartment to switch the valve back to seawater intake should the bilge intake stop drawing water, a job for which few would readily volunteer aboard a sinking vessel.

Instead of potentially handicapping a vessel with such an arrangement, I recommend installing an independent, high-capacity, submersible, centrifugal electric bilge pump. Some off-the-shelf models have a capacity of 8,000 gph (30,283 lph).

Installation

Whatever pump you choose, a proper manufacturer and ABYC-compliant installation is key to the reliability and efficiency of the system, starting at the pump intake and electrical connections and ending at the overboard discharge.

Pumps should be installed as low in the bilge as possible. Many builders conveniently provide a prepared pad for pump installation, but it's not always in the lowest section of a bilge compartment when the vessel is afloat. Avoid screwing the pump's base plate directly to the hull. I've seen more than one hole drilled through the bottom of a boat by an installer who misjudged its thickness. The pump should rest on a perfectly flat, not necessarily level (although that's ideal), surface to prevent the base from distorting when it's fastened in place. Distortion of the base is the primary cause of pumps breaking free of their mounts and drifting around the bilge. If there's no properly placed base pad, and a remote L bracket cannot be installed, a custom pad can be epoxied in place. Avoid wood for this component. I prefer a solid fiberglass laminate product such as GPO-3. Make it as thin as possible to avoid elevating the pump any more than necessary, while still offering enough material for fasteners to engage.

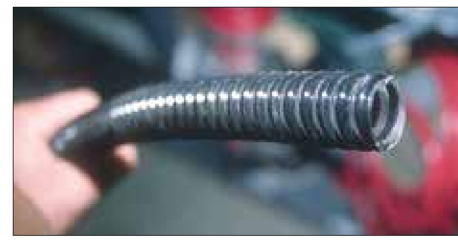
The pump should be affixed as low as possible in the bilge, to a flat surface that doesn't distort the pump's base. The L-bracket supporting this 24V model includes space for the float switch as well.

Next, choose the hose wisely. The familiar black or white corrugated-plastic bilge-pump hose is too delicate for service aboard seagoing vessels, and the corrugated interior has a propensity to trap debris and increase resistance. Ideally, bilge-pump hose should be kink resistant, able to withstand being stepped on without crushing or damage, and be specifically designed and rated for below-the-waterline applications. Several manufacturers offer dedicated bilge-pump and livewell hose that meets these criteria.

The hose run between the pump and the overboard discharge should be as short and straight as possible to limit resistance and avoid dips that will trap water and act as air locks, preventing the pump from priming. Ideally, the hose path from the pump to the discharge or riser (more on those below) should be a continuous uphill run.

Do not install a hose and fitting of a diameter smaller than the outlet size of the pump. Many pump outlets require 1⅛″-inside-diameter (29mm) hose. Avoid the more common 1″ hose, particularly if 1⅛″ hose and fittings are available for the installation. The 1⅛″ components were once difficult if not impossible to find; that's no longer the case, although you may need to search a bit harder for them.

The through-hull discharge should be located above the maximum heeled waterline and never below the resting waterline. Pump manufacturers



This ideal bilge pump hose is smooth walled as well as crush and kink resistant. Standard corrugated-plastic bilge-pump hose is too delicate for service on a seagoing vessel, and its rough interior surface traps debris and increases flow resistance.

Bilge pump discharge plumbing should be as short and direct as possible. If the discharge is below the heeled waterline, then an antisiphon valve must be included. While the riser loops in this installation will prevent down-flooding, they will not prevent a siphon. Also, pump discharges should never be paralleled to share a through-hull as they are here.

typically call for the discharge to be installed a minimum of 12″ (305mm) above the waterline. For powerboats, the maximum heeled waterline is described when a vessel is heeled 7°; for sailboats the demarcation is heeling to the toerail; any fittings submerged on the low side under these conditions are considered below the waterline. If you can't avoid installing the discharge in this location, then the plumbing *must* include a riser, which is simply a hose loop that runs well above the *heeled* waterline and is fitted with an anti-siphon device. Note that a check valve is *not* considered an antisiphon device and is expressly prohibited for this use under ABYC standards.

