GOOD OLD BOAT

presents

Sailboats 101

by Don Launer

LAYOUT AND ILLUSTRATIONS BY TED TOLLEFSON

This collection of Sailboats 101 articles begins with the first article published in the July/August 2003 issue and concludes with the November/December 2011 issue.

Good Old Boat presents Sailboats 101

Thanks for purchasing *Sailboats 101*!

The *Sailboats 101* series of articles — written by Don Launer and illustrated by Ted Tollefson — were introduced in 2003 in our July issue. Some of our readers asked for a basic overview of technical information and we realized that each issue of our magazine lands in a household, a family, or a boat crew with widely differing backgrounds and skill sets. We thought it would be a good idea to address this wide range of experience among our readers with two pages devoted to the basics.

There's no one better at explaining something concisely than Don Launer, a lifetime do-it-yourselfer, sailor, engineer, and tinkerer. We asked him to write no more than 900 words on any topic and to work with Ted Tollefson, another sailor who would be doing the layout and developing the illustrations.

Beginning with *Depth Sounders 101*, Don came up with the subjects for each 101 article. Subject matter has varied widely and includes binoculars, bilge pumps, bronze, and brass. This *Sailboats 101* collection contains all of Don's articles from July 2003 to November 2011.

Much more technical and detailed articles on similar topics ran in other issues of *Good Old Boat*. The *Sailboats 101* series was never intended to lead anyone through a complete project, to teach him or her everything there is to know on a subject, or to manage an entire installation. As their name suggests, 101 topics offer introductory information on a variety of subjects covered in other ways in our pages.

We've enjoyed bringing each two-page spread to you over the years and hope you'll enjoy this collection as much as we enjoyed gathering the articles for it.

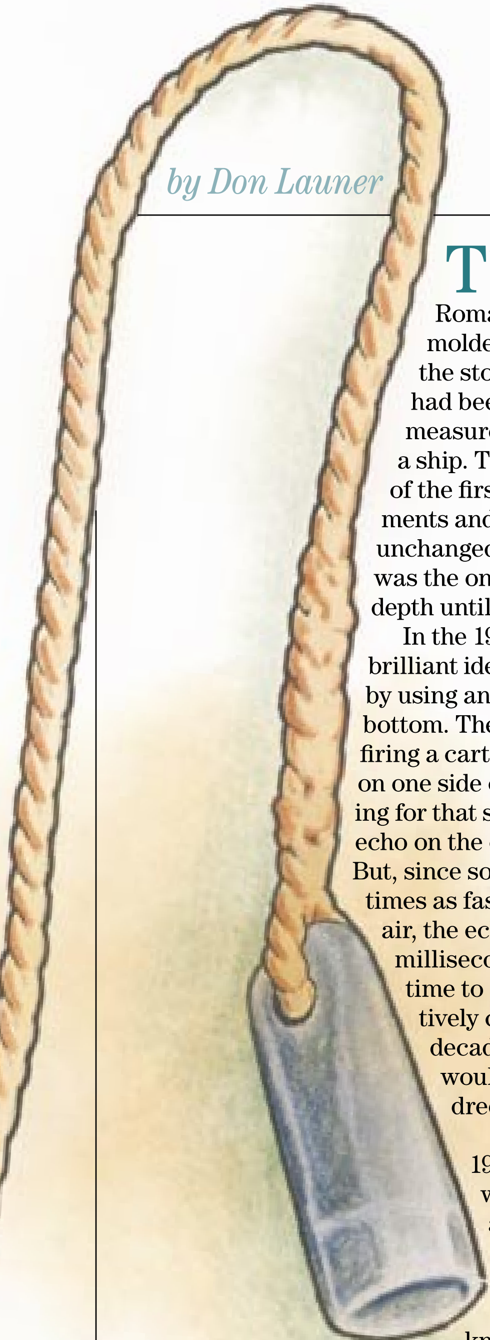
The *Good Old Boat* crew

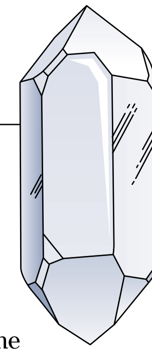
CONTENTS

DEPTH SOUNDERS 101

The short course — the first in a series of overview articles for those who want just the big picture

by Don Launer





TWO THOUSAND YEARS AGO, during the age of the Roman Empire, weights were molded from lead to replace the stone tied to a string that had been used previously to measure depths off the side of a ship. This lead line was one of the first navigational instruments and remained relatively unchanged for two millennia. It was the only method of measuring depth until the late 1930s.

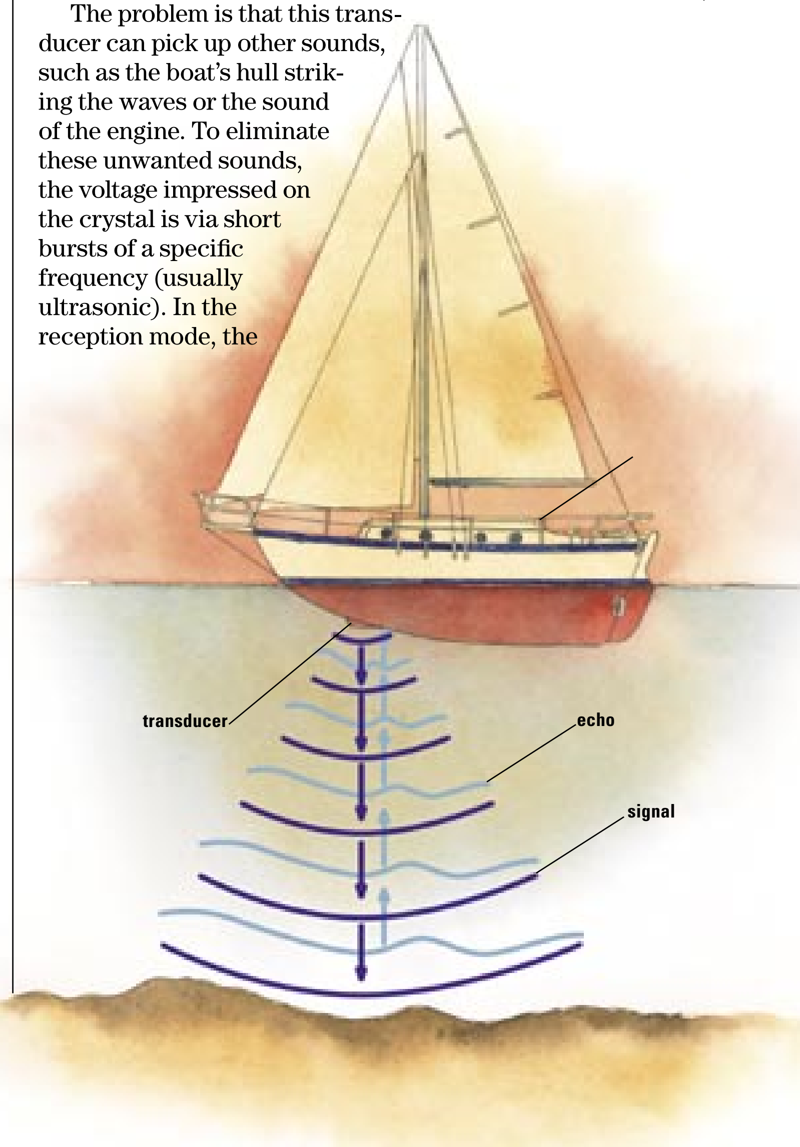
In the 1920s, someone got the brilliant idea of measuring depth by using an echo from the sea bottom. The first attempt was by firing a cartridge into the water on one side of the ship and listening for that sound and the return echo on the other side of the ship. But, since sound travels about four times as fast in water as it does in air, the echo, which returned in milliseconds, was too short a time to measure with the relatively crude technology of that decade. At 24 feet, the sound would be returned in a hundredth of a second.

It wasn't until the late 1930s, when electronics was progressing by leaps and bounds, that echo depth sounding became practical, using an electrical phenomenon known as the piezoelectric effect.

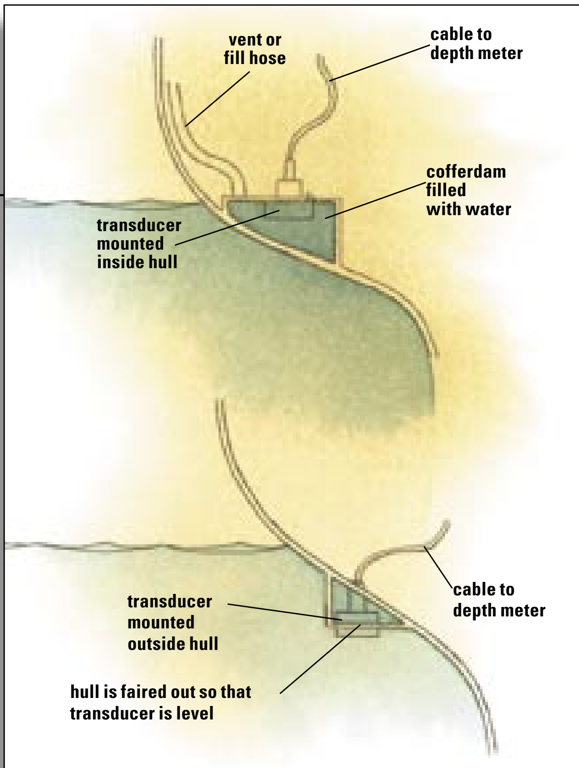
The piezoelectric effect was first discovered in 1880 by scientists Pierre and Jacques Curie. They discovered that if you take certain crystalline substances, such as quartz, put a metal plate on each side of it, and apply a voltage to these metal plates, the crystal physically changes shape. Now, if you put this mechanism under water and hit those electric plates with a sudden, short, high voltage, the crystal changes shape so suddenly that it creates an underwater sound. This sound could then be used to replicate the crude method of firing a cartridge into the water that was used in the 1920s experiment.

This same quartz crystal also works similarly in the reverse direction. If you put pressure on this crystal, a voltage is developed between the two plates, and if tension is applied to the crystal, an opposite voltage is developed. Using this reverse technology, the quartz crystal can be used to receive the return sound (a pressure-wave), which strikes it and creates a voltage. By measuring the time difference between the sound initiated by applying the sudden voltage between the crystal's two plates and the voltage generated when the return sound strikes the crystal — and knowing how fast sound travels in water — the depth of the water can be determined. A device that can change energy from one system to another — in this case from electrical energy to sound and vice versa — is known as a transducer. Although the same crystal can be used to generate and receive the sound waves, in some applications two separate crystals are used.

The problem is that this transducer can pick up other sounds, such as the boat's hull striking the waves or the sound of the engine. To eliminate these unwanted sounds, the voltage impressed on the crystal is via short bursts of a specific frequency (usually ultrasonic). In the reception mode, the



Layout and illustrations by Ted Tollefson

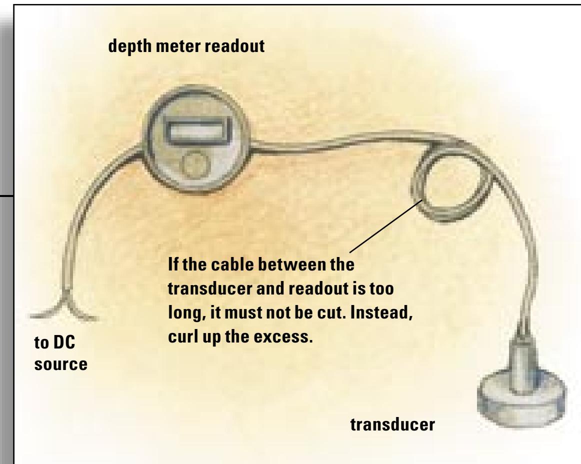


receiver is tuned to receive only this same reflected specific frequency, excluding all other un-wanted sounds.

The sound radiated into the water is in the shape of a cone. This shape is determined by the frequency of the pulsed signal and the physical characteristics of the transducer. The area of the bottom covered by the cone is a function of depth. A reflection occurs whenever the sound strikes a boundary whose propagation characteristics are different from those of the water into which the sound was transmitted.

Although much of the early experimentation was done with quartz crystals, other crystalline substances are now generally used for the transducer.

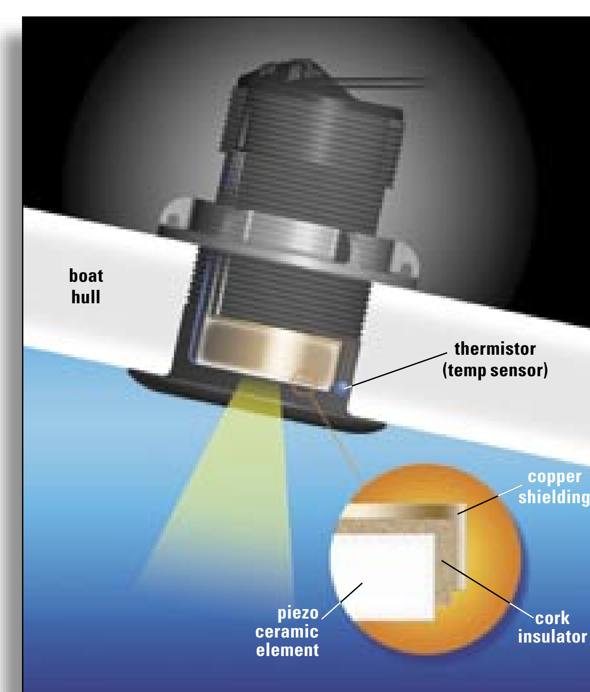
So now we have a system for measuring depth that is just as accurate as the lead line — or do we? Sound travels faster as the transmission medium becomes denser. So sound travels about four times faster in water than in air — about 4,800 feet per second. But there are varying densities of water. If you measure a depth using an echo sounder in the Great Lakes and then measure that same depth off the New England coast, you'll get two different readings. Since the salt water of the Atlantic is denser than the fresh water of the Great Lakes, the sound will travel faster, the return time will be shorter, and the depth finder will indicate a shallower depth. Similarly, if you measure the same depth in the Gulf of Mexico, there will be yet a third reading because the Gulf of Mexico has lower salinity than the waters off New England. So there is always some difference between the actual depth and the depth indicated. Although these differences are relatively minor, often bathymetric depth measurements



are still being done by the most accurate method — the 2,000-year-old lead line.

Other factors can also affect the accuracy of the echo depth sounder, such as seaweed or grass, a soft mud bottom, a school of fish or plankton, or a thermocline (a horizontal interface between cold and warm water). Also, since the sound pulses are propagated down in the shape of a cone, the first reflected sound will be interpreted as the depth beneath the boat, when these reflections may actually be coming from objects at the edge of the cone. Another source of error is the heel of a sailboat or rolling of the boat, which causes the transmission cone to become canted. Compensation must also be made for how deep the transducer is below the surface of the water.

However, the modern depth sounder is much more user-friendly than the old lead line and is now the instrument of choice on modern sailboats.



AIRMAR Technology Corporation

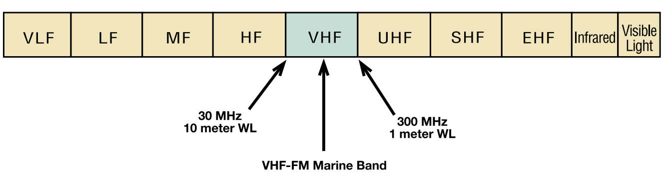
Understanding and using your marine-band radio

by Don Launer

THE PRIMARY SHORT-RANGE RADIO-COMMUNICATION SYSTEM for most small craft is the VHF-FM marine-band radio. It is the communications method of choice for the recreational boater, and a station license from the FCC is no longer required for use within the United States.

VHF stands for Very High Frequency — the band of frequencies between 30 and 300 megahertz (MHz), with wavelengths of 10 meters to 1 meter, respectively. The marine band, with frequencies between 156 and 163 MHz, is located in this broad VHF band, which is home to a variety of services, including FM radio, aviation, police, commercial uses such as trucks and taxis, garage-door openers, scientific and medical uses, cordless phones, amateur radio, radio control, and television channels 2 through 13.

Just like those television signals, this marine band is usually described as "line-of-sight," which means that the higher the antenna is, the greater the range will be. Actually, VHF signals bend slightly, attempting to follow the contour of the earth. Infrequently, when special layers of



the ionosphere form a reflective path, they can travel hundreds or thousands of miles.

FM stands for Frequency Modulation — the same type of signal that brings us our FM broadcast stations static-free, as well as the sound on our TV.

Although some people new to boating eschew the marine-band radio in favor of their cell phones, this is a bad idea. In an emergency situation, when you're using the marine band, you can reach the Coast Guard directly, and other boaters nearby can also hear your Mayday call and come to your assistance. (Mayday is a phonetic way for the English-speaking world to say the French phrase, "Help Me." This term was established in the early part of the last century, before English took over from French as the language of diplomacy and international travel).

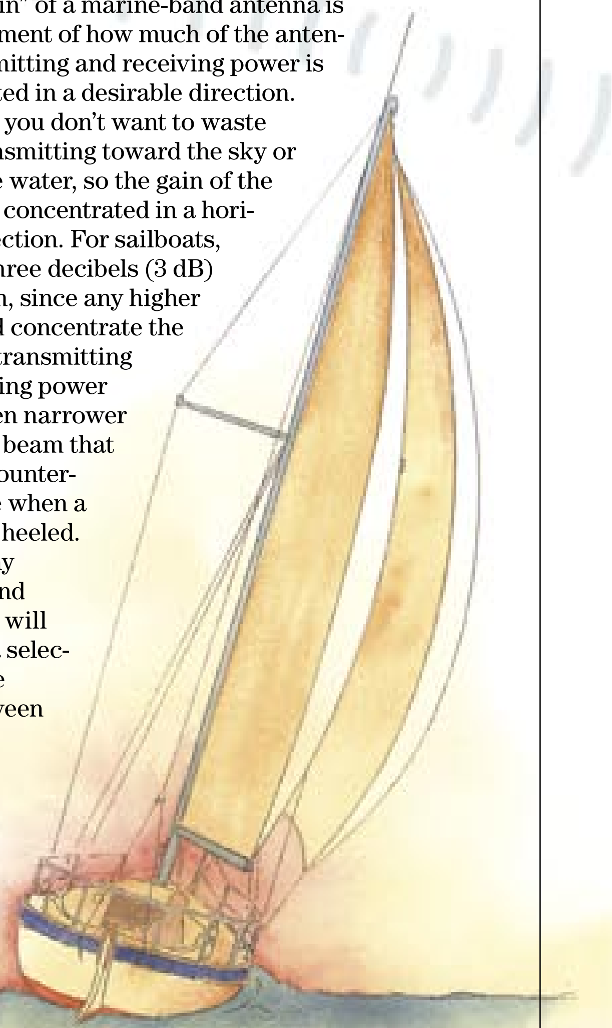
Power limited

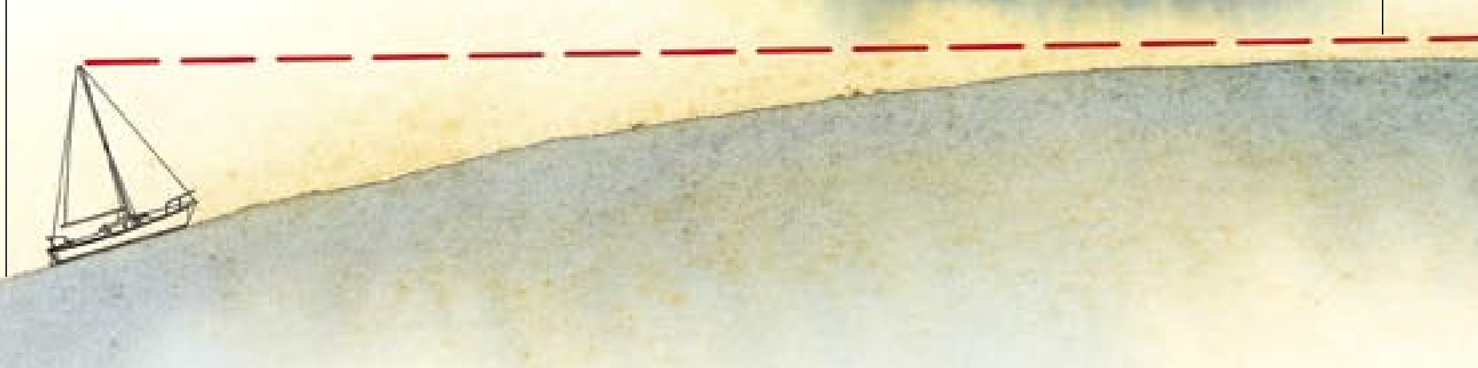
The power of a marine-band transmitter is limited to 25 watts, the amount of radio-frequency energy that goes into the antenna. It is also required that this power can be readily reduced to 1 watt for short-range communications.

Antennas for the marine band are vertically polarized. This means that the transmitting antenna element is vertical and, for optimum performance, receiving antennas should also be vertical. (TV antennas, as we have all observed, have horizontal polarization).

The "gain" of a marine-band antenna is a measurement of how much of the antenna's transmitting and receiving power is concentrated in a desirable direction. Obviously, you don't want to waste power transmitting toward the sky or toward the water, so the gain of the antenna is concentrated in a horizontal direction. For sailboats, a gain of three decibels (3 dB) is the norm, since any higher gain would concentrate the antenna's transmitting and receiving power into an even narrower horizontal beam that could be counter-productive when a sailboat is heeled.

On many marine-band radios you will note that a selection can be made between





Layout and illustrations by Ted Tollefson

"International" and "USA." This is because on some channels there is a frequency difference between the two. Thus, for routine communications with the U. S. Coast Guard, you must tune to Channel 22 with the American frequency (which is easily remembered by the suffix "A"). Hence, the Coast Guard is listed as Channel 22A. If you were to transmit on the International frequency of Channel 22, the Coast Guard wouldn't hear you.

Relatively simple

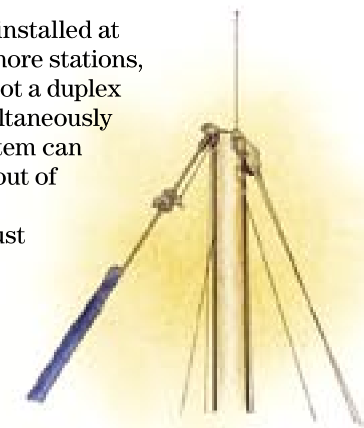
As originally conceived, the marine band was relatively simple and straightforward. Channels were allocated for distress, safety, and calling; the Coast Guard; commercial vessels; recreational boats; ship-to-ship calls; ship-to-shore calls; marine operators (who can connect you into the land-line telephone system); and weather forecasts.

But the marine band is no longer as simple as was originally envisioned. Digital Selective Calling (DSC) technology is now a part of new 25-watt marine-band radios. Although commercial vessels have had DSC since 1988, it has just recently become available to recreational boaters. With DSC, at the touch of a button, an automatic Mayday call can be transmitted that includes your Maritime Mobile Service Identification (MMSI) Number, which describes your vessel. Also, through an interface with your GPS or Loran, your latitude and longitude can be automatically transmitted, and these DSC-equipped radios can continue transmitting the emergency message even when the boat has been abandoned.

Unfortunately, in many parts of the country the Coast Guard is still a couple of years away from having DSC receiving equipment, but many towing companies and yacht clubs can monitor DSC Channel 70 and will relay emergency information to the Coast Guard. The Coast Guard is expected to be fully online with DSC by 2006.

DSC can also be used for making direct calls without going through the marine operator and ship-to-ship calls to other DSC-equipped vessels. As one way of relieving the congestion heard on channel 16 in some areas, the hailing part of these calls will not be heard by every other boat in the vicinity. Once the hail is completed and the radios are connected, however, the voice part of the call is conducted on ordinary analog VHF channels so anyone with a scanner or who happens to be tuned in to that channel can hear the conversation.

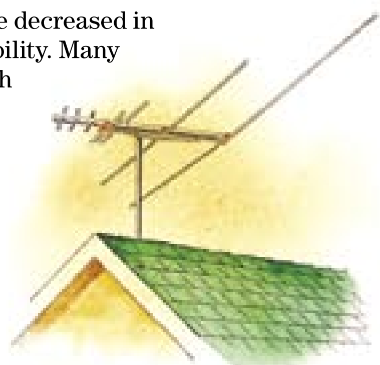
Big asset



DSC capability is still being installed at MariTel's marine-operator shore stations, and although the system is not a duplex system (where you can simultaneously talk and listen) this new system can be a big asset when you are out of range of a cell-phone tower.

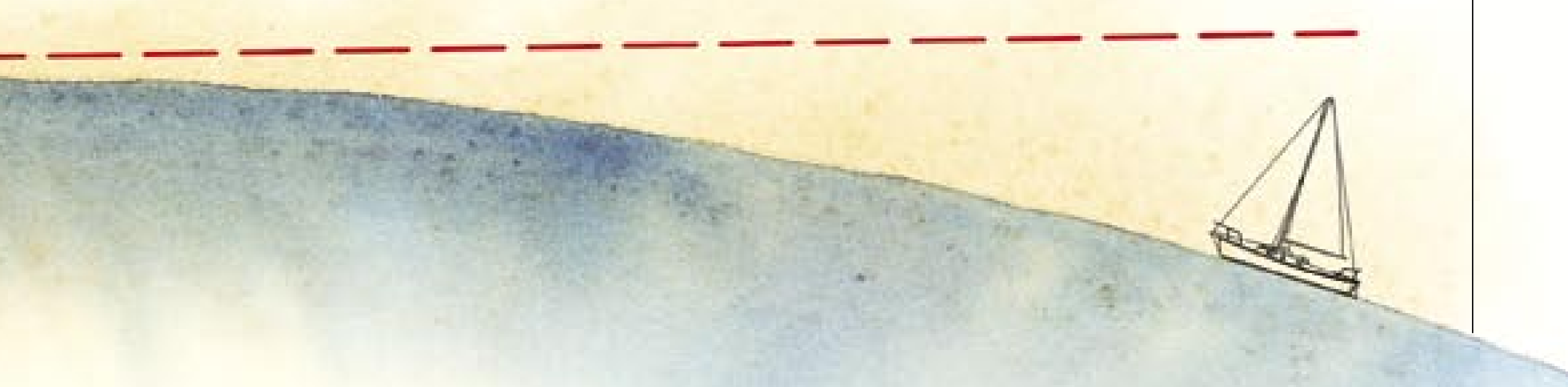
A DSC-equipped radio must be registered with the FCC, which can be easily done through BoatU.S. The MMSI number of each of these radios is similar to a telephone number, so when making a DSC ship-to-ship call, you must know the MMSI number of the other party.

Hand-helds



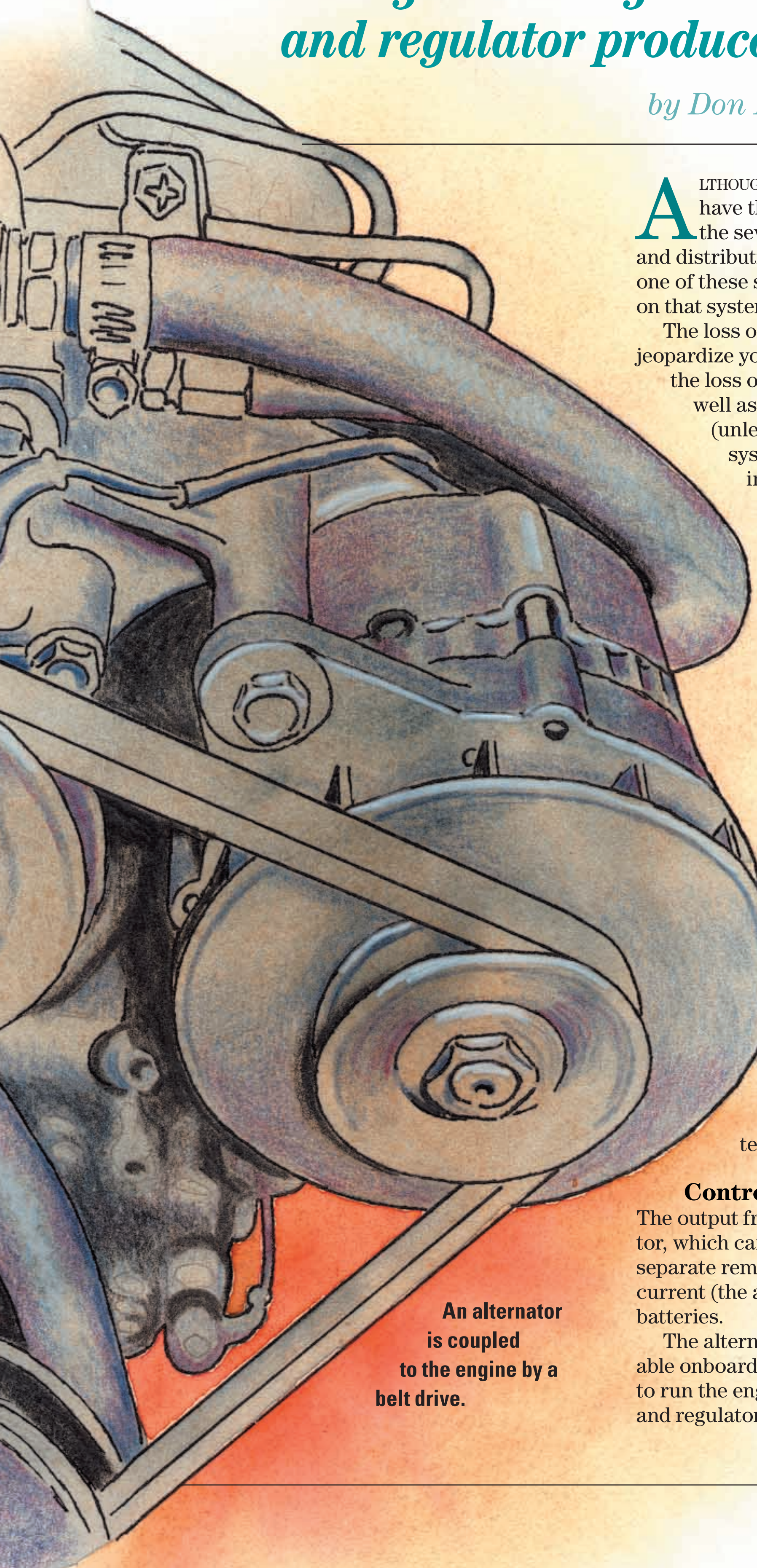
Hand-held VHF radios have decreased in size and increased in reliability. Many are now submersible, which makes them great for your abandon-ship bag. Since most sailboats have their 25-watt, fixed-mount VHF radio in the cabin, a hand-held can be a great asset in the cockpit, especially when entering a strange marina and receiving directions from the dock-master or when talking to a drawbridge operator. But for newer cabin-installed radios there is an alternative: remote microphones that allow channel-selection, entire LCD displays, and a speaker, all in the palm of your hand.

