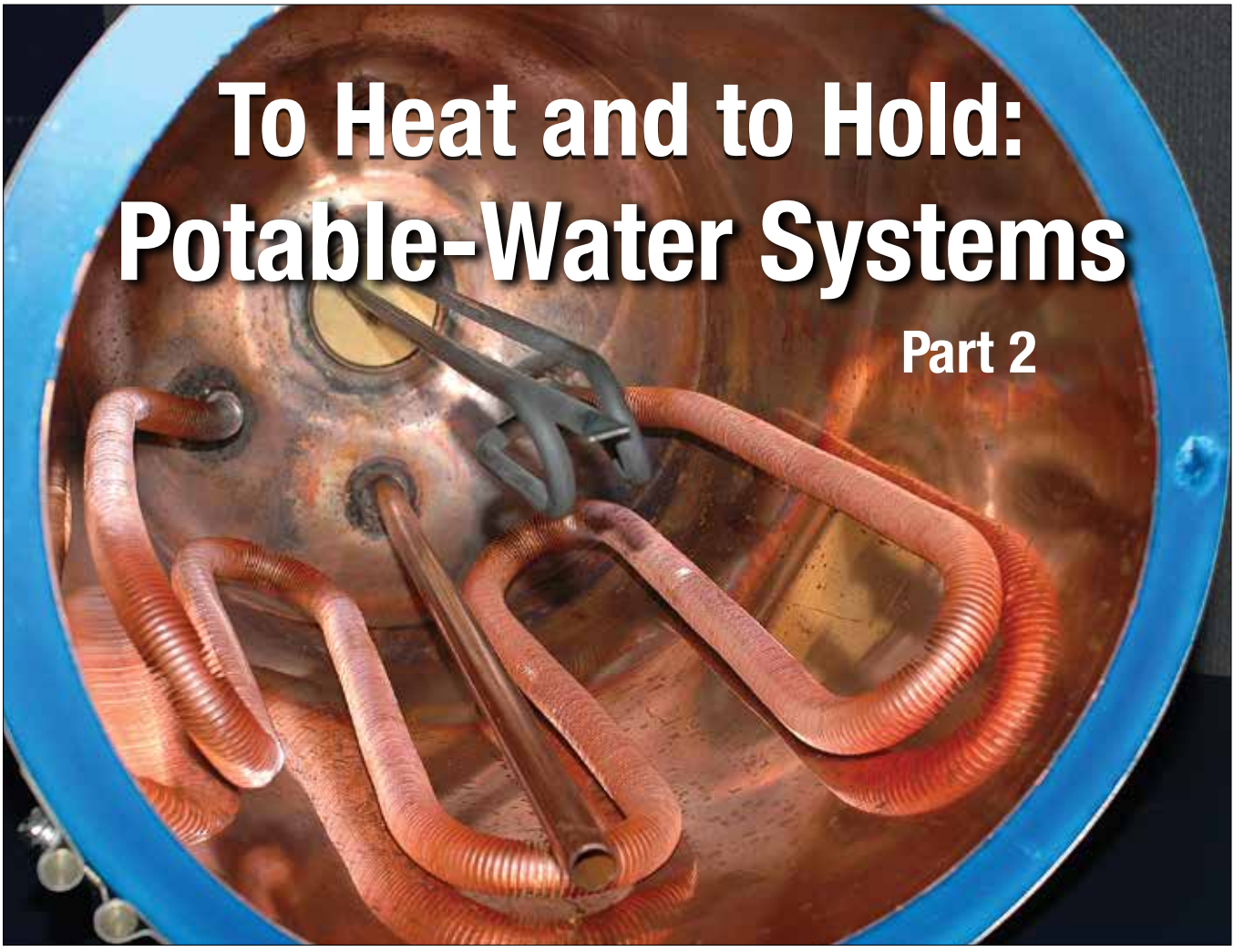

To Heat and to Hold: Potable-Water Systems

Part 2

Choosing materials and following design guidelines go a long way toward assuring the safety and effectiveness of a hot-water system. The second of our two-part series also includes tips for installing potable-water tanks.