An acceptable antisiphon device admits air into the bilge-pump discharge hose whenever a vacuum is present, effectively preventing establishment of a siphon. A variety of antisiphon valves, sometimes called siphon breaks or vented loops, are commercially available. Choose one that incorporates a replaceable or serviceable/cleanable valve assembly—either a small rubber flap or spring-loaded ball—that allows air to enter while preventing water from leaking out. These valves are prone to salt or debris encrustation and should be serviced at least annually, so ensure that they are installed in accessible locations. Provide a diagram or map in new and refit vessels, and for single installations, brief the owner on the location and service requirements of the valve. Additionally, resist the temptation to add hoses to the vents to direct leaks safely to bilges. If those hoses become clogged or kinked, the antisiphon valves will no longer function as intended. I've seen this happen, and it led to flooding a new engine and a new generator. If the valve leaks, it needs to be serviced, period.

Pumping water from one compartment

to another before discharging it is a plumbing error that limits the boat's pumping capacity to just one pump. Likewise, plumbing multiple pump outputs to a single manifold is undesirable if the manifold cannot prevent backflooding and cannot support the full capacity of all pumps operating simultaneously.

Ideally, each pump should be plumbed to its own overboard discharge hose, vented loop, and seacock if warranted. More stringent than current ABYC requirements, my preference is for installing a seacock on *every* hull penetration below the heeled waterline.

Wiring

Electrical faults and flaws offer the greatest opportunity for a bilge pump failure. Misunderstanding the electrical demands of a bilge pump can start even before you remove the unit from its box. In the same way pumps are rated at open-flow, with no head or hose resistance, they are also rated at so-called design voltage, or 113% of nominal voltage. This means the output of 12V and 24V pumps are rated at 13.6V and 27.2V, respectively. So unless a charge source is feeding into the system during operation, the output of the pump will be less than its maximum rated flow. While nearly all pump manufacturers follow this protocol, it's important to apply the degradation when calculating overall vessel pump capacity. Using a 2,000-gph pump as an example, with an open-flow and 13.6V, the capacity is 2,000 gph. However, when the voltage is reduced to 12V, a likely level if several pumps are running simultaneously and the engine or generator is not, the output drops to 1,700 gph (6,435 gph). Now add 6.5′ (2m) of static head, and the output drops to 1,160 gph (4,391 lph).

Ideally, the voltage drop imparted by bilge pump wiring should not exceed 3%. As the distance between the pump and the power source increases, so too must the wire size. The wiring for this high-volume 12V crash pump reflects that standard.

Additional voltage drops due to incorrect wire size and fuse or circuit breaker selection can significantly impair a pump's operation. Here's an example from a boat I inspected a few years ago.

The 12V pump was located in the engineroom about 25′ (7.6m) from the power source at the electrical panel. Electrical-resistance calculations require the round trip distance, so now we have 50′ (15.2m) of wire.

High-quality bilge pumps are manufactured with leads long enough so installers can make connections well above ordinary and high-bilgewater levels. This pump's leads are over 60" (1.5m), which is ideal. The common practice of coiling up such ample leads and installing them adjacent to the pump leaves the pump needlessly vulnerable.

Consult the table in the ABYC standards or any marine electrical book to determine the voltage drop. (Voltage drop calculation for a bilge pump should be no more than 10%, but preferably 3%.) In the voltage drop table, a 50′ run at 12V and 15 amps requires a pair of #6 wires to achieve a 3% voltage drop. These large wires are rarely seen in a bilge pump installation even though they would support optimal pump performance. A less-desirable but acceptable 10% voltage drop (13.6V falls to 12.24V) could be achieved with #10 wire. The wire that had been installed was #14, which no doubt accounted for substantially reduced voltage (roughly a 20% drop to 10.88V available at the pump).