New battery technology has also given longer life to hand-helds, with the new nickel-metal-hydride batteries providing twice as long a time between chargings as the old nickel-cadmium rechargeable batteries. But it's still a good idea to keep alkaline batteries in your abandon-ship bag, since they have a shelf life of more than five years, whereas a rechargeable battery can self-discharge in a few months.



Generating electricity — how the alternator and regulator produce their magic

by Don Launer



An alternator is coupled to the engine by a belt drive.

Although sailboats are usually small and compact, they have the infrastructure of a large city: the waterworks, the sewage disposal plant, and the electrical generating and distribution systems. And, just as happens on land, when one of these systems fails, it reminds us how dependent we are on that system's technology.

The loss of dependable electricity aboard your boat can jeopardize your enjoyment as well as your safety. It means the loss of the electric bilge pump; lights (navigational as well as cabin lights); the VHF-FM radio, Loran, and GPS (unless you have handheld ones); electronic chart systems; and the radar. Also, and perhaps more importantly, you will be unable to start your engine — unless you can hand-crank it.

Except for some megayachts that have motor generators constantly running, our electrical needs, when away from the dock, are completely supplied from a storage battery or batteries, which have the capacity to "store" electricity. These batteries, which usually supply 12 volts of direct-current (DC) power, have a finite capacity and must be kept charged, or supplied, from an outside source.

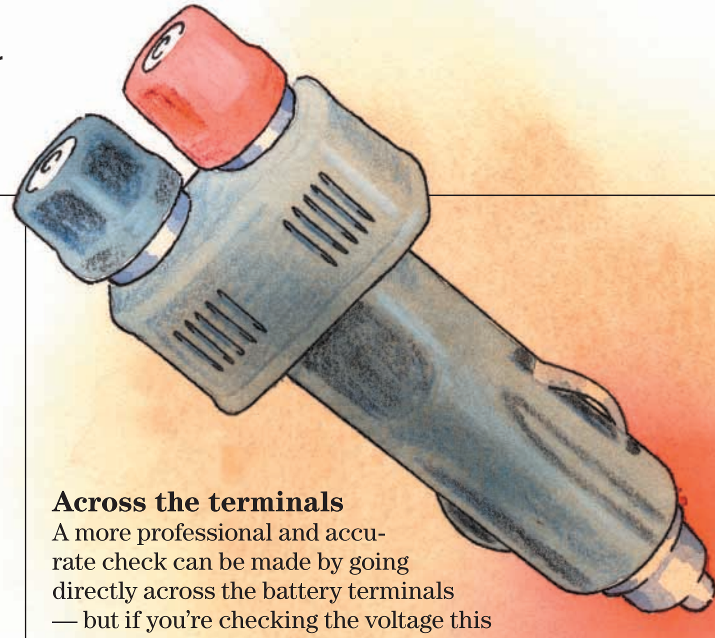
At a marina, that source can be from a shorepower connection to an onboard battery charger, which converts the shorepower's alternating current (AC) to the DC required to charge the batteries.

On the water, the source of this DC charging power comes from an alternator, which is driven by the engine. This alternator, as its name implies, creates alternating-current electricity (similar to shorepower) that is then converted, within the alternator, to DC electricity. A boat's battery, then, is like a city's reservoir, and unless that reservoir is periodically supplied with water, it will run dry. The alternator replenishes your boat's electrical reservoir — the battery — and keeps it from "running dry."

Controlled output

The output from the alternator is controlled by a regulator, which can either be built into the alternator or exist as a separate remote device. This regulator controls the amount of current (the amperage) that the alternator is supplying to the batteries.

The alternator and regulator, then, are the keys to dependable onboard electricity, and that's contingent on being able to run the engine. This, of course, assumes that the alternator and regulator are functioning properly. But how do we know



Measuring battery/alternator voltage is most safely done with a cigarette-lighter adapter.

if the alternator and regulator are working? We can check the voltage of the boat's electrical system, when the engine is running, with an inexpensive digital voltmeter; analog meters are just not accurate enough.

This check can be made most easily and safely at a cigarette-lighter outlet in the cabin — provided you're not using any lights or appliances at the time. The test is done by placing the voltmeter's probes on the socket's two contacts. For added safety and convenience, or if you're not sure where to check inside the socket, a Radio Shack cigarette-lighter adapter with test terminals can be used (Radio Shack part # 270-1521, $6.99). This adapter reduces the possibility of accidentally causing a short circuit while testing and, for added safety, has a built-in, replaceable fuse. You can buy a simple, shirt-pocket-size digital voltmeter for this kind of test for less than $20.

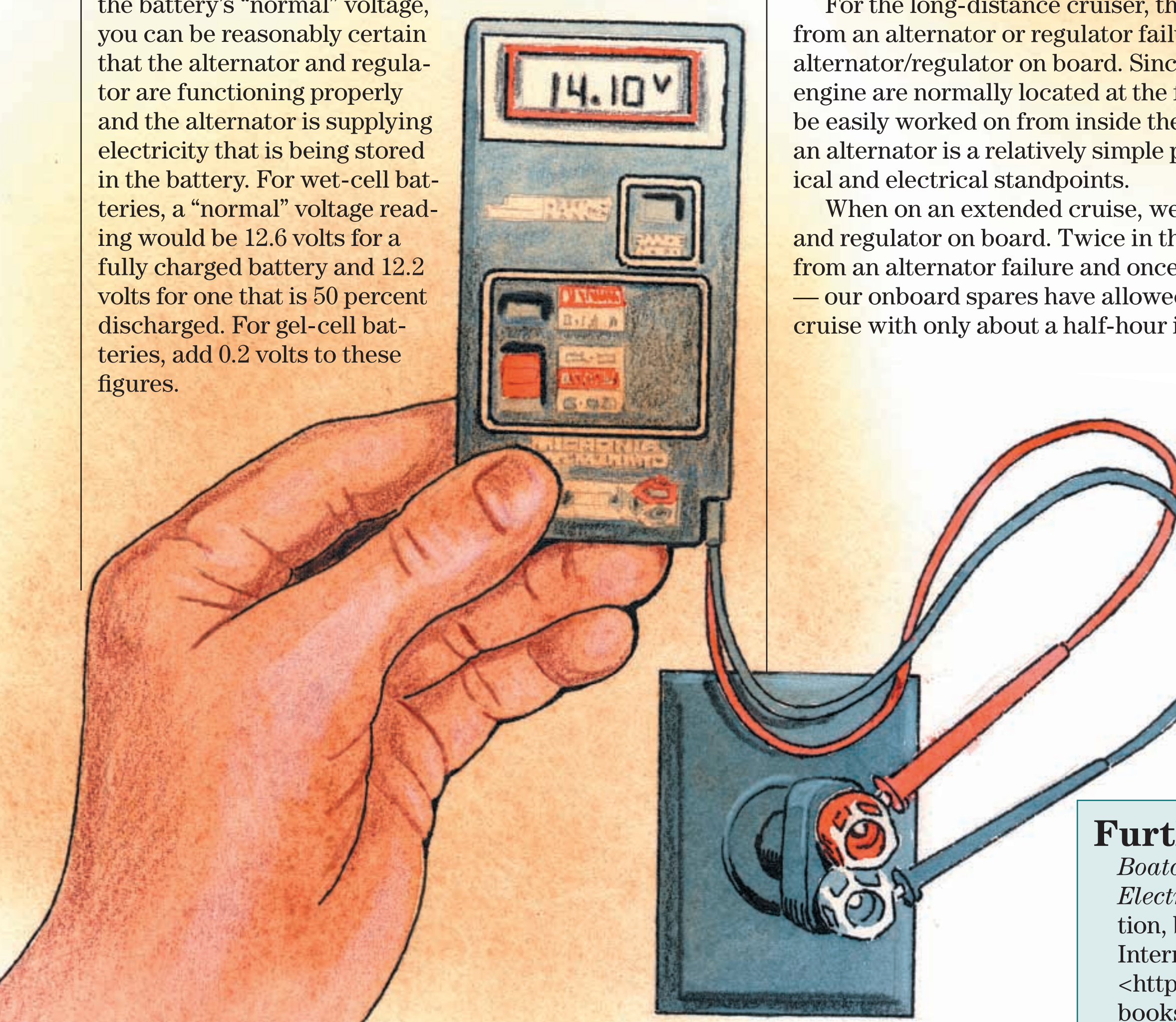
If your voltmeter shows a voltage of 1 or 2 volts above the battery's "normal" voltage, you can be reasonably certain that the alternator and regulator are functioning properly and the alternator is supplying electricity that is being stored in the battery. For wet-cell batteries, a "normal" voltage reading would be 12.6 volts for a fully charged battery and 12.2 volts for one that is 50 percent discharged. For gel-cell batteries, add 0.2 volts to these figures.

Across the terminals

A more professional and accurate check can be made by going directly across the battery terminals — but if you're checking the voltage this way, inside the engine compartment with the engine running, be sure to stay well away from the engine's spinning belts.

For the long-distance cruiser, the ultimate protection from an alternator or regulator failure is having a spare alternator/regulator on board. Since alternators on the engine are normally located at the forward end, they can be easily worked on from inside the cabin — and replacing an alternator is a relatively simple procedure from mechanical and electrical standpoints.

When on an extended cruise, we keep a spare alternator and regulator on board. Twice in the last 25 years — once from an alternator failure and once from a regulator failure — our onboard spares have allowed us to continue our cruise with only about a half-hour interruption.



With the engine running, a digital voltmeter reading can determine if an alternator/regulator is charging the battery.

Further reading

Boatowner's Mechanical and Electrical Manual, 2nd edition, by Nigel Calder (1995, International Marine).
<http://www.goodoldboat.com/bookshelf.html>
or call 763-420-8923

Layout and illustrations by Ted Tollefson

A little tender loving care brings longer trouble-free life

by Don Launer

DIESEL ENGINES ARE NOW THE ENGINES OF CHOICE FOR auxiliary sailboats, and with good reason. They have a superior record of reliability, use a safer fuel, produce fewer hazardous exhaust pollutants, have better fuel economy, and are nearly immune to the moisture that plays havoc with the complicated high-voltage spark-plug system of their gasoline counterparts.

Even though, in many ways, the operation of a diesel is easier to understand than that of a gasoline engine, many owners tend to look at it as mysterious. But with a basic understanding of its operation, coupled with tender loving care, a diesel auxiliary engine can provide years, or decades, of trouble-free service.

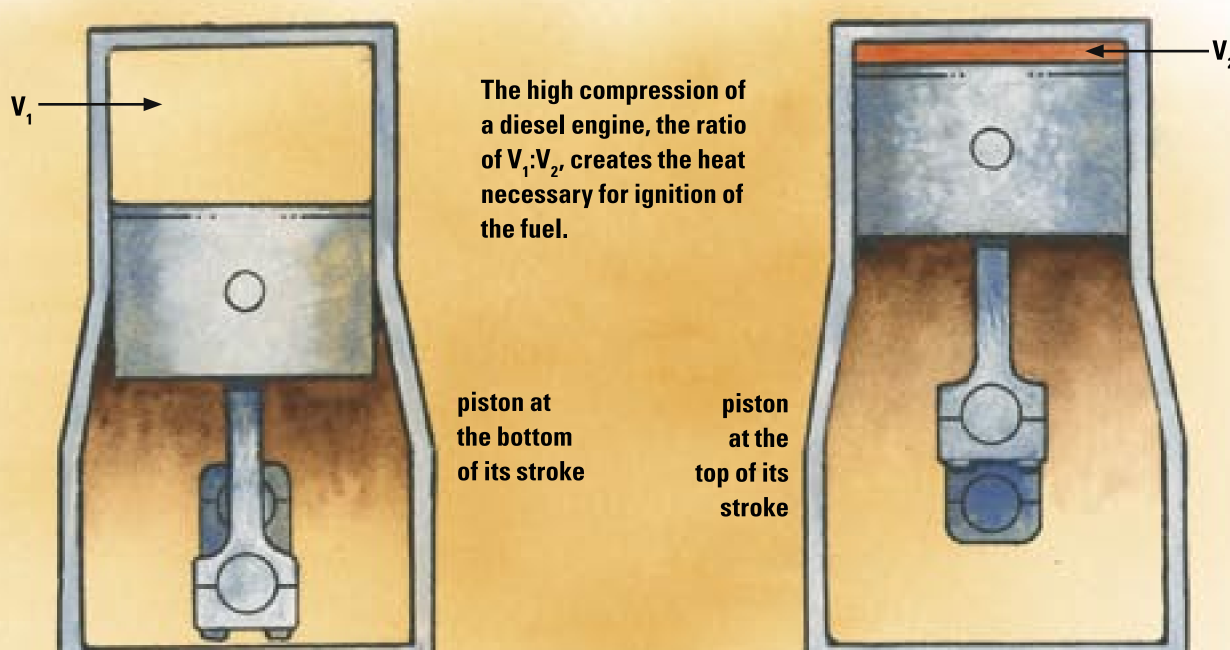
When Rudolf Diesel first patented his namesake in 1892, it was a revolutionary idea in internal combustion engines. His engine used the principle of auto-ignition of the fuel. The idea of his engine, based on the work of English scientist Robert Boyle (1627-91), was that you could ignite the fuel in the cylinder from the heat produced by compressing the air inside the cylinder. In modern diesel engines this compression is usually in the range of 16:1 to 23:1; that is, the air in the cylinder is compressed to $\frac{1}{16}$ to $\frac{1}{23}$ of its original volume. This raises the temperature of the air in the cylinder to between 800 and 1,000˚F. At that point, diesel fuel is sprayed into the cylinder through an injector. Since diesel ignites at about 500 to 660˚F, it will immediately catch fire.

Compression, then, is the key to a successfully operating diesel, and to meet the stresses of this compression a diesel engine must be built stronger and with closer tolerances than a gasoline engine. This increases the weight and cost of a diesel engine over a gasoline engine of similar horsepower.

Little maintenance

Diesel engines have a remarkably long life and reliability and require very little maintenance. But that minimum maintenance is of utmost importance in sustaining their long, trouble-free life span. A diesel requires clean fuel, clean lubricating oil, and a clean air supply. Owners of diesel engines should be almost fanatical in making sure these cleanliness standards are met; otherwise, the result is shorter trouble-free operating hours and expensive repairs.

The injector on a diesel engine is the most precisely built, expensive, and critical component in the engine. Even microscopic amounts of dirt, water, or bacteria in the fuel supply can ruin the injectors and score the engine's cylinders and pistons. Clean fuel, treated with a biocide, filtered while filling the tanks, and filtered again by regularly changed primary and secondary filters, is a requirement that can't be neglected. It has been estimated that 90 percent of all diesel engine problems are the result of contaminated fuel, so maintaining a clean fuel supply is one of the most important jobs for the diesel owner.



The high compression of a diesel engine, the ratio of V_1:V_2, creates the heat necessary for ignition of the fuel.

The injector sprays fuel into the cylinder at an incredible pressure of between 1,500 and 5,000 pounds-per-square-inch (depending on the injector type).

Clean lubricating oil is also essential. Lubricating oils for diesel engines have a prefix "C" ("compression" is a good memory aid), while gasoline lubricating oils use the prefix "S" ("spark" is a good memory aid). Using the correctly labeled oil in a diesel and changing it frequently are vitally important. Changing the oil often, while the oil is hot, is a job that should be done more often than in a gasoline engine.

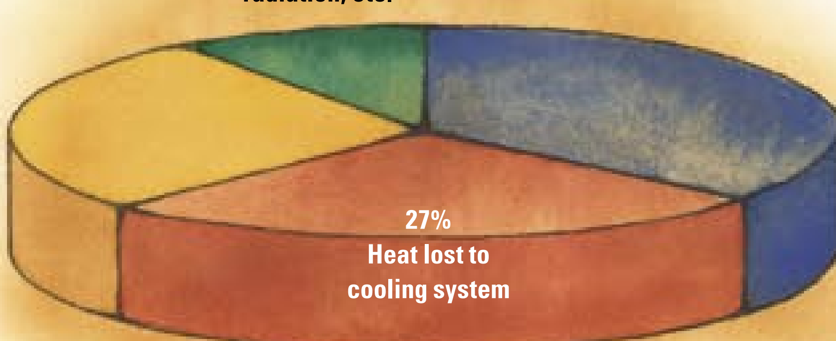
Accelerated wear

And don't neglect the air filter. If dust particles pass through a ruptured air filter, they can score the piston and cylinder walls, accelerating wear and resulting in costly repairs. To prevent a ruptured air filter, it should be changed in accordance with the engine manufacturer's schedule.

Diesel engines like to work under a load. Operating a diesel under low load, such as running the engine for just charging the battery, creates more carbon than normal. This carbon then gums up the piston rings and coats the valves and valve stems. With little load, the engine runs cool and water condenses inside the engine, combining with sulfur in the diesel fuel, and resulting in sulfuric acid that attacks the engine's internal surfaces. So, low-load, low-temperature running should always be avoided .

But even for well-maintained diesels, after years or decades of operation, cylinder walls and piston rings eventually become worn and fouled with deposits, and internal parts become attacked by acids, so that they no longer make a good seal. Valves and valve-seats also become pitted and fouled and don't seal properly. Thus, it becomes much more difficult to get the compression necessary to create the required heat for ignition, especially when the engine block is very cold and rapidly saps away this heat. Injectors also will have become worn and inefficient, compounding the problem. For the owner of an old diesel, difficulty in starting, especially in cold weather, is usually a harbinger of some major repair problems.

Nevertheless, in exchange for regular care with the fuel supply, lubricating oil, and air intake, your diesel auxiliary will repay you with long years of reliable and trouble-free service.



The average diesel has an efficiency of about 30 to 40 percent. Although this may seem low, diesels have a considerably higher efficiency than the 25- to 35-percent efficiency of gasoline engines.

Layout and illustrations by Ted Tollefson

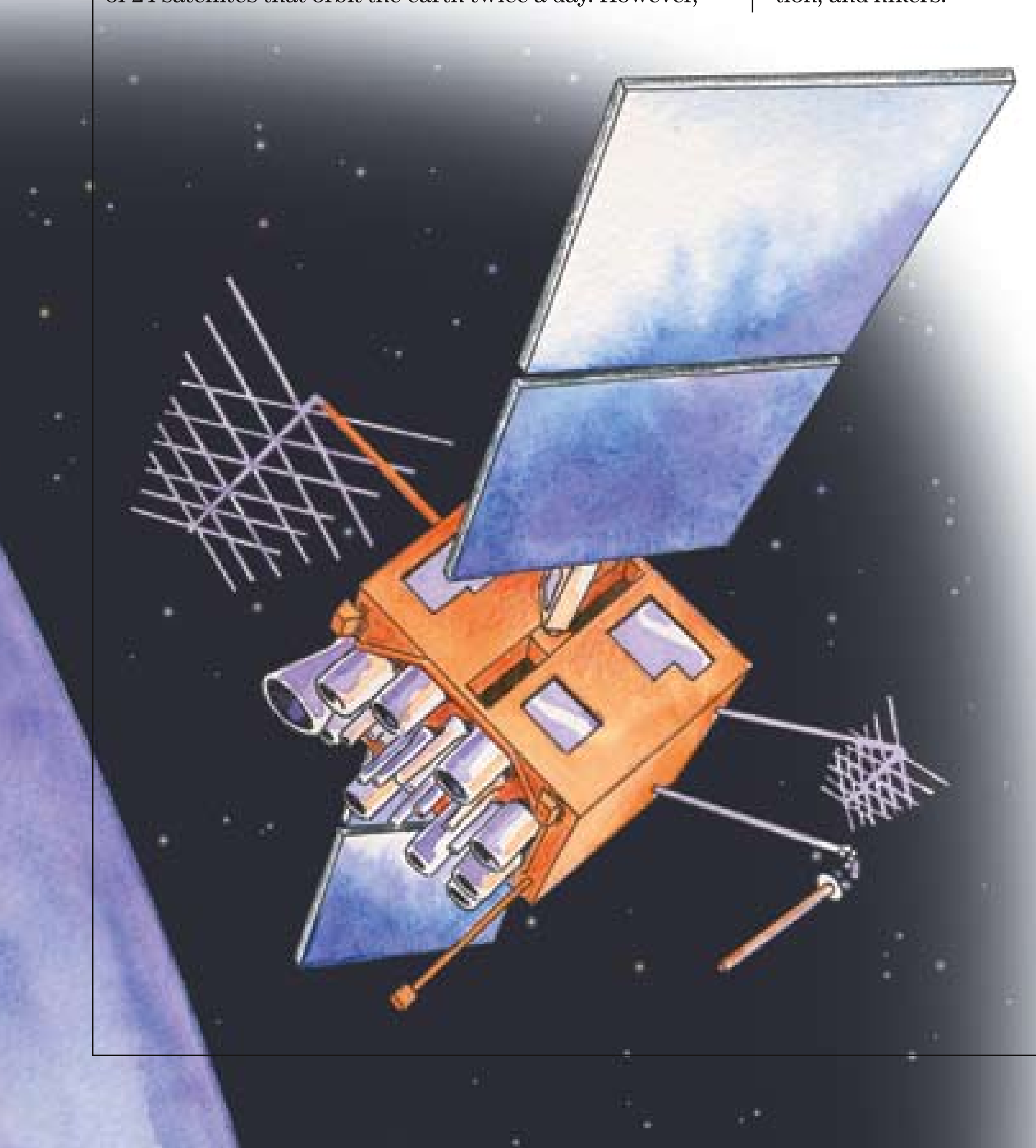
GPS, the system that supports your navigational eyes in the sky

by Don Launer

In October 1957, the first man-made satellite was thrust into orbit around the earth. The USSR's tiny *Sputnik* had beaten the United States into space. The United States, in an effort to learn as much about *Sputnik* as possible, monitored the beeping signal it transmitted and was able to determine its location through the Doppler effect. This was the genesis of using man-made satellites to determine navigational information. But it wasn't until the 1970s that the satellite navigation system, as we now know it, began to take shape.

The Global Positioning System (GPS) is a satellite navigation system that was designed for, and is operated by, the U.S. military, but it is now also used by millions of civilians worldwide. The basic space segment of this system, known as the GPS Operational Constellation, consists of 24 satellites that orbit the earth twice a day. However, there are often more than 24 in space as new ones are placed in orbit to replace those that have exhausted their fuel.

There are six separate satellite orbits, usually with four satellites traveling in each orbital path. These orbits are spaced around the equator 60 degrees apart, and their orbital planes are canted about 55 degrees to the equatorial plane. Thus, a user at any point on earth has five or more satellites visible at any time (see illustration on Page 39). With access to just three satellites, a two-dimensional fix (latitude and longitude) can be determined. When in contact with four satellites, GPS receivers can compute a location in three dimensions — latitude, longitude, and altitude. This makes the GPS navigation system ideal for aircraft, as well as for boats, ground transportation, and hikers.



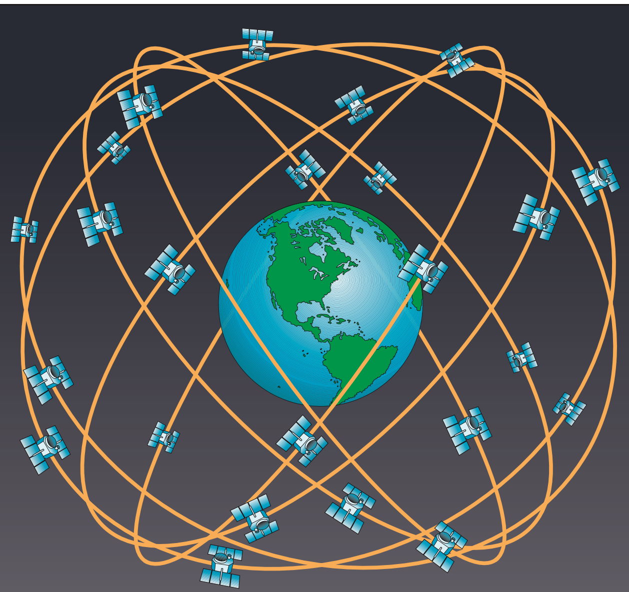
Atomic clocks

Each GPS satellite contains an atomic clock and, by measuring the time interval between the transmission and reception of a satellite signal, a spherical "line-of-position" is created around each satellite. The intersection of these spherical lines-of-position determines your location.

The satellites transmit in the microwave spectrum. At these frequencies, the wavelength is very short and the receiving antenna can consequently be very small. One of the problems with this frequency is that it does not easily pass through things such as house roofs, cabintops, or people. If you're holding a hand-held GPS at waist height, the receiver has difficulty acquiring a satellite on the other side of your body.

Each GPS satellite contains an atomic clock, and by measuring the time interval between the transmission and reception of a satellite signal, a spherical "line-of-position" is created around each satellite.

Layout and illustrations by Ted Tollefson



GPS nominal constellation
24 satellites in 6 orbital planes
4 satellites in each plane
20,200 km altitudes, 55-degree inclination

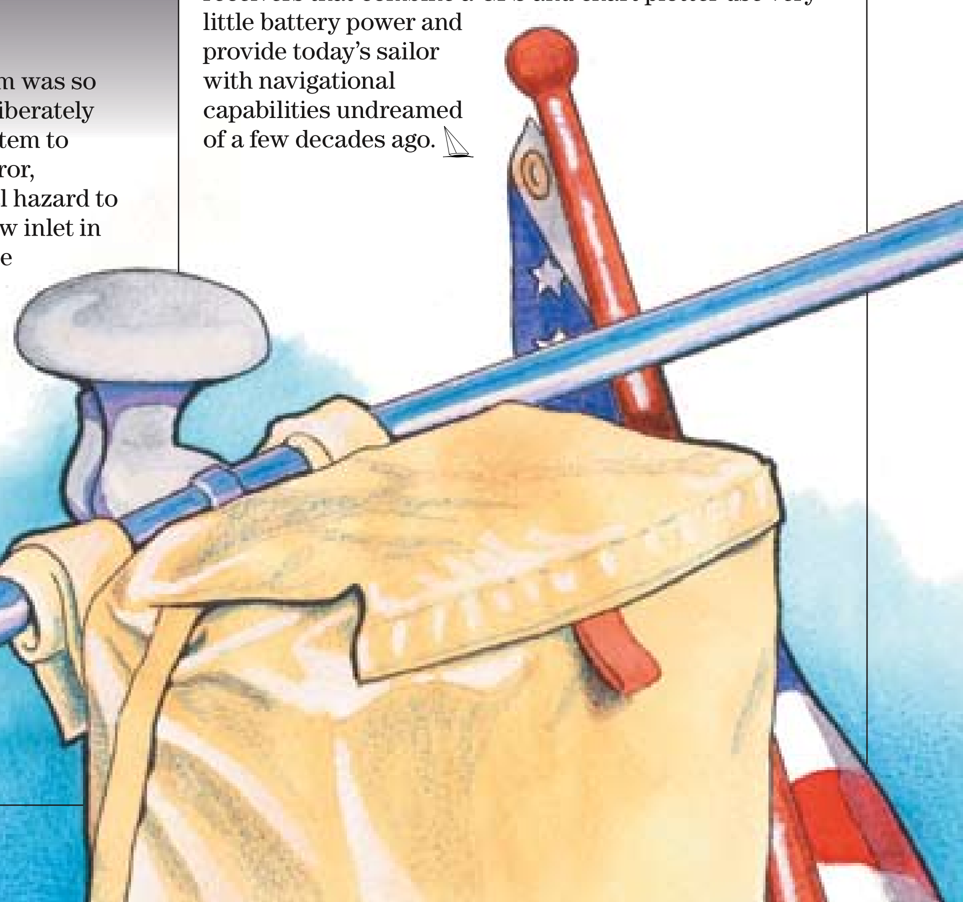
When first put into service, the GPS system was so accurate that the Department of Defense deliberately introduced an error into the civilian GPS system to prevent its use by terrorists. However this error, Selective Availability (SA), caused a potential hazard to users. If a boat were coming through a narrow inlet in a fog, the error was big enough to put it on the rocks. So the U.S. Coast Guard established low-frequency AM ground stations along the coast to take out the error introduced by the Department of Defense. This system, Differential GPS (DGPS), requires a separate antenna system and receiver that is frequently more expensive than the GPS receiver itself. Finally, in May 2000, the Selective Availability error was discontinued, and GPS users all over the world enjoyed a dramatically more accurate system.