Text and photographs by Steve D'Antonio

What is "hot" water? In my research, the difference between a hot shower and a chilly one is just a few degrees. In round numbers, 105°F (41°C) is roughly the demarcation. Showers below this temperature will be short.

If 105°F is just hot enough, how hot is too hot? Most domestic-water-heater thermostats are set between 120°F and 130°F (49°C and 54°C), which is considered below the region for *rapid* scald potential; i.e., there's time to jump out of the shower before being burned. However, it's vitally important to remember that most marine water heaters make hot water using the engine's hot coolant (or seawater for open systems) as well as an electric heating element. There is typically no thermostatic control other than the engine's own thermostat, which could be anywhere between 165°F and 205°F (74°C and 96°C). If a water heater is close to the engine, water may become heated to these high temperatures, particularly on a long passage. That's well within the region capable of immediate scalding, especially children and older people. Use extreme caution and consider installing an external mixing valve (more on this later) or anti-scald faucets, especially if children are aboard. Also note that extremely hot water often exceeds the rated capacities of nonmetallic plumbing (polyethylene, PVC, etc.), leading to dramatic and dangerous failures.

***Above**—Copper's only disadvantage for water heaters is its expense. It's naturally resistant to corrosion, and a copper tank, like this one from U.K. manufacturer Surejust, acts as a natural biocide. The finned-copper heat exchanger improves efficiency.*

While making hot water is the primary task of a water heater, making it quickly is nearly as important. Taking too long can be maddening, particularly if the sink is full of dirty dishes or people need showers. Recovery rate is a measure of a water heater's ability to generate hot water with a constant source of heat. For the two heating sources—the engine's cooling circuit and electric heating elements—there are often wide disparities between manufacturers. If 240VAC is available aboard, it makes sense to specify a 240V water heater element. However, while higher wattage elements heat water more quickly, these can also overload shoreside circuit breakers, particularly when several boats share the same circuit. A 750-watt heating element will draw about 6 amps at 120V, while a 1,500-watt element will draw 12.5 amps; the latter will heat water faster but will consume nearly half of a 30-amp shore service and dock breaker's capacity.

A heat exchanger, based on the same principle as the engine's closed cooling system, supplies heat from the engine's cooling circuit to the water heater's domestic water with the two fluids never mixing. A large, well-designed heat exchanger efficiently employs conductive metal alloys to transfer heat—the more surface area the better. Smaller, poorly designed units are slower, requiring more engine run time before water gets hot. When considering a heat exchanger, be aware that "safer," double-wall units are less likely to leak coolant into the water heater's potable circuit (these will weep coolant externally in the event of a failure, giving a warning that something is amiss). However, the air between the inner and outer walls considerably reduces efficiency.

In my experience, heat exchanger leaks are rare, and you get what you pay for: I've never seen a high-quality, name-brand water heater suffer a heat exchanger leak. On the other hand, I have seen a cheaply made one leak. Regardless of how unusual such leaks may be, pay attention to customer reports of water that has an unusual chemical odor or taste. If it bears the slightest hint of coolant (its smell and taste are somewhat sweet), pressure-test the system immediately and ensure that no one uses the water until the problem is resolved.

***Above**—Hot domestic water can cause serious burns, particularly if thermostats are set incorrectly, or if water is heated by engine coolant. In the latter case, mixing valves and anti-scald faucets can prevent dangerously hot water at the tap. **Right**—This infrared pyrometer is measuring the temperature of coolant as it enters a water heater.*

Water Heater Materials

The materials that make up a water heater can tell you a great deal about its performance and longevity. Choices for the inner pressure tank include glass-lined steel (similar to baked-on enamel), aluminum, copper, and stainless steel 304 or 316.