Start-up load is another important electrical factor to take into account. When a pump or any electric motor first starts, it draws more current—known as inrush or start-up load—than when it's running in what's know as a steady-state. It's one reason the fuse or circuit breaker value is specified as larger than the constant load of the pump. If jammed or clogged with debris, the pump is in a state of suspended inrush or start-up, and the current draw remains high indefinitely. This is another reason for sizing wiring conservatively so it is fully capable of supplying full locked-rotor current, which in turn will trip the breaker or blow the fuse. If the wire is undersized, it's more likely that insufficient amperage will reach the pump to cause the fuse or breaker to trip, which in turn may cause the pump to overheat and possibly catch fire. Note that pumps in compliance with current ABYC standards must include a means by which power is shut off in the event of overheating, regardless of the cause. To meet the same ABYC guidelines, bilge pumps must be capable of running continuously for 24 hours at their design voltage.

Other considerations include connections, terminations, wire routing, fuses, and circuit breakers. Most submersible pumps are available with wire leads long enough (6′/1.8m) that electrical connections may be made well above even maximum bilgewater levels. Despite that, I routinely see long pump leads and their vulnerable butt-splice connections coiled up a few inches above the pump. The best protection from water compromising

It's important that all wiring connections to pumps and switches be kept well clear of water that may accumulate in the bilge. ***Left—****At less than 12" (305mm) above the bilge pump, this terminal strip is vulnerable to corrosion and short circuits.* ***Right—****This pump's crimp connections are not waterproof and have been made incorrectly, allowing them to be separated with just a light tug. Bilge pump wiring must be robust, with connections located well above bilgewater or completely waterproofed.*

electrical connections is to locate the connections as high as possible and to rely on waterproof connectors only as secondary protection.

A tinned-copper terminal strip with an insulating cover installed 4′ to 5′ (1.2m to 1.5m) above the bilge and then coated with corrosion inhibitor makes low-resistance connections secure yet accessible for inspection and testing. If this arrangement isn't feasible, connections must be made as watertight as possible. Regardless of location, conductors should be coated with a conductive paste such as Thomas & Betts Kopr-Shield prior to installing crimp connectors. Connections should be made with high-quality heat-shrink tubing. When applying heat, be certain the resin completely encapsulates the wiring as it exits the tubing ends, and use caution when crimping such terminals, as overly aggressive dies can pierce heat-shrink insulation. Inspect the insulation carefully after heating, looking for areas that have been

Appropriately sized circuit breakers that meet the pump manufacturer's specifications for over-current protection should be equipped with locks to prevent inadvertent disconnection when someone brushes by the panel.

pierced (see the photo on page **xx**). Secure all connections as far above bilgewater as possible.

Secure wiring leading from the pump in such a way that it does not bridge any "air gaps," meaning, it shouldn't pass through space between the pump and a bulkhead or stringer. Wiring should be continuously supported and secured at least every 18″ (457mm) with wire ties or P clips. If the wires pass over moving machinery such as shafts or belts, secure them with metallic rather than plastic clips. (For more on bilge pump wiring, see "Wet-Wiring Autopsy," *Professional BoatBuilder* No. 143, page 22.)

My preference is to supply bilge pumps with power independent of the vessel's house battery switch and distribution panel's main circuit breaker. With pumps wired in this manner, a vessel can be left with nearly all its DC circuits de-energized (the safest approach for fire prevention) and its pumps operational. Accomplish this by either 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. In either case, every conductor must have over-current protection—an appropriately sized fuse or circuit breaker (I'd choose breakers, provided they are equipped with locks to prevent inadvertent disconnection) that meets the pump manufacturer's guidelines. The fuse or breaker must also protect the wire that supplies the pump, but if the wire is sized for no more than a 10% voltage drop, and the pump-manufacturer-specified fuse/breaker is in place, the protection will almost certainly be adequate.