However, there were still potential errors in the system — such as clock errors, ionospheric and tropospheric delays as the signal travels from the satellites to earth, earth reflections, satellite orbital drifts, and control errors. The DGPS ground stations could reduce most of these errors but they had limited range and were subject to noise and fading.

Same frequency band

Eventually, geostationary satellites operating in the same frequency band as the GPS satellites were put into orbit, and these new "stationary" satellites provided corrections that could be received directly on a GPS antenna without the need for a separate receiver and antenna system. This improved correction system is known as the Wide Area Augmentation System (WAAS).

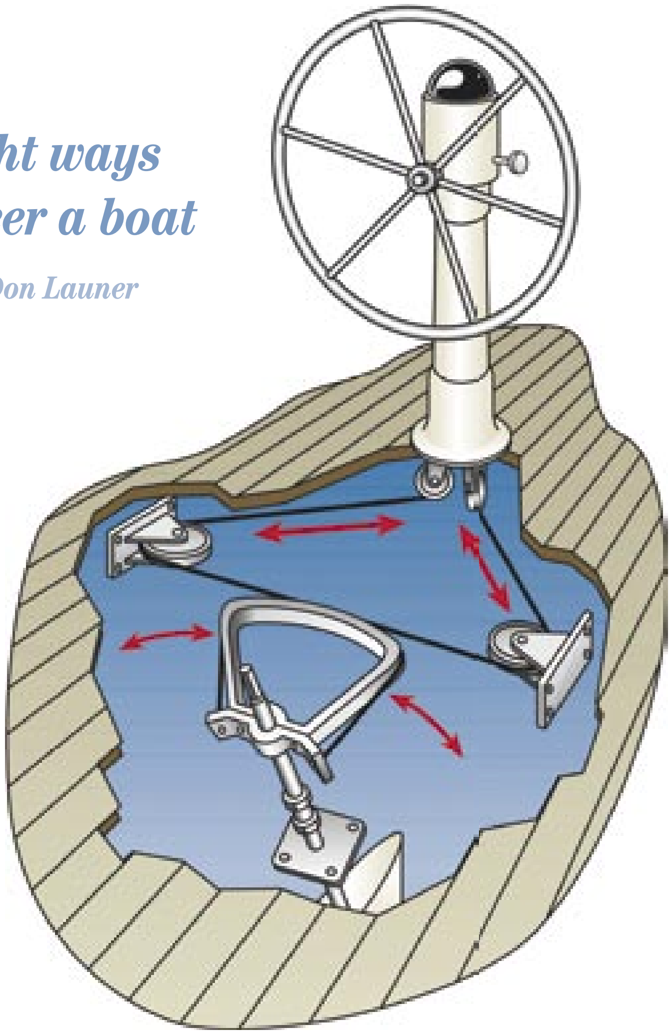
As improvements continue, consumer prices for GPS receivers keep dropping, while accuracy, operational simplicity, and extra features are expanding. GPS receivers have the ability to communicate with other electronic equipment on board, such as electronic chart plotters, autopilots, VHF-FM radios, radar, and so on. The current communication protocol is known as NMEA 0183. Newer receivers that combine a GPS and chart plotter use very little battery power and provide today's sailor with navigational capabilities undreamed of a few decades ago.



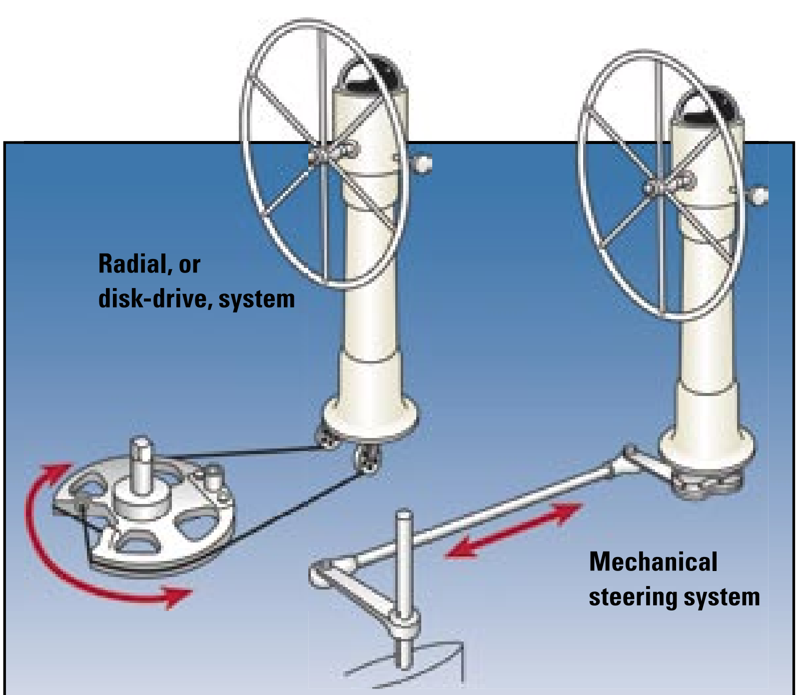
A GPS antenna resembles a mushroom.

Eight ways to steer a boat

by Don Launer



Cable-and-sheave steering system



WHEN IT COMES TO STEERING A SAILBOAT, even die-hard wheel enthusiasts agree there is no steering system that is simpler, more affordable, or offers better "rudder feel" than the tiller. Wheel systems, on the other hand, provide power equal to or exceeding that of a tiller and usually take up less cockpit space. Loads imposed on all steering systems can be extreme, and fittings and fastenings should be commensurate.

Wheels can be mounted on bulkheads, consoles, or pedestals. Pedestals merely contain the sprocket, roller chain, and cables and lead them belowdecks. Pedestals are manufactured from non-magnetic materials — such as bronze, aluminum, stainless steel, brass, or fiberglass — and are frequently topped with a binnacle. Engine controls are also often mounted on the pedestal, along with a wheel brake. A brake on any wheel-steering system is a must, since it enables the person at the helm to leave for a short time to tend sail. An A-frame pedestal, instead of a vertical steering column, offers benefits in that the steering cables can be led directly down the legs, sometimes eliminating a set of sheaves and their associated friction.

There are several basic types of wheel-steering systems, the most common being ***the cable-and-sheave***. This system employs a quadrant on the steering shaft that is rotated by 7 x 19 stainless-steel cables — type 305 being preferred because it is non-magnetic. These cables are led from the rudder quadrant through sheaves to the wheel location, where they are fastened to a non-magnetic roller chain that is driven by a sprocket on the wheel shaft.

The radial, or disk-drive, system, is a modified version of the cable-and-sheave system. The difference is that instead of a quadrant, the rudder-shaft fitting is actually circular, or disk-like. In boats whose configuration allows it, this can often eliminate one pair of sheaves, which, in turn, increases "feel" because of decreased friction.

The so-called ***mechanical steering system*** uses a rod that goes from the base of the steering position to a strut on the steering shaft. This system has excellent feel with precise rudder control and is easily adaptable to accessories such as a second steering station, windvane, or autopilot.

Push-pull steering is available in two configurations: double-cable or single-cable.

Illustrations by Ted Tollefson

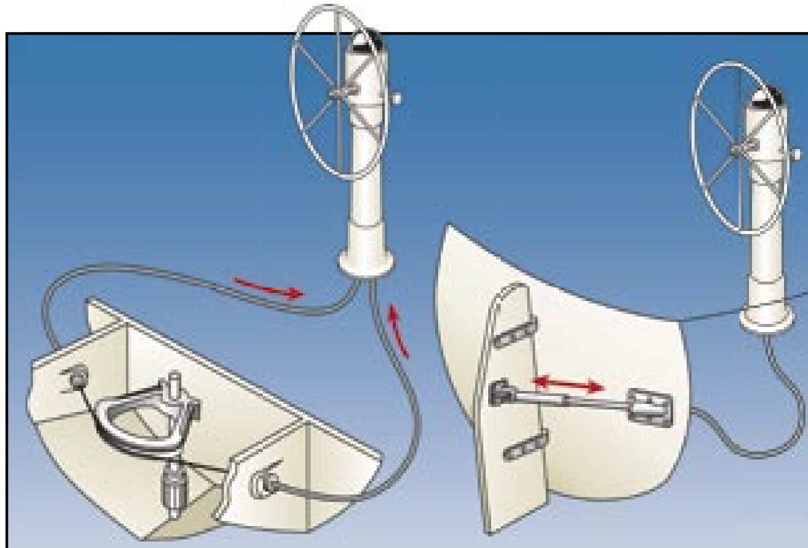
In the ***double-cable system***, two 7 x 19 cables, contained in a flexible conduit, lead from the steering position to a quadrant on the steering shaft. In this steering system, the wheel can be placed nearly anywhere, and the cables can be snaked around obstructions between the steering station and the rudder. This makes it particularly practical in center-cockpit boats. The relatively high friction in this system, due to bends in the push-pull cable, limits feel and response, however. ***The single-cable push-pull system*** is common on powerboats with large outboards as well as on some sailboats. With this system, a single push-pull cable drives the rudder directly. This system requires a wide transom and is not easily adaptable to double-enders.

Worm-gear steering provides little feel and is usually used on long-keeled cruising sailboats with heavy rudders, where a large number of turns from stop to stop and feedback from the rudder are not of prime importance. The system is fastened directly to the top of the rudder post. It is extremely reliable, with little to go wrong, and lasts almost forever with just an occasional greasing.

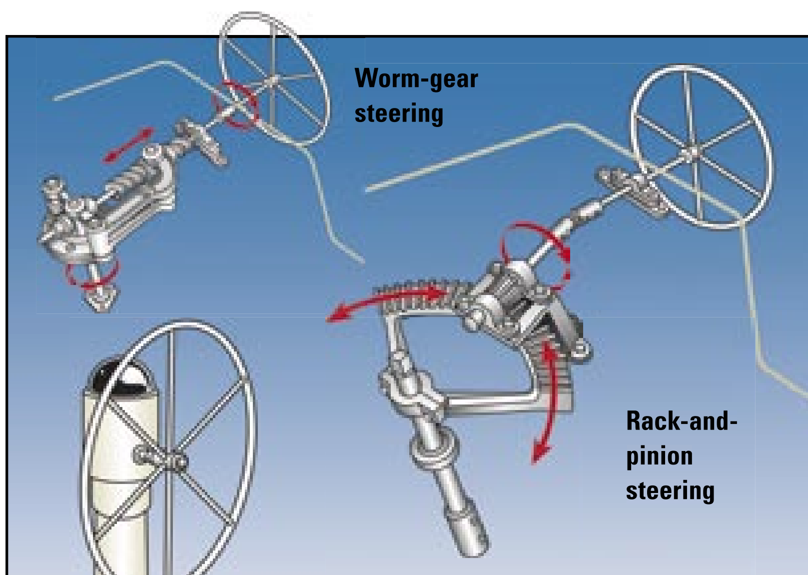
Rack-and-pinion, the automotive steering system, provides the person at the helm with absolute feel — in fact every wave hitting the rudder will be transmitted to the person steering. This system is also best suited to long-keel cruising sailboats.

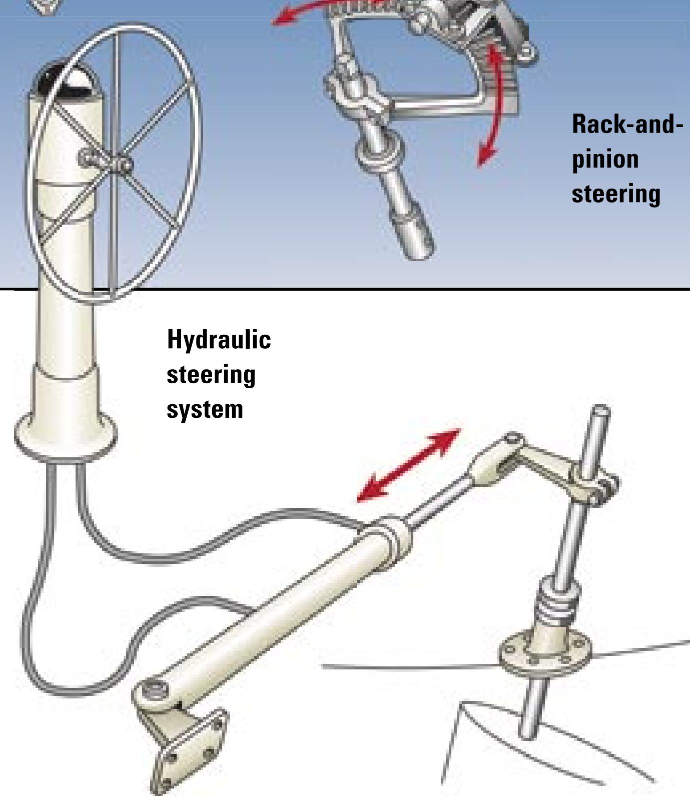
Hydraulic steering systems offer immediate rudder movement without the slack that is inherent in cable systems and, when properly matched to the boat, provide sensitivity and feel. When the wheel is turned, a hydraulic pump activates a piston in a hydraulic cylinder. The thrust of this piston is then transferred to the rudder through a short arm on the rudder shaft. With hydraulic systems the wheel can be mounted anywhere and more than one steering position can be used on the same system.

No matter what the steering system, provision has to be made for emergency steering if the system becomes disabled (see "Emergency tillers" on Page 26). Since backup systems are usually not provided by manufacturers, it's up to the responsible skipper to develop his own practical emergency steering system — and to try it out *before* the dreaded day comes when it has to be used.



Double-cable and single-cable push-pull systems





The magic combination of plastic and glass that changed boatbuilding

by Don Launer

Composite construction in the United States began in the 1940s — during World War II — when a southern California company, Chemold, was contracted by the military to produce molded plastic hulls. It used an acetate resin with a cotton fabric as the reinforcing agent. After the war, the tooling was sold to Wizard Boat Company, which produced a line of small outboard hulls for the recreational boating market. In 1946, the Wizard Company began using polyester resin and eventually switched to a reinforcing material made from glass fibers. In June of that year, the Winner Company, in Trenton, New Jersey, received a Navy contract to develop 28-foot motorboats from this new material. Those early boats were formed over a male mold. Sailboats were first produced by this new process in 1947 by the Glasspar Company.

The original polyester resin was a difficult material to use and required a sunlight cure. Not surprisingly, many of the first companies to use this process were based in southern California. This curing process was soon replaced by curing the polyester resin with a catalyst mixed into the resin before application. This catalyst, methyl-ethyl-ketone-peroxide (MEKP), along with a cobalt accelerator that is usually pre-mixed in the resin, allows the builder a limited amount of layup time, depending on the amount and type of catalyst and the ambient temperature.

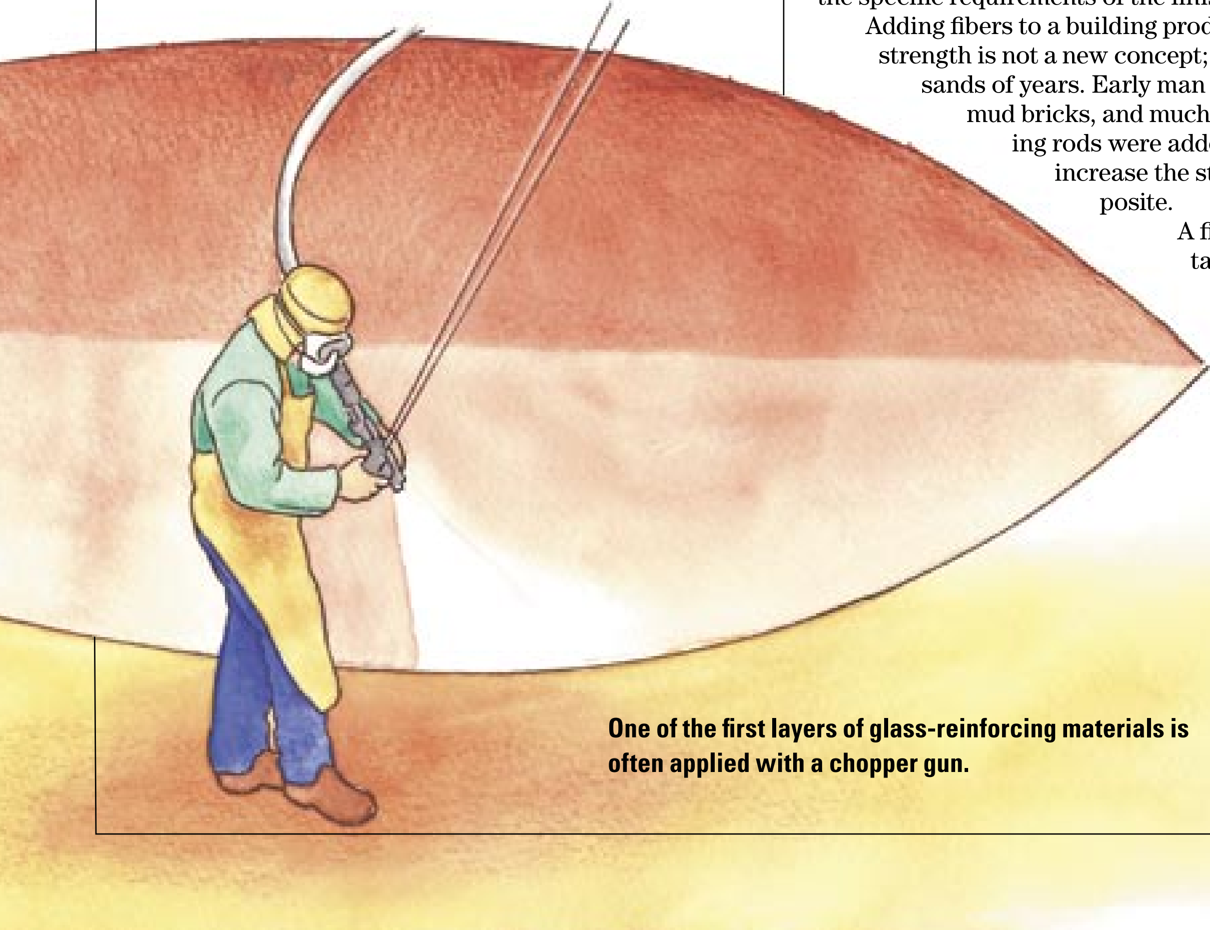
It wasn't long before boatbuilders around the world began using this new technique. However, the word "plastic" was regarded with distrust in the mid-1950s, so manufacturers avoided the term in their advertising. Instead, "fiberglass" became the generic term for this new product. Fiberglass-reinforced plastic, FRP, is the proper name for this material. In Europe it is called GRP, for glass-reinforced plastic.

Low-strength resin

Basic construction of a fiberglass hull uses a relatively low-strength resin, reinforced and made stronger with internal fibers of various types. The most common of these fibers is glass, although Kevlar and graphite fibers are also sometimes used. The plastic, mainly polymers, but sometimes epoxy or vinylesters, is usually of a thermosetting type. Thermosetting is the capability of a substance to become permanently rigid when heated. The thermal agitation of the molecules of the resin aids the chemical process that links the molecules together in a process called polymerization. There are wide variations in the formulations of these resins, depending on the specific requirements of the finished product.

Adding fibers to a building product to increase its strength is not a new concept; it goes back thousands of years. Early man mixed straw into mud bricks, and much later steel reinforcing rods were added to concrete to increase the strength of the composite.

A fiberglass hull usually takes its shape inside a female mold, onto which a special wax with no affinity for the resin is applied. This prevents the layup from sticking to



One of the first layers of glass-reinforcing materials is often applied with a chopper gun.

the mold. A gelcoat is then applied, usually by spraying. This is a special thin, pigmented formulation, which contains no reinforcement. It is followed by alternate layers of fiberglass reinforcements, plastic resin, and sometimes core material. These are applied until the desired thickness and strength are obtained.

One of the first layers of glass-reinforcing materials is often applied with a chopper gun, which sprays the resin and the catalyzer, in the proper proportions, while simultaneously cutting a loose bundle of continuous glass-fiber strands, or rovings, into short pieces and projecting the composite mix into the mold. It has the advantage of filling the angles and corners in the mold and making the layup of subsequent layers easier. Since these glass fibers are in random orientation, strength will be equal in all directions.

Woven roving

The bundles of fiberglass rovings used in the chopper gun can also be woven together at right angles into a coarse cloth, which has the appropriate name of woven roving; when laid at right angles and stitched together, it is known as stitch mat. These materials are the basis of most laminates, but since they have a coarse texture, chopped stranded mat (CSM) is usually interspersed between layers.

Chopped stranded mat, commonly known as mat, consists of chopped fiberglass fibers, about 2 inches long, that are compressed and loosely bound together in random directions into a mat with a binder that dissolves in the resin. Mat produces a layer similar to that of the chopper gun and is the most used material in fabricating boat hulls.

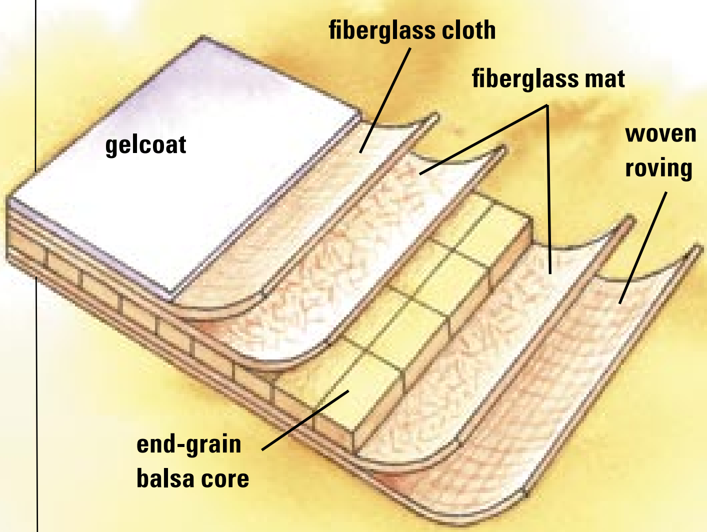
Fiberglass cloth is a fine and tightly woven fabric made from continuous glass fibers. It gives a nice smooth finish and was widely used in the early days, but because of the expense, it is now seldom used except in places that demand a high strength-to-weight ratio. Cloth, woven roving, and stitch mat have strands at right angles and are said to have bidirectional strength.

Unidirectional fabric consists of fibers that only run in one direction and are held together with a binder. These fabrics are used when strength in only one direction is required.

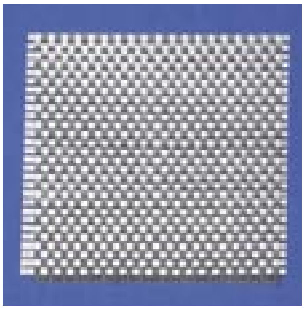
During hand layup, the resin can be applied by brushing, troweling, rolling, or spraying. The resin penetrates the reinforcing fibers and, when cured, the result is a strong monolith.

Weight-saving stiffeners, or cores, are often incorporated in the layup and can be materials such as plywood, end-grain balsa, or synthetics.

Although fiberglass weighs about 106 pounds per cubic foot — about three times the weight of hardwood — it only needs to be about half the thickness of the hull of a wooden boat and will not require heavy frames, so the entire hull ends up weighing less than a wooden boat of similar size.




Fiberglass mat/CSM


Woven roving

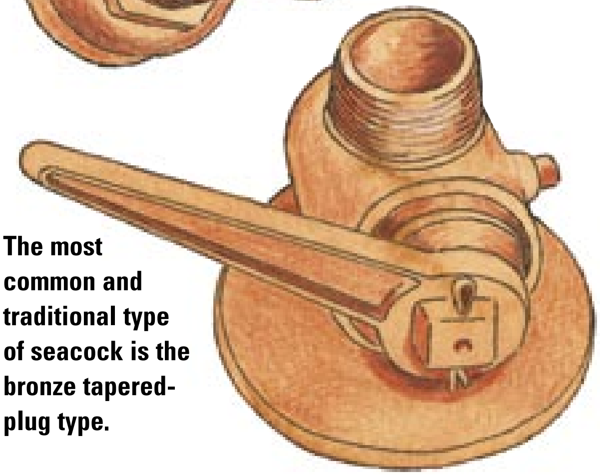

Fiberglass cloth


End-grain balsa core

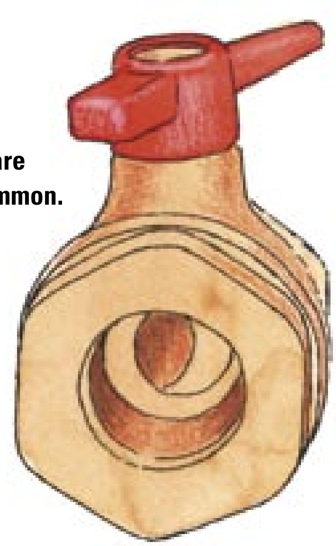
Inspecting and maintaining seacocks

by Don Launer

Bronze gate valves are found in many boats, but have several disadvantages.



The most common and traditional type of seacock is the bronze tapered-plug type.



Ball-valve seacocks are increasingly more common. Although they require an occasional light lubrication, this is not necessary in order to maintain watertightness, as with a tapered-plug seacock.

THE HULL OF A BOAT IS DESIGNED TO KEEP THE WATER OUT, but most boats also have through-hull fittings and seacocks that are designed to allow water to enter the boat safely. These seacocks are metal or plastic valves that are screwed onto through-hull fittings. They can be opened or closed to allow you to control movement of fluids either way through the hull. BoatU.S. reports, however, that seacocks are responsible for a large percentage of the sinkings that occur every year. These sinkings are most often due to improper installation as well as a lack of inspection and routine maintenance.

There are three basic types of seacocks: the traditional bronze tapered-plug seacock with a handle that rotates 90 degrees between open and closed; ball-valve seacocks that also have a handle that rotates 90 degrees between open and closed; and gate valves, which require several rotations of a faucet-style handle to open or close.

The traditional material for seacocks is bronze, but there are also non-metallic seacocks available. Although many sailors are skeptical about these “plastic” seacocks, the best ones — such as those made from reinforced nylon marketed under the name Marelon — have enormous tensile strengths. For owners of steel or aluminum boats, these non-metallic seacocks eliminate the corrosion problem caused by the galvanic action of dissimilar metals.

If gate valves are used, they should be bronze, not brass, but even the bronze ones usually include parts, such as the stem, which are made of dissimilar metals, inviting trouble. Another problem with gate valves is that they do not have a positive action. In other words, you can never be sure if they are completely closed or whether there might be a foreign object lodged inside. Also, they usually don’t have large flanges that can be secured directly to the hull and can therefore be broken off accidentally if subjected to a strong sideways blow.

Backing plates

All seacocks should be mounted with a backing plate or hull-reinforcement with bolts that go through the hull, backing block, and flange. Wood backing plates should not be used with synthetic seacocks, since the wood’s expansion can strain the plastic. Also, whenever a through-hull is installed on a cored hull, the soft core must be cut away between the fiberglass layers and the void must be filled with epoxy and fiberglass to increase the compression strength of the area where the through-hull will be mounted.

The through-hull is the part on the exterior of the hull. It screws into the seacock, which is inside the hull. The threads on this mushroom come in either straight, termed NPS for “National Pipe Straight” (sometimes called parallel threads) or tapered, termed NPT for “National Pipe Tapered.” Proper modern seacocks have a female straight pipe thread on the inlet side and a tapered pipe thread on the outlet side, while ball valves and gate valves without the flange have tapered pipe threads on both the inlet and outlet. When installing a seacock, it is of vital importance

Layout and illustrations by Ted Tollefson

that the thread type on the outside through-hull fitting match that of the valve thread. Unfortunately, many boats have been built with, or later equipped with, a through-hull with straight threads and a valve with tapered threads. This gives about two threads of engagement and is easily broken.

Only heavy-duty reinforced hose should be fastened to seacocks, and it must be secured with two stainless-steel clamps, since ice inside the hose can exert enormous pressure and easily lift a single-clamped hose off the seacock tailpiece. As for those clamps, be sure you get them at a reputable marine-supply store. Very often those purchased at a hardware store will be labeled "stainless steel," but only the band is stainless, and very soon you'll find the screw mechanism rusted, weakened, and unusable. All through-hulls, except for the cockpit drains, should be closed whenever you leave your boat.

A selection of tapered softwood plugs should be kept on board. These can be used to stop the water flow from a deteriorated hose and inoperable seacock, or they can be pounded into place should there a be a catastrophic seacock failure. If such a failure occurs, there's not much time to react. A 1½-inch hole, 2 feet below the waterline, will gush more than 70 gallons of water a minute into the hull. For this reason, it's a good idea to tether a wooden plug to each seacock, so one will be readily available if needed.

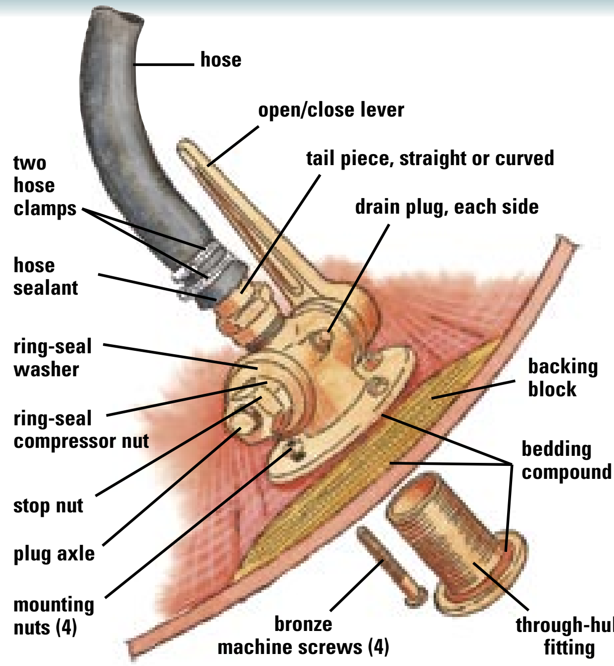
Tend to seize up

Most tapered-plug seacocks tend to become hard to rotate if they haven't been used in many months. To prevent this seizing, they should be worked open and shut occasionally. (To make it easier to remember, I make it a point to exercise mine the first week of every month.)

