PLUMBING

A plumbing leak can ruin your whole day! It pays to limit through-hull fittings, use double hose clamps, and make sure that all salt-water plumbing materials are of the best quality.

The basic rule with all plumbing aboard is: Only use the best materials. If there's a budget constraint, cut corners somewhere else, not in the plumbing.

While a variety of hoses are available, you generally get what you pay for. For pressure I like to use reinforced nylon, although some high-pressure plastic tubing systems with special fittings have been used with success.

Hot-water pressure pipe should be capable of operating at 180–200 degrees Fahrenheit.

Fuel hose will need to be heavily reinforced to resist chafe and — when used in the engine room — heat and even fire. Remember, diesel takes a special type of hose and valves.

For toilet exhaust, a special sanitation hose should be used; otherwise algae will grow in the pipes, giving off a sulphurous rotten-egg smell.

Anything plumbing connected with propane must be the best you can buy, heavily reinforced, and in one piece from the gas locker to the stove. Your life may depend upon this hose.

Bilge pumps require the use of a ribbed hose to resist suction pressure. Don't even consider the very light varieties that are available. If you can't stand on the hose without ruining the shape, don't use it.

Hose clamps should be made of stainless — 304 grade is the most common. The 316 grade costs two or three times more and lasts a lot longer. Make sure the screw as well as the band are stainless. Use wide, heavy-duty clamps. Any fitting below the waterline should be double-clamped. Keep the clamps lubricated. PVC irrigation pipe also works well, as long as heavy-duty stock is chosen (schedule 40 or schedule 80) and there's plenty of allowance for expansion and contraction in soft hose connections.

It's common to have too tight a fit between hose and fittings. One school of thought says this is good, since a tightly fitting hose probably won't leak if a hose clamp fails — the hose is slipped into place after being heated, either with a hair drier/heat gun, or by placing the hose end in hot water. The problem comes when it's time to redo some section of plumbing or remove a piece of gear. Now the hose is frozen solid onto the fitting. It will take heat (or a knife) to soften the hose in order to remove it. My preference is to avoid interference fits and make sure everything is easy to take apart. If I'm worried about flooding, I use extra heavy-duty clamps.

Salt-Water System

The salt-water system and its various through-hull fittings require careful thought on installation and consistent maintenance. A mistake in this area can easily lead to flooding the boat.

The chief aim should be to simplify the basic system, minimizing plumbing connections and through-hull fittings. Since there may be a conflict between these two issues, give priority to getting rid of through-hulls.

The above comments may seem self-evident, but what's best for the boat and easiest for the builder are two different things. The quickest way to plumb a boat is with lots of through-hulls. It's not unusual to find 10 or 15 holes below the waterline on a 40- or 50-footer (12.3 to 15.4m). Of course, the fewer the through-hulls, the safer the boat.

Through-hull fittings are probably the most critical piece of gear aboard your boat, in terms of keeping it afloat. If a problem occurs in this area, you will need some big bilge pumps or wooden plugs in a hurry!

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How Many Skin Fittings Do You Need?

Most yachts are built with holes all over below the waterline — often one for each toilet, sink, and bilge pump, plus a couple more for incoming salt water and deck drains. Every one of these holes can sink your boat! It is much better to double up where possible and/or eliminate below-waterline fittings entirely (by dicharging through the transom or at topside level). On most of our boats we are able to reduce total below-waterline fittings to two or three. This works out as follows: one through-hull for all incoming saltwater, a discharge for each toilet (usualy in the form of a standpipe), with sink and bilge exhausts through the transom or another standpipe.

Lightning Risks

Before going further we need to chat about the risk of a lightning hit. Lightning prefers a straight path to the water. If there's a through-hull near a chainplate, providing an easier path for the lightning bolt than following the mast to the keel, the lightning will head for the underwater fitting. The result is likely to be a large hole below the waterline. To reduce this risk if you have bronze through-hull fittings, you will want a good lightning bonding system.

Electrolysis

You also have to be concerned with electrolysis, especially if you spend much time connected to shorepower. Unfortunately, if you bond things together for lightning protection (not to mention the AC ground) you are introducing a possibility of electrolysis.

There is no easy answer to this conundrum. Our preference is to tie everything together with a bonding system, and then use an isolation transformer in the shore-power system to keep shore power–related electrolysis off the boat.

Hull Penetration

Where you penetrate the hull, be sure there is an area of solid laminate, to eliminate risk of the core getting wet. If you do have a cored hull, the core should be removed in the area of the fittings and replaced with a resin/fiber putty.

The next question is: plastic or bronze for the fitting? Bronze is stronger and not a problem in freezing climates. However, you have to worry about electrolysis and lightening. Structural plastics do not have lightning or electrolysis problems, but they do have a problem in cold climates.

If freezing is not an issue, my preference is for plastic.

Sea Cocks

There are three choices for through-hull fittings. The first is a bronze seacock, usually bolted directly to the hull (the best way) but occasionally threaded on a tail piece bedded to the hull. Bronze seacocks are almost indestructible but have potential problems with electrolysis and/or lightning.

The next approach is to use plastic seacocks, usually glass-filled nylon in one form or another. These fittings, pioneered by the RC Marine Company in New Zealand years ago, have received general approval in the last few years. They offer a solution to both of the problems mentioned above, but also pose a bigger risk if there's a fire aboard. In addition, they're not as strong as bronze and are more subject to damage if frozen or abused.

We've used plastic valves supplied to us by Forespar on our aluminum boats — and more recently on the Sundeer production yachts — for years without problems. We do, however, make sure they're installed so that it's impossible to step on them.

Regardless of which type of valves you choose, they should be opened and closed monthly to keep everything free. Keep wrenches aboard capable of servicing the valves, usually giant crescent or pipe wrenches. Each through-hull should have a soft, tapered wooden plug hung near in case of a failure.

Gate or Ball Valve?

Before leaving the valve topic, we should make some comments on design. In recent years it has been possible to purchase ball valves for virtually every type of application. In our experience, these are less prone to maintenance headaches than gate valves. Only slightly more expensive, they make the most sense.

SALT-WATER FEED

Using the logic discussed so far, let's look at the ideal salt-water feed system.

First, there's a single incoming salt-water through-hull for the entire boat. This should be close to the engine compartment, where it's easy to get at the valve to close it off when the boat is left unattended.

The size of the fitting varies with engine requirements, how many compressors there are to cool, if a genset will be running at the same fitting, and the length of the runs. When in doubt, make it bigger.

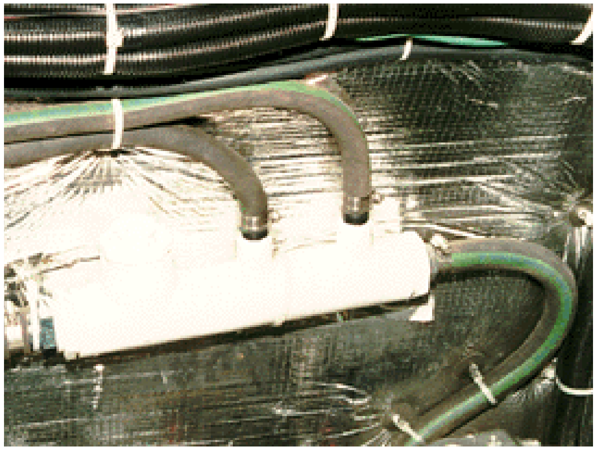
On *Sundeer* we ran a 150-horsepower engine, a watermaker, two fridge compressors, and the toilets from a single 2-inch (50mm) fitting. The same approach was used on the Sundeer production series, and more recently on our larger motorsailers.

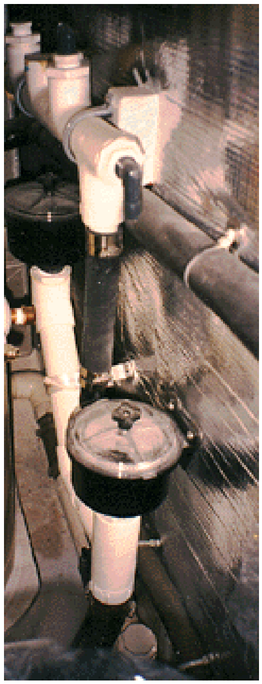
Next there will be a large-capacity sea strainer. It sometimes makes sense to have double strainers, if you intend to cruise in areas with lots of floating weed or jellyfish. The strainers must be easily accessible, and the water that leaks when they're cleaned won't create any problems.

Next comes a distribution manifold. This can be a stainless-steel weldment or made from heavy PVC pipe. Bronze pipe fittings are also usable. Keep in mind two things here. One, it must be easy to disassemble the system for maintenance. This means strategically placed soft-hose connections between manifold and strainers. Second, it's vital that the plumbing be either level or, better yet, plumbed with a slight rise. This prevents air locks. When there are dips or loops, water flow is restricted and centrifugal-style pumps don't work well.

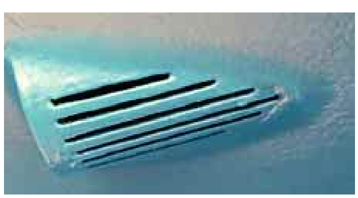
The manifold distributes the seawater to the various accessories. If the engine is the last takeoff, its positive-action impeller pump will pull out any accumulations of air.

If the engine is in a watertight compartment, having a shutoff valve on the feed line to the interior makes it possible to keep the seacock open when you leave the boat. The interior feed line then goes to the toilets, galley sink, and to the deck-wash pump (if it's mounted forward). A 3/4-inch line easily takes care of these four needs .





Three different approaches (above and left) to PVC-based intake manifolds on a salt-water system. Two-inch (50mm) Ts and elbows are used, then reduced down to the needed size as they run along the manifold. The PVC is quite strong and not subject to electrolysis. However, it does need to be mounted where there is no danger of being stepped on, as it will not survive that sort of abuse.



It is sometime necessary to have a forward-facing scoop to force water into the salt-water system. Ideally this will have some form of grating or screening to keep trash and weed out of the strainer.

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TOILETS

A number of good toilets are on the market, most of which are reasonably priced. We've succesfully used the Raritan PHll models for years.