Glass-lined steel, in most household water heaters, is extremely popular and relatively inexpensive to manufacture. The problem arises when the glass lining separates from the steel substrate, as it eventually will, usually around the orifices for the inlet, outlet, heat exchanger, and electric heating element. Once water reaches the steel tank, rust quickly sets in, contaminating the water and, over time, corroding the tank. It's not uncommon, however, for glass-lined steel tanks to last a decade or more. With the wide range of quality in glass-lined tanks, the duration of the warranty is often a good indicator of how long a unit may last. To reduce corrosion, steel tanks are usually

Water heaters equipped with heat exchangers can transfer waste heat from the engine to the water heater via the coolant. If installed near the engine, these units may deliver dangerously hot domestic water.

equipped with a magnesium anode, which must be accessible for periodic inspection and replacement. Many installations I encounter impede access, at best, and some anodes are impossible to reach without completely removing the water heater.

Aluminum is not an ideal material for water-heater-tank construction (I also specifically recommend against aluminum for potable-water tanks; see the sidebar on page **xx**). Aluminum-tank water heaters don't require a glass lining, because the aluminum develops a natural oxide anticorrosive layer, much like unpainted aluminum hardware and vessels. Most manufacturers who offer these heaters make the warranty contingent upon the installation of a galvanic isolator, suggesting a sensitivity to corrosion; manufacturers of water heaters whose tanks are not aluminum have no such caveat. If the vessel is equipped with one of these water heaters but no galvanic isolator, then the warranty may be void. While galvanic isolators are a valuable addition to any AC electrical system, it's debatable whether they are capable of preventing corrosion of aluminum water-heater tanks.

Galvanic isolator issues aside, aluminum can have major drawbacks. Minerals in shore-water supplies (particularly those derived from well water) as well as even the minutest amount of copper from plumbing fittings can play galvanic havoc with aluminum tanks. Also, water from reverse osmosis, bereft of minerals and therefore slightly acidic, adversely affects aluminum water tanks. In any of these scenarios, the result may be a holed or contaminated tank.

Water heaters are available in a wide variety of materials and sizes, from large to compact units like the one here with a 316 stainless steel case and tank. Other common tank materials include 304 stainless steel, copper, glass-lined steel, and aluminum.

While not especially common, copper-tank water heaters offer several benefits. Copper is naturally corrosion-resistant and a natural biocide, minimizing the likelihood of bacterial growth within the water tank. Bacterial growth is worth some concern. Water heaters that are run continuously, and therefore remain hot, discourage growth; when not in use, water heaters cool, allowing biological colonies to establish. While chlorinated water should prevent this, a copper tank is even less likely to experience these problems. Copper's chief drawback is expense.

Stainless steel is also an expensive tank material; but, if the correct grade is applied and welded properly, it may outlast the vessel in which it is installed. For water heaters (or ordinary potable-water tanks), passivated 316L stainless steel is ideal. Preferable to more crevice-corrosion-prone 304 stainless alloy, this material is highly corrosion-resistant and not likely to rust or produce aluminum oxide (that white powdery stuff found on oxidizing aluminum).

Aluminum's versatility doesn't extend to potable water applications, where the alloy is prone to corrosion, and often produces copious quantities of aluminum oxide—the white granular material shown here.

Insulation

Keeping the water hot is nearly as important as heating it. Ideally, the water heater will maintain water hot enough (again, about 105° F) for a shower at least 12 hours after the engine is shut down or shore/generator power is turned off. Some especially well-designed water heaters will maintain this temperature for 20 or more hours. Consider 12 hours a minimum and 20 hours an ideal. Before making a selection, determine how your customer uses his or her boat: Owners of vessels without generators will appreciate more efficient temperature retention than owners of boats with power to spare. The same is often true of sailing vessels, where engines (and generators, if present) will be run less frequently. Be prepared to pay a premium for more effective insulation.