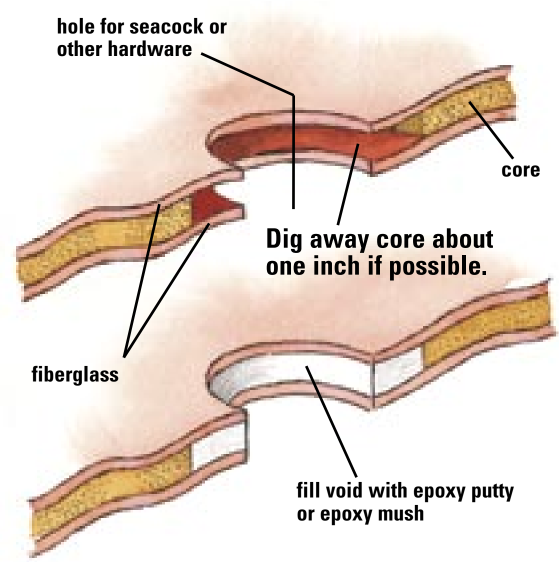
All seacocks should be serviced annually. Follow the manufacturer's recommendations. For ball-valve seacocks, just a small amount of grease is necessary. For tapered-plug seacocks, disassembly, inspection, cleaning, and regreasing with a waterproof grease should be an annual task. Special seacock grease works better than an automotive grease.

Occasionally you'll find that sand or mud may have scored the tapered plug. For light scoring, smooth out the scratches with an emery cloth. For heavy grooves, apply a valve-grinding compound and rotate the plug inside its housing until it fits snugly; then thoroughly clean both parts and regrease. Since tapered-plug seacocks depend on this grease for their watertightness, they should be greased liberally and not overtightened.

Finally, avoid using a seacock to supply water to both an engine and a saltwater galley pump, air conditioner, or watermaker. If this is done, very often the suction of an engine operating at high speed will draw air back through that second device and decrease the engine's cooling capacity. This use of a "manifold" to supply more than one source from a single seacock has been the cause of many perplexing engine-cooling problems.



All seacocks should be through-bolted to the hull, with a block of wood, or other material, on the inside of the hull to distribute the load.



With cored hulls, the core must be dug out to beyond the area of the seacock flange and then filled with a mixture of epoxy and glass fibers. This increases the compression strength of the hull where the seacock is mounted.

Tapered, soft-wood plugs should be readily available as an emergency repair.

How to put that water back outside where it belongs

by Don Launer

THERE IS AN ENORMOUS VARIETY OF BILGE PUMPS ON the market. Some are electric, some manual, and some are belt-driven from the engine. Bilge pumps are designed to get rid of the routine water that enters the bilge from a dripping stuffing box, water that comes down into the cabin through keel-stepped masts, or rain or spray that enters the cabin through hatches or ports, but virtually no bilge pump is large enough to keep up with a catastrophic leak caused by hull damage.

Regardless of the type of pump that is used, it won't be able to do its job if the bilge is full of foreign matter such as sawdust, wood shavings, or other debris. A little oil in the bilge can coagulate this foreign material and make things even worse. Although regular cleaning of the bilge is not the most pleasant of jobs, it's a necessity if the bilge pump is to operate properly. Even with relatively clean bilges, a strainer is necessary. This strainer should have the largest area possible, at least twice the suction hose area, but the holes in the strainer should be small.

Nearly all cruising sailboats have an automatic electric bilge pump and at least one manual pump as a backup. However, for offshore racing sailboats, race requirements usually specify two permanently installed manual pumps, one in the cockpit and one down below.

Electric centrifugal pumps cost little, are easily installed, and move a good amount of water. The general rule is: use the largest electric pump that is practical. When purchasing an electric bilge pump, some things to consider are: Is it self-priming? Can it be run dry? Is it submersible? Will it be able to lift the water to the desired height?

Installation usually includes an automatic switch that will actuate the pump when there is water in the bilge. These switches, especially on small pumps, are often integral with, and mounted on, the pump. On larger pumps the switches are separate.

Prone to jamming

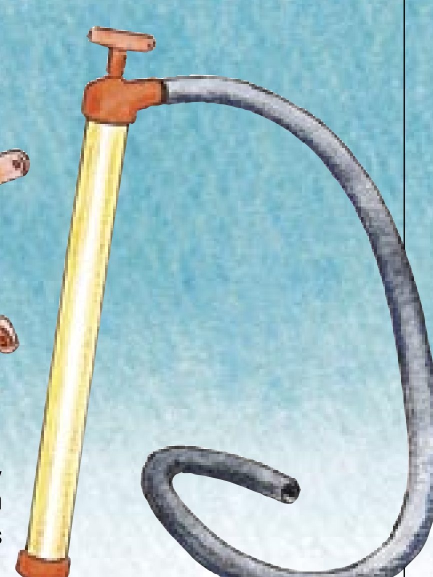
A large variety of automatic switches is available such as the simple open float switch, which is prone to jam when there is debris in the bilge, or the enclosed float switches that usually eliminate the jamming problem. There are solid-state non-mechanical switches that operate in diverse ways, such as sensing the water level by sonar, or by using differential field sensors. Some of these solid-state switches have an extended running feature, which lets the pump run for several seconds beyond the time of normal shut-off. This is handy for boats with small bilges, where return water from the discharge hose, after the pump turns off, can make the pump cycle again.

All electrical connections to a bilge pump should be with connectors with waterproof heat-shrink sleeves. It's important that electric bilge pumps be on their own electrical circuit, protected by a fuse or circuit breaker with

Electric bilge pump, to be used with an external switch

Electric bilge pump with integral, attached automatic switch

A typical manual diaphragm pump



Small hand bilge pump, commonly used in small open boats

Layout and illustrations by Ted Tollefson

the recommended amperage printed on the pump, and using properly sized wire. When a pump is not fused properly, a jammed float switch can cause it to run continuously without water. Overheating, in such a scenario, has been the cause of many boat fires.

Boats that are left unattended for long periods often power the automatic bilge pump directly from the battery, bypassing the main electrical panel, which can then be turned off when the boat is left unattended. This practice is acceptable, provided that the pump is protected with a fuse or circuit breaker of proper size.

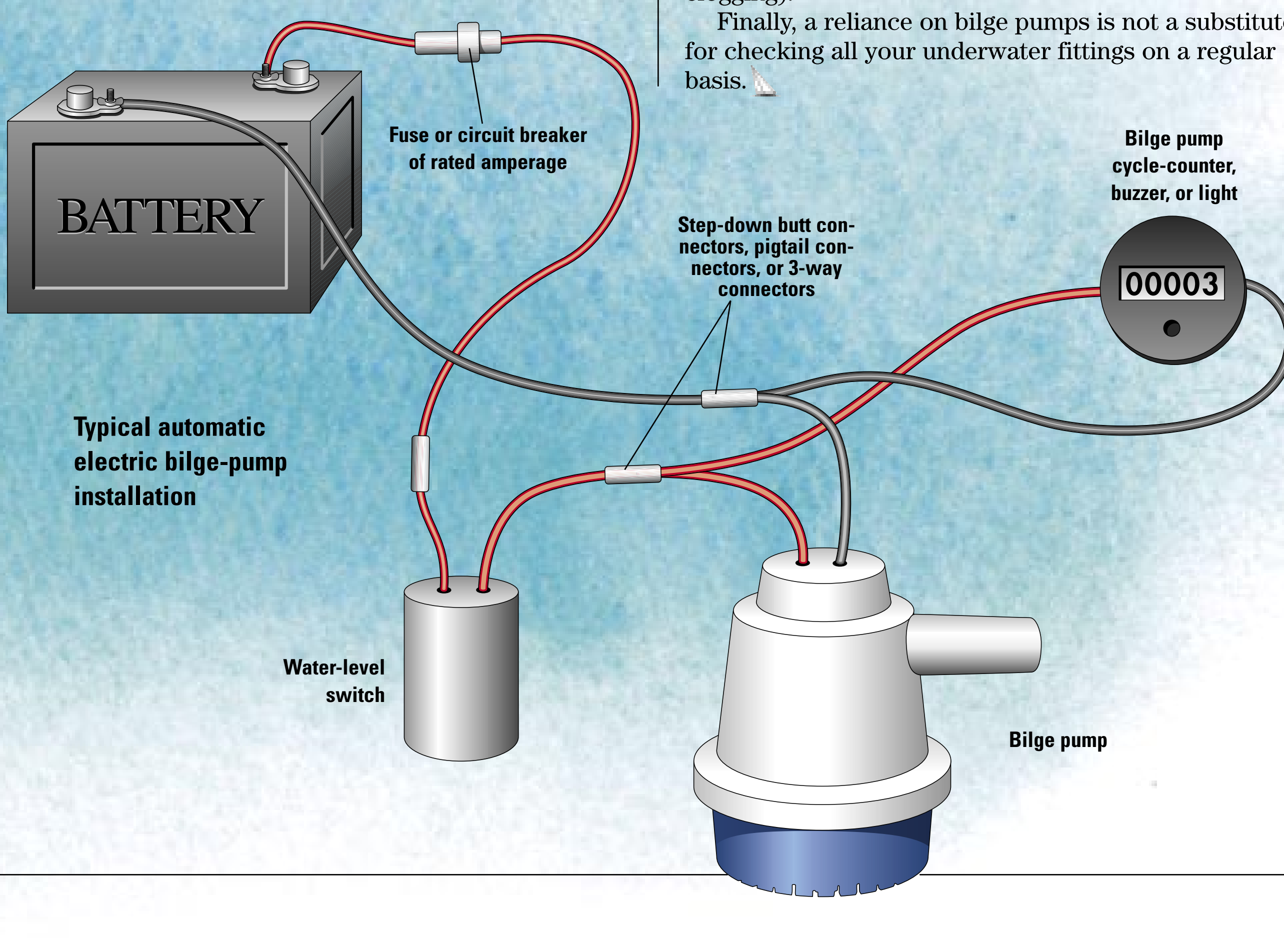
Unfortunately, automatic bilge pumps have a flaw that can lull the boatowner into a false sense of security. With an automatic pump, every time you check your bilge you see no increase in the water level — even though a cracked hose, severely dripping stuffing box, or leaking seacock may be constantly dumping water into the bilge. To alert you to this problem, a cycle-counter with reset button, such as those available at many marine-supply stores, will let you know if the bilge pump is cycling on more often than normal. A light and/or buzzer will also do the job for live-aboards.

Manual pump too

Needless to say, automatic electric pumps will only operate if the electrical system is functioning, so at least one manual pump should also be available. The most common manual pump is the diaphragm pump, which is able to move a large amount of water and can pass small debris without clogging. These may be either permanently mounted or mounted on a board and stowed away for emergencies. A permanently mounted cockpit pump should have the handle within reach of the helmsman.

The discharge hose from any bilge pump should have a smooth interior to reduce friction. Most bilge pumps discharge through the transom or through the side of the hull well above the waterline; but remember, the higher the water has to be lifted, the less efficient the pump. Sometimes bilge pumps discharge into a self-draining cockpit or onto the deck. In these cases, however, any oil in the bilge can create a hazardous walking surface. If there's any possibility of water coming back through the discharge hose when the boat is heeled, a loop can be used, an external neoprene flap, or a one-way valve (however, a one-way valve is very prone to clogging).

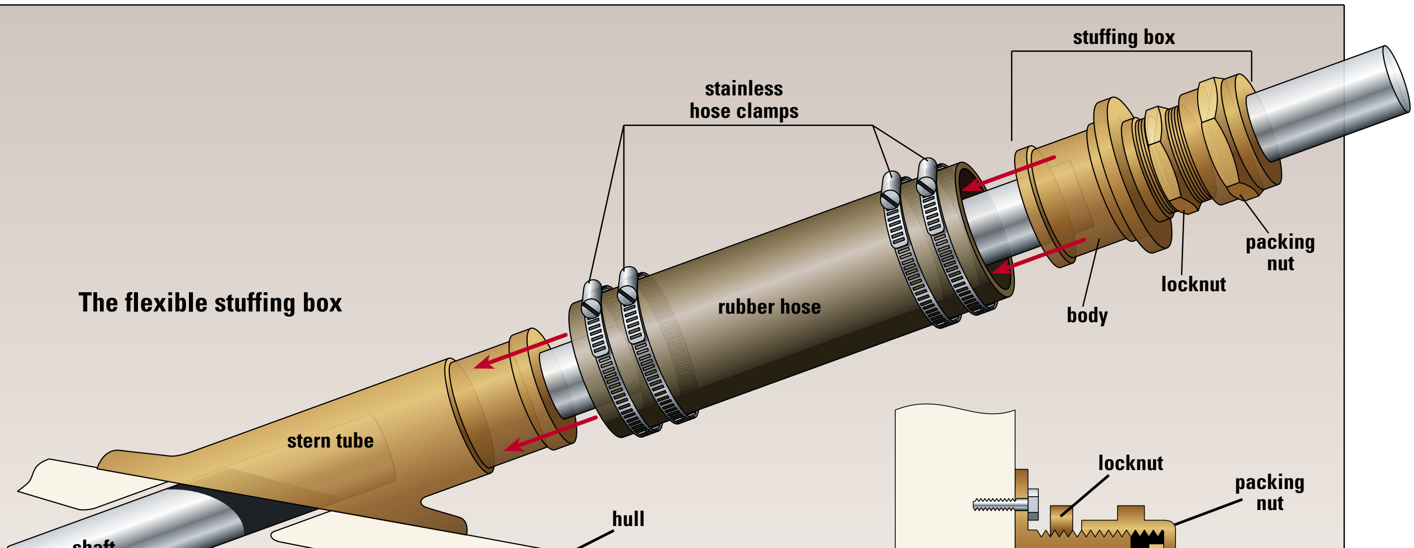
Finally, a reliance on bilge pumps is not a substitute for checking all your underwater fittings on a regular basis.



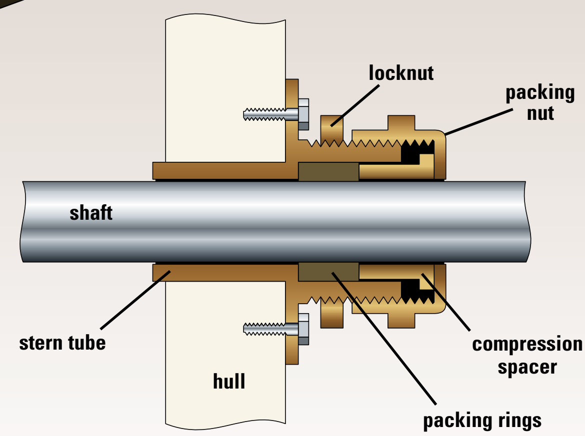
Typical automatic electric bilge-pump installation

Keeping that drip-drip-drip under control

by Don Launer



The flexible stuffing box



The rigid stuffing box

A SHAFT LOG GUIDES THE PROPELLER SHAFT THROUGH THE hull while keeping watertight integrity. It consists of two parts, a watertight seal and a bearing that supports the shaft. When inboard engines were initially installed in early wooden boats, the shaft exited through the sternpost and relied on a reasonably tight fit between the wood and propeller shaft to keep the water out. But since this usually meant regular pumping of the bilge, a better solution — the stuffing box and Cutless bearing — came into widespread use.

The stuffing box — sometimes called the packing gland — eliminated most of the leakage around the shaft by compressing stuffing, or grease-impregnated flax packing, tightly around the shaft. Some stuffing boxes have grease fittings, so this grease can be easily replaced.

The stuffing, which is a square, plaited material, usually flax, comes in various sizes to match your stuffing box. This flax is now usually impregnated with paraffin or Teflon. To keep the stuffing box cool and lubricated, a small amount of water from outside the hull is allowed passage through this compression seal. This cooling water should consist of about one drop every 10 seconds when the shaft is rotating. Although there is some disagreement as to the drip rate, the rule of thumb is that the stuffing box should feel warm, but never hot, after prolonged use.

Level of perfection

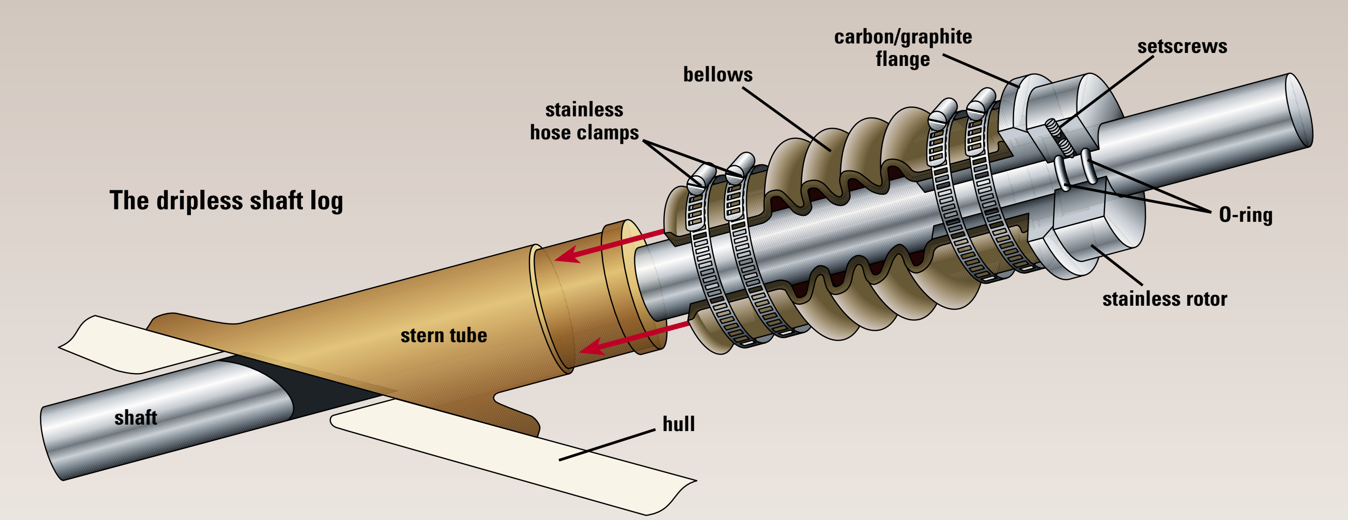
Although the stuffing box *should not* drip water when the shaft is not turning, this is only an ideal. Few stuffing boxes meet this level of perfection, so when a boat is left for long periods of time an automatic bilge pump is often necessary. Eventually, the packing in the stuffing box gets worn away and has to be replaced. To do this the old, hardened packing must be removed. Special tools are available for this purpose. The stuffing box can then be cleaned and new packing installed. When the vessel is relaunched, the drip rate must be checked and the compression nut adjusted as necessary. This drip rate should be checked again during the next few times out.

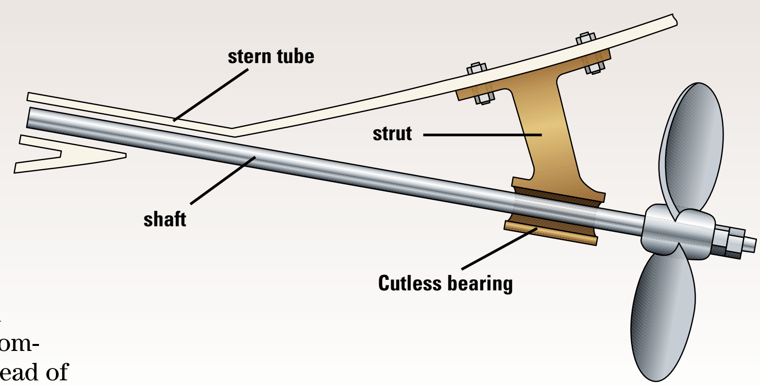
There is also self-lubricating, low-friction packing available. A clay-like compound is inserted in the stuffing box and compressed by rings of conventional packing. Then the packing compression nut can be adjusted so there are no drips. Although more expensive than conventional packing, after the initial adjustment this system rarely needs readjustment.

There are two basic styles of stuffing boxes, rigid and flexible. In the rigid style the stuffing box is bolted directly to the hull or stern tube. The flexible type connects the stuffing box to the stern tube or Cutless bearing by a short, flexible length of rubber hose double-clamped at both ends.

For those who find the constant drip of water into

Layout and illustrations by Ted Tollefson





the bilge to be disconcerting or for those who find it difficult or impossible to accomplish the contortions required to adjust the compression and lock nuts on the stuffing box, a dripless seal is the answer.

Newer method

Dripless shaft seals replace the stuffing box and are a newer method of providing a seal that is completely watertight. A rubber bellows is used instead of the straight rubber hose to connect the dripless seal to the stern tube or Cutless bearing. At the forward end of this bellows is fastened a polished carbon flange, which is compressed by the bellows against a polished stainless-steel rotor attached to the shaft. Thus, the carbon flange remains fixed to the rubber bellows, while the stainless-steel rotor rotates with the shaft. The tolerances on this seal are so close that there is no drip, and heat from friction is reduced by the natural lubricating properties of the carbon and the cooling water just behind the seal. This seal does not require the frequent, awkward readjustments that are required by the conventional stuffing box or the periodic removal of the old packing and its replacement. It also prevents the scoring of the propeller shaft that is a long-term problem with stuffing boxes.

The Cutless bearing provides support and alignment for the propeller shaft. It is a bronze, stainless-steel, or fiberglass tube with a grooved nitrile-rubber or plastic liner inside. The propeller shaft is supported by this Cutless bearing inside the stern tube or in an external strut and, when new, should allow little or no play in the propeller shaft. The grooves in the liner allow outside cooling water to enter the Cutless bearing to cool both the propeller shaft and seal.

Signs that a Cutless bearing needs replacement are vibration when in gear and a propeller shaft that shows 1⁄16 inch or more of play. Replacing a Cutless bearing can be quite a task. Although the bearing itself is relatively inexpensive, the replacement process can be complicated and frustrating. It usually requires the removal of the propeller shaft that, in turn, often means removal of the rudder. The setscrews holding the Cutless bearing to the stern tube are then removed, and a Cutless-bearing puller is used to remove the old bearing. A new bearing can then be slid in place. If it's a tight fit, keeping it in the refrigerator or freezer overnight will usually shrink it enough to make the job easier. Then the greased propeller shaft can be slid into place, coupled to the engine, the propeller and rudder installed, and the engine's alignment checked.

A properly aligned Cutless bearing should last for several thousand hours.

Electronic charts offer choices for every budget

by Don Launer

THE TYPICAL CHART PLOTTER CONSISTS OF A DISPLAY UNIT, either black-and-white or color, and a GPS. The plotter displays your boat's position as a symbol superimposed on an electronic chart. This symbol is frequently boat-shaped with a small dot in the center. That dot shows your position.

Electronic chart plotters come in a wide range of sizes, options, and prices and are available as either hand-held or fixed-mount. While some systems' sole function is to provide an electronic chart, the majority are integrated with a GPS receiver. Sometimes an external GPS is interfaced with the dedicated plotter, using NMEA protocol. More often, since there are no universally accepted standards for the chart display, most manufacturers of chart plotters use a proprietary electronic format. Thus, your choice of a manufacturer determines the type of chart cartridges that can be used, the software, and the display options.

Some of the basic requirements of GPS chart plotters are that there should be a fast processor and at least a 12-channel GPS receiver with WAAS, which should provide a repeatable accuracy of location within about 10 feet. The GPS antenna should be located out in the open as much as possible, since the short wavelengths and low power of the GPS signals don't easily pass through metal, fiberglass, or people.

The LCD raster display should be easily viewable in direct sunlight, and the chart display should be capable of being oriented in "north up" or "course up." Although units with color displays are considerably more expensive than monochrome, they provide substantially better apparent resolution and, because of the color differences, it is easier to differentiate between land, navigable water, and shoal water.

The typical GPS satellite-receiving antenna associated with a chart plotter is about the size and shape of a doorknob.

Most units feature automatic track plotting, so a track is saved on your outbound and return voyages. At night or during inclement weather, the outbound track can be followed for a safe return.

Hand-held plotters are often able to save more than 20 routes and 50 waypoints. Fixed units usually can store more than 1,000 waypoints. Variable scaling, or the ability to zoom in and out, should also include a scale showing distance in miles, nautical miles, or kilometers. When heading for a waypoint, distance, direction, speed, and estimated time of arrival should be prominently displayed. The ability to measure range and bearing to any point on the chart is also important.

There are basically two forms of electronic charts, *raster charts* and *vector charts*. Raster charts are scanned images of NOAA government paper charts and, as a result, have some limitations in their electronic capabilities. Vector charts start as scanned images of the NOAA charts, but the data is stored in "layers," giving the user options in eliminating specific data layers that are not of interest.

In the recreational boating electronic industry, three software formats have come to dominate the chart-plotter market: Garmin BlueChart, C-Map, and Navionics.

Garmin BlueChart chips provide a display that looks very similar to paper charts, but with a single keystroke additional information on marinas, tides, and hazards is available. The operator can also overlay and store waypoints in the chart display. These vector-based BlueChart charts are available on a CD and can be downloaded into a fixed or hand-held plotter from a laptop or desktop computer.

C-Map is a vector-based chart system that provides such features as an alarm when the vessel is approaching shoal waters and a search mode for locating harbors and services.

Navionics cartridges cover large areas; only 17 are required to cover the entire U.S. coastal and Great Lakes waters. Also vector-based, these chart cartridges are available in the "Gold format" for various chart-plotter manufacturers, including Furuno, Lawrence, Raymarine, Northstar, Eagle, and Humminbird.

Layout by Ted Tollefson

Dedicated chart plotters feature only the chart and GPS displays. They are high-resolution LCD displays in either black-and-white or color with the vessel's position superimposed on the chart.

Combination chart plotters, made by several manufacturers, also give the chart and GPS fix, but may also offer more than one service on the same screen. These additional displays might include a fishfinder, depthsounder, and radar. Some manufacturers have the capability of displaying the picture from an external video camera or even your favorite movie. In some combination chart plotters the display can also be routed to a remote monitor. Many of these combination chart plotters have the ability to include expanded coverage for future accessories.

Laptop or desktop computers on board can use a variety of computer programs to display charts with excellent resolution onto a screen larger than that available with cockpit chart plotters. Their disadvantage is that, with a few expensive exceptions, they are not resistant to spray, are not easily mounted in place, often cannot be comfortably viewed in direct sunlight, and can rarely be seen by the helmsman. For the on-board computer, there are software chart packages available in various formats. Several options are available, such as Offshore Navigator's interface that allows your computer to drive your autopilot.

Prices of chart plotters vary between about $600 for a black-and-white low-end unit and about $18,000 for a top-of-the-line combination-display model.

Wireless technology and solar power for navigational instruments is now expanding in the marketplace. By using radio-frequency signals and built-in solar panels, these new instruments can be installed as either primary or remote monitors with no cables whatsoever.

Chart plotter showing chart display

Chart plotter display, showing a sky view of the available satellites, with bar-graph of each satellite's receiving strength

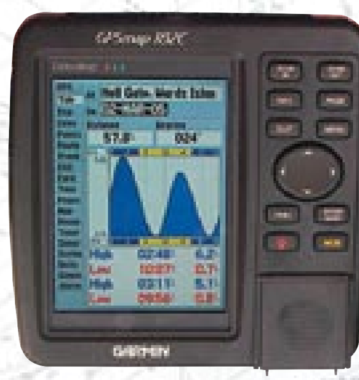


Chart plotter with graphical picture of tides, along with a listing of the times of high and low tides for the date selected

The chart chip is easily accessible, and changing it takes only a few seconds

Treat them with care and they'll serve you well

by Don Launer

A BINOCULAR IS AN ESSENTIAL PIECE OF BOATING equipment, and the selection of this item of navigational gear requires some basic knowledge of terminology as well as options available.

Optical terms

Three sets of numbers are used to describe a binocular's characteristics. The typical marine binocular is a 7 x 50. This gives a field of view of 7.4 degrees, or one that covers 188 feet at 1,000 yards. The 7 specifies the magnification: seven times. For on-board use, seven is about the highest magnification that is practical, since a higher one would make it difficult to hold the image steady enough to see details, such as a buoy number; and in rough seas, even a magnification of seven is sometimes too much.

The 50, in the 7 x 50, is the diameter in millimeters of the front lens of the binocular, the objective lens. The larger this lens, the greater its light-gathering capability.

The third number, which is often unlisted, is also expressed in millimeters and describes how far the binocular's eye lens can be held from the observer's eye while still enabling the observer to see the entire scene. If eyeglasses must be worn when using a binocular, this number should be at least 18 mm.

Coated lenses

A proper binocular, like a good camera, has optical coatings on its lenses and prisms. This magnesium fluoride coating reduces internal reflections and increases clarity and brightness. The higher the quality and number of the coatings, the better the image reaching your eyes. Inexpensive binoculars may have no coating, with less than half the light reaching your eyes, while an expensive pair may have as many as 20 layers with more than 90 percent of the light being transmitted.