The lip of the toilet bowl should be placed above the floating waterline if possible. Thus if there's a leak in the saltwater feed valve or check valve, it won't overflow (unless, of course, you are heeled). There should be an anti-siphon loop if the bowl is below the waterline. Check valves on the exhaust side of toilets don't work, as they always get plugged.

Good access for pump removal is essential, as this is a procedure with which you'll become very familiar. To make life simple, we always carry a complete spare pump for each head, along with an overhaul kit. That way I can change the pump in question, get the head going again, and then do the overhaul job at my leisure.

A major problem with the head components is a buildup of mineral deposits inside the pump and exhaust hose. This is particularly troublesome behind the check valve and will often lead to blockage of the head. Cleaning the exhaust line and pump twice a year it will usually prevent blockages from occurring. (They always seem to occur at embarrassing moments.)

The toilet exhaust, ideally, will be above the waterline. That's one less below-waterline fitting to worry about. A compromise for the squeamish is to have the exhaust point just barely below the waterline. This minimizes back pressure on the exhaust and reduces inflow should there ever be a leak.

Above: Two simple yet effective approaches to the marine toilet.The bowl on the left is emptied with a medium-sized bilge pump — no choker valves to clog, and very little to go wrong.This type of pump is also much easier to operate than a built-in pump with its tiny handle.

It's easy to convert an existing marine head to this approach by installing two pumps — one for emptying, and a second for filling.You will find that two inexpensive bilge pumps connected like this cost less than a replacement toilet pump and provide much better service.

Above right is a LAVAC head that works somewhat the same way.A bilge-type pump empties the bowl, while a gasket seal is maintained by the lid. Because of the vacuum created, clean water is being drawn in as waste is being emptied.

A Y valve (left), used to divert the toilet exhaust either overboard or to a holding tank. These require some maintenance, so should be mounted where access is good.

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HOLDING TANKS

The city of Los Angeles can dump 25,000,000 gallons (100,000,000 liters) of partially treated sewage per day into Santa Monica Bay, but let one yacht from Marina del Rey sally forth without a holding tank and the bureaucrats come unglued. Of course there are only a few pump-out stations in the whole U.S.A. But we're an easy target for the pollution-busting politicos, hence these laws. Now, don't get me wrong. I want my anchorages and beaches to be pristine. But rules should apply to everyone — governments, merchant shipping, industrial concerns, and yachts.

In any case, to be legal you do need to do something. The basic question to answer first is: Are you installing a system just to keep officials happy, or do you want it to be functional for everyday use?

Tank Capacity

Tank capacity is very much a function of the type of head system you have and how much water it takes per cycle. For example, hand-pump heads require around 1 gallon (3.7 liters) per flush for hard waste and about 1 quart (1 liter) if the head is just being used for urine. On the other hand, systems like Vacu-Flush require only 1 quart (1 liter) for hard waste.

Once you've decided on the head system, the next question is: How many people, and for how many days? In many situations, when the head only needs to take care of two people for a couple of days, a small holding tank will get the job done. However, since the tank itself is not that expensive, and the plumbing and pumps are the same regardless of tank size, it is usually best to fit the largest tank possible.

Tank Construction

Sewage is a smelly, toxic, and chemically active medium best contained in inert plastic. As a result, rotationally molded linear low-density polyethylene is most commonly used.

Fabric tanks are used occasionally, but these tend to have more problems with leaks (usually at the fittings) and odors (permeating through the fabric), and are not a good choice for long-term usage. Metal is not a good bet due to corrosion issues.

In evaluating a tank, there are a couple of key issues. First is structural integrity — wall thickness is critical. Second is how fittings are attached. If there are nipples for the hose to attach to, these should be round and smooth for a good seal. If there are connections made with pipe threads, be sure the threads are well-formed and even. Test the threads with a PVC fitting to see if they snug down smoothly rather than grabbing as you rotate the fitting.

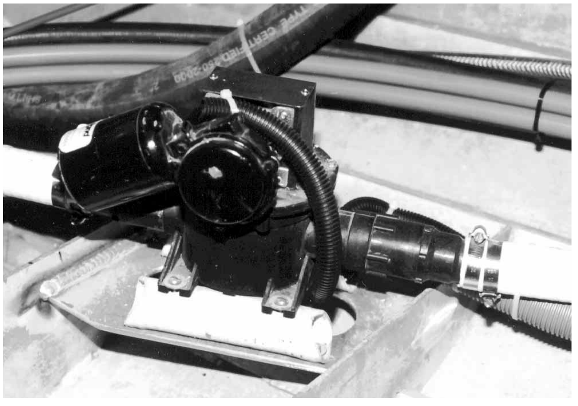
It makes sense to have an access port in the top for visual inspection and eventually a thorough clean out. (Yuck!) This port requires an O-ring for a seal.

After looking at a lot of tanks, we like the units made by SeaLand the best. They seem to have by far the thickest walls.

Tank Plumbing

The top of the tank will have plumbing fittings for the toilet exhaust, a breather (which should have a fitted charcoal filter) and a tank-level indicator (although you can usually see the level with most tanks, if a section of side wall is visible).

The tank drains from the bottom. The norm is to have a vacuum fitting to the deck for shoreside pump-out, with a diverter valve to a macerator pump for pumping the tank overboard.



A SeaLand macerator pump for emptying a sewage tank. Note the simple isolation mounts for noise reduction. This is nothing more than two pieces of hose to which the pump is bolted — inexpensive and very effective.

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GRAY WATER

Shower and sink exhausts can have a major impact on the complexity of the plumbing system.

Head Sinks

The easiest and safest approach for head sinks is to have them empty into the toilet bowl. Then use the toilet exhaust pump to get rid of the water. This is usually a small volume and can be flushed in a few strokes, calling for no extra pumps or through-hulls and a minimum of hose.

Shower Sumps

Shower sumps, since they're below the waterline, need some form of a sump pump, either hand-operated or electric. This pump should exhaust *above* the waterline, either on its own or in a manifold with other outlets aboard.

Once this pump is in the system, if a Y-valve is tied in under the sink, the shower sump pump can be used to evacuate the head sink.

If the sump pump exits high up on the transom, there will never be a problem with back siphoning. However, if it is in the topsides or below the waterline, you will need a siphon breaker to eliminate the possibility of back flooding.

Galley Sinks

The galley sink is a little more complex. With the prospect of food particles and lots of soapy water in the works, it's a little harder to empty out. If the sink is close enough to the centerline so that it won't flood when you're heeled, then a straight drop to a skin fitting begins to make sense. This same exhaust fitting can also be used for the various bilge and sump pumps aboard.

If the sink is outboard there will be a flooding problem when heeled. The same applies to head sinks. On *Intermezzo II* we used a skin fitting, and then shut the sink off when we were heeled to starboard. If Linda needed to drain the sink, I would ease off on the sails or change course. Maybe not the most practical approach, but it kept the plumbing simple.

Another way to go is with a straight drop for use in port, and a Y-valve connected to a macerator pump (the type used to empty holding tanks) for use when heeled; or simpler yet, just a macerator pump and a vented loop to prevent back-siphoning. If this last method is adopted, carry several spare pumps.

Gray-Water Tanks

There's yet another approach. This is to take all head and galley sinks and showers to a single gray-water tank, which is pumped out periodically. This has the advantage of minimizing discharges and the number of pumps. But to be successful, the plumbing has to be run very carefully, with a constant downward slope toward the tank (this requires a moderate-to-heavy-displacement hull shape with deep bilges. Dips in the piping must be avoided, which means using rigid pipe, typically PVC. If you choose this route, allow plenty of soft hose connections so the pipes can be opened up to clean blockages. There should be a float switch in the tank to signal when it's time to pump out.

A major drawback of the gray-water tank system is odor. In order to prevent this from permeating the interior, water traps, like those used in a house, should be employed at each sink and shower. The tank has to be cleaned out periodically — a somewhat gruesome task.

A derivative approach is to plumb everything to a single macerator pump rather than to the tank. This can be done in a boat with flatter bilges, with the pump connected where the tank top would normally be. Even though there's a constant drop, it will probably be necessary to close off the shower sumps and unused sinks, to allow the one area being evacuated to get a good vacuum. We've used this system ourselves with excellent results.

Fridge Drains

Cleaning the fridge is easier if it has a drain. But the drain needs a valve to prevent cold air from leaking out. And, it should be tied into a gray-water tank or some form of pump. Allowing the fridge drain to drop directly into the bilge is asking for a substantial dose of olfactory trouble.

DECK WASH

A good deck-wash pump makes anchor handling much easier. With a nozzle, either handheld or built in to the anchor roller, the clingiest mud will cascade from your chain. There will be dinghies to wash, as well as fish blood, and the normal debris that accumulates on deck from the skies (even in mid-ocean).

If there is no shut-off valve on the nozzle of the deck-wash hose, you can dispense with a pressure switch on the pump. That's a step towards reliability.

You can also adapt the deck-wash pump to other chores —i.e., a bilgepump with yet another Y-valve. Or pumps set up for other duty — say, a damage-control pump — can be plumbed to also handle deck-wash.

Kelly Archer has a devilishly clever and simple system, using a large-scale engine-driven impeller pump for his fridge system, which sends its exhaust flow forward out of the anchor chock. In an emergency he can throw two valves and have a big engine-driven bilge pump ready to go, killing three birds with one pump.

PLUMBING ODORS

As we briefly discussed in the Cruising Preparation section, nothing is quite as nauseating as funky plumbing smells. It goes without saying that these are usually at their worst when beating, with lots of motion and all ports shut due to water on deck.

A lot of folks consider this the norm. However, I am here to tell you that you do not have to live with smelly plumbing.

Salt-Water Feed

The salt-water feed to your toilets and galley sink is a major source of odor. When the boat hasn't been used for a while, algae begins to grow and then die inside of the salt-water hose. When you come back aboard after a week or so away and pump the head, a rotten-egg smell pervades the interior.