Placeholder for web reference space

Most tank insulation falls into two categories: fiberglass and closed-cell polyurethane foam. Fiberglass, with its lower R-value per inch, tends to be less effective and less expensive than "blown" or molded polyurethane foam. Also, if fiberglass insulation gets wet, it becomes ineffective and promotes the corrosion of steel tanks and outer covers by holding water against these surfaces. Adhering to the tank surface, blown polyurethane is non-hygroscopic and doesn't suffer from either of these maladies. Open-cell

Higher quality water heater manufacturers go to great lengths to use the most efficient insulation. Augmenting existing insulation with a water heater blanket is also a viable option.

polyurethane foam may have a higher R-value than fiberglass, but it will absorb water and cause the same detrimental side effects as wet fiberglass insulation.

Note that supplemental insulation can be added to a water heater to improve its heat retention—to a point. In *theory*, added insulation increases the surface area of the water heater, promoting heat loss. In *practice*, I've found that adding a 1″ (25mm) insulating blanket to a water heater can increase heat retention by six hours or more. Beyond that, it has little effect. The material covering the outside of the water heater's insulation is much less critical than the interior components. In years past, marine water heaters were simply bantam-sized household units. Their shells were painted steel, which quickly rusted in the marine environment. Still, unless the shell incorporated the mounting feet, this was more a cosmetic than an operational issue. It looked bad, but it still worked.

Water heater manufacturers have wised up; even many of the less expensive units now have rustproof polymer or plastic shells. Units may also be sheathed in fiberglass or more expensive but not necessarily better stainless steel. This looks great, but it's not a reason in and of itself to choose one unit over another. Additionally, just because the outer shell is stainless, which may be heavily emphasized in the manufacturer's literature, doesn't mean the important part, the tank, is stainless as well. Remember, the ability to heat and retain water while offering a long service life is the primary function of a water heater. If it looks good, that's an added benefit, but not a prerequisite.

Design and Installation

The design of a marine water heater, from capacity to mounting

Potable-Water Tanks

Materials. Water tanks are made from a variety of materials, including stainless steel, polyethylene, and fiberglass. Aluminum is used occasionally, particularly on aluminum vessels, but it is prone to corrosion and eventual failure, along with the production of aluminum oxide crystals, which clog pumps, filters, and fixture aerators. Corrosion and aluminum oxide production are even bigger problems when aluminum tanks are employed with reverse-osmosis watermakers, whose slight acidity accelerates the corrosion and corrosion by-product process. Mineral-neutralizing filters are available to offset this reaction. (For a case study of failed aluminum water tanks, see Roby Scalvini's "The Case of the Corroded Tanks," *Professional BoatBuilder* No. 130.)

Stainless steel is an acceptable metallic alternative for fabricating potable-water tanks. If properly designed, and constructed from 12–10 gauge (0.105″–0.135″) or thicker 316L or 317L stainless steel, they are strong and long-lived. Stainless steel tanks require no paint or coatings.

Crevice corrosion and weld migration are the primary enemies of stainless steel tanks; 316L or 317L alloys will reduce vulnerability to these weaknesses. The L suffix in this alloy denotes low carbon, which is a prerequisite for any stainless steel to be welded (see "The Power and Peril of Stainless," PBB No. 146). If low-carbon stainless steel is not employed, the heat of welding drives the chrome ions out of the weld area, essentially leaving a strip of mild steel on either side of the weld, which quickly begins to rust. This is a common tank defect noticeable to even the inexperienced observer.

Stainless steel potentially suffers from another weakness. The welded seams along 90° corners tend to be brittle, and over time

Weld migration reduces stainless steel's resistance to corrosion adjacent to the weld. The problem can be prevented by choosing an alloy designed to be welded, preferably 316L. The L suffix denotes low carbon-alloy.

options, will play an important role in its performance. One of the first decisions to make before purchasing a water heater will be about its capacity. This may be easy: If the vessel has space for nothing larger than a 6-gallon (22.8-l) unit, then you can move on to the next criteria. If more room exists, do some simple math based on the size of the crew and how frequently they will use hot water, and not just for showers. More people mean more dishes to wash and more hand-washing after head calls (hopefully). While larger units provide more hot water, once hot, they often take longer to heat water from a cold start.