Switches

Even the largest bilge pump will be of little use if it can't be reliably turned on and off automatically and manually. Manual switches should be rugged and reliable, and conveniently located at the helm or electrical panel. Avoid spring-loaded momentary-on switches for manual activation. If your automatic float switch fails during a flooding scenario, you don't want a crew member to be stuck holding this switch. Instead, go with a positive on–off switch, and wire the automatic portion of the pump circuit so it is *always* energized via the pump's fuse or circuit breaker. This makes it virtually impossible to forget to leave the pump in automatic mode. I often see pumps that have been inadvertently switched off, leaving the vessel unprotected from even the smallest leaks. Perhaps the most critical aspect in selecting a switch is its ampacity. Switch and wiring must be capable of accommodating the pump's steady-state and locked-rotor ampere draw. Under no circumstances should a switch's ampacity be less than the over-current protection serving the circuit.

For automatic float switches located in the bilge adjacent to a pump, I prefer the potted reed type. In my experience with hundreds of these switches, they've proven exceptionally reliable. Among other options and features, they offer extended hysteresis, or differential—the vertical distance in water height between when the switch activates and deactivates the pump. An extended hysteresis can obviate the need for a check valve where long discharge lines and small bilge wells cause excessive pump cycling. The only real weaknesses of these switches are that oil from a fouled bilge may enter the switch cylinder and prevent it from rising or falling, and they are difficult to test, the most reliable way being to fill the bilge with water.

Like the manual switch, any float switch must be capable of carrying the steady-state and locked-rotor loads of the pump. If the pump manufacturer calls for a 15-amp fuse, the float switch must be rated for this load, continuously.

Always wire a float switch into the positive side of the pump's circuit. If the negative leg is switched, the inside of the pump remains positively energized at all times, which means the smallest breakdown in insulation, or carbon arcing inside the pump housing, could allow electricity to leak through the pump's shaft into bilgewater, where it will cause stray-current corrosion in immersed metals

Most off-the-shelf bilge pump switches that incorporate an indicator light and fuse holder have one drawback: the manual on position is spring-loaded. If a float switch fails, this arrangement requires the user to hold the switch in the on position to operate the pump.

A shallow bilge can be challenging for many centrifugal pumps. Even when functioning as designed, they can leave enough water behind to cause odors and accelerate corrosion. For more effective water removal, employ a drying pump.

such as seacocks and shaftlogs.

For many years the most common automatic bilge-pump switch looked vaguely like a hinged paddle. Inside the switch was small drop of electrically conductive mercury. As the paddle floated upward, the mercury rolled back into a set of contacts, activating the pump. Because mercury is an environmental hazard, these switches are no longer manufactured, but many are still out there. When you encounter one, beware of the mercury. If the paddle is crushed, the mercury could escape, presenting a health risk to anyone aboard. Also, aluminum hulls and steel hulls can corrode, as they are less noble than mercury.

Alarms and Counters

When a bilge pump runs, those on board should be alerted to its operation. The most common alert is a console light readily visible from the helm. Whenever a bilge pump operates, regardless of whether it's been manually or automatically activated, the light illuminates. With this arrangement, if a bilge pump runs erratically, cycling on every few minutes while under way for instance, the crew will know the bilge needs to be checked. This simple warning light is inexpensive, effective, and required under ABYC standards.

The second method of monitoring bilge pump activity is by a counter. The simplest is a mechanical counter that rolls up one number every time the pump cycles on. If, when leaving the boat, you set it to zero by pushing a small lever, when you return you'll

Left—*All the electrical components in the bilge pump system—manual and float switches, as well as wiring—must be capable of supporting the maximum anticipated current load. This float switch overheated because it was not appropriately over-current protected and/or because it was undersized for the load the pump put on it.* ***Right***—*A simple bilge counter tallies the number of times a pump cycles on. More-sophisticated models will record the duration of each run cycle as well.*

see how many times the pump cycled. The drawback is that it doesn't tell you how long each cycle lasted. If the pump ran continuously since you left the boat, the counter would read 1. More-sophisticated digital electronic counters can, among other things, monitor multiple pumps and record how many times each one ran and for how long. They are a worthwhile addition to any bilge pump system.