There are several ways around this. The easiest is to tie all interior salt-water requirements to a single line that starts aft. At the forward end of this line place your deck-wash pump (or the Y-valve for the bilge pump that is acting as a deck-wash pump. Then, when you first come aboard, run the deck wash pump for 10 or 15 minutes. The pump will pull all of the bad-smelling water out of the feed line.

Another approach is to have a T fitted to the salt-water feed so that you can flush the line with fresh water before leaving. As long as you are leaving the boat for no more than a month or so this works well, and also allows you to flush out various pumps and valves with fresh water.

If the engine is connected to this circuit, be careful not to flood the engine! Do not pressurize the hose unless the engine is running.

Toilet Exhaust

The odors of human waste are not that difficult to contain in the toilet plumbing system. However, if the waste sits around in the pipes for a while, it changes to some really nasty bacteria with the ability to slip through just about anything man has been able to devise.

However, there are a series of things you can do to reduce the problem. To begin with, the shorter the hose run, the less problem you will have. On our own boats we've typically had a seacock or standpipe right next to the toilet, so odor has not been a problem,

Next, be sure that all connections are tightly made. We use *double* sets of hose clamps just to be sure. Next, avoid low spots in the run that result in waste lying around and breeding.

A system in continuous use will have fewer problems than one which is used on occasion.

Hose quality varies. Use the best stuff you can get. We've found that SeaLand hose works quite well.

Follow the manufacturer's recommendations about what chemicals not to put into the toilet — i.e., most hose has a problem with antifreeze.

If you have long runs in the toilet exhaust, use PVC pipe wherever possible. This does not pass odor as readily as soft hose.

Finally, be prepared to replace the toilet exhaust hose every couple of years.

Gray Water

Gray-water plumbing and especially sump tanks can generate some nasty smells. A diluted solution of bleach and hot water does a good job of killing bacteria and odor. However, take care with the bleach around your plumbing fittings, as it will strip off their chrome finish.

Two separate bilge-pump installations (above) with pumps bench-mounted. Large strainers are located under the pumps and are easily cleaned (without dropping the contents on any critical gear!)

Above: A pump cabinet with a damage control pump (far left), two bilge pumps (middle), a freshwater pressure pump, and a large expansion tank.

PUMPS

Cruising life has been characterized as going from one pump repair to the next. That's a pretty accurate assessment. Therefore, make sure access to your pumps is easy — they'll take lots of maintenance! Hoses should be easy to remove, and electrical connections are best made through a terminal strip or with plug-in connectors. In either case, be sure to seal the connection with waterproof tape or with a lacquer spray.

Also be sure there's plenty of slack in hose connections and wiring, if it's necessary to remove the pump for maintenance work. Sometimes an extra 6 inches of length makes all the difference.

Pump Capacity

Always go with the largest practical pump. The bigger the pump, the better the capacity, and the less it will run for any given job. If you reduce running time, you enhance the pump's life and reduce maintenance chores.

Electrical consumption is not affected, as DC motors only draw current commensurate to their load. A larger motor running for a short time will use the same power as a smaller motor running for a longer period.

Lift and Discharge Length

The farther a pump is from what it's pumping, the more difficult its job will be. This distance is measured both horizontally and vertically. Vertical lift is obviously more difficult, and this applies to both intake and discharge.

Where a diaphragm pump may lift 6 feet (1.85 m) easily, a centrifugal design might have a hard time with 12 inches (300 mm).

Check pump specifications carefully against the type of conditions in which you expect them to perform. Since capacity is very much affected by these factors, try to engineer the installation so that lift and discharge loads are minimized.

Dry-Running Protection

Dry running can cause impeller-style pumps to burn out quickly. (With diaphragm-style pumps this isn't an issue.) Some form of a safety system, such as a heat sensor (which is standard with some water-pressure pumps) should be built into the impeller pump. Larger impeller pumps may have a vacuum switch fitted to sense lack of water flow.

Strainers

Most pumps are sensitive to debris — some more than others. Each pump inlet should be fitted with a large strainer of appropriate fineness. The better the pump is at handling solids, the larger can be the strainer mesh, and the longer it can go without cleaning.

Obviously the large strainers will also last longer between cleanings. I like to use strainers at least the size of a large coffee mug (even with the smallest pumps), and then match the larger size strainer bowl with finer sized filter screens for the best protection.

Since strainers may need frequent cleaning, they must be located for easy access, and where it won't ruin anything if you spill a little water in the changing process.

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Check Valves

In some applications, such as water-pressure or circulation pumps, check valves (allowing liquid to flow in only one direction) may be necessary or make the pump's job easier. However, check valves are easily clogged and won't tolerate any dirt in the line, so good strainers are a must.

If the water being dealt with is fresh, bronze valves can be used. For salt water I prefer plastic valves.

Try to avoid check valves in bilge-pump applications. Debris can create too many problems.

Check valves take a lot of maintenance, so carry spares and keep them accessible.

Anti-Siphon Loops

If a pump is located below the waterline with a discharge that may become submerged when sailing, an anti-siphon loop — also known as a siphon breaker — must be in the line. This can be as crude as a pinhole at the top of a high loop in the discharge line. The pinhole prevents a back-siphon from forming when the pump shuts down, leading to flooding of the bilges. However, it is better to have a proper siphon breaker that includes a small check valve to minimize leaks. The loop should be located so that at maximum heel angle the top of the loop is still above the waterline. The closer to the centerline this is, the lower it can be. There's usually a small cap at the top of the siphon breaker that can be removed for cleaning, and to adjust the air flow. Remember that if the opening becomes clogged, it will no longer function. In some situations the air vent may bleed a little of the water, or whatever is being pumped. If possible, fit an exhaust line from the cap to the bilge. But make sure there aren't any sharp bends or loops that can trap water.

Diaphragm Pumps

The big advantages of diaphragm pumps is their ability to run dry (very important in bilge-pump applications) and high lift capability. The small models will lift 6 feet (1.85 m). This means the pumps can be located where they will stay dry and be easy to get at, and still do a reasonable job of pumping.

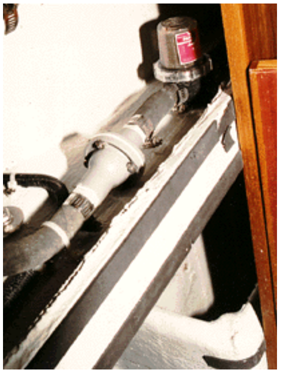
The only difference between the bilge-pump and pressure-pump models is a pressure switch and the style of valve. This way, spare parts inventory can be reduced.

In addition to bilge duty, diaphragm pumps work well for pressure fresh and salt water, and as gray-water exhaust pumps on sinks and showers. They don't work well for pumping fuel. While they can be used for circulation duty with the fridge compressors, they're not really suited to that style of continuous duty.

Submersible Pumps

For basic bilge pumping, with high capacity, low cost, and low maintenance as major issues, it's hard to beat the submersibles. Some of the pumps will move 60 or more gallons (230 liters) per minute, while a diaphragm pump is hard-pressed to pump 7 gallons (27 liters).

However, submersibles have several major drawbacks. First, they won't pump out that last little bit of water, which a diaphragm pump will get. In a shallow-bilged, modern design, this can be a real headache. Second, in a metal boat there's always a chance of electrical leakage from the pump into the bilge water, which will almost certainly cause electrolysis. Third, their capacity is very sensitive to lift height. Last, the design of the pump and its location can mean severe back siphoning in the anti-siphon loop, so careful installation is in order.



Above: Check valves (shown here to the left of the strainer) do not usually work well in bilge-pump applications. Any little piece of dirt that catches in the valve will cause it to malfunction. If you do have a check valve, make sure there is a fine mesh strainer *ahead* of it.

A toilet, the bowl of which is close to the waterline, should be fitted with anti-siphon breaks on both salt-water feed and exhaust. The closer these are to the centerline, the more effective they will be. However, this usually means the plumbing is exposed. Plastic is a bit ugly, but stainless pipes can be bent and polished so that they are, if not attractive, at least acceptable.

You will want to periodically check the condition of the check valve at the top.

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A related problem occurs when these pumps shut down. There's always a certain amount of water left in the exhaust line, and it floods back into the bilge sump. This is okay with a large sump, but if the sump is small, the pump can begin to oscillate on and off on its own exhaust-line leakage. The longer the exhaust line, the worse the problem becomes. A check valve can be used to stop it, but this creates the need for another strainer, which makes a nice, simple system much more complex.

A compromise with small sumps and/or flat bilges is to have the high-capacity submersible for big leaks and a diaphragm for everyday use and complete suction.

Centrifugal Circulation Pumps

A spinning impeller that doesn't contact the pump housing provides the driving force in this design. In concept it's similar to the submersible bilge pump, but its flow rate is less, and it's designed for continuous operation. These pumps are more reliable than others since they have only one moving part. The only maintenance problem comes if they're allowed to run dry, in which case the shaft seal will burn up. They also will push more water with less electricity than diaphragm designs.

Centrifugal pumps must be installed *below* the waterline to operate, as they are not self-priming. The salt-water feed line must be a fair run from the seacock to prevent the air from being trapped in bends or loops. If you have one of these pumps installed and it keeps stalling with air when you're sailing, the odds are you'll find the problem in the feed line.

Manual Pumps

There are a number of good hand- and foot-operated diaphragm pumps on the market. Many of the applications discussed for the electrics can be taken care of with a hand pump. In exchange for a little exercise, you get a more reliable pumping system, and save a few bucks to boot.

The manual pump's large-scale valves will pass all sorts of junk, reducing or eliminating the need for straining. A 10-gallon-per-minute (38-liter) pump will empty a shower sump with half a dozen strokes, a sink with just one. Makes sense, doesn't it?

Of course, it's important to choose the right pump for various applications. I would go with the 10-gpm units for all miscellaneous chores, and jump up to 25- or 30-gpm for the bilge. Install the pump so that it's easy to operate on both tacks.