Most marine water heaters are equipped with conventional, household, adjustable thermostats (usually from 120°F to 180°F/49°C to 82°C). A few do not offer an adjustable thermostat or provide it as an option. Naturally, it's desirable to be able to choose the water temperature maintained by a water heater.

Some heater manufacturers install a nonadjustable thermostat with a built-in adjustable mixing valve. Typically, the fixed-thermostat and mixing-valve combination works well, maintaining the contents of the water heater at a higher temperature, usually around 165°F (174°C) (reducing the likelihood of bacterial growth), and then mixing this water that's too hot for ordinary domestic use with cold water outside the heater. The adjustable mixing valve determines the temperature of the water delivered to sinks and showers. The clear advantage is that after many hours, the water in the heater may still be hot enough, albeit without mixing with cold water, for bathing or galley chores. It essentially enables the water heater to produce more hot water at a

Mixing valves regulate temperature by mixing cold water with hot as it leaves the water heater. While they can reduce water temperature to safe levels, their comparatively slow reaction time makes them unsuitable as anti-scald devices.

they harden and crack. Substantial baffles and stiffeners can eliminate this problem. Because of this, if the job is to be subcontracted out, the services of a proprietary tank fabricator, instead of a generic metal fabricator, are invaluable.

Roto-molded linear polyethylene, or LPE, like its cousin cross-linked polyethylene, or XPE, is durable, corrosion-proof, and ideally suited for potable-water storage. Tanks are available in hundreds of shapes and sizes, so a model can usually be found to fit a particular application. Of late, custom-sized welded polyethylene tanks have become available, enabling builders and refit installers to custom-design a one-off tank for a specific application. Full baffles in welded LPE tanks are possible only in custom-made tanks. Thin-walled tanks can distort enough to cause fittings to leak (the thicker the wall, the better: 0.25"/6.35mm is ideal), and fittings are susceptible to damage if stepped on or sat on. A note of warning: the polyethylene for water tanks must be FDA approved, meaning it has to be virgin (unrecycled). Finally, because poly tanks are translucent, which promotes bacterial growth, they require more frequent cleaning and chlorine treatment than metal tanks, which are opaque.

Polyethylene has become especially popular for potable water storage, with good reason: it's inexpensive, long-lasting, and corrosion-proof. Custom-made welded polyethylene tanks are practical replacements for custom-made metallic tanks.

Fiberglass may also be employed for water-storage tanks; described as "forever" tanks, they have all the previously mentioned criteria, and one addition: All resin, gelcoat, and release agents must be food-grade FDA or equivalent approved. Fiberglass tanks may be integral with FRP hulls, or freestanding with shapes conforming to the hull to take maximum advantage of the available space. Fully tabbed in place, they represent a double hull of sorts, helping to stem flooding in the event of a hull breach.

Installation. Potable-water tanks often require scrubbing. Tanks should be equipped with inspection ports large enough for access to clean every baffled chamber. Additionally, the

usable temperature by keeping the contents well above the conventional thermostat setting.

A mixing valve can be added to nearly any water heater installation, with a higher thermostat setting on the electric side. Note that mixing-valve manufacturers' literature often points out that their products *do not* act quickly enough to be effective anti-scald devices.

Coolant plumbing hoses from engines to water heaters must be rugged, and capable of withstanding heat and pressure. At the very least, designated "heater hose" should be installed; hose carrying a marine wet-exhaust SEAJ2006R rating is even better. In the event of a failure, unless the system is equipped with an at-the-engine water-heater heat exchanger, engine coolant will be lost, disabling the vessel's propulsion system. Additionally, isolation valves should be installed at the engine block, enabling the water heater's heating loop to be serviced or turned off in the event of a failure.