Waterproof

A binocular that is completely waterproof — not "water-resistant" or "splash-proof" — is desirable since, inevitably, the binocular is going to get soaked. This feature can also prevent internal fogging of the lenses or prisms due to moisture entering the case. With a totally waterproof binocular, you are also able to wash the case and lenses with fresh water after rough use. After washing, it's a good idea to clean the lenses carefully with lens tissue.

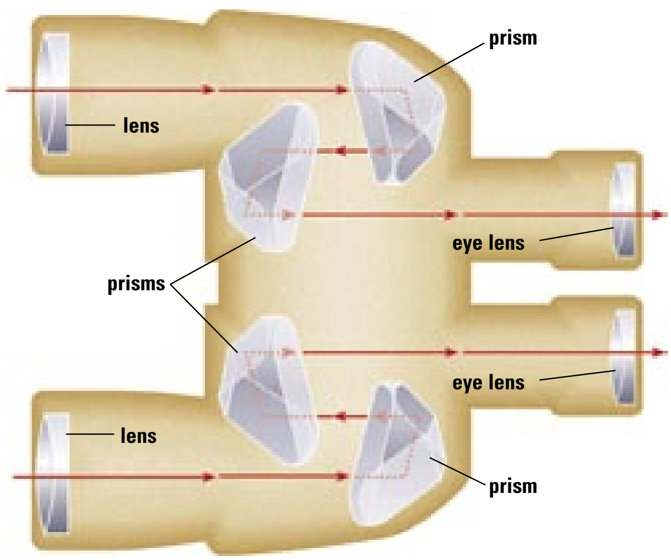
High-quality, completely waterproof binoculars are often filled with dry nitrogen gas and have O-ring seals. One manufacturer even submerges each binocular in 12 inches of water for two weeks to check these seals. Some of the completely waterproof ones also have positive flotation in case you drop them overboard.

Focusing

Often a user will have a different prescription in each eye. Binoculars with a main focusing control should also have one of the scopes focused separately to compensate for this. Some binoculars only have individual eye focusing, with no dual focusing control; but since the binocular is usually used only to observe distant objects, this individual focusing rarely needs to be reset. The individually focused binocular is also more likely to remain completely waterproof than its counterpart.

Electric focusing, with a small motor in the binocular doing the job, is also an option.

Illustration and layout by Ted Tollefson



Covering

Unfortunately, on small boats a binocular takes a beating. To help protect this delicate optical instrument, the outer case of the binocular is often rubber.

Image stabilizing

An electronically stabilized binocular allows the use of a higher magnification power than a non-stabilized one. This makes reading buoy numbers and identifying navigational hazards possible at a much greater distance. Whereas a non-stabilized binocular has a practical limit of about 7 magnifications, an image-stabilized one will generally have a magnification of 14. Originally this stabilization was accomplished by incorporating small, power-hungry gyroscopes into the binocular, but that original system has now been replaced with systems that use piezo-electric crystals that sense movement and send digital signals to a set of gimbaled servos which adjust the optical platform. These systems generally use AA batteries as a source of power, with a battery life of several hours of usage.

The ability of image-stabilizing binoculars to correct for unwanted motion is expressed in the maximum number of degrees of correction possible, such as +/- 1 degree or +/- 5 degrees. Whereas the +/- 1 degree units can correct for hand-tremor, the +/- 5 degree units will also help correct for boat motion. Some models can be switched between "Land," where +/- 1 degree is fine and conserves power, to "Onboard," which gives maximum correction.

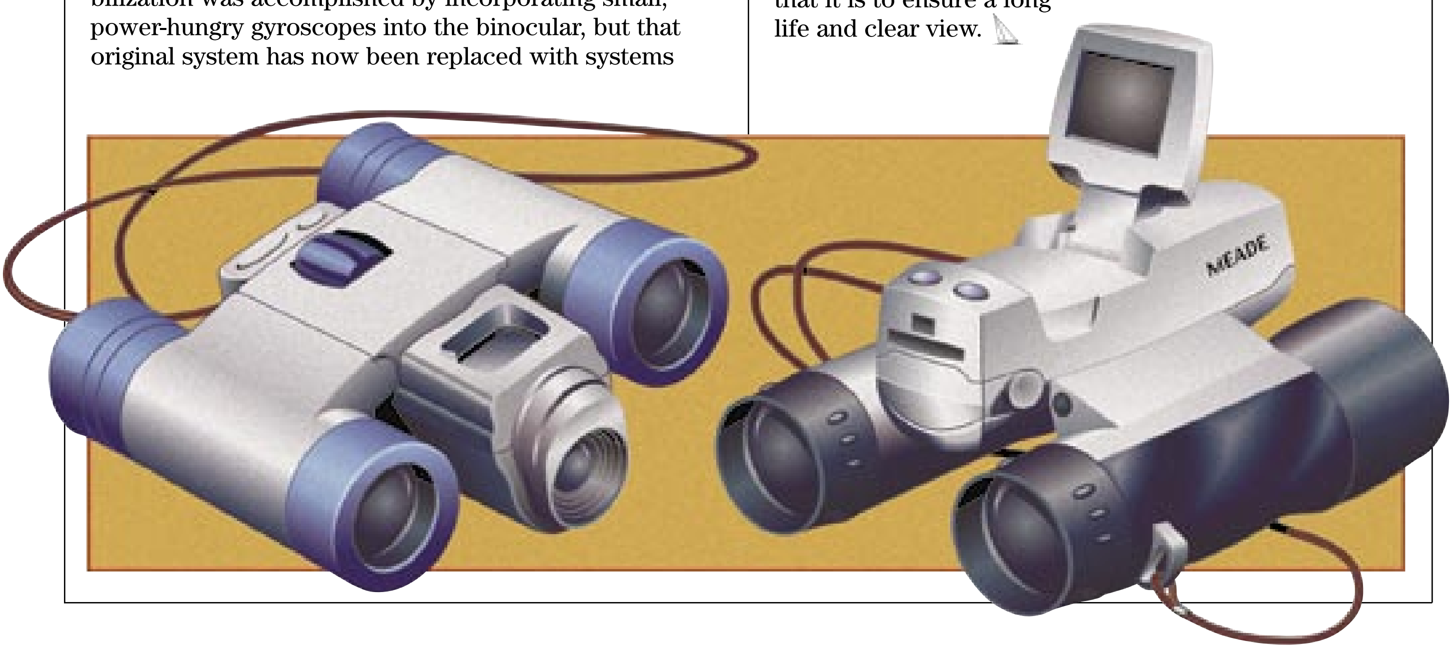
Although the best of these image stabilizing binoculars are expensive (in the $1,000-plus range for image-stabilized waterproof ones), many users count them among their most valuable navigational tools.

Specialized binoculars

Binoculars are also available with a built-in bearing compass display (some are digital), in which you can simultaneously identify a navigational point and determine a compass heading. There are also binoculars available with a range-finding reticule which, if you know the height or width of the object you're looking at (such as a lighthouse), will let you determine its distance.

A recent innovation is a binocular with a digital display that can take digital pictures of the object you're viewing.

Regardless of the type of binocular on board, it should be treated as the delicate optical instrument that it is to ensure a long life and clear view.



This proven safety feature is now practical for all sailboats

by Don Launer

RADAR IS AN ACRONYM FOR **RA**DIO **D**ETECTING **A**ND **R**anging. A marine radar is used to determine the distances and azimuths of landmasses, boats, and buoys by measuring the time between the transmission and return of an electromagnetic microwave signal that has been transmitted and reflected back from the target. In some cases this return signal may also be retransmitted by a transponder on the target, which is triggered by the original signal.

A single, rotating, highly directional antenna is used for transmitting and receiving. The size of the antenna and the frequency of the radar determine the beam width of the transmitted signal, with a very narrow "horizontal beam width" being optimal. This antenna, which rotates through 360 degrees, may be an open array, which presents the most precise display, or a rotating antenna enclosed within a radome (preferable for sailboats since there is no rotating antenna to foul the running rigging). Some radomes are as small as 12 inches in diameter — but as the diameter of a radome becomes smaller, the resulting display is less precise.

Since radar frequencies are nearly line-of-sight transmission, the height of the antenna and the height of the target determine the radar's maximum range. The radar transmits very short, yet very high-powered, bursts of microwave energy thousands of times a second. Between the transmitted bursts, the radar is in the receive mode for the reflected signals returning from the target. Due to the high intensity and frequency of this microwave beam and the fact that the vertical beam width is much greater than the horizontal beam width, the radar's antenna should not be located where the microwave energy will be directed toward any people or animals on board or toward other onboard antennas, such as a GPS.

Radar signals can be attenuated by rain and, to a lesser extent, fog. The higher a radar's output power, the greater its ability to produce a usable return signal under these conditions.

Although a radar's power is rated in kilowatts, this power level is only transmitted for short periods (usually considerably less than a microsecond), so a modern 12-volt radar unit does not consume much overall power. In addition, these units take up very little physical space. Even the smallest of boats, for an investment of less than $1,000, can now have the security of a radar when the fog rolls in.

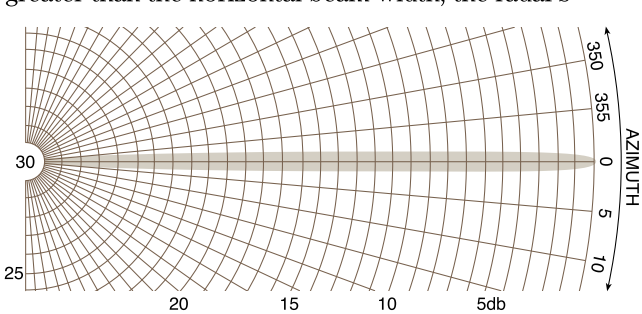
"Even the smallest of boats, for an investment of less than $1,000, can now have the security of a radar when the fog rolls in."

Operational controls

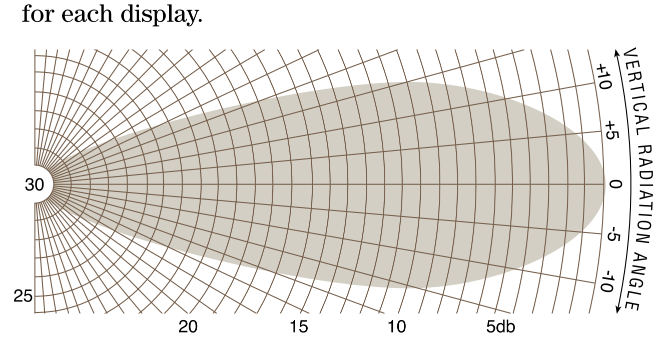
All modern radar units feature automatic and manual controls. Usually the automatic mode results in the most satisfactory display, but manual adjustments are also available and can be handy under special circumstances. The range, of course, is operator-selected.

Dual-range displays

As the name implies, a dual-range display allows the simultaneous display of two ranges on a split screen. Typically this would be a detailed display of the immediate area and a long-range display that allows a sailor to keep a watchful eye on what is approaching in the distance. The operator has the option of selecting the range for each display.



The horizontal beam width of a radar is very narrow, and is constantly rotating through 360 degrees (with the exception of some specialized radars that scan only a prescribed sector).



The vertical beam width of a radar is broad, so close targets, as well as distant ones, will be covered. The radar's antenna should not direct microwave energy toward people or animals.

Layout and illustrations by Ted Tollefson

Multi-function displays

In the past few years there have been incredible changes in marine electronics. One of these is the multi-function display, which can provide two or more of your boat's navigational electronics on one screen. Multi-function displays allow you to select and view radar, GPS, an electronic chart plotter, depth sounder, and other onboard electronics on one display unit. Usually these displays use a wide, split screen.

Although seldom used except aboard the largest of sailboats, networking allows more than one multi-functional display in different locations, such as at the helm or in the cabin at the nav station. At each location, the display unit can access and control any of the functions available in the system. Most marine electronic manufacturers have their own proprietary networking systems and equipment that allow for future expandability.

Radar overlay

One of the biggest recent advances in today's radars is the chart/radar overlay, in which the radar display is overlaid on a GPS-controlled electronic chart, eliminating many of the problems associated with trying to monitor and interpret separate displays.

Misinterpretation

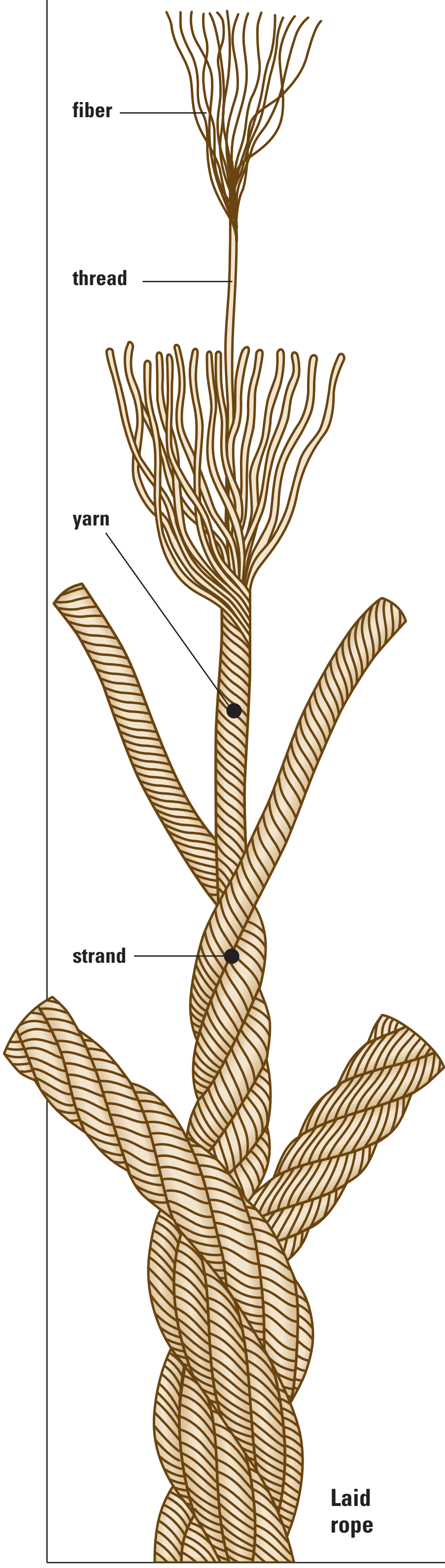
With any radar, it's of vital importance to spend time using your radar on days with good visibility. It's best, when the visibility is good, to use the controls and display options while comparing the appearance of various types of targets on the screen with those you can see.

If you wait for a foggy day to use the radar for the first time, you might be better off not having a radar on board at all. Even with trained, professional crews, many ship collisions have resulted from misinterpretation of the radar display — especially in the early days of radar's use at sea. Notable were the collisions of the *Neceto de Lorrinage* with the *Sitala* and the *Crystal Jewel* with the *British Aviator*. The collision of the *Andrea Doria* with the *Stockholm* in 1956, which sank the *Andrea Doria*, occurred even though both vessels were monitoring (but misinterpreting) their radar displays.

Typical multi-function, single-station display.

Making sense of the bewildering range of boating lines

by Don Launer



ROPE IS THE PRODUCT OF CORDAGE MANUFACTURERS BUT, with a few exceptions, when ropes of less than 1-inch diameter are used aboard a sailboat for a specific function, they are known as lines. (The etymology of the word *line* is from the Latin, *linea*, which means, um, rope.) Until relatively recently, the dimension given for a rope was its circumference — thus, a 3-inch hawser was one of 3 inches in circumference. Now, rope dimension is usually given as the diameter.

Until the middle of the 1900s there was a very limited choice of rope (or line, if you wish) from which the sailor could choose — hemp, sisal, and cotton. Now, many synthetic lines have come on the market and, surprisingly, they are often cheaper than their natural-fiber counterparts.

The manufacturing of three-stranded rope has not appreciably changed, however. It starts with a small *fiber*. Several of these fibers are twisted into a *thread*. These threads, in turn, are twisted into *yarns*. The yarns are twisted into *strands*. Finally, three of these strands are twisted into a "three-stranded laid rope," the traditional form of rope that was first made from natural fibers.

It is common practice that three-stranded rope has a right-hand twist, although a left-hand twisted rope is sometimes encountered. With three-stranded twisted and laid rope, there is considerable stretch, however, since the three twisted strands tend to straighten out under tension. The construction of the more modern braided rope reduces this stretching tendency.

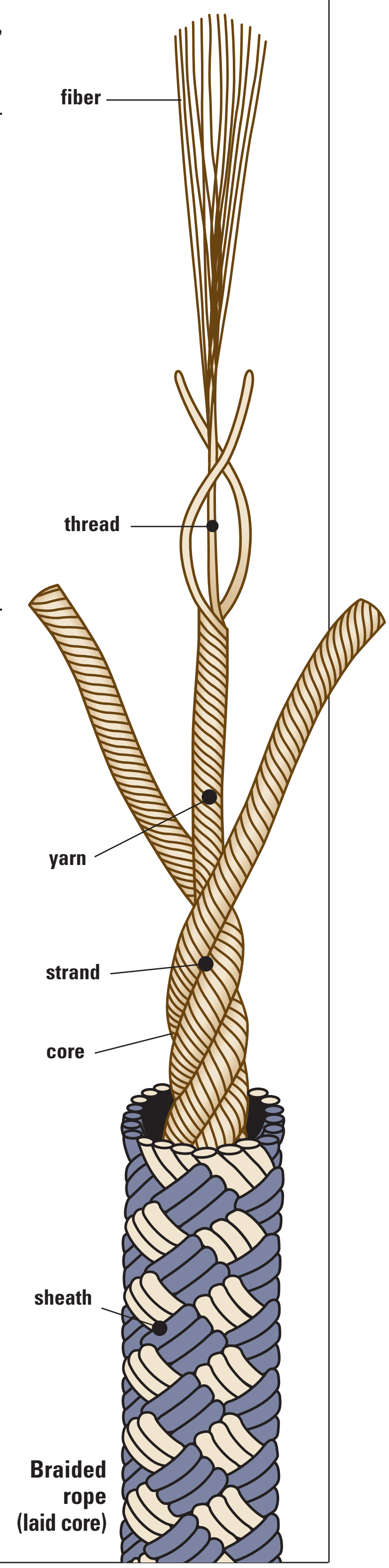
Braided rope has a braided outside sheath and an inner core, which can be one of several varieties:

- ***Parallel core*** is a braided cover enclosing a core whose bundle of fibers and threads are oriented parallel to the line's axis.
- ***Double-braid*** is a braided cover over a braided core of the same material.
- ***Core-loaded double-braid*** is a braided cover over a braided low-stretch core of a different material.

There are three basic man-made fibers that have been used by sailors for decades: nylon, polyester (called Dacron in the United States and Terylene in Great Britain), and polypropylene. Of these three basic synthetic ropes, nylon is the strongest, with polyester a close second, and finally polypropylene.

Best choice

Since nylon has high-strength, excellent abrasion-resistance, and great elasticity, it is the best choice for use when there will be shock loads, such as for docklines and anchor lines. But those same attributes make it completely unsuited for use as running rigging, such as halyards, where stretch would be a detriment.



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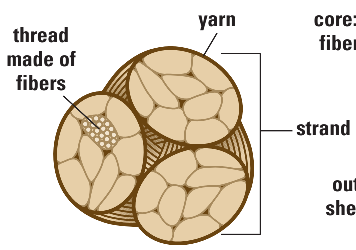
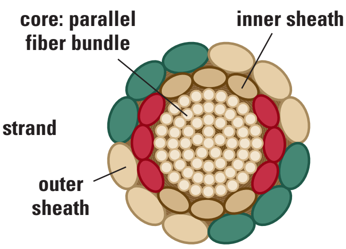


Cross-section of laid rope



Braided rope with parallel core

Polyester, on the other hand, provides almost as much strength as nylon, but with little stretch. When purchased "pre-stretched," its elongation under load is even less. It also has good abrasion-resistance. This makes it the all-around choice for most other applications on board.

Polypropylene has the lowest strength of the three. It is relatively cheap and has the advantage of being lighter than water, so it floats. This makes it the line of choice for dinghy painters, reducing the possibility of its sinking and fouling the propeller. Polypropylene, though, is more susceptible to ultraviolet deterioration and is subject to melting when cornering through a chock under high tension.

Beyond these three basic fiber groups is a range of more expensive options, as well as their associated high-tech terminology. Some of these new terms are:

- ***High modulus,*** which basically means low-stretch. Most of the high-modulus lines are very slippery and, when tied using the knots that we know well, are prone to failure. Although a bowline in a nylon or polyester line decreases the strength of that line by about 40 percent, in a high-modulus line the strength is reduced by an astounding 70 percent or more. For this reason, knots should be avoided in high-modulus lines, in favor of splices.
- ***LCP*** *(liquid crystal polymer)*, such as Vectran, is one of the latest rope-making fibers. These thermoplastics are very strong and abrasion-resistant, but they have low UV-resistance.
- ***HMWPE*** *(high-molecular weight polyethylene)* includes ropes such as Spectra, Amsteel, and Dyneema. Despite its high strength, HMWPE is so lightweight that it floats. Pound for pound, it has 10 times the strength of steel and is three times stronger than polyester. It is also low-stretch (stretching takes place during the manufacturing process). It has good abrasion- and UV-resistance, but it is high-priced and very slippery.
- ***Aramids*** are in the nylon family and are marketed under the names Kevlar, Technora, and Twaron. Although they are high-strength with relatively low-stretch, they have poor UV- and abrasion-resistance, especially when subjected to sharp bends under load.

Line care

There are general rules that apply to all types of lines to help extend their life:

During the boating season, hose off lines with fresh water to wash away dirt and salt crystals. At the end of the season, soak the lines in warm soapy water, then rinse them and hang them up to dry.

During the off-season, remove as many lines as possible from your boat, especially those with a low UV-tolerance. This will extend their life considerably.

3-Stranded laid | Braided with laid core | Double-braid | Braided with parallel core | 8-Plaited

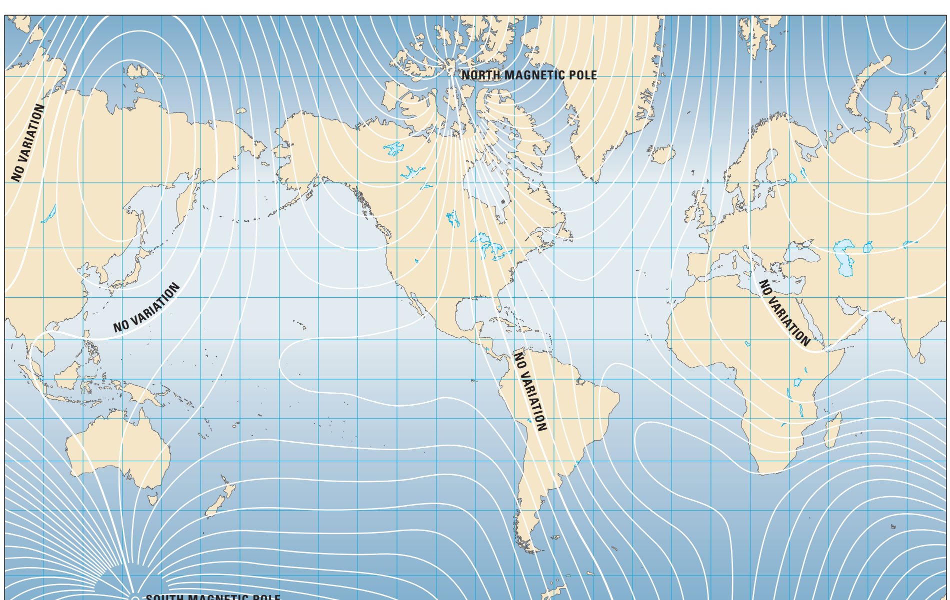
NAUTICAL COMPASS 101

It's the simplest, most reliable instrument on your boat

by Don Launer

THERE ARE MANY TYPES OF COMPASSES THAT HELP THE mariner determine direction: the electronic flux-gate compass, an electronic magnetic compass; the gyro compass, which is aligned with the earth's axis and shows true north; and the compass displays derived from global positioning satellites, which can either show true north or magnetic north. In this discussion, we'll limit ourselves to the non-electronic, magnetic compass — the basic navigational tool that has been in use since before 1100 A.D.

Early compasses used a magnetic needle that indicated directions over a fixed card at the bottom of the compass case, but now nearly all boat compasses use a rotating card, with two or more bar magnets fastened beneath the card. In earlier times this card was graduated in 8, 16, or 32 points, but now almost all cards are graduated from 0 to 360 degrees. Some of these cards are inscribed to be viewed from above and some have edge markings, while other cards combine both displays. The card is balanced on a pivot, frequently jeweled to reduce friction, and the whole assembly is enclosed in a dome filled with liquid to dampen any oscillations of the card due to rough seas (or cannon fire). The greater the diameter of the compass card, the better its stability and visibility.

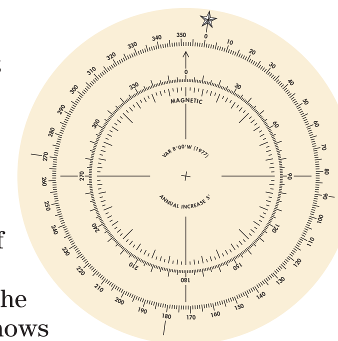


An isogonic chart

Variation

Lines of longitude on a chart are always aligned with true north. The direction to the magnetic north pole varies with location and with time. The difference between magnetic north and true north at any location is termed variation, which is expressed in degrees east or west of true north. But since the magnetic poles are continuously migrating, this variation, for any one position on the face of the earth, changes year by year. Charts of lines of equal variation, called isogonic lines, are available for local areas as well as worldwide.

Compass rose



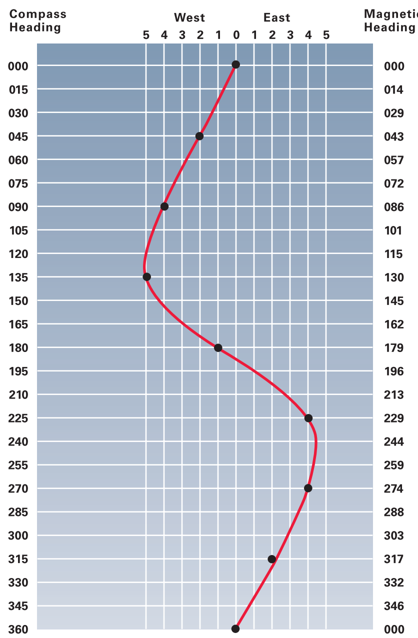
The compass rose

The compass rose on a chart distills all this theoretical information into a convenient, simple, and usable form. The outer ring of the rose shows bearings to the true north pole — the axis of the earth, which coincides with the lines of longitude. The next inner ring of the rose shows magnetic bearings — the actual direction to the magnetic north pole for the area covered by that particular chart. The center ring also shows the variation printed in degrees east or west, as well as the annual predicted change in that variation, along with the date that this change was predicted. This yearly predicted change in variation is only applicable for a few years from the date shown on the chart, since the movement of the magnetic north pole is erratic and unpredictable in the long term, but when using old charts, the yearly change can be extrapolated with reasonable accuracy.

Deviation

Most magnetic compasses aboard boats don't actually point to magnetic north, however, due to other magnetic influences aboard the boat: ferrous materials, magnets, and electric currents. The difference between the true magnetic heading and the heading that the compass is show-

Layout and illustrations by Ted Tollefson



A typical deviation chart resulting from "swinging the compass"

ing is termed deviation. Because deviation is particular to each boat, this cannot be shown on a chart. To complicate things even more, this deviation changes with the boat's change in direction and its angle of heel.

Thus, the difference between the true heading and the compass reading is the result of both variation and deviation. Since variation is fairly constant at any given location, this can easily be added or subtracted from the compass reading, but a deviation table must be created for each boat. Creating this table is done by swinging the compass — that is, by turning the boat through 360 degrees and adjusting the small compensating magnets within the compass until the deviation errors are minimized. The resultant, uncorrectable errors are used to create the deviation table. The details of this procedure are usually outlined in the instruction sheet when buying a new compass. They can also be found in such publications as *Chapman Piloting*, but by using GPS instead of the traditional methods, these compensations and adjustments have become a much simpler operation.

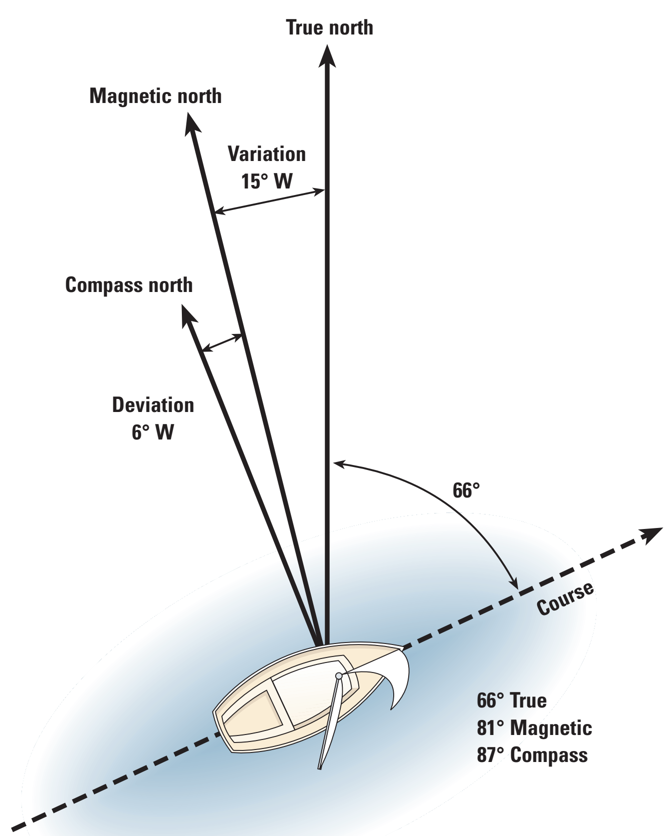
With a deviation table for your boat in hand, then the algebraic sum of variation and deviation, applied to the compass reading, will result in the true heading.