BILGE PUMPING SYSTEMS

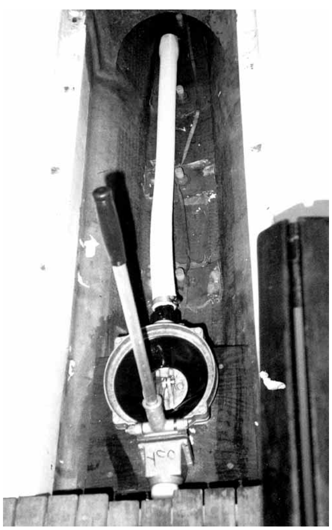
If you haven't yet fallen asleep, we need to finish this discussion with some thoughts on the overall bilge-pumping system. There are two levels of consideration: First is everyday condensation or leakage from the stuffing box, a keelbolt, or the mast boot.

Here the choice is really one of convenience. Because electric pumps are so inexpensive and offer some protection when the boat is unattended, they're really the way to go. My preference, if there's one central sump, is two electric pumps — one a large diaphragm, and the second a submersible of the largest size — operated on separate float switches with manual overrides.

However, you cannot totally depend upon electric pumps. There must be a manual pumping system, preferably operable from the helm, just in case the electrics go down the tubes. My preference here is the Edson 30-gpm diaphragm pump. It's easy to service, has tremendous capacity, and can be pumped for days on end if need be. (Be sure to carry spare check valves and a diaphragm.)

Another simple back-up is to put a Y-valve on the intake of the engine-cooling water pump. This can be plumbed to the sump and used to suck the bilge dry. Just remember that a strainer should be fitted, and if the pump runs dry the impeller will burn out. Keep a careful watch.

Every effort should be made to keep the bilges clean. This will pay lots of maintenance dividends downstream and may



The Edson 30-gpm manual pump is an excellent piece of gear. It has a long handle, which makes pumping much easier than with some pumps you'll find.

This unit is permanently mounted in the bilge. They also make board-mounted pumps that can be moved from place to place on board. (You stand on the mounting board as you pump.)

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have an impact on your survival in case a serious leak develops. Remember that when the boat is bounced around at sea, with a bilge full of water, all sorts of debris will be dislodged. Give the bilges a thorough, periodic cleaning with plenty of high-pressure water.

FLOAT SWITCHES

Pity the poor float switch. It has to live in a dark, damp hole, be bounced around by all sorts of waves, and transmit electrical energy under the most arduous conditions. Is it any wonder then that a high percentage of float switches commit suicide at a very early age? The pressure of modern cruising is just too much for them.

Mercury Switches

Conventional float switches, with capsules of mercury as the switching agent, are okay for the occasional cruise, but even the best won't stand any sort of real punishment.

One of the problems, which you can do something about, is switching current. It isn't fair to ask any of these switches to carry 10 or more amps of current in an on/off cycling mode. But if a relay is employed to carry the load, then the float switch is used to trigger the relay, and it only sees a fraction of an amp. Reliability goes up an order of magnitude.

A bit of PVC pipe makes an excellent pump pick-up.

Reed Switches

Sealed-reed switches offer a much better approach. Here you have a reed switch, totally sealed from the environment, activated by a floating magnet. This carries just a signal current to activate a relay. This is the approach used in commercial shipping. National Magnetic Sensors makes units based on this principle for the yachting trade. We've succesfully used these on most of our custom yachts.

Electronic Switches

Switches are also available to sense moisture. However, the ones we've looked at to date have problems with dirty bilges and splashing.

Using Relays

As already mentioned, using a small relay to transmit the power to your pump goes a long way toward enhancing switch and motor life. Ten to 15-amp relays can be bought for around $10 that work quite well for this purpose.

Timed Circuits

No float switch can read that last bit of water in the sump. To get it out, you need a manual override switch or a circuit timer.

The circuit timer simply keeps the pump running for a user adjustable time after the float switch has given it the off signal.

Cycle Counters

Cycle counters, which measure how often your pump comes on, give an idea of what has been happening with your bilges. Otherwise, if you have been away from the boat, you won't know how often the pump has been cycling (if at all).

Is Your Pump Running?

I like to know when my pumps are running, especially the bilge pumps. Mounting them on a hard surface, without rubber mounts, helps to transmit their vibration when they run. Sometimes pumps are just too quiet, or perhaps mounted where they cannot be heard. In this case, you can connect a signal light to the float switch signal. When the float switch triggers, it turns on the light (and perhaps a small buzzer or bell).

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DAMAGE-CONTROL PUMPS

Some provision must be made for a serious leak, perhaps from a collision or grounding — or maybe the starboard strake has started to open up. Even a 1-inch (25mm) diameter hole will leak much more than the capacity of the largest normal electric pump.

The solution is a substantial pump belted to the main engine or generator set. If you have a choice in mounting, choose the engine that will be flooded last in an emergency, typically the genset.

Rubber Impeller Pumps

There are two types of damage-control pumps. The easiest to install are the large impeller pumps, like the ones made by Jabsco. A 2-inch (50mm) impeller pump running at 3,600 rpm will pull 80 gpm (310 liters/minute) — that's almost two barrels full of water every minute. These pumps are relatively compact and easy to mount. However, the mounting must be beefy as they can pull upwards of 4 horsepower.

The only negative here is the rubber impeller. Run it dry for more than a minute, and it's ruined. This means a close watch must be maintained on the pump, or it should have an electric clutch that is float switch activated with a manual override.

Centrifugal Designs

Even more powerful are the commercial-grade self-priming centrifugal pumps such as those made by MP Pumps in Tecumseh, Michigan. A modest-sized MP will pull 200 gpm (775 liters/minute) at 3,600 pump rpm! Obviously this is a better bet in a dangerous situation. These pumps have the further advantage of being able to run dry. They can also eat all sorts of garbage, up to about 1 inch in diameter. The negatives come at the cash register and at installation time. They're about a third more money, and four or five times as bulky. But where do you draw the line, when floating or sinking may be involved?

With either style pump, one must decide on an electric or hand-operated clutching mechanism. I prefer electric because it's so much easier to control, although it can be somewhat less reliable than a hand-operated clutch mechanism.

Plumbing Issues

Plumbing in a damage-control pump must be done carefully, with heavy-wall tubing or pipe (to withstand the suction), and with care at joints to ensure there are *no suction-side leaks*. Even a tiny leak will make it almost impossible for the centrifugal pump to self-prime — although the impeller design is not quite as critical in this regard.

A Pacer gas-driven "de-watering" pump. With a plastic body and impeller, it is ideal for the marine environment. And this unit will pump more than 150 gpm (580 liters/minute).

A large Jabsco engine-driven rubber impeller pump. These units can self-prime at very high lifts and can tolerate small suction side leaks.

An engine-driven centrifugal pump by Tecumseh. This is the ultimate damage-control pump. It will pass large bits of debris and can pump 200 gpm (775 liters per minute).

A third approach that makes sense is to purchase a gasoline engine–driven centrifugal pump used for irrigation and for removing water at construction sites. This eliminates the hassle of brackets and plumbing and leaves you with a pump that can help someone else as well. The only problems are availability of gas, and convenience of use in rough weather. If you do go this route, be sure the pump will handle salt-water corrosion. Some are made of non-marine aluminum and won't stand the gaff. However, several plastic encased pumps, ideal in a salty environment, are available.

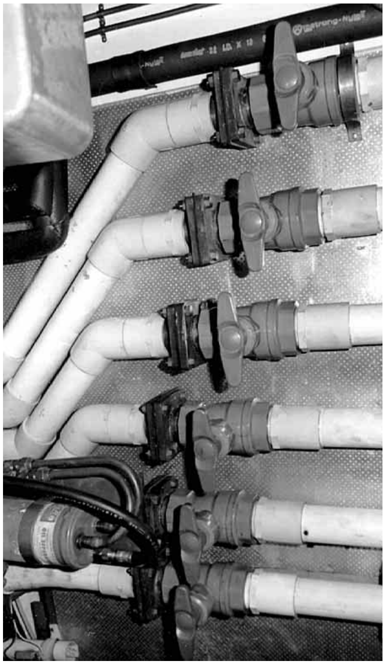
Pump prices, reliability, and suitability vary greatly. I always like to try to limit brands, sizes, and types in order to reduce spares inventory. This also makes it easier to cobble up a jury rig when spares are at a premium. Certain types of pumps are much better at some jobs than others. Try to pick your pumps so they have an easy job.

Using the Engine

As we've already briefly mentioned, the engine-cooling pump can be used to pump the bilges. All it takes is a T in the feed line and an extra valve. If you close the seacock and open the valve in the hose to the bilge, the engine will begin to draw from wherever the end of the hose is placed.

If you are contemplating this route, there are several caveats. First, the suction line to the bilge should come up above the water line and include a siphon break. Otherwise, if you forget to close the bilge-pumping valve, and then reopen the seacock, sea water will backflood!

If your engine salt-water supply is shared with other systems, you will need a valve to shut off that side of the plumbing circuit. Otherwise, the engine will try to pump from those areas, reducing its effectiveness in your bilge.



If you have watertight bulkheads the odds are you will bring all of your bilge pump suction lines to a central area, and then tie them to a single pump.

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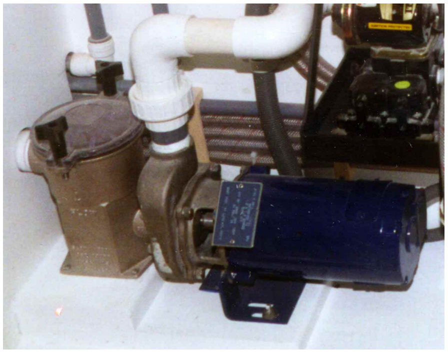
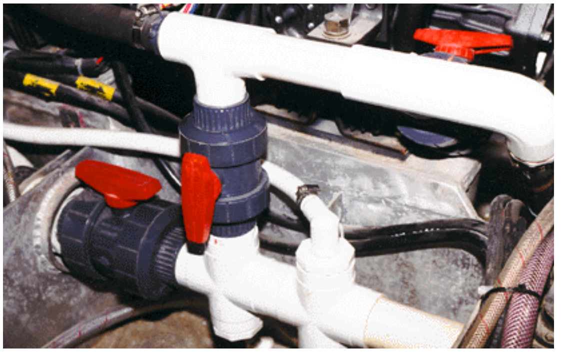




On *Beowulf*, with three watertight compartments, we have taken a somewhat different approach. In the engine room we use the engine-cooling pump as the damage-control pump (there are three diaphragm pumps — centerline, port, and starboard) for small leaks.