When I first began working in the marine industry 25 years ago, one of the greatest mistakes a mechanic could make during winterizing or spring commissioning was to burn out an electric-water-heater heating element by turning the unit on with no water inside. With no water, the element quickly overheats (sometimes in just a few seconds) and self-destructs. Thankfully, many modern water heaters include an overheat-protection circuit that prevents the unwary boat owner or inexperienced mechanic from learning this lesson the hard way. The water heater you choose for your customer should include this feature.

Back in those days, you could find the electric heating elements for most marine water heaters at the local hardware store or plumbing supplier. Today, some dedicated marine water heaters require proprietary heating elements and are not so easily found. If your customer plans to cruise and rely heavily on the electric heating element, it would be wise to lay in a spare, regardless of the type. Heating elements are available, depending on the manufacturer, in several materials: plain copper, tin or nickel-plated copper, stainless steel, or Incoloy.

An all stainless steel water heater could very well outlast the boat. While more costly than mild steel, stainless steel, and particularly the 316L alloy, is well suited to water heater tank fabrication.

design should incorporate female pipe welding bosses for plumbing fittings, rather than pipe couplings, and mounting flanges, which facilitate through-bolting. To isolate their bottoms from a shelf on which they rest, stainless tanks should be installed on non-hygroscopic 4″-wide by 0.25″-thick (101.6mm by 6.35mm) risers or insulators; spaced 4″ apart, these can be pre-fabricated fiberglass, or GPO-3, or high-density polyethylene, among other materials. They should be thoroughly bedded to the tank bottom with polyurethane bedding compound, to prevent water migration between risers and the tank's bottom exterior surface. Riser strips should be mounted athwartships to enable water to drain when the vessel rolls.

Above—*To reduce the likelihood of corrosion, metallic water tanks should never rest directly against a hull or shelf. Access ports enable inspection and cleaning.* ***Right—****To keep stainless steel tanks out of standing water, mount them on risers, or insulators, fully bonded to the tank.*

Fresh water weighs approximately 8 lbs per gal (0.96 kg/l), which means a full 100-gal (378.5-l) water tank weighs in excess of 800 lbs (362.9 kg). This calls for extremely secure mounting fixtures. The aforementioned flanges are more secure than straps or cribbing, and through-bolts are better than tapping or lag screws (other than the very smallest examples, this applies to all tanks—fuel, water, or waste). Water tanks benefit from drains installed at the bottom to facilitate cleaning and winterization.

—Steve D'Antonio

In that order, from least to most, these are more resistant to corrosion caused by water with high mineral and salt content as well as increased acidity.

An essential safety device for every marine water heater is an overpressure/temperature relief valve. It's standard equipment on virtually every production water heater. In some cases, if the electric thermostat fails in the closed or "on" position, or if the engine coolant imparts enough heat to the water heater's contents, the heat and resultant pressure within the heater's tank may become dangerously high. The overpressure relief valve prevents this situation from going supercritical by venting off the pressure at somewhere between 60 psi and 90 psi/0.4 Nmm^2 and 0.6 Nmm^2 (most water heater tanks are rated for a maximum pressure of 200 psi–300 psi/1.4 Nmm^2–2.1 Nmm^2), with a working pressure of 50 psi to 100 psi (0.3 Nmm^2 to 0.7 Nmm^2). These figures vary from one manufacturer to another.

If the water heater is installed in a location where crew may be present, even an engine compartment or sail locker, safely plumb the overtemperature discharge where it won't splatter scalding water on an unsuspecting crew member (but don't plumb it *into* bilgewater).

Mixing valves can be added to virtually any water heater installation. Some water heaters include them as standard equipment; in other cases, they are optional.