I consider bilge alarms to be as vital as the bilge pumps themselves. In its simplest form, such an alarm is a bell or buzzer connected to a float switch. When water rises high enough to trigger the switch, the alarm sounds. More-sophisticated systems monitor multiple bilge compartments; some include their own power supply; and others can call or text-message an owner or caretaker if bilgewater reaches a critical level. The cost of the latter has dropped significantly in recent years, making them attractive for smaller vessels.

As with the electrical bilge pump, the wiring for a bilge alarm must be virtually failure proof. All connections should be made well above maximum bilgewater level and/or be thoroughly waterproofed. The switch, regardless of variety, should be well secured and protected from being hit by feet, gear, and tools. Placement is critical. Install the switch as vertically close as

This audible high-water alarm has LED indicators that specify which bilge has been flooded.

The input for a bilge alarm comes from a standard float switch installed no more than 2" (51mm) above the switch for the bilge pump, so that an operator will be alerted to a pump system failure as soon as possible. By the time the switch shown here is triggered, vital gear may already be submerged.

possible to the conventional bilge-pump float switch without triggering false alarms, meaning 2″ above is preferable to 2′. If the bilge pumps stop working or can't keep up with a torrent, it's best to know about it as quickly as possible.

An audible alarm should be loud enough to be heard over any other operating equipment such as engines, stereo, and television, and it should awaken even the soundest sleeper. Boat owners have asked me to install loud hailer alarms and/or strobes on the weather decks, so that if the bilges flood while the vessel is unattended, there's a chance others will notice. These devices make good sense.

Testing

High-water alarms and bilge pumps should be tested upon installation and seasonally, or at least annually, thereafter. Testing does not mean just lifting the float switch. Filling the bilge with water until bilge-pump float switches activate and pumps evacuate water overboard will reveal whether the system works properly. It also lets the boat operator judge how long it will take to pump out a flooded bilge. In a similar manner, high-water alarms should be tested after disabling the bilge pumps and allowing water to reach the alarm switch. The alarm should sound long before water reaches critical mechanical or electrical equipment.

As thorough as your understanding and approach might be, no bilge pump system is 100% effective or reliable; there's always a way to make it fail. I recall salvaging a small powerboat that had been partially flooded from 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 until I noticed a pencil stuck in the float switch, jamming it in the off position. Why it hadn't floated free of the switch remains a mystery, but it was a reminder 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 boats; in the vast majority of new ones I inspect, the bilges are seriously contaminated with what I call new-boat detritus: fiberglass shards, wood chips, wire ties (I've seen single wire-tie clippings stop a 2,000-gph centrifugal pump), crimp connectors, screws, and wire trimmings, all of which ultimately clog bilge pumps.

Bilge pumps are not designed to deal with the trash, dirt, or hair that can accumulate in bilges. A pump may also be fouled by new-boat detritus: fiberglass shards, wood chips, wire-ties, screws, foam, and wire insulation trimmings. The need for clean bilges is about more than just good housekeeping.

When properly designed, installed, and maintained, bilge pump systems are reliable and effective. Scrutinize installations for the common faults mentioned above, and ensure that your shop installs pumps according to manufacturers' and ABYC guidelines.

Also, by encouraging owners to keep the bilge clean and regularly inspect and maintain the system, including antisiphon valves, they, and you, will have few worries about this vital system. PBB

About the Author: *For many years a full-service yard manager, Steve now works with boat builders and owners and others in the industry as "Steve D'Antonio Marine Consulting." He is the technical editor of* Professional BoatBuilder*, and is writing a book on marine systems, to be published by McGraw-Hill/International Marine.*