The forepeak is such a small area that when flooded it has little impact on stability. In that area we have a single diaphragm pump. This is not enough to keep up with a breach in the hull, but since that would have little noticeable affect we feel this is fine, and makes for much simpler plumbing.

The central portion (living area) of the hull has a double bottom in all areas except for the keel sump, so the risk of flooding is quite limited. In this area we have two bilge pumps. A small diaphragm pump (the same as in the engine room and forepeak) and a 3/4-horsepower Scott electric pump that pumps 60 gpm (232 liters/minute).

This electric pump has its own float switch (which also functions as the high-water alarm), or it can be manually operated. It empties on deck, where you can't miss the flow from the helm or pilothouse.

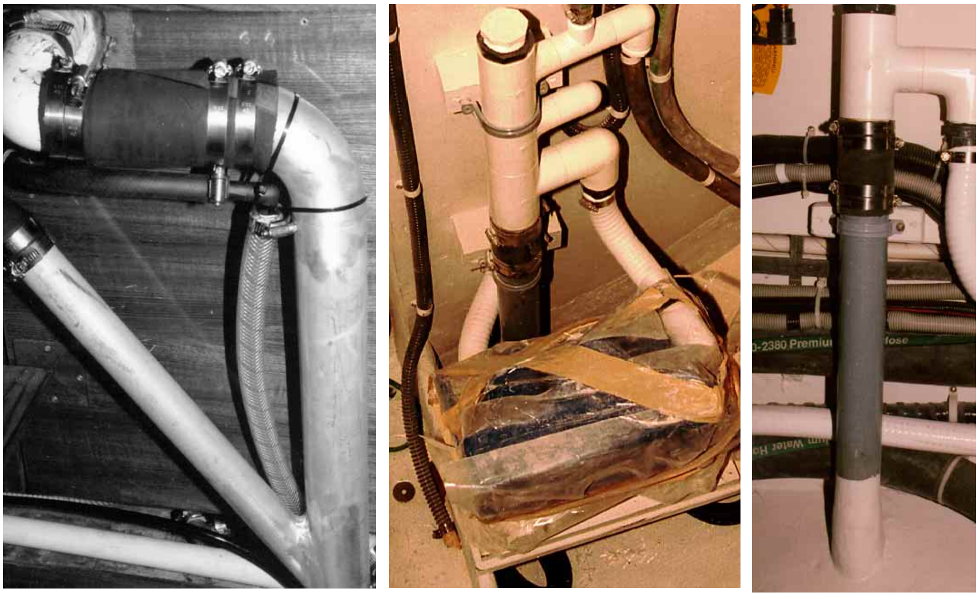
MINIMIZING THE RISK OF SINKING

As we've mentioned briefly so far, *every fitting installed near or below the waterline has the potential to sink the boat*. It therefore stands to reason that a worthwhile goal is to minimize the number of fittings that could flood the boat. You must have at least one through-hull fitting for incoming sea water. Beyond that, it is possible to do all exhausts far enough above the waterline to avoid risk. This is, however, sometimes impractical.

Standpipes

One answer to this exhaust problem is to use a standpipe. Basically, a standpipe is a metal or fiberglass pipe that has been welded (on a metal hull) or glassed to the hull skin. The standpipe then becomes the vehicle through which all discharges find their way overboard.

The first discharge is connected well above the heeled waterline. In theory, you could remove the various hoses connected to the standpipe, and no water will come into the boat. There are no valves to worry about. We've used this solution on all our yachts for years.



Three different standpipe details. Left: A welded assembly on *Sundeer.* The 2-inch (50mm) pipe at the top receives all bilge, sump, and galley sink pump discharges. The smaller welded pipe at the bottom is the toilet discharge. There was some question if this would prove a problem, mixing the two types of effluent. However, it never became an issue. The center and right photos show Sundeer 56 and 64 standpipes. These are fiberglass pipes, laminated to the hull skin, with PVC manifolds hose-clamped to the top.

Exhausts mounted on the forward areas of modern, flat hulls sometimes have a problem with water being driven against pump check valves when slamming to windward. Whenever this has happened to us, we've put a cover over the standpipe opening. The cover is larger aft than forward. This creates a Venturi effect, sucking the standpipe dry while at the same time protecting it from slamming pressure. Short pieces of hose are often used to connect sections of hard plumbing. Each side should be double-clamped.

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FITTINGS

One of the keys to a good-looking and functional plumbing system is the use of the proper fittings to tie things together. When you first walk into the plumbing supply store, you'll be amazed at the variety and complexity of what's available. There are pipe threads, gas threads, plastic and bronze, brass and galvanized steel — all sorts of connectors, reducers, angles, elbows, and nipples. It's hard to choose!

Here are a couple of rules I've learned the hard way to help you along. First, try outlining your needs on paper. Develop a plan that is as simple as possible, with the fewest feet of hose and the least number of fittings.

Next, avoid those complex assemblies of fittings that develop when the right part isn't at hand. Order what you need to do the job right the first time, rather than Mickey Mouse something up from what's on hand.

Finally, minimize the amount of hose-clamped connections in the system. Each clamp is a maintenance point, and its failure may cause additional problems.

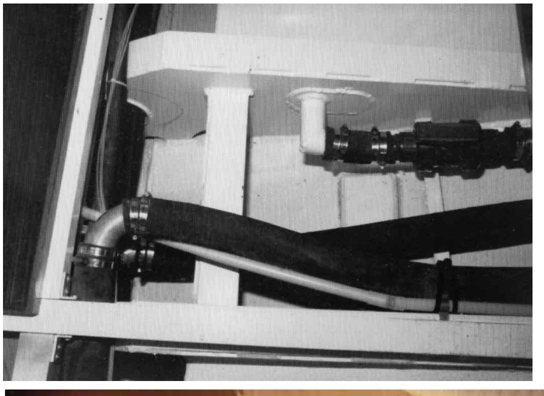
Where possible I prefer to use plastic fittings rather than bronze, which is subject to corrosion and electrolysis. In a pinch, galvanized steel can be used. Brass should never be used in the presence of seawater. Plastic comes in a variety of qualities. Use only the best.

Check the inside diameter of fittings for restrictions. The interior design will vary, and every time the internal cross-sectional area is reduced, the water flow of the entire system in constrained.

Pump Discharge

Pump discharges can usually be tied into a common exhaust line, saving space and plumbing. When this is done, if an angled T is employed, it will keep the exhaust flow heading in the right direction. (When a straight T is used, the exhaust can back into the check

A number of snap-together systems that use O-rings for sealing are neat-looking and quick to install. This is a New Zealand–made system.



Rubber hose will not make a tight bend. Where that is necessary, use stainless, aluminum, or fiberglass elbows.

Use double hose clamps when plumbing diesel fuel or salt water.

PVC pipe and fittings work very well for both fresh- and salt water and for toilet plumbing. The variety of fittings available allows all sorts of creativity. White plastic typically denotes schedule 40 pipe, while gray fittings are usually schedule 80 (which is much heavier).

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valves upstream.) Damage-control pumps should always have their own exhaust because of the very high back pressure created. Also, you may want to have separate fridge or air-conditioning cooling water outlets so you can keep an eye on their water flow.

PVC

We've already briefly discussed PVC fittings. We've found them quite reliable and use them for our salt-water manifolds, pump exhausts, toilet systems, and just about anywhere else they will fit. A large irrigation fitting supplier will have the best prices and the best selection. When using PVC, be sure to use the correct type of assembly cement, and take care to clean fittings before coating.

Try to stay with one manufacturer, as fitting design and appearance varies. A system made up this way will be much nicer-looking.

You will find two weights of materials: schedule 40 is typically white in color and for low-pressure work, and schedule 80 is usually gray and for higher pressures. In most yacht applications schedule 40 will work fine. We typically specify schedule 80 if fittings in question are subject to breakage from an crewmember falling or stepping on the items in question.

If you are watching your weight, keep a close eye on PVC fittings and pipe. They tend to come in at about twice the weight of other materials.

SCHEDULE 40 PVC PIPE

Nominal Pipe Size	Nominal Outside Diameter	Nominal Inside Diameter	Nominal Wall Thickness	Maximum Working Pressure at 73.4º F	Approx. Weight Per 100 ’
1/2	0.840	0.622	0.109	600 PSI	16.5
3/4	1.050	0.824	0.113	480 PSI	21.9
1	1.315	1.049	0.133	450 PSI	32.5
1 1/4	1.660	1.380	0.140	370 PSI	43.4
1 /12	1.900	1.610	0.145	330 PSI	51.8
2	2.375	2.067	0.154	280 PSI	69.6
2 1/2	2.875	2.469	0.203	300 PSI	110.0
3	3.500	3.068	0.216	260 PSI	144.0

SCHEDULE 80 PVC PIPE

Nominal Pipe Size	Nominal Outside Diameter	Nominal Inside Diameter	Nominal Wall Thickness	Maximum Working Pressure at 73.4º F	Approx. Weight Per 100 ’
1/2	0.840	0.546	0.147	850 PSI	20.7
3/4	1.050	0.742	0.154	690 PSI	28.1
1	1.315	.957	0.175	630 PSI	41.5
1 1/4	1.660	1.278	0.191	520 PSI	57.0
1 /12	1.900	1.500	0.200	470 PSI	69.2
2	2.375	1.939	0.218	400 PSI	98.0
2 1/2	2.875	2.323	0.276	420 PSI	146.2
3	3.500	2.900	0.300	370 PSI	195.0

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FRESHWATER SYSTEM

Of all the systems aboard, none is more important to your physical well-being than the freshwater system. Even beyond the life-giving qualities of the water system, nothing makes you feel good at sea like a quick hot shower, or just washing your face in fresh water.



Here are two approaches to showering. One way is to use a quick disconnect fitting on the sink faucet (top two photos). An alternative is to mount a hand-held wand with its own mixer valve (right). The wand can be adjusted in height or used by hand, which is more efficient with water consumption.