Compass styles

The primary mounting styles for boat compasses are binnacle mount, bulkhead mount, flush mount, surface mount, and bracket mount. The type of mount is usually determined by the physical layout of the sailboat's cockpit, as well as the skipper's preference. In addition, there are three basic card types available. For the direct-reading card, the heading is read from the edge of the card. Flat cards are read by looking down inside the compass bowl at the forward edge of the card, and these displays usually also include lubber lines, at 45 and 90 degrees. Dual-reading cards are a combination of direct-reading and flat cards and show the heading either by looking down inside the bowl or by looking at the edge of the card.

Hand bearing

A hand bearing compass is used to measure the direction of a sighted object relative to the user. These compasses are available either as the "hockey-puck" variety, held close to the eye, or the pistol-grip type, held at arm's length. Both types have a means of sighting that shows the bearing of the target in degrees. The hand bearing compass is not only handy for determining your location by intersecting lines of position, it is also good to have as a backup compass or for use in the ship's dinghy.



The relationship of deviation and variation to compass, magnetic, and true headings

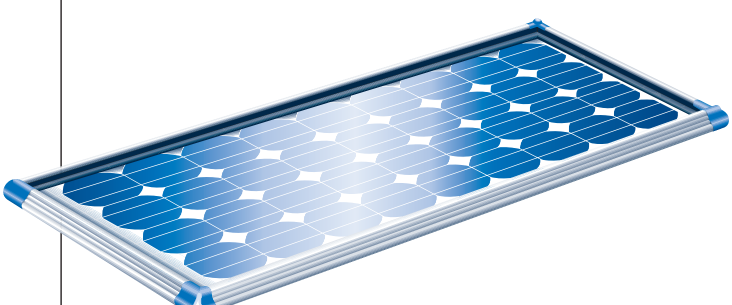
Keep your batteries topped up with a slow but steady charge

by Don Launer

On a bright, sunny day, with the sun directly overhead, the sun supplies about 1,000 watts of energy per square meter. If all the energy across the sun's electromagnetic spectrum could be collected, it wouldn't take a very large solar array to supply all our needs on shore and on the water.

To convert a portion of this energy into electricity, we use photovoltaic cells (*photo*, meaning light, and *voltaic*, pertaining to electricity). But these systems are usually less than 15 percent efficient at the most, since, in the wide range of wavelengths that reach us from the sun, only a very limited range can be converted into electricity by these cells. In addition, the necessary grid on top of a photovoltaic cell can block some of the incoming light, and the solar panels are made from highly reflective silicon-based semi-conductors.

The cells used in a solar panel are generally constructed of one of several types of impure silicon, and each of these individual cells has a maximum output of about 0.5 volt. When light — in the form of photons — strikes a cell, it knocks electrons loose. These electrons are directed so they create a current flow between the metal contacts at the top and the bottom of the cell and, combined with the cell's electric field, create a voltage from which the cell can produce power.



A polycrystalline solar panel is easily recognizable by its structure, which resembles tiles.

Amorphous solar panels are characterized by their uniform appearance, with no cell-structure apparent

Types of solar panels

There are three basic types of solar panels available:

- ***Monocrystalline*** panels are recognizable by their black, round, or semi-circular cells, connected by silver wires. The use of these has dwindled in recent years.
- ***Polycrystalline*** cells use a different type of manufacturing process. These panels can be recognized as black, rectangular cells, closely packed together, resembling a tiled wall. Polycrystalline panels can reach about 11 percent efficiency and are a common product in the solar-panel marketplace.

  Solar panels of monocrystalline or polycrystalline cells consist of 30 to 36 individual cells (for a 12-volt system) wired in series.
- ***Amorphous*** panels are built up as a single unit with combinations of parallel and series cells and conductors linking them. Amorphous panels, as the name implies, have a uniform surface with no apparent individual cell structure. Electrically, they are a combination of series and parallel cells and typically incorporate numerous by-pass diodes, which give them a distinct advantage where shadows are present. But, since amorphous panels only reach 6 to 7 percent efficiency (about half that of monocrystalline and polycrystalline panels), they need to be bigger for a given output.

Amperage available from any solar panel is proportional to the area of each cell. The cost-per-watt of the three panels is about the same, and a rough estimate is that a solar panel system aboard a boat will run about $6 to $8 per watt, with amorphous panels at the high end of the price range. The space required is vastly different, though. For a given power output, the space required for the less-efficient amorphous panels is about twice that of the monocrystalline and polycrystalline panels.

All three types of panels — when properly cared for — have a life expectancy of more than 20 years. Typically, these panels will give about 80 percent of their rated output when they're 20 years old.

Panel mounting

Panels should not be in a location where they might be walked on, and they must be firmly attached so they can't be dislodged by wind or waves.

The performance of a solar panel is highly dependent on the panel's orientation to the sun, the latitude it's

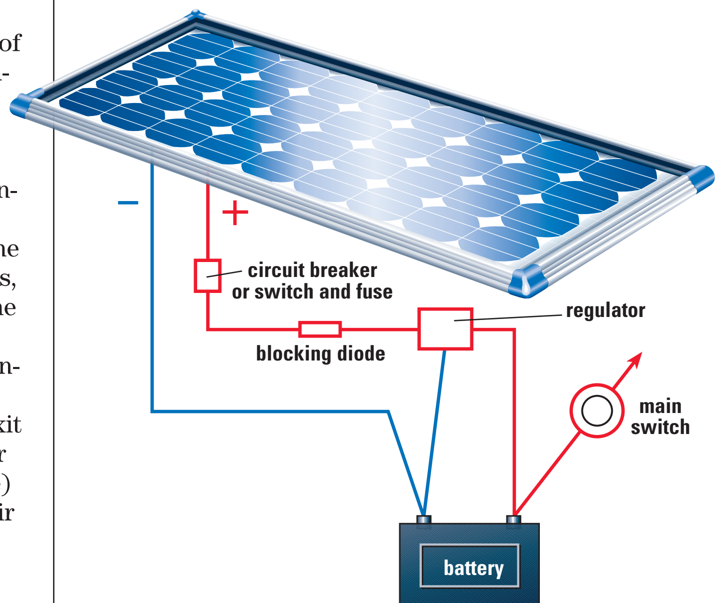
Layout and illustrations by Ted Tollefson

operating in, the season of the year, cloud-cover, time of day, shadows, and temperature. For maximum efficiency, it should be oriented at right angles to the rays from the sun.

Shadows on these panels are a big problem aboard sailboats. With monocrystalline and polycrystalline panels, a cell with a shadow on it not only doesn't contribute power, it also blocks the power generated by the other cells. The cells in these panels are wired in series, much like a string of Christmas tree bulbs, so when one bulb (or cell) is out, the whole string goes dark.

In mounting solar panels it is best to use framed panels with glass overlays. Particular attention should be given to possible corrosion where the electric wires exit the panels. Panels facing south, toward the equator (or north, toward the equator in the Southern Hemisphere) should be tilted at an angle to the horizon equal to their latitude for best overall results. Modifying this angle, due to the changing declination of the sun throughout the year, is also helpful. There are solar-panel-tracking devices available that perform this function automatically.

Sailboats on a mooring must take into account the direction of the prevailing winds when selecting the best position for a panel.



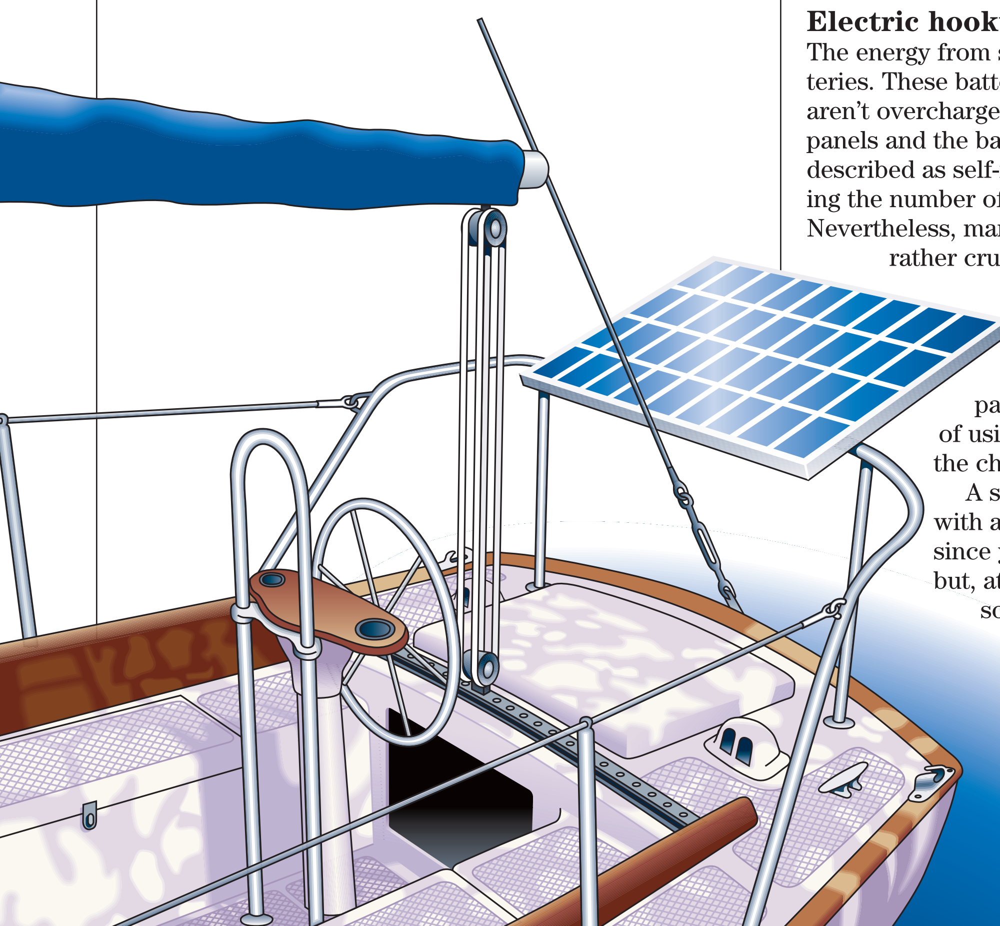
A typical wiring diagram for a single solar panel. An ammeter can be inserted in the positive line from the solar panel for monitoring output.

Electric hookup

The energy from solar panels on boats is stored in batteries. These batteries will last much longer if they aren't overcharged, so a regulator between the solar panels and the battery is necessary. Some panels are described as self-regulating, which is done by decreasing the number of cells in the panel from 36 to 32 or 30. Nevertheless, many batteries have been ruined by this rather crude method of preventing overcharging.

Blocking diodes in the circuit are also necessary to prevent the panel from draining the battery at night or from a boat's alternator feeding into the panel and burning it out. The downside of using blocking diodes is that they reduce the charging voltage to the battery.

A solar panel's output voltage reduces with a rise in temperature. This is a paradox, since you want the most sunlight possible but, at the same time, the least heat. Thus, solar panels are at their most efficient on cool, sunny days.



Available fuel choices for cruising sailboats

by Don Launer

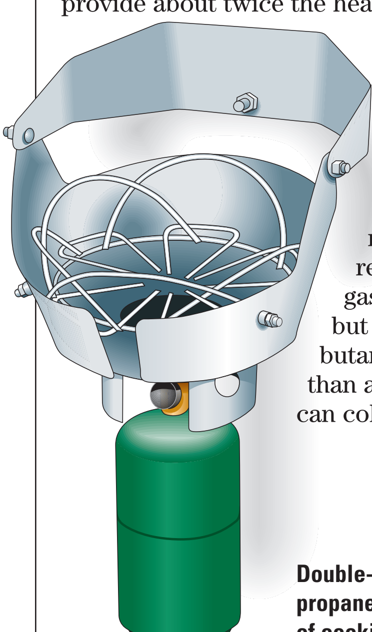
THE SELECTION OF THE BEST GALLEY STOVE FOR USE aboard your sailboat depends on the size of the boat, the layout of the galley, and the type and amount of cooking you plan to do. Your selection will also depend on your budget as galley stoves run from $40 to $4,000.

There is a wide variety of galley stoves and fuels: non-pressurized alcohol, pressurized alcohol, small liquefied propane or butane canisters, liquefied propane using large pressure tanks, compressed natural gas, kerosene, diesel, electric, ceramic-glass electric, and microwave. Galley stoves are also available as combinations, such as an alcohol/electric combo or an electric burner/microwave-oven combination.

These stoves come as a simple single-burner or as multi-burners with ovens. A galley stove that is gimbaled has a distinct advantage and is usually mounted facing athwartships so level cooking can occur when the sailboat is heeled. Gimbaled stoves should also have a method for preventing the stove from gimbaling — usually a barrel-bolt. The pivots for a gimbaled stove should be at the level of the bottom of the cooking pan. Fiddles around the edge of the stove-top with adjustable arms that encircle the pots should be high enough to prevent pots from moving. Galley stoves should be corrosion-resistant, preferably made of stainless steel.

Liquefied petroleum gas (LPG)

Most boatowners select LPG for their galley stoves, since these stoves operate much like home stoves and provide about twice the heat of alcohol. LPG can be butane, propane, or a mixture of the two. These gases become liquid under pressure and must be contained in specially designed tanks, with aluminum the preferred tank material. When pressure is released, the liquid becomes a gas that burns hot and clean but is very explosive. Both butane and propane are heavier than air, which means that the gas can collect in the bilge, so the strict safety protocols established by the American Boat and Yacht Council (ABYC) must be observed in the installation and operation of an LPG stove. Gas detectors, or "sniffers," should be part of the installation. LPG is available worldwide, however outside the United States metric adapter fittings are necessary to refill a tank that has American threads. Small camping-style LPG stoves use canisters that are discarded after use. These canisters are usually available in hardware or camping stores. They should be treated like large tanks used for LPG. When not in use, they must not be stored belowdecks.



Double-gimbaled single-burner propane stoves provide 3½ hours of cooking time.

Alcohol

Other than the small, camping-stove-type canister LPG stoves, alcohol stoves are the most inexpensive type of galley stove available, but their heat output is less than compressed natural gas and only about half that of propane and butane. Alcohol vapor is heavier than air, so alcohol — which was once proclaimed the safest of fuels — is now also considered dangerous when improperly or casually used.

Non-pressurized alcohol stoves — those containing a material saturated with alcohol and operating much like a Sterno stove — are much safer than pressurized alcohol models. These non-pressurized stoves require no preheating, which can sometimes be a hazardous operation.

The pressure for pressurized alcohol stoves comes from a tank that has to be pumped up with air. Alcohol is expensive in the United States and very expensive and difficult to obtain elsewhere in the world.

Three-burner propane stoves with ovens have been installed in most medium to large sailboats in recent years.

Layout and illustrations by Ted Tollefson

Compressed natural gas (CNG)

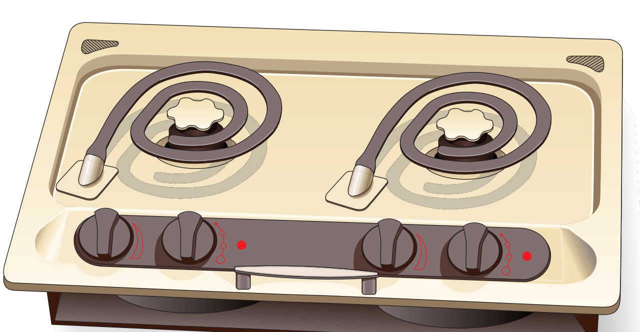
The main advantage of CNG fuel (primarily methane) is safety since this fuel is lighter than air and will not accumulate in the bilge. Nevertheless, one should apply the safety standards of LPG to CNG. The tanks should not be stored in the cabin, although many installations ignore this admonition. As with LPG, ABYC recommendations should be followed in the installation. These tanks are leased, not purchased. When refueling, the empty tank is exchanged for a full one. CNG is more difficult to obtain than LPG and has a higher cost, mostly due to a more limited distribution infrastructure. CNG has lower Btu-per-pound than LPG. In any installation, a CNG tank cannot be substituted for LPG or vice versa.

Kerosene

Though kerosene is universally available and relatively inexpensive, kerosene galley stoves are seldom seen, except aboard some older boats. Pressurized kerosene stoves burn kerosene vapor and have a blue flame similar to an LPG stove. However, just as with pressurized alcohol stoves, the burners must be pre-heated with alcohol to vaporize the kerosene before use. The pressure for kerosene stoves comes from a pressure tank that has to be pumped up with air. In some cases pressure is supplied by a gravity feed.

Electricity

Only sailboats with very high-output generators will have enough power to operate an all-electric galley since the power needed can be in the multiple thousands of watts. On small sailboats, however, a single-burner electric hotplate can be useful in a marina when you're connected to adequate shorepower. For the ultimate in electric cooking tops, ceramic-glass electric galley stoves are also available, as well as 12-volt DC or 120-volt AC microwave ovens.

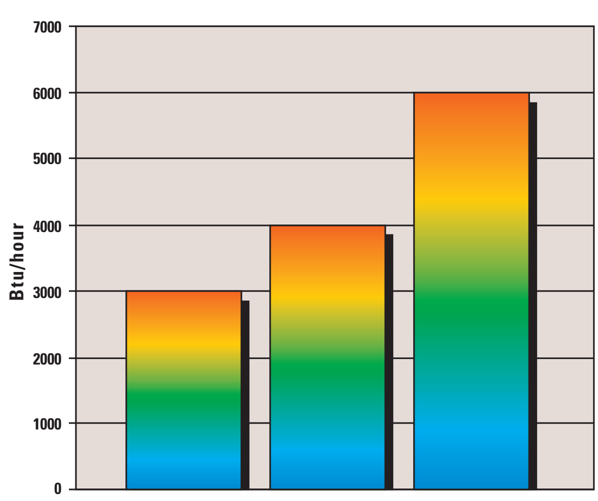


Electric countertop stoves provide dockside cooking for many small sailboats.

Diesel

Diesel stoves are seldom seen on recreational sailboats, except on large boats operating in very cold climates where the stoves double as cabin heaters. Diesel stoves, which are usually quite heavy, provide a very hot flame. In a boat with a diesel engine, the fuel can be supplied from the engine's fuel tanks. Often the fuel is pumped from the engine's tanks into a small overhead tank, using a gravity feed from there to the stove. Pre-heating the burner is necessary, and diesel stoves must be vented through a Charlie Noble on deck.

Diesel stoves are heavily built and require a flue-pipe. They double as cabin heaters and are especially practical in cold climates.



Comparison of the potential heat available from three common galley-stove fuels.

NAUTICAL TIME 101

The way we keep time at sea

by Don Launer

THE CONCEPT OF LATITUDE AND LONGITUDE HAVE BEEN known since the early days of sail, but without accurate timepieces longitude readings required long and cumbersome mathematical calculations, and the instruments for measuring latitude were very crude at best. Sailors primarily depended on dead reckoning (or ded reckoning, which was a contraction of deduced reckoning) to determine their position. But even dead reckoning required rudimentary timekeeping, since to calculate the distance traveled you had to multiply speed by time: D = S x T.

Clocks existed during the Elizabethan era, but they generally used a pendulum, which was incompatible with a rolling, pitching vessel. Even the best of these clocks had to be corrected frequently by sun sightings. Water clocks and sundials were often much more accurate, but both had serious disadvantages at sea; so the sandglass or hourglass became the early timepiece of choice aboard ship.

Sandglasses

The most commonly used sandglass was the half-hour sandglass (although four-hour sandglasses were sometimes also used). The ship's boy or the seaman at the helm tended the half-hour sandglass. As soon as the sand ran out he would turn it over and strike the ship's bell, adding one bell every half hour until, at the end of the four-hour watch, it was eight bells. These bells were grouped in twos, with each group of two signaling an hour. Thus, at two-and-a-half hours into a watch it would be five bells rung as two bells, pause, two bells, pause, one bell.

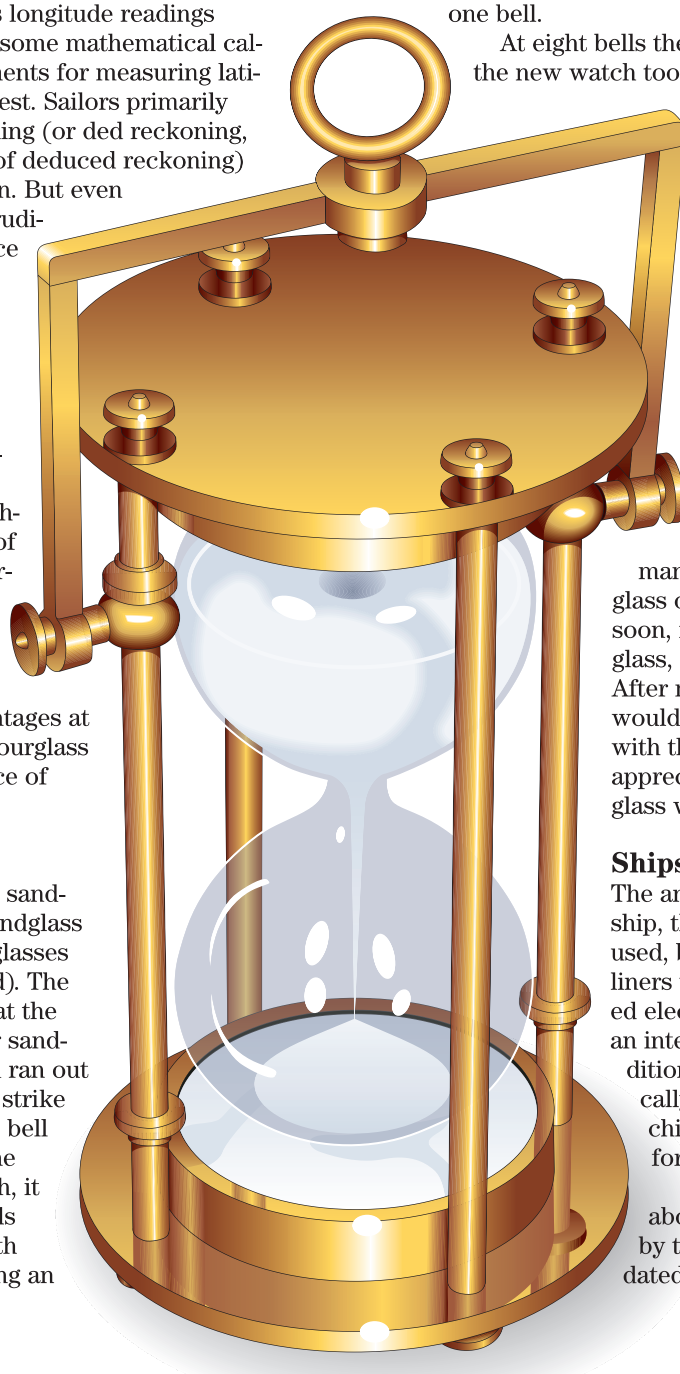
At eight bells the four-hour watch was finished, the new watch took over, and the process was repeated.

During the 1700s and 1800s, whaling voyages and voyages of discovery could last two years or more. For voyages of this length, several sandglasses were part of the ship's inventory. Not because of breakage — always a possibility — but because a sandglass would wear out. Sand was going through the narrow neck of the glass from one chamber to another 24 hours a day, and sand is abrasive. After many months of use the narrow glass opening became larger and soon, instead of a half-hour sandglass, it was a 25-minute sandglass. After months at sea, a new glass would be brought out and compared with the old one. If there was an appreciable difference, the old sandglass would be retired.

Ships' bells

The announcement of time aboard ship, the ship's bell, is still often used, but these days on large ocean liners the bell sound is now generated electronically and broadcast on an intercom. Nevertheless, many traditional ship's clocks, sold to nautically-minded customers, still chime the four-hour watch bells for telling time.

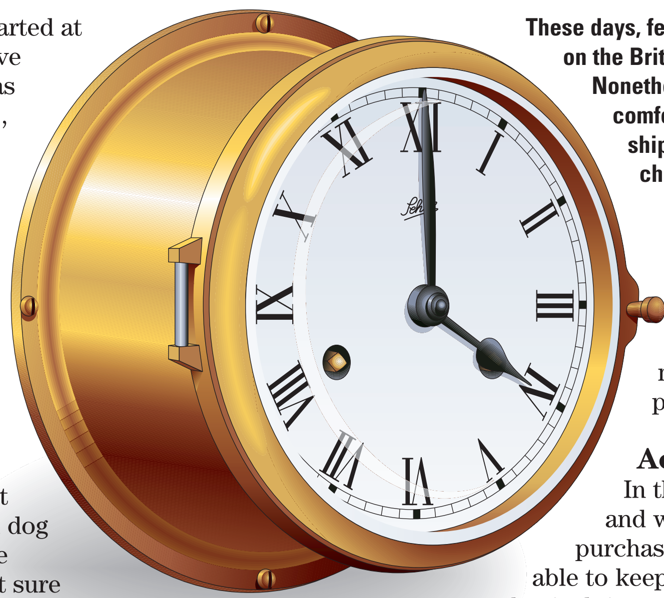
The standard watch system aboard ship was first established by the British Navy, which mandated six watches each day of four



Although various-sized sandglasses could tell time in half-hour, one-hour, and four-hour increments, the half-hour glass was the most common aboard ships.

Layout and illustrations by Ted Tollefson

hours each. These watches started at 12, 4, and 8; so if you heard five bells you would know that was 2:30 a.m., 6:30 a.m., 10:30 a.m., 2:30 p.m., 6:30 p.m., or 10:30 p.m. To prevent sailors from always being on the same watch and to allow both watches to have supper, the watch between 4 and 8 p.m. (1800 and 2000) was modified into two two-hour watches. The first of these watches, from 4 to 6 p.m. was called the first dog watch, and the second two-hour watch was called the last dog watch. Although the term dog watch has been used since the 1700s, naval historians are not sure how that term originated.



These days, few cruisers set watches based on the British Navy's six-watch schedule. Nonetheless, there's something comforting in having a traditional ship's clock aboard which quietly chimes the four-hour watch bells.

Name that watch

Each watch was given a name. The watch starting at 8 p.m. (2000) was called the first watch; the midnight watch was called the middle watch; the 4 a.m. watch was the morning watch; the 8 a.m. watch was the forenoon watch; then came the afternoon watch; first dog watch; and last dog watch. The two watch crews aboard ship were often given the names of the port watch and the starboard watch.

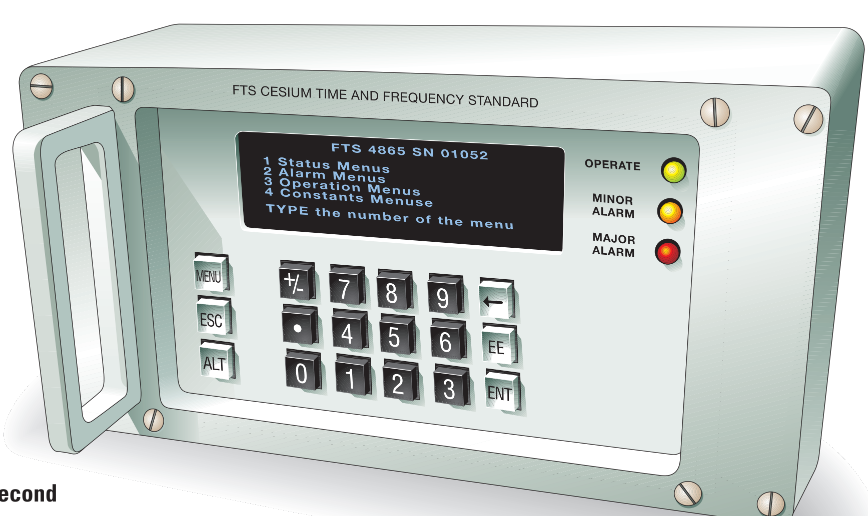
In the 1700s the search for a reliable method of measuring longitude intensified. Many scientists believed it would never be possible to create a ship's clock accurate enough for this task because of the large variations in temperature and humidity, coupled with the ship's wild gyrations. They opted, instead, to find an astronomical solution.

But finally, in 1764, carpenter John Harrison refined his ship's chronometer to an accuracy that resolved this dilemma. However, these new clocks were rare and expensive and only found aboard government and naval vessels. It wasn't until well into the 1800s that the average sea captain or packet company could afford a clock that would make determining longitude possible.

Accurate timepieces

In the mid 1900s quartz clocks and wristwatches, which could be purchased for a few dollars, were able to keep time better than the best mechanical timepieces ever made. These watches made practical use of the piezo-electric effect, which was first discovered in 1880 by scientists Pierre and Jacques Curie. Now we have clocks and wristwatches that can pick up the time signals broadcast from the atomic clocks in Fort Collins, Colorado, and our GPS receivers show the time from the atomic clocks aboard the GPS satellites, giving us access to time within a small fraction of a second.

Although the sandglass has now been relegated to the mantelpiece, it's still a nostalgic reminder of our nautical past.



Atomic clocks, such as this one, have been used by many time-sensitive businesses (such as television stations) to coordinate the split-second timing of broadcasts and other events.