Another feature unique to larger marine water heaters is a cold-water deflector, installed where cold water enters within the heater's tank. The idea is to deflect the flow of cold water, because it tends to mix with and lower the temperature of water being drawn at the top of the tank. This simple component requires only a few cents worth of stainless steel but significantly increases the amount of usable hot water the heater can deliver.

When full, water heaters can weigh in excess of 100 lbs (45 kg), requiring proper attention to their installation. A high-quality 8-gal (30-l) water heater may weigh 38 lbs (17 kg) empty; add the weight of 8 gal of water, and the assembly will tip the scales at 104 lbs (47 kg). Add a little g-force to this package, and an improperly secured

Large tanks full of water are heavy and can become dangerous missiles in rough seas. This accumulator tank is properly mounted and secured with straps that encircle the unit.

unit can quickly become a blunt but destructive missile inside a vessel's hull. For anything other than a slow, inshore vessel, secure the unit with properly sized and backed through-bolts, rather than tapping screws or, worse, fabric webbing. Well-made water heaters provide hefty mounting feet or straps that encircle the unit. These are sturdier than light-gauge sheet-metal "tabs" attached only to the outer shell casing. Mounts that are welded to the inner water tank and protrude through the insulation are strong but accelerate heat loss. Consider how and where the vessel will be used. A displacement family day-cruiser is less likely to encounter conditions that will dislodge a water heater, while offshore sailing vessels, bluewater power cruisers, and high-speed boats will place greater demands on water heater mounts and restraints. For offshore sailing, tanks must remain secure in a knockdown or inversion.

Customer Service

Finally, when choosing a marine water heater, familiarize yourself with the manufacturer's warranty. I've had to make only two claims on water heater warranties for my customers (one tank was stainless, the other aluminum). After taking into account the labor for removal and installation, shipping both ways, and prorating, it scarcely seemed worth the effort. Therefore, I'd be reluctant to purchase a water heater with a tank warranty of less than five years (the overall parts warranty should be a minimum of two years). Check out the fine print. Most

manufacturers do not cover labor or shipping (a pet peeve in my Parting Shot in PBB No. 147); and depending on the fine print in the warranty, there may be substantial prorating of reimbursement for failed tanks based on the length of service, even if failure falls within the warranty period.

It's important to note that even the least expensive marine water heaters typically last for a decade or more. Disuse and corrosion, as with so much marine gear, are their greatest nemeses. 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.*

PBB+

For a potable water primer, go to ProBoat.com and read the latest entry in Steve's Attention to Detail column.

ProBoat Online

For a potable water primer, go to ProBoat.com and read the latest entry in Steve's Attention to Detail column.

Hot Water Alternatives

In the early '80s, an innovative LP-gas-fired product called the Wolter Marine Water Heater provided on-demand hot water for as long as the water supply held out. It seemed like a great idea, much like on-demand gas-fired water heaters installed in European and now many U.S. homes and apartments.

The plan went horribly wrong. Like many devices that have a flame, these units produce deadly carbon monoxide (CO) gas when operated. As the oxygen is consumed by the flame, CO production skyrockets. If installed without proper ventilation in an small space like a head, this unit can produce a deadly amount of CO in less time than the duration of even a "navy" shower. At least one skipper died as a result of CO from an on-demand LP water heater.

Today, few if any new boats offer on-demand gas-fired water heaters, although many older units are still operating. *In theory* these units are safe if: installed outside living spaces and are extremely well ventilated; and incorporate thermocouples, which shut off the gas supply when the flame is extinguished, and CO couples that shut the unit off if the CO level becomes dangerously high. I would not choose to install, service, or recommend them.

Diesel-fired water heaters have been available for several years from companies like Kabola, Espar, International Thermal Research, and Webasto. These hydronic heat systems are designed primarily to heat cabins, with an added benefit of being able to produce domestic hot water. Because they burn diesel rather than LP, the CO problem is significantly reduced. These systems work well and are exceptionally safe; however, they may seem costly, especially if cabin heat is not needed. —*S.D.*