Pressure Water Pumps

This pump will probably cause more headaches and frustration than any other problem aboard the boat. However, pumps have improved with the growth in the marine industry.

We've found Shurflo pumps to be quite reliable. We use one of their units on *Beowulf* — which most folks would say required a much larger pump — and it does fine.

Accumulator Tanks

There are a couple of things you can do to help the pump out. First, use an accumulator tank. This tank absorbs and builds up water pressure, and dispenses that pressure when you open the tap, reducing the pump cycles. The bigger the tank, the better.

Pressure Switches

Next, replace the marine-style pressure switch with a good old-fashioned industrial pressure contactor. It will last many times as long. Just be careful it's not used anywhere that needs to be explosion-proof, as these can generate a spark when cycling.

I like to have the pump mounted so you can't miss the noise when it's running. That serves as a deterrent to water usage, and if a line ever breaks, you'll know right away. Also, you can tell if you run out of water and the pump continues to cycle (although most pumps are much quieter when running dry).

Electric Timer Switch

It makes sense to put a timer switch, similar to what is used with a jacuzzi, in the pump circuit. We did this after a broken pipe drained a tank one day. Set it for 15 or 20 minutes, and you won't have to worry about forgetting to turn off the pump switch when you leave the boat.

Since water pumps seem to require so much maintenance, I like to carry one complete pump as a spare, as well as an overhaul kit and at least one pressure switch.

Suction Side Leaks

Be certain that there are no leaks in the suction side of the plumbing, between the pump and the tank. Even a tiny leak, which doesn't drip but does allow air into the line, can cause all sorts of problems with the pump. This problem will be more noticeable when the tanks are low. The air-vent hoses into the tanks should be on a fair, upward run to the vent. Any bends trap water, which in turn blocks air trying to get into the tank to replace water being drawn out. This causes suction problems at the pump.

We typically fit a 1- or 2-gallon (4- or 8-liter) accumulator tank in our water systems.

Manual Backup

After all is said and done, the day will come when your pressure system fails. Perhaps the pumps will go bad, or you'll spring a leak which only manifests itself under pressure. When this occurs, you will want a manual backup pump installed at the galley sink.

This pump should have its own direct tap onto the tank (or tank manifold). Thus, if there's a problem on the suction side of the electric pump, the manual unit still works.

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A swim-step shower is a great way to get your feet clean and the salt off your body before it has a chance to dry after you've taken a dip.

Freshwater Filters

There are three basic ways to filter your freshwater supply. The first is a simple activated charcoal filter. This unit is usually installed at the galley sink in an easy-to-reach spot, so the filters can be conveniently changed. It does a reasonable job with most odor and taste. (Note that some forms of rubber hose leave a definite taste in water.)

The next step up is a filter that uses a combination of materials to strain out taste, certain chemicals, and even bacteria. Capacity varies, but generally, the better the filtering job, the sooner the filter will have to be changed. With extra-fine filters, it's a good idea to use the filter at a special spigot especially for drinking water.

The last approach is a low-pressure reverse-osmosis membrane. The home-style units that fit under the kitchen sink can be used on board, perhaps with a smaller accumulator tank. The only problem is the operating pressure. RO units like to see 45 to 60 psi of pressure, and most boats operate in the 20-pound range, so a small booster pump is usually installed right before the membrane.

One problem to watch for is mineral intake, or lack thereof. Extremely effective filters and RO membranes filter out minerals that the body needs to stay healthy. If you drink this water, increase intake of fresh fruit and vegetables. If that's difficult to do, as it often is when cruising, use vitamin supplements.

FRESHWATER TANKS

A variety of tank materials are available. Just about any modern material, well-executed, does an effective job with fresh water — although all have trade-offs.

As with all tanks, baffle design is something to consider. We like to see baffles at a maximum of 24-inches (610mm) on center. This limits sloshing, which can be quite noisy at sea, especially if you are rolling in the trades.

Each tank should tie into a single manifold with valves on leg. This way you can easily select which tank to draw on.

A lot of builders vent freshwater tanks into the galley sink. This is okay as long as the sink has a direct overboard discharge.

Tank Plumbing

Tank vents must be mounted where they cannot be flooded with saltwater. We usually bring our breathers to the centerline of the boat, up to the deck head, and then down to the bilge. *If the top of the breather is above the fill, you will never have an overflow into the interior.* Once the tank is filled, it will overflow via the fill on deck.

Deck fills should seal with an O-ring, and you will want to make checking them a part of the pre-departure list.

One caution when filling from a pressurized shore hose: Shore water typically runs at about 50 psi. Most tanks are only designed for 5 psi. If the shore hose is stuffed down far into your fill, and if air cannot escape fast enough, the tank will eventually become pressurized beyond its capacity. The results can be disastrous!

For efficient rain catchment, the deck fill should be at least an inch and a half (37 mm). Two inches (50 mm) is better. Vents are typically half the diameter of fills.

Some form of a crossover between tanks is helpful. This way you can run one tank until it is dry, then split what is left of your water. Then you know that you have half a tank on each side. When you use up that half, re-split the water, and you know you have a quarter tank on each side. This is an effective way of managing water consumption.

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Stainless Steel

The preferred material for water tanks is 316 stainless. It is essentially inert as far as fresh water is concerned and does not react badly when you introduce a bit of chlorine for water purification.

Aluminum

With an aluminum hull, aluminum tanks will be built into the boat. Aluminum is okay except for two issues. One, it does not do well with chlorine. Clean tanks with chlorine only occasionally, rather than routinely.

Second, there may be a link between aluminum and Alzheimer's Disease. However, everything we've been able to find on this subject indicates that aluminum as we use it in tank construction is a non-issue with health problems.

Still, being more concerned with our health and/or mortality in middle age, we now fit a small stainless tank for drinking water on our aluminum boats. The watermaker feeds the drinking water tank first, and then it overflows to the main tanks after the drinking tank is filled.

Fiberglass

As long as fiberglass tanks are correctly done, they work fine. They should, however, be coated with a potable water–approved coating. Even with this coating, there will still be a taste and odor problem for some time after the tanks are built. The only way around this is to fit charcoal water filters to remove contaminants.

Polyethylene

High-density cross-linked polyethylene tanks are excellent for water, as long as they are heavily made, securely supported, and without hard spots to create cracks in later life. The tank material is inert and will last indefinitely if of good quality.

Bladders

Bladder tanks can be just the ticket for backup water supplies, and for installation in areas where a solid tank would prove troublesome. However, they should be carefully secured, and any sharp edges should be smoothed off in the tank vicinity.

Bladder tanks need a smooth, constrained space. Although high, the cockpit well makes an excellent temporary location.

Deck Catchment

In most cruising areas, an efficient water-catchment system can keep tanks filled most of the time. There are many ways to catch water, some of which are dealt with in the awning chapter.

If you have a trunk cabin, the cabin top can be surrounded with a solid hand rail, with pipes or spigots let into each side. A hose is then led from there to the deck fills.

An even better approach is to use the entire deck as a catchment. Any chocks through the toe rail will have to be plugged. A rag will usually do the job.

A small dam in front of the fill will trap silt which may have accumulated on deck.

Water Capacity

Water capacity is very much a question of trade-offs, vessel size, and the area in which you cruise, as well as by your approach to watermakers. (For a preliminary discussion of this issue see "Fresh Water" in the "Cruising Life" section.)

At a minimum you will need 1 quart (1 liter) of fresh water per person per day.

On *Intermezzo* we averaged right around 4 gallons (15 liters) per day for the four of us. This included a quick shower each day for Linda and me, and every second day or so for the kids. Showers, dish washing, and clothes were done in a combination of salt for primary wash, and fresh for rinsing.

We rarely used more than half of our 210 gallons (813 liters) before we were able to catch rain water or fill up on shore.

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HOT WATER

Of all the systems to consider aboard the cruising sailboat, none is more important to *civilized* life afloat than *hot* water! When properly integrated into the rest of your ship's systems, plentiful supplies of hot water can be taken for granted. With the right approach to plumbing, the domestic hot-water supply can also keep your lockers warm and act as an emergency cooling system for the engine. We'll even show you how to take a *long* hot shower with limited tankage.

There are three major areas to look into when thinking about a new hot-water system or upgrading your present approach. The heat source is first, next is the storage system, and finally, the approach to plumbing.

Defining Requirements

Before you can evaluate different approaches to making hot water, you need to evaluate your requirements. If you are keeping things relatively simple, showers will be short, and a hot-water cylinder that runs off of waste engine heat will be fine.

But if you want lots of hot water, for the dishes, multiple showers, and perhaps a washing machine, then things get more complicated.

Sun-Based Systems

Al and Beth Liggett cruised and lived aboard for years with just a simple sun shower hung in the cockpit. In the tropics, at least, this sort of system generates hot water for a couple of quick showers with surprisingly rapid recovery time on the tank.

Another approach to this concept is to take a large black bladder tank, tie it to the top of the cabin when anchored, and create plenty of hot water at once! The tank could then be gravity-fed to the shower. You wouldn't want this weight on the cabin top at sea, however.

Engine-Based Hot Water

Whenever the auxiliary or genset is running, a huge amount of waste heat is available from the diesel's cooling system. Tapping into this source, just as you would for a car heater, provides a virtually unlimited source of hot water.

It is not recommended to run the engine only to make hot water. The short running time and lack of load would shorten the life of the engine. However, if you use a diesel for daily charging, this approach makes lots of sense.

Diesel Heaters

The minute you start to think about heating the boat, you introduce a diesel heater into the equation. (More about this in the chapter on heating and air conditioning.) Even the smallest water-based system will have the ability to heat a large hot water tank in a matter of minutes.

Now you are no longer dependent on the engine for your hot water. If using solar or wind energy for the rest of your needs (including refrigeration), then a diesel heater or a sun shower are the only alternatives for hot water.

Propane Water Heaters

Propane water heaters make a lot of theoretical sense. However, the concept of an unattended propane source, run more or less automatically, scares the hell out of me. On the other hand, if the heater were isolated in its own vapor-proof locker, and used like a stove with a solenoid in the gas line, it might make sense. These heaters are light in weight, and provide 1 gallon (4 liters) or more of hot water per minute, on demand.