Check out the various ways to reduce sail area

by Don Launer

When the wind suddenly picks up or a squall line is approaching, the ability to douse the sails or reduce sail area quickly, efficiently, and safely is vital. If you're sailing solo, shorthanded, or with infirmities, this important job can be particularly difficult and dangerous. There are high-tech hydraulic and electrical systems that can accomplish this, but for the average sailor, it has to be done manually by either furling or reefing the sails.

Furling means to roll up, or gather, a lowered sail and tie it to prevent it from blowing in the wind.

Reefing means reducing the area of a sail, allowing the boat to continue sailing under heavier wind conditions.

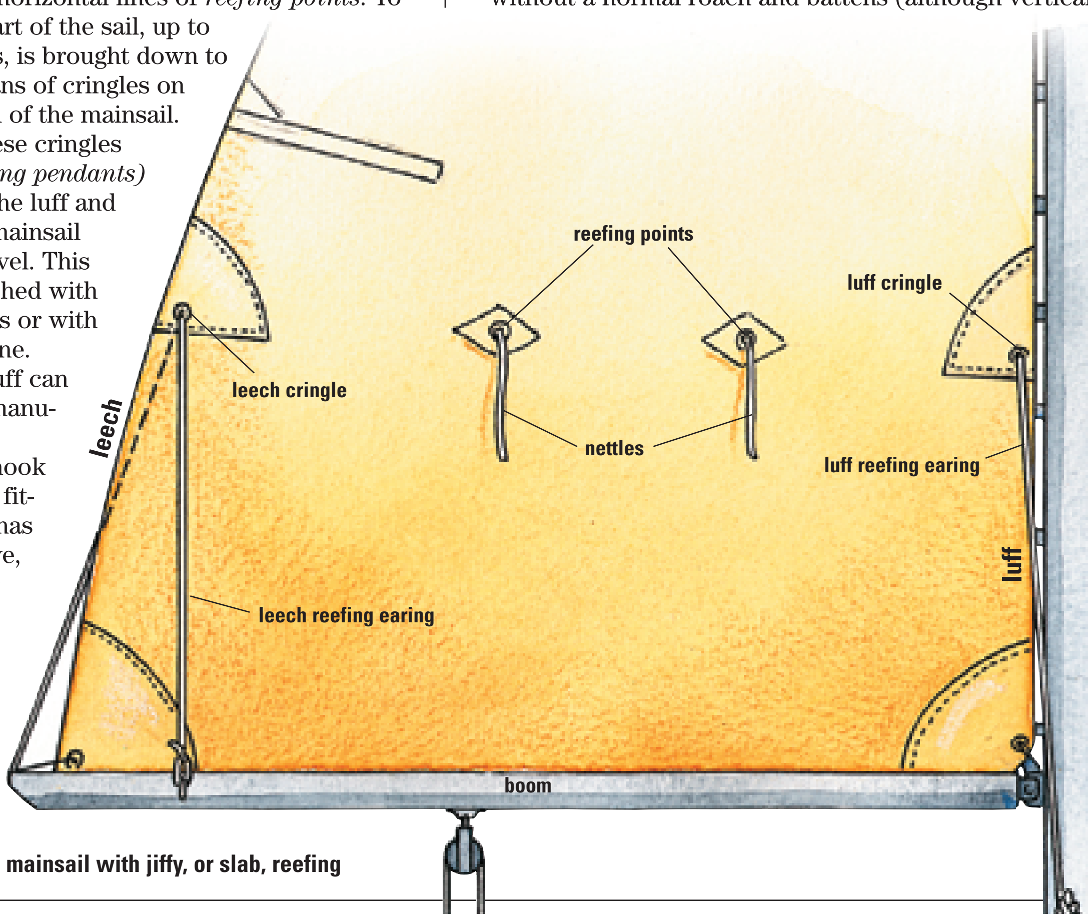
Reefing can be accomplished by many of the same methods used for furling, as long as the reefing gear has been designed to take the loads of a partially furled (reefed) sail.

There are several ways of reefing a mainsail:

- **Jiffy, or slab, reefing** – This is the most traditional type of mainsail reefing system. In this system the sail has one or more horizontal lines of *reefing points*. To reef, the lower part of the sail, up to the reefing points, is brought down to the boom by means of cringles on the luff and leech of the mainsail. Lines through these cringles *(earings, or reefing pendants)* are used to pull the luff and the leech of the mainsail down to boom level. This can be accomplished with two separate lines or with a single reefing line. Alternately, the luff can be pulled down manually and the luff cringle put on a hook at the gooseneck fitting (if the hook has a compound curve, it's called a *ram's horn)*. Then, the unused portion of the sail *(the bunt)* is tied along the boom using reefing lines on the sail *(nettles)*. These lines pass through the horizontal line of reinforced grommets (reefing points) and hang down on each side of the sail.

  The earings, or reefing pendants, that pull the luff and leech of the sail down to the boom take most of the load on the sail, with the nettles merely confining the reefed portion of the sail.

  Generally, the sail sets better if you use jiffy, or slab, reefing than with other types of reefing systems.
- **Vertical in-mast mainsail reefing –** Rolling the mainsail up inside the mast requires a specially designed mast and roller system, which means a substantial investment if this system is retrofitted on a boat that did not have it. Vertical or horizontal roller reefing for mainsails makes reducing sail much faster and easier for the shorthanded or solo sailor. The trade-offs for vertical reefing are more weight aloft (higher center of gravity), even when the sail is furled, and increased windage, due to the larger mast extrusion. This system also requires a flatter-cut mainsail without a normal roach and battens (although vertical



A fully-raised mainsail with jiffy, or slab, reefing

Layout and illustrations by Ted Tollefson

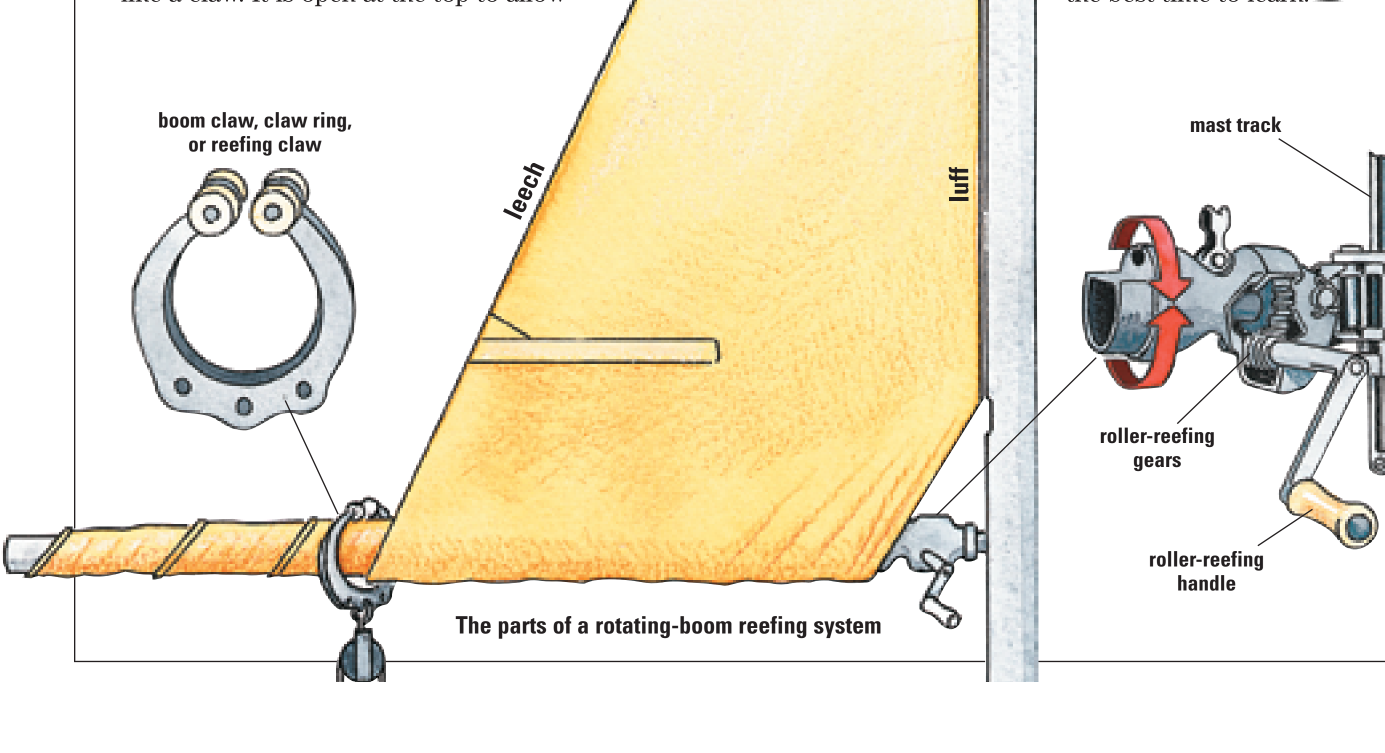
battens are sometimes used), reducing the mainsail area and efficiency. As with all "in the spar" roller-reefing systems, there is the possibility of a jam, which is usually due to operator error.

- **Vertical aft-mast mainsail reefing –** This system rolls the mainsail up on a wire just aft of the mast and thus can often be adapted to an existing mast; however, a new mainsail will be required. As with in-mast reefing, a sail with a roach and battens cannot be used, and the furled sail creates more weight aloft and increased windage.
- **Vertical retrofitted in-mast mainsail reefing –** This system uses an additional aluminum extrusion in which the mainsail is roller-reefed. The extrusion is riveted to the aft side of the existing mast. This usually requires a new boom or one that is modified. The problems of added weight aloft and windage, as well as a special flatter-cut mainsail with no roach or battens, still exist.
- **Horizontal rotating-boom mainsail reefing –** In this system, the sail is rolled up on a rotating boom. This requires a specially designed boom and gooseneck. On smaller sailboats, the boom is manually pulled out of a spring-loaded gooseneck and rotated as necessary. On larger boats heavier, geared, equipment is necessary to rotate the boom. If the mainsheet block is not located at the extreme end of the boom, then a fitting called a *boom claw*, *reefing claw*, or *claw ring* must be used. This fitting encircles the boom and rolled-up sail like a claw. It is open at the top to allow room for the hoisted part of the sail, with rollers around this top opening and an eye at the bottom to which the mainsheet block is attached.

One of the disadvantages of rotating-boom reefing is that the sail's luff rope builds up around the forward end of the boom if more than a couple of rotations are made. In addition, there is no clew outhaul, which allows the clew to creep forward. Also, as more turns are taken, the more the end of the boom droops. However, the weight and windage aloft are as low as with a conventional rig, and the sail can have a roach and battens (if the battens are horizontal).

- **Horizontal in-boom mainsail reefing –** In this system, the mainsail is rolled up on a roller inside the boom's special extrusion. The added weight and windage aloft are much less than with a vertical roller-reefing system, and the sail can have a roach and horizontal battens, as with rotating-boom reefing. With this type of reefing system the mainsheet block location is not the problem that it is with a rotating-boom system, but there is still the lack of a clew outhaul. An advantage of this system is that, should there be a jam, the mainsail can still be lowered, an option that is sometimes impossible with an in-mast jam.

Whichever system is selected, it's important that you and your crew practice reefing or furling under ideal conditions. A white-knuckles blow is not the best time to learn.



The parts of a rotating-boom reefing system

CABIN HEATERS 101

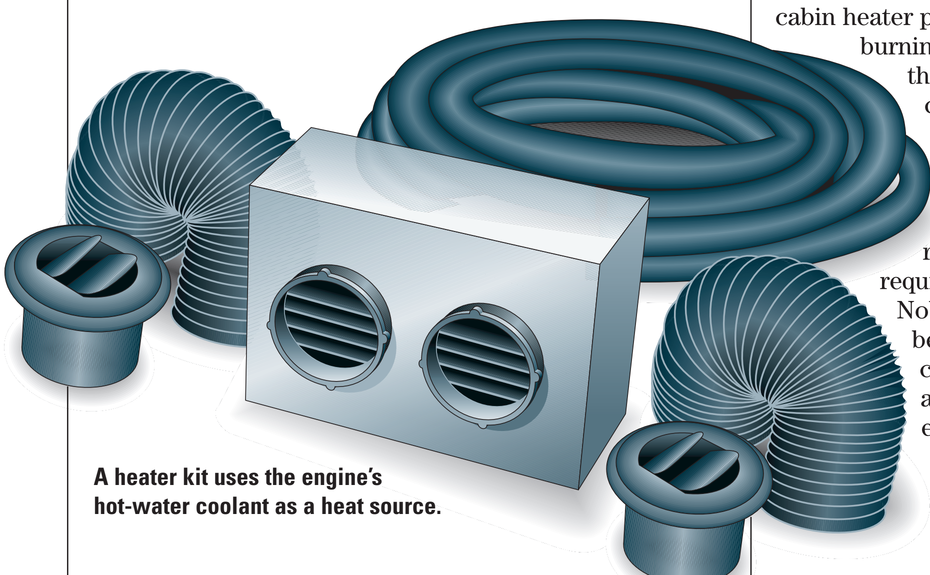
Extend your time cruising ... in comfort

by Don Launer

HEATING YOUR BOAT IN THE OFF-SEASONS MAKES SAILING more enjoyable and extends your time on the water. For any planned heater installation, three things must be considered: ventilation, insulation, and safety.

Moisture is constantly being produced in the cabin from breathing, condensation, cooking, and open flames. This moist warm air must be replaced with dry cool outside air, even though this seems counterproductive. Ventilation is necessary to reduce the moisture in the cabin and to maintain proper oxygen content in the cabin air. Also, since any flame from either a stove or a heater can be potentially lethal, a carbon monoxide monitor is mandatory.

Insulation is important, not only for heat conservation, but also since a well-insulated boat will produce less condensation.



A heater kit uses the engine's hot-water coolant as a heat source.

Types of heaters

Hydronic heaters – While motoring, your engine is an excellent source of heat. Using an automobile-type heater with a blower (built to marine specifications) allows you to use the heated engine coolant to heat the cabin, just as with an automobile. These heaters are often marketed as *hydronic heaters*. When motoring on a cold day, the "free" heat that is normally wasted helps makes the cabin snug and cozy with 28,000 to 40,000 Btu/hr available. Kits can be purchased for the conversion, which will also allow this heat to be ducted into separate cabins.

Electric heaters – If you are at a dock with adequate shorepower, an electric heater is very convenient. This can be either a portable heater or a bulkhead-mounted recessed heater that is hard-wired into the boat's shorepower system. This is convenient at the dock but doesn't solve the problem when you're out on the water, unless you have a very large generator.

Unvented kerosene or propane floor heaters – Any unvented open flame in the cabin produces huge amounts of moisture and eats up oxygen, so this heating option requires a very large amount of ventilation (outside air). Coupled with the possibility that the heater could tip over, this choice is a poor one.

Bulkhead-mounted vented LPG heaters – A bulkhead-mounted vented liquefied petroleum gas (LPG) cabin heater provides a high heat output and a clean-burning flame, with the only electric drain being the LPG shut-off solenoid and, in some cases, a small fan drawing less than two-tenths of an amp. As with all LPG installations, American Boat and Yacht Council (ABYC) specifications must be followed in the installation and operation for safety reasons. All deck-vented installations require a "smokestack" on deck — a Charlie Nobel. This usually requires a compromise between the ideal interior location for the cabin heater and the ideal deck location for a stack. About 3,000 to 11,500 Btu/hr can be expected.

A bulkhead-mounted vented LPG heater provides a clean-burning flame.

Layout and illustrations by Ted Tollefson

Physically, this cabin heater resembles the bulkhead-mounted kerosene or diesel heater.

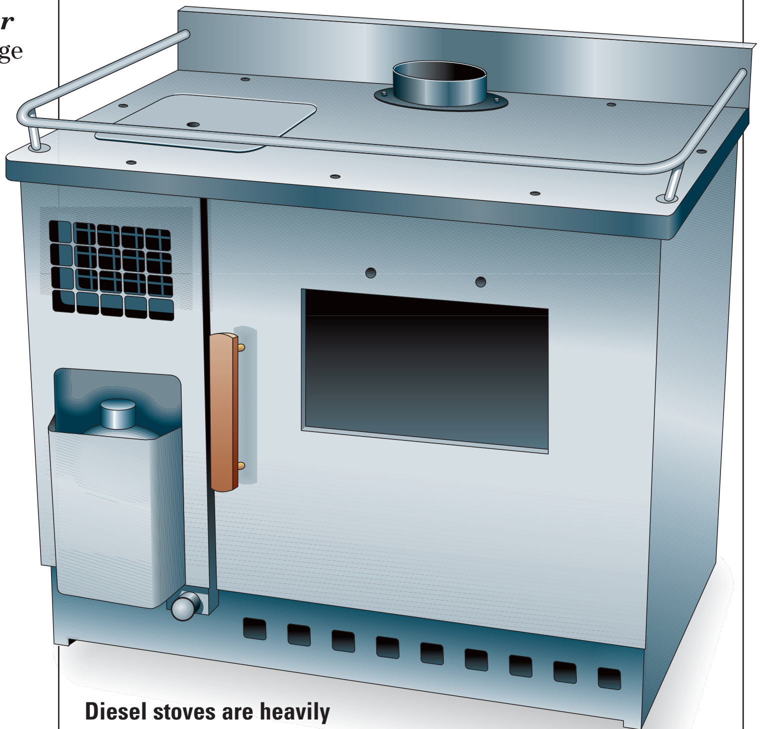
Bulkhead-mounted vented kerosene or diesel heaters – This is a common heating system aboard sailboats. It requires no electricity, the moisture it creates is vented outside, it burns easily available fuel, and it is not complicated to maintain or repair. However, pre-heating is necessary when lighting the heater. On sailboats, the deck location for the stack is very important. It must be positioned so that it doesn't interfere with deck work and is not subject to backdrafts from a dodger or other deck gear.

Ducted gasoline/kerosene/diesel/LPG forced-air heaters – A ducted forced-air heater has the advantage of being able to supply heat to several cabins. It does not use the cabin air for combustion but is otherwise very similar to a home's oil-burner furnace. Since this type of heater requires a powerful fan and a fuel pump, as well as a glow plug for ignition, this installation has a relatively high current drain. This type of heater is available for gasoline, kerosene, diesel, or LPG fuel.

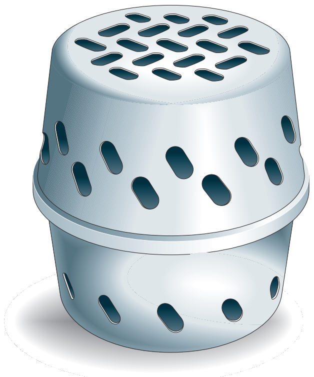
Fireplaces/stoves – These small, vented fireplaces burn solid fuel in the form of charcoal briquettes, coal, or wood. Although they have a special charm and produce a very dry heat, they have disadvantages: cleaning and disposal of ashes are difficult, and the vented smoke can stain the cabintop, sailcovers, and sails.

Alcohol heaters – These self-standing heaters are non-pressurized rustproof heaters that require no priming. Instead, an absorbent material is saturated with the alcohol fuel (which helps prevent spills). Heaters of this type can also double as single-burner stoves. The downsides are the alcohol aroma, the high price of the heating fuel, and the lack of venting.

Diesel ranges – Diesel cooking stoves are seldom seen on recreational sailboats, except on large boats operating in very cold climates, where the stoves double as cabin heaters. Diesel stoves, which are usually quite heavy, provide a very hot flame and, in a boat with a diesel engine, the fuel can be supplied from the engine's fuel tanks. Pre-heating the burner is necessary, and diesel stoves must be vented through a stack on deck, where the precautions of interfering with deck work and possible backdrafts must be contended with.



Diesel stoves are heavily built and require a flue pipe. They double as cabin heaters and are especially practical in cold climates.



With no rigid mount, a portable alcohol heater can be used, with caution, when the boat is not underway.

Aladdin lamp – The kerosene Aladdin lamp, which uses a fragile mantle, produces a bright light as well as a large amount of heat. In the evening, when both light and heat are required, very often the Aladdin lamp will supply both needs. Ventilation is required for this unvented flame, and heat is not available without the associated bright light.

The basics on auxiliary propulsion systems

by Don Launer

UNLESS YOU ARE EXCEPTIONAL SAILORS AND PURISTS, like Lin and Larry Pardey, you probably have a mechanical propulsion system on board — an iron wind. These mechanical propulsion systems can take many forms.

Fossil-fuel inboards

The oldest mechanical propulsion system is the inboard engine with a straight shaft. Originally this shaft was rotated by a steam engine. The choice for a fossil-fuel engine now comes down to gasoline or diesel (although diesel engines can also run on soybean oil). For those on the cutting edge of technology, an electric motor is another option.

Engines are coupled to the propeller shaft through a transmission that usually allows shifting between forward, neutral, and reverse. Steering a boat with a straight shaft is accomplished with a rudder that is just aft of the propeller so the water thrust can be diverted to either port or starboard. But in close-quarters handling, the straight shaft is not nearly as versatile as a sterndrive, IPS (Volvo's new rotatable propulsion system), or an outboard. Neither a sterndrive nor an IPS is seen aboard sailboats, however.

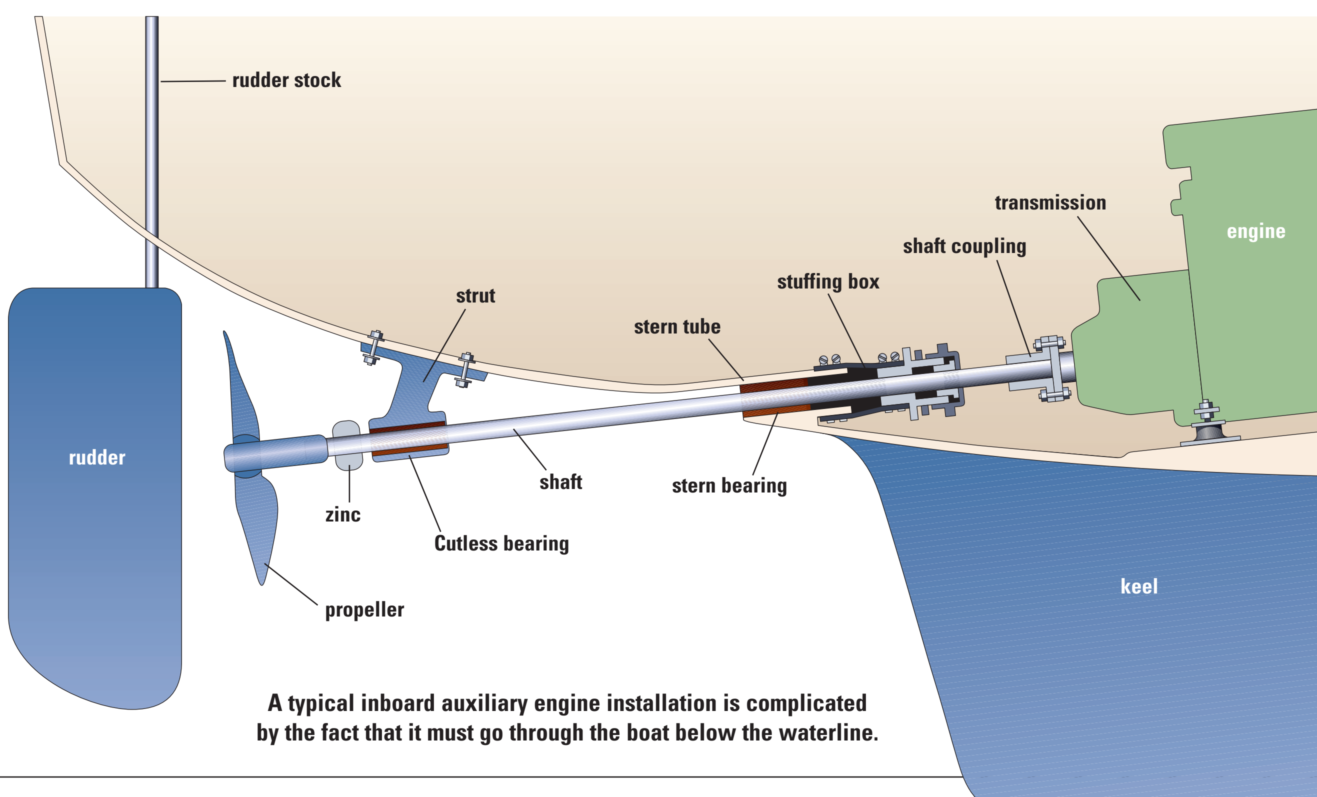
An inboard with a straight-shaft system is relatively uncomplicated, but the interior space required is a limiting factor in interior design. In addition, cooling fossil-fuel engines becomes more complicated since they require through-hull fittings. These are, of course, not necessary with an outboard or electric motor. Nevertheless, the straight-shaft freshwater-cooled inboard engine (using a heat exchanger in a saltwater environment) presents fewer corrosion problems than an outboard. The propeller drag, when under sail, can be reduced with a folding or feathering prop.

Fossil-fuel outboards

An outboard motor consists of a powerhead, shaft, bevel gears, and propeller, all in one package, and is the most common method of propelling small craft. As well as propulsion, outboards provide steering control. When the motor is not being used, the outboard can be tipped up, reducing drag and corrosion.

Most outboards use gasoline as a fuel, but there are also small electric outboards that are usually used on small craft while trolling for fish, and diesel outboards are also available, although their weight and cost makes them unsuitable for most purposes.

Small gasoline outboard motors have integral fuel tanks, while the larger versions have separate tanks con-



A typical inboard auxiliary engine installation is complicated by the fact that it must go through the boat below the waterline.

Layout and illustrations by Ted Tollefson

nected to the engine with a fuel hose. In the past, outboards used two-stroke engines, due to their lighter weight, simplicity, and lower cost, but the two-stroke's higher emissions, coupled with environmental concerns, has led to the popularity of four-stroke outboards, especially in the lower horsepower range. Fuel injection, which increases efficiency and reduces emissions, is available for either type.

"An outboard motor consists of a powerhead, shaft, bevel gears, and propeller, all in one package, and is the most common method of propelling small craft."

Electric motors

Twelve-volt DC electric trolling outboards have been in use for years, but their use is generally limited to small boats — canoes, rowboats, and small fishing skiffs. Using 12 volts makes them convenient for the average boat. However for a true auxiliary engine for a medium-sized sailboat, 12 volts is out of the question.

Although electric engines are nearly noiseless, with zero emissions (or, more accurately, displaced emissions) they currently require a large number of heavy, space-consuming batteries that provide limited operating time, and the electric motors usually operate on voltages between 150 and 600. When discharged, these batteries must be recharged, either from shore-power or from an onboard gasoline or diesel generator. The net result is a system that is less flexible, heavier and, in many cases, less efficient than traditional propulsion systems.

What the future holds

The future of an electric iron wind could change, however, with the advent of compact fuel-cell technology and the infrastructure necessary to provide the necessary hydrogen fuel.

Another positive factor is the constant refinement of high-efficiency brushless DC motors, which operate without commutator brushes.

All in all, it's a brave new world in the vehicle propulsion field. Boatowners will be among the eventual beneficiaries as positive advances are introduced.

Small sailboats often use outboard motors for auxiliary power: The motor may be mounted on the transom, on a bracket bolted to the stern, or on a vertical sliding mount.

What it's made of and how to check it

by Don Launer

STANDING RIGGING IS THE TERM GIVEN TO THE CABLES that support a sailboat's mast(s): the forestay, backstay, and shrouds, as well as specialized cables such as the bobstay and triatic stay. *Standing* indicates a fixed cable that stands in place and does not move, as opposed to *running* rigging, which is used for sheets and halyards and often runs over sheaves.

In the early days of the square-riggers, masts were held up with tarred hemp, one of the earliest types of standing rigging. Later, galvanized multi-strand iron cable was used. The next refinement was *wire rope* made of steel. Much later, stainless-steel wire became the standing rigging of choice.

The fittings at each end of a piece of standing rigging attach the standing rigging to the mast and hull and are known as terminals, end terminals, or end-fittings (see *Good Old Boat*, May 2004).