Hot-Water Tanks

With engine waste heat, a diesel boiler, or shore power, you will have some form of hot water tank. How this is made, the type of heat exchangers, and the insulation involved will have a big impact on how good a job it does for you.

Insulation

Let's talk about insulation first. Most heaters have 1 inch (25mm) or so of fiberglass batting around the basic tank. This is next to worthless as an insulator. Much better is a tank with polyeurethane foam. We look for tanks with a heat loss rating of less than 1 degree Fahrenheit per hour.

Size

Assuming you have good insulation and efficient heat exchangers, then bigger is better — within the context of what you can fit into the boat. If you run the engine or genset for an hour for daily electrical/fridge needs, you have the capacity to make huge amounts of hot water. Why not store as much as possible?

Once the hot water in the tank is up to engine temperature (typically 180 degrees Fahrenheit), it will be necessary to mix it with cold to bring it down 60 or more degrees to a usable temperature. This means that whatever you've got in the tank can be multiplied by at least 1.5 for usable hot water.

We typically try to fit at least 12-gallon (46 liter) tanks. This is enough hot water, if you've got good insulation, to last several days for two people — or one day for four people consuming lots of water.

Assuming there is plenty of space for the heater, is there such a thing as too big a unit? Heaters do take up space, and while the tanks themselves are light, the water is heavy. It is best to balance the heater size against your daily charging cycle, if there is one. If the engine is run every day, the tank only needs to be big enough for a single day's needs. If you rarely use the engine for charging, the tank should span several days, so that each time the boat is moved, enough water is made to last until the next move.

With a diesel-fired boiler tank, size can be minimal since you can heat water on demand. However, the tank should be large enough to avoid short-cycling the boiler. In this case, about 6 gallons (23 liters) is about right.

Tank Construction

Stainless or ceramic/glass-lined steel are the materials of choice for tank construction, although there can be corrosion problems over time. Of the two, I prefer lined steel, which doesn't have the corrosion problems sometimes inherent with stainless. If you do use stainless, it should be at least 1/10-inch thick (2.5mm).

With the tank subject to system pressure, it has to be round in shape to take the loads. Flat tanks rarely hold their shape and tend to buckle with time, eventually leaking.

The cover should be plastic or stainless steel.

Heat Exchangers

Now we get into the critical part of the equation. How long the heater takes to make a tank of hot water, and how quickly it recovers, is a function of heat exchanger size and capacity.

Most units barely handle 4,000 Btu per hour. Good units, on the other hand, have heat exchangers rated at 20,000 to 30,000 Btu. A heat exchanger like this will give as much as a 100-degree Fahrenheit rise in water temperature at the rate of 3 gallons (11 liters) per minute! Now, that's some serious water heating.

The most efficient heat exchangers consist of large coils of finned cupra nickel tubing. The combination of fins and length provide surface area, and surface area is what transfers the heat.

We typically fit several heat exchangers to a tank, one for each source. If there's a main engine, genset, and boiler, there will be three heat exchangers in the tank. You may also want one or more electric elements. The norm is a single unit of about 1,200 watts. With an electric genset, it's a good idea to fit several large electric elements, providing a load for the genset to work against when not many other accessories are being run.

Safety

All the diesel sources mentioned produce extremely hot water. Contact with water of 180 degrees Fahrenheit (or hotter) results in a severe scalding. For this reason, take care working with and around this gear. A blown hose on a hot heater could lead to a serious medical problem.

At the same time, be careful in the shower. Warn crewmembers not familiar with the system to start with the water tap in the cool range, and work it up to the required heat. Remember that household hot water is rarely above 120 degrees Fahrenheit, and even that can scald you.

Hot-Water Plumbing Layout

Most boats are plumbed with hot-water service running in a straight line, from the closest faucet to the hot-water tank, to the one that is farthest away. You couldn't pick a more inefficient way to do things.

First of all, you need to wait for the hot water to arrive. If water consumption is an issue (and when isn't it?) you end up with buckets filled with cool shower or galley water to be dumped back into the tank later. Also, as you are washing, turning the water off and on as needed, temperature varies each time you turn the faucet back on!

If this sounds familiar, there's an easy fix. Find the end of your hot-water run — the last point on the hose, farthest from the heater, usually in the forward head — and install a valve. The exhaust from the valve goes back to the freshwater tank.

When you need hot water, open the valve and allow the cool water in the lines to pass directly back to the tank. You'll feel the water temperature rise right through the valve handle (use metal rather than plastic). When things have warmed up proceed to use water in the galley or shower without carrying buckets of slopping water through the interior.

There is a second significant advantage to this approach if the heat source is your engine. In case you lose saltwater cooling due to a bad impeller or blocked water sea strainer, the heat exchanger in the hot water tank will help cool the engine by opening the fresh water valve and dumping water back into the tank. The smaller the engine, and/or the larger the heat exchanger capacity in the tank, the better job it will do. We once ran the 50-horsepower engine on *Intermezzo* for several hours this way!

Hot Water Circulation

The next step is to use a circulating pump to move the hot water in a circle from the heater and back. We used this method on *Sundeer,* and it works well. This works as follows: Cold water from the pressure pump enters the water heater through a one-way flow or check valve. It exits at the top, as usual. The water flows in a circle around the boat, ending at the cold-water inlet, with another check valve. (Both the cold water from the pressure pump and the end of the circuit come together in a T.) A pump, usually a centrifugal model mounted near the heater, pushes the water around in a circle.

If you're moving the hot water far, keep the pipes insulated with 1/2-inch neoprene. Otherwise, heat loss will be substantial.

Insulation

For the most efficient use of hot water, especially with a recirculating system, be sure to insulate all hose. A stop at the local builder's supply will yield inexpensive closed-cell foam piping, with just the interior diameter you need. Try to cover as much of the system as possible, bringing insulation right to the mixer valves or faucets in your system.

Locker Drying

On the other hand, you might want to use your hot-water circuit for drying lockers. This may be for a specific area, perhaps to keep crackers and cereals crisp, or the foul-weather gear locker less damp. With the circulation pump turned on and the heat source (shore power, engine, or diesel heater) engaged, you can radiate heat wherever those hot pipes travel.

To increase heat radiation, insert a section of copper tubing into the circuit. This is good for about 75 to 100 Btu per foot (300mm) of copper pipe. Most plastics radiate at less than half this rate. In any case, insulation should be left off in these areas.

Long Showers

Twenty years ago, when we first started cruising, the one thing I really missed from shoreside living was a long shower. This is where I had always done my best thinking. But with a limited supply of water to last for four people on long ocean passages, the quick on/off treatment became a necessity —that is, until the day our salt-water pressure pump (used to supply deck wash, galley and shower water) gave out. When the time came to replace it, I decided to plumb the pump pickup hose into the water injection elbow of the engine. This is the point at which the salt water that has been used to cool the engine is injected into the wet exhaust system.

And guess what? That water is warm! From that point on we had warm to hot salt water for use in the galley and shower. It is amazing what a difference this makes when washing greasy dishes or rinsing soap off your body.

There's another way to get long freshwater showers with minimal consumption. This involves reusing the shower water. With a second shower drain or a T into the existing drain line, a new pressure pump is installed (usually your spare pump). The output of this pump is divided into two lines just as with the basic freshwater system. One side is ambient-temperature water (that which is picked up from the shower sump) while the other goes through an in-line heat exchanger. If the engine or a diesel furnace is being used to provide heat, and a circulating pump is used in the main hot-water circuit, the heat exchanger can go right into the primary line. If a propane heater is being used, use a Y-valve to switch the heater's water supply from primary to the shower system.

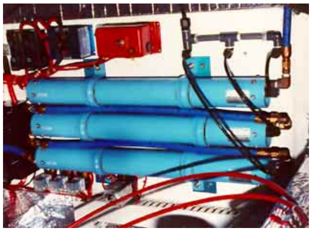
Basically, you take a quick shower in the normal manner. After rinsing and draining the sump, allow 1 gallon (4 liters) or so of clean water into the sump, switch valves, and you can shower all day in hot water.

WATERMAKERS

I confess to some ambivalence on the subject of watermakers. While we've always fitted them to the yachts we've built for others, I've felt uncomfortable with their level of complexity and so have shied away.

In the early days of the watermaker industry, the machines were a headache to maintain. But they've improved. Now, the major consideration in keeping them operating is usage. Used on a regular basis, good-quality units seem to go on for years, albeit with a high degree of maintenance in the process. Regular usage is at least once a week. If the watermaker is laid up for a while, special chemicals clean and protect the membranes. Better yet is to flush fresh water through the system on a monthly basis.

Two small units from PUR. The electric models (above and left) are very efficient in terms of power consumption. However, maintenance reviews have been mixed. Left: An alternative, for those who don't mind working for their water, is a small hand operated unit (which also works in the life raft).



A panel-mounted Sea Recovery unit. This has all the bits out where you can see what is going on.

Full-time cruisers with space and budget to devote to a unit will certainly find the abundant supply of fresh water a benefit to life on board. But if you only cruise in the summers, the maintenance, cost, and space hassles of a watermaker probably outweigh the time needed for an occasional extra trip to the dock for a tank fill-up.

Drive Type

If you feel that a watermaker is in your future, the first decision is drive type. There are three choices. Engine drives make sense where electrical power is already in short supply. The only drawback is the allowable rpm range. Above this range, the overpressure switch will kick out. Going below this range causes problems with the membranes. You have to pick an engine rpm range that allows you to power and to charge batteries with the watermaker's high-pressure pump engaged. This is possible with slow-speed engines. But with higher speed engines it's impossible, forcing you to pick an unhappy compromise.

The advantage of engine-drive units is that they produce huge quantities of water very quickly — typically 25 gallons (97 liters) or more per hour. So, running one hour every third day or so will do the trick for most cruisers.

AC motor-driven systems used to be the most common. These generally take about 1.5kW to run, and about twice that to start. This calls for a genset and a large inverter (with a big alternator on the engine) or a cruise generator on the main engine to run the watermaker.