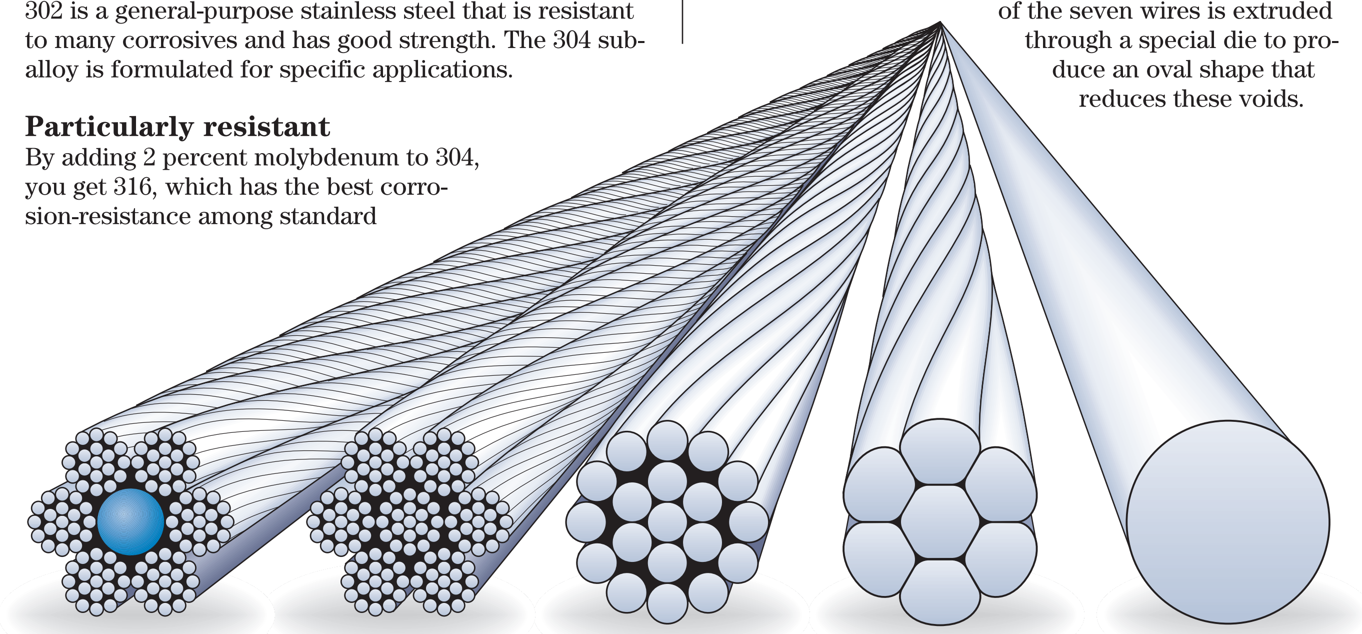
The requirements for standing rigging are strength, minimal stretch, and corrosion resistance. Flexibility is not the major factor, as it is with running rigging. In marine applications the stainless steel is an alloy of steel, chromium, and nickel and is identified with a 300-series designation. Types 302 and 304 are the most common and are widely used for rigging and fasteners. Type 302 is a general-purpose stainless steel that is resistant to many corrosives and has good strength. The 304 sub-alloy is formulated for specific applications.

Particularly resistant

By adding 2 percent molybdenum to 304, you get 316, which has the best corrosion-resistance among standard stainless steels and is particularly resistant to saltwater corrosion. However, 316 is only about 85 percent as strong as 302 and 304. Standing rigging of type 316 will generally outlive 302 and 304, especially in tropical climates, but the wire size may have to be increased, which also results in larger turnbuckles, jaws, eyes, and clevis pins, as well as higher windage and weight aloft.

Wire rope is identified by the diameter of the cable, the number of strands (bundles) of wire, and the number of individual wires in each bundle; the type of wire material; and the core. This core can be either wire or fiber. A fiber-cored wire rope is often used in running rigging on larger vessels, rather than on pleasure craft. The core is saturated with oil, which helps to lubricate the individual wires as they slide against each other while making their turns around sheaves. Wire-core cable is primarily used for standing rigging.

The typical wire rope for standing rigging is 1 x 19, which indicates one bundle of 19 wires. Because the cross-section of a wire rope should have as much metal and as few voids as possible, racing sailboats often use rod rigging. It is solid and has no voids but is expensive and more vulnerable to damage. Another choice is Dyform 1 x 7 wire, where each of the seven wires is extruded through a special die to produce an oval shape that reduces these voids.



A fiber-cored wire rope used for running rigging on larger vessels. It is seldom seen on pleasure craft.

The 7 x 19 is the most commonly used wire rope for running rigging.

The less flexible 1 x 19 is the most commonly used wire rope for standing rigging.

The Dynaform wire rope, used for standing rigging, increases the amount of steel in a given cross-section.

Rod rigging is the strongest standing rigging for a given diameter but has some drawbacks.

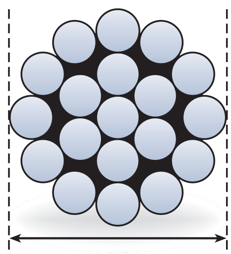
Layout and illustrations by Ted Tollefson

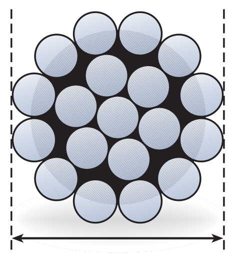
Increased windage

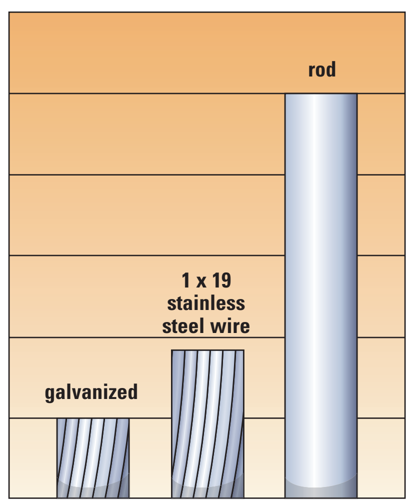
From a safety point of view, it would seem that standing rigging should have the greatest diameter possible, but increasing the diameter of the wire rope beyond the designer's specifications leads to increased windage and weight aloft as well as increased size of all associated fittings.

Standing rigging rarely fails in the middle of its span. About 99 percent of standing rigging failures occur close to the terminal fittings, with the bottom fitting being the major culprit, since it is exposed to spray. The first indication will usually be a broken strand. Toggles should be used at the terminal fittings to correct for misalignment and to prevent metal fatigue caused by frequent bending.

You can inspect your wire rope standing rigging by running a rag or cotton ball down the cable and feeling for snags caused by the ends of broken wires, known as meat hooks. Don't use your fingers because you'll find that these meat hooks cut like razor blades. If you find a broken wire, replace that cable immediately. And remember that it's a very likely indication that other cables of the same age are in similar condition. A cruising sailboat should carry a coil of 1 x 19 wire and some swageless fittings. These make replacing a failed piece of standing rigging an easy job with just the use of simple hand tools.


The correct way to measure wire rope.


The incorrect way to measure wire rope.



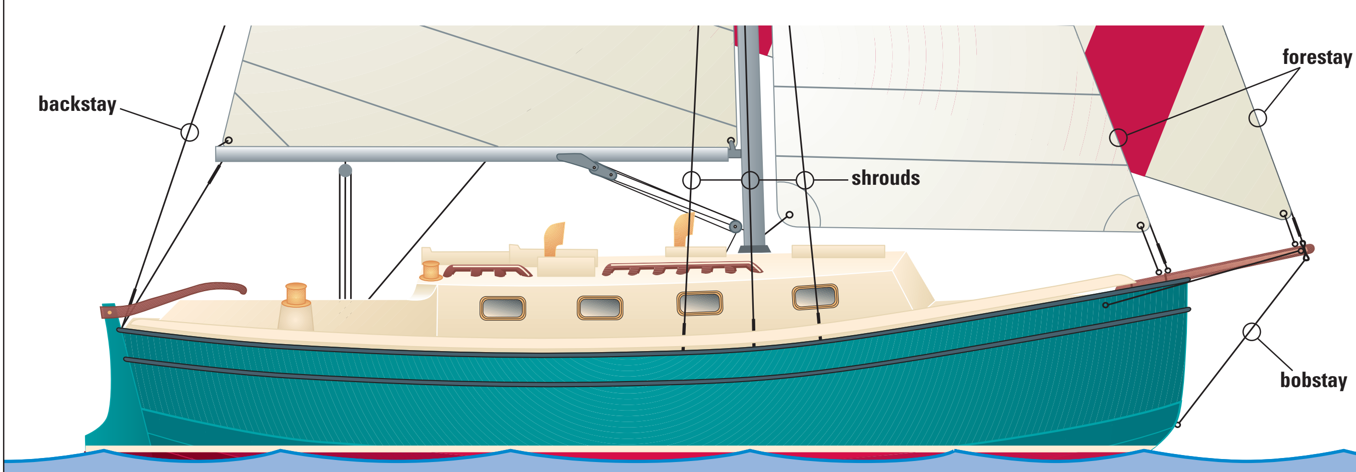
Comparative costs of standing rigging.

Rod rigging, though, does not develop meat hooks and gives few advance signs of failure, so there is little that can be done by the boatowner to determine the rod's condition, short of an X-ray. Also, one good snag on a piling while docking can mean the end of that rod.

One location that should be checked regularly is where the upper shrouds bend around the tips of the spreaders. In addition to the bend, there is another problem at this location, since this is usually also the meeting point of two dissimilar metals, the tip of the spreader and the standing rigging. With rod rigging, this bend around the spreader needs special fittings and should be done by a professional rigger.

There is no rule as to when standing rigging has to be replaced. The standing rigging on boats used in fresh water will last longer than on boats used in salt water. In the salt waters of the semi-tropics, many riggers suggest replacing the standing rigging every 10 years.

For preventive maintenance the standing rigging should be rinsed off at the end of the day or as often as possible, especially after sailing with salt spray coming over the deck.



Modern systems for stowing sails and reducing area

by Don Launer

WHEN THE WIND SUDDENLY PICKS UP OR A SQUALL LINE is approaching, the ability to furl or reef sails efficiently and safely is vital.

Furling means to completely drop, roll up, or gather a sail to its spar and to prevent it from blowing in the wind by securing it with gaskets.

Reefing means reducing the area of a sail so a boat can continue sailing in heavier winds.

Hanked-on (traditional) foresails

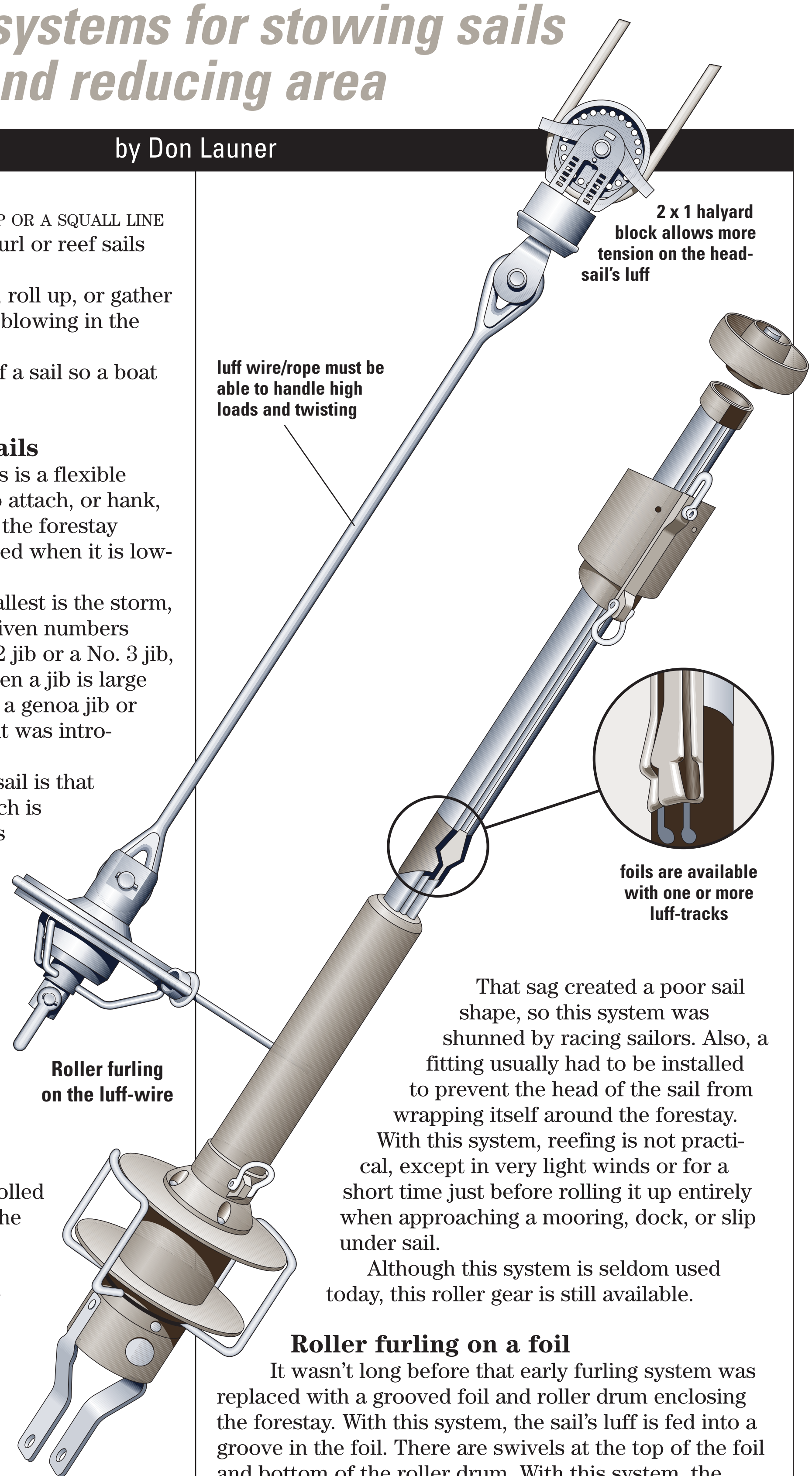
The traditional luff system for headsails is a flexible wire or rope luff with snap-fasteners to attach, or hank, it to the forestay. The jib is fastened to the forestay before being raised and remains attached when it is lowered.

Hanked-on jibs vary in size. The smallest is the storm, or spitfire, jib. Working jibs are often given numbers depending on their size, such as a No. 2 jib or a No. 3 jib, with the No. 1 jib being the largest. When a jib is large enough to overlap the mast, it is called a genoa jib or just a genoa, after Genoa, Italy, where it was introduced by a Swedish sailing team.

The advantage of a hanked-on headsail is that the luff is attached to the forestay, which is strong and relatively rigid. Because it is not rolled up and need not serve multiple purposes, this type of sail can be shaped for maximum efficiency. Some traditional jibs are set up to be reefed using reef points similar to those on mainsails using slab reefing. The downside of the hanked-on jibs is that in deteriorating conditions, when they must be reefed or a smaller jib must be substituted, working on the foredeck can be unpleasant.

Roller furling on the luff-wire

The first roller-furling headsails were rolled up on their own luff-wire, just behind the forestay. The tack (forward lower corner) was attached to a deck-mounted drum and the head was attached to the halyard through a swivel aft of the forestay. Thus, the headsail could be furled from the cockpit without the need to go onto the foredeck. But the tension required on the halyard to reduce unwanted sagging of the center of the headsail was enormous.



That sag created a poor sail shape, so this system was shunned by racing sailors. Also, a fitting usually had to be installed to prevent the head of the sail from wrapping itself around the forestay. With this system, reefing is not practical, except in very light winds or for a short time just before rolling it up entirely when approaching a mooring, dock, or slip under sail.

Although this system is seldom used today, this roller gear is still available.

Roller furling on a foil

It wasn't long before that early furling system was replaced with a grooved foil and roller drum enclosing the forestay. With this system, the sail's luff is fed into a groove in the foil. There are swivels at the top of the foil and bottom of the roller drum. With this system, the

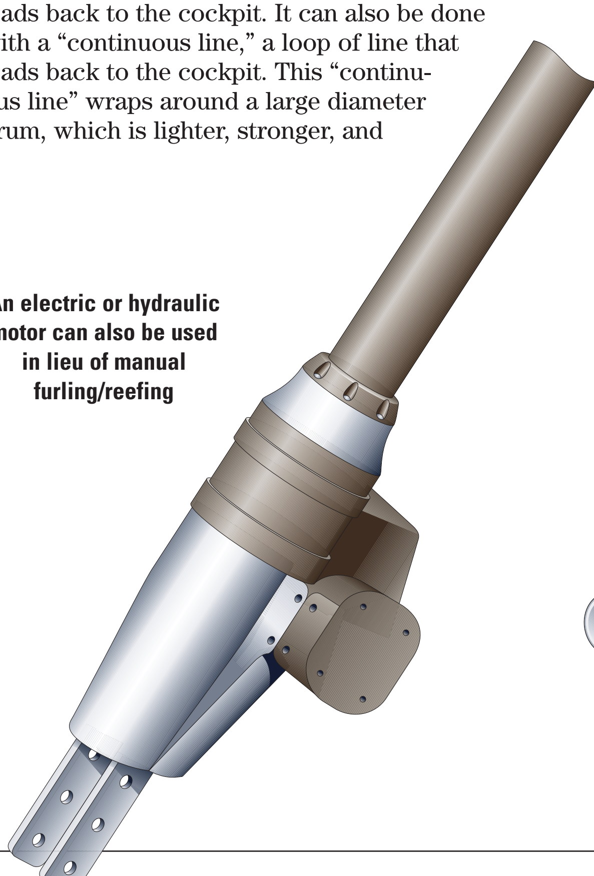
Layout and illustrations by Ted Tollefson

headsail can be rolled up around the foil and, since it is on the forestay, sag is no greater than that of a hanked-on headsail. This system can accommodate a working jib, genoa, and even a large gennaker or Code-Zero (a new development which combines the laminate materials of a jib with some features of an asymmetrical spinnaker). With the added rigidity of the forestay and foil, it now becomes practical to reef a larger headsail, resulting in fewer required headsail changes. In addition to the convenience, these foils provide a more aerodynamically efficient leading edge.

Although roller-reefing jibs can be partially rolled up (reefed), they lose efficiency when rolled up more than 15 to 20 percent. In addition, the center of effort of a partially furled jib of this type is higher off the deck than that of a storm jib — something that doesn't help the situation as the winds begin increasing. These jibs cannot replace a proper storm jib under really bad conditions.

Rotating systems

Rotating the foil to furl or reef the sail can be done in several ways. Most often it is with a single line that is wound around a drum at the base of the foil. This line leads back to the cockpit. It can also be done with a "continuous line," a loop of line that leads back to the cockpit. This "continuous line" wraps around a large diameter drum, which is lighter, stronger, and safer than the traditional single-line drum system but a bit harder to handle. One advantage of this system is that, since there is no drum at the base of the sail to store the furling line, the headsail can be several inches closer to the deck.



An electric or hydraulic motor can also be used in lieu of manual furling/reefing

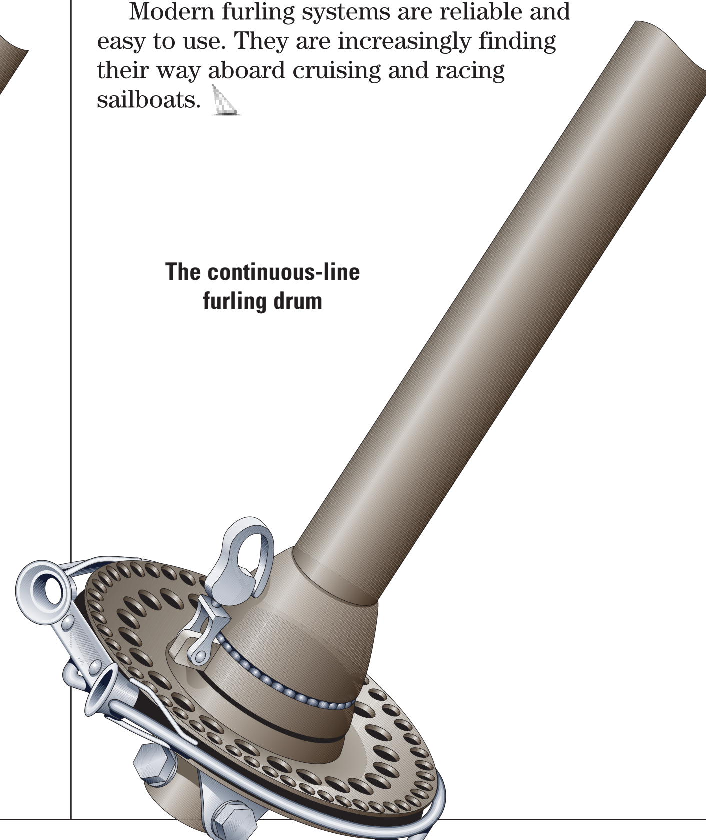
In lieu of manually furling the headsail there are electric and hydraulic systems available. These have a motor at the base of the foil, replacing the drums of the manual systems. Most of these electric or hydraulic furlers have a winch-handle socket or a continuous line manual backup system in case of electrical or mechanical failure.

In modern furling systems the basic components are the lower swivel and drum assembly, including furling line; the foil extrusion; the upper swivel; and possibly a halyard retainer, which keeps the foresail halyard from wrapping around the forestay/foil.

Installation

The size of the furling system will depend on the length of the forestay and its wire diameter. Some roller-furler installations require that the forestay be cut and a new bottom terminal or forestay be purchased. Other manufacturers provide roller systems that can be installed without cutting the stay.

Modern furling systems are reliable and easy to use. They are increasingly finding their way aboard cruising and racing sailboats.



The continuous-line furling drum

Adding staying power to your ground tackle

by Don Launer

THE ANCHOR SENTINEL HAS BEEN USED BY MARINERS FOR thousands of years. It is known by many other names throughout the world: the kellet, sentinel, chum, Sent Angel, Rode Rider, Anchor Buddy, and anchor weight. Anchor weight is probably the most descriptive term, since this object is a weight that is hung from the center, or slightly beyond the center, of the anchor rode to increase an anchor's holding power. Nevertheless, sentinel and kellet are the two most commonly used names.

Two thousand years ago those master sailors, the Phoenicians, used this method to hold their primitive anchors more securely, and the same system is still being used today by knowledgeable sailors. The Phoenicians' *catenary stone* was the genesis of today's modern sentinel. Although nothing can correct for improper anchoring technique, the sentinel's advantages are complementary, resulting in greater holding power and decreased arc of swing once the anchor has been properly set.

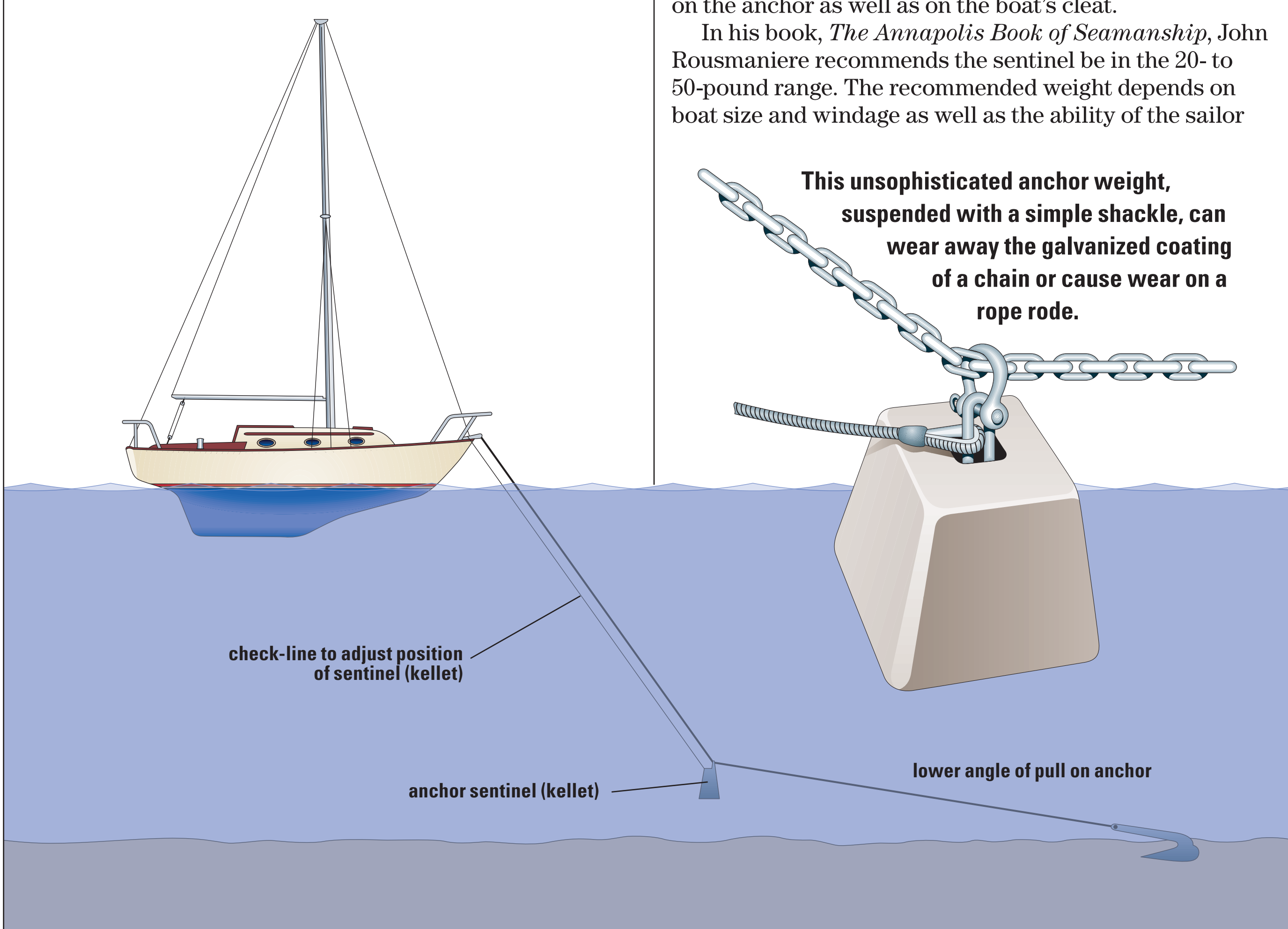
How it works

An anchor's holding power is greatest when the pull on the rode is horizontal. As this angle is increased from the horizontal, the holding power of the anchor is reduced by a surprising and alarming percentage. Royal navy tests in Britain showed that when the anchor rode is only at the small angle of 10 degrees, the anchor's holding power is already down to about 60 percent, compared with a horizontal pull. At an angle of only 15 degrees, the holding power is down to 40 percent, as is described in the *Admiralty Manual of Seamanship*.

The sentinel increases the catenary (the curve) of the anchor rode and keeps the angle of pull on the anchor lower. In many cases it can nearly double the anchor's holding power. This weight also decreases the hunting action of a boat at anchor as well as acting as a shock-absorber during sudden gusts or wave action. In these cases the weight is lifted while continuing to maintain a fairly constant pull on the anchor as well as on the boat's cleat.

In his book, *The Annapolis Book of Seamanship*, John Rousmaniere recommends the sentinel be in the 20- to 50-pound range. The recommended weight depends on boat size and windage as well as the ability of the sailor

This unsophisticated anchor weight, suspended with a simple shackle, can wear away the galvanized coating of a chain or cause wear on a rope rode.



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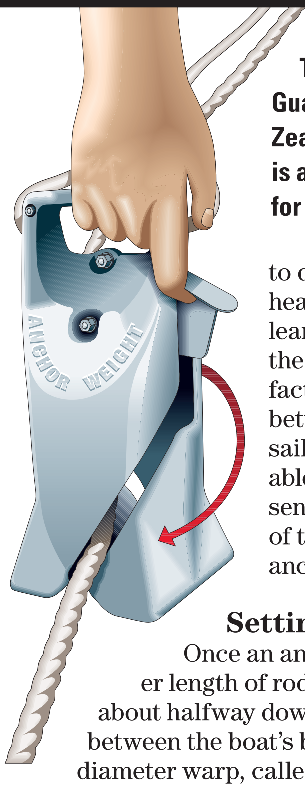


The Kiwi Anchor Rider, by Guardian Marine of New Zealand, twists onto the rode and is available in three weight sizes for either rope or chain rode.

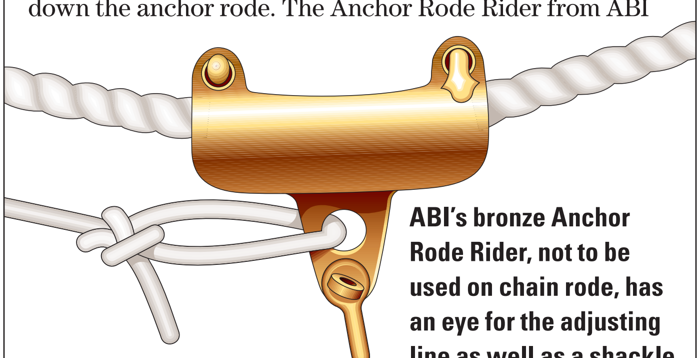
to deploy it easily. Although a very heavy weight would be the ideal, leaning over the bow to attach it to the anchor line presents a limiting factor and becomes a compromise between a heavy weight and the sailor's ability. A sailor should be able to set and retrieve an anchor sentinel easily, since time is often of the essence when weighing anchor.

Setting and retrieving

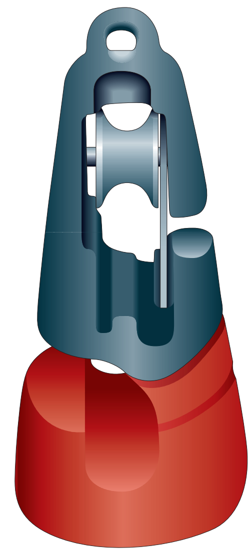
Once an anchor has been set and the proper length of rode deployed, the sentinel is sent about halfway down or a bit more, as measured between the boat's bow and the anchor. A small-diameter warp, called a check-line or buddy-rope, usually a ¼-inch line, is attached to the sentinel to control this distance. When leaving an anchorage, the sentinel is brought back on board again using this warp, before the anchor is weighed.

Sentinels can be used on anchor rodes that are all-chain, rodes that use a short length of chain at the anchor end, or rodes with a rope-to-chain splice. However, it's difficult, or sometimes impossible, to use a sentinel where (partway down the anchor rode) there is a line-to-chain connection, if this connection includes a shackle.

The sentinel itself can take many forms. Some weights are hung from a Rode Rider (usually bronze) that rides down the anchor rode. The Anchor Rode Rider from ABI Marine opens in half for easy attachment. It has no internal rollers, relying on the sentinel's weight to let it slide down the rope anchor rode. It is not