The advantage of an AC unit (compared to DC) is a lightweight motor, as well as a system independent of your engine rpm. With an AC genset, this is obviously the way to go.

A couple of small DC units are now on the market. These take 4 to 12 amps (12-volt systems) and produce anywhere from 1 1/2 gallon to 5 gallons (6 to 19 liters) per hour.

Recovery Engineering and Village Marine Tech have been battling over this market for several years. We prefer the Village Marine unit.

There is little difference in cost between these smaller units and a simple engine-driven system. The small DC systems are easier to install, but it's annoying to listen to them pumping away for a long period of time every day.

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Filters

Having decided on the drive system, you then need to look at the filters. The better the filter system, the longer the membrane and pump will last. It's usually best to start with a 400-micron (60 mesh) cleanable screen. If you cruise in areas rich in plankton — Alaska, the Baltic, or anywhere whales feed — a cleanable plankton screen of about 100 microns makes sense. Then comes a 25-micron disposable paper cartridge, and then usually a 5-micron cartridge. Finally, if you expect to use your unit in oily harbors, an oil/water separator with a 5-micron filter is a necessity. Oil will ruin the RO membrane.

Pressure gauges at each filter to tell can indicate when it needs to be changed. Also, consider a charcoal filter for use on the product-water side.

Booster Pumps

Most RO systems offer a booster pump to help push water through filters and to the high-pressure pump. The booster pump, typically a centrifugal-style unit, will lengthen the lives of the filter elements. A self-priming booster pump can also help to keep a prime in the system when underway (which is sometimes a problem on modern, shallow-bilged designs).

We've had success using normal salt-water deck-wash pumps for this purpose. Be sure they have a capacity equal to the needs of your high-pressure pump.

Ultraviolet Sterilization

Then there's the question of ultraviolet sterilization. This kills salt-water bacteria that squeeze through the RO membranes. If you plan to be use your system in harbors or anywhere near sewer outfalls, UV sterilizers make sense. On the other hand, chlorinating the tanks periodically will do the job, too.

Mounting Issues

The last consideration is the style of mounting. There are compact boxes with everything contained inside, kits which you assemble yourself, and panel-mounted systems — or combinations of all of the above. The most important consideration is space. You must be able to change the filters easily, adjust belt tension, check oil level in the high-pressure pump, and keep an eye on the high-pressure hose fittings. Don't be afraid of kit-style systems. The plumbing is usually quite easy.

We started off by saying we hadn't used a watermaker before. Well, when we were putting together *Sundeer*, Steve Rollins at Sea Recovery sold me on giving the concept a try. He even offered to take our unit back if I didn't like the corruption of my simple lifestyle. By the time we'd finished installing the unit in the engine room I had decided that as soon as we got back to Los Angeles he would be the first person I'd call. Who needed this ugly monster, anyway? But then I started to wipe down the hatches with fresh water at sea, and take long hot showers, sometimes actually letting the water run over my body after I had finished rinsing! When we did *Beowulf* we decided to try one of the small DC-based units. A Little Wonder from Village Marine did an excellent job. However, it seemed to be running three or four hours per day, and the noise, while slight, was annoying.

When we finished the engine room in New Zealand, we added a DC genset of our own design. To this we mounted a 50-gallon-per-day (193 liter) Village Marine engine drive system. This unit makes all the water required with the genset running for an hour every third day. The small DC set is left as a backup.

Frills

Watermakers come with all sorts of frills, a number of which we've discussed. There are also very simple models on the market without automated controls. Our own feeling is the simpler the better. Fewer automated gears means there is less to go wrong.

We prefer a high-quality high-pressure pump, good membranes, a product flow meter, and that's it. All manual. As simple as you can get. This is less costly, and far more reliable.

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PROPANE SYSTEM

Before we leave the topic of plumbing, we need to discuss the propane system.

While propane introduces risk of explosion, it is by far the most efficient cooking fuel. As a result, this is what the vast majority of cruisers use in the galley. However, it is extremely important to carefully plumb, maintain, and use the propane (or butane) system.

Flammable Stores Storage

Store propane tanks either on deck, where a leak will not infiltrate the interior, or in a self-draining gas-tight locker. On most modern yachts a gas-tight locker is built-in. Hopefully it will be a single-part molding, allowing no possibility of a leak. There will need to be drain holes at the bottom, through which water or gas can exit. Make sure that this drain hole, which goes through the locker liner and then through the hull, is a gas-tight connection. Access to the gas locker should be through the top.

Alternately, your propane tanks may be mounted on the stern deck, stern pulpit, swimstep, or perhaps at the aft end of the cockpit.

Propane tanks should be well secured. Ideally, they will not share storage area with anything else — and especially not with anything that could cause chafe or wear.

Note — these same issues apply to all flammable stores, including outboard fuel, paints, and thinners, as well as portable propane cylinders used with torches.

Tank Types

Propane tanks are available in both horizontal and vertical configurations. The main difference is how the gas is picked up. What you want is a situation where you get gas and not liquid coming through the valve. Using a vertical tank in a horizontal mode (and visa versa) means you'll be getting liquid into the system any time the tank is more than halfway filled.

Old tanks were usually steel. These are still available, but aluminum tanks (most of which are built by Worthington Manufacturing) are a far better choice for cruisers. These last indefinitely, are much lighter to carry, and don't have a problem with rust.

Aluminum tanks are typically left bare. Steel tanks must be painted to protect them from rust. Be sure they are painted white. A dark color left in the sun will raise tank temperature and pressure, to dangerous levels.

Capacity

Capacity is a question of storage, handling, and how long you want to go before refilling.

Most folks carry two 20-pound cylinders. In aluminum, this makes the tank and gas when filled come in at about 30 pounds — a too bit much to carry far, but a good compromise, considering capacity.

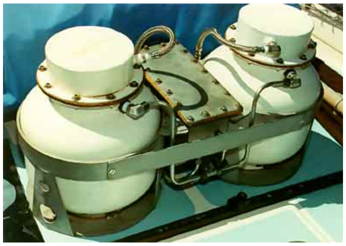
Over the years we've found that with four of us on the boat, if we supplement stove use with a microwave and a toaster, a single tank lasts 10 to 12 weeks.

Multiple Tanks

There is a temptation with two or more tanks to connect both tanks to a manifold. Unfortunately, this significantly increases the complexity of the system and doubles chances for leaks. It is usually best to go with a single plumbing set, then take a couple of minutes from time to time to check tank capacity. This way you can change before running out.

Solenoid Valves

Immediately after the tank, you will want to install an electric solenoid valve. Locate the control in a convenient spot near the stove. This is not just a convenience, but a significant safety feature. Whenever the stove is not in use the valve is left off, reducing any chances of leaks.



Two approaches to dual tank storage. If you have a clear spot on deck, you need only provide a secure mounting, and eventually a cover. This is the safest system. A built-in gas locker must be carefully sealed and must drain overboard.

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Warning Lights

Install a big, clearly visible warning light — we typically use a 1/2-inch (12mm) red LED — as a reminder that the propane solenoid is on.

Pressure Gauge

Immediately after the solenoid valve, install a pressure gauge. The chief purpose of this is to check for leaks. With the stove turned off, note the pressure reading. Then turn the tank off on the tank leaving the solenoid on. Come back in twenty minutes and recheck the pressure. It should be the same. If it has dropped, you have a leak.

Pressure Regulator

The pressure at the tank is too high to be used in the stove, and dangerous to deal with in all of the plumbing connections downstream of the solenoid valve. So the next piece of equipment is a pressure regulator. This reduces gas pressure to a fraction of the native tank pressure.

Pressure regulators occasionally fail. Without one you cannot use the stove, so you may want to carry a spare.

The pressure regulator is installed with its vent hole facing down, so that water does not accumulate inside.

Hose

From the pressure regulator to the stove, use a Coast Guard–approved section of 3/8-inch (10mm) propane hose. This should be run in such a fashion that it does not chafe. Some form of a grommet should be used to protect the hose where it passes through bulkheads or furniture. Make sure that stored goods cannot chafe or cut into the hose.

Where the hose passes through the gas locker, you will need some form of a gas-tight seal. This is most easily accomplished with a flange slipped over the hose before the end fittings are attached. This flange is then fastened to the wall of the gas locker, using generous amounts of sealants.

Pay particular attention to chafe around the stove area. With the stove swinging back and forth as the boat heels, you have a natural chafe condition. A generous loop of hose, well secured at each end, needs to be in place. Carefully check how the hose reacts to movement of the stove.

Connections

Connections should be carefully made in good plumbing fashion to be sure they are gas tight. Use wrenches of the correct size, rather than crescent wrenches. Pipe threads are usually tapered and seat without the use of sealant or Teflon tape. However, if you are using untapered British pipe threads, some form of thread sealant is recommended.

Always use soap and water to check connections for gas tightness.

Cold-Weather Considerations

As temperatures drop, pressure in the propane tank drops. After a while this affects gas flow from tank to stove. The first sign of this will be when it becomes difficult to use more than one burner at a time. With more drop in temperature, even that single burner gets low.

Aside from sailing closer to the equator, is there anything you can do? Yes — by insulating the tank you can delay the onset of these problems.

With propane, as long as the tank's ambient temperature is above -20 degrees Fahrenheit (-29 degrees Celsius) it will work fine. Butane, however, needs the ambient temperature must be much higher or it will not flow through the regulator. Below 32 degrees Fahrenheit (0 degrees Celsius), butane starts to have problems.

Electronic Gas Sniffer

An explosive gas sniffer in the lowest part of the boat is a good insurance policy. These are easy to install and take negligible power. Take care with the probe to mount it low but also in a place where it will stay dry. Since probes typically fail after several dunkings, keep an extra probe or two in your spares kit.

Biological Sniffers

Propane and butane in their natural state are odorless. In most parts of the world a chemical is added to give the gas a distinctive odor. Even if you have an electronic sniffer, periodically rely your nose to check any closed spaces that could accumulate gas.

Although all the gas we've ever purchased has been odorized, we've heard stories about Third World countries where this is not done. If you run into this situation, avoid using odorless gas. It represents too big a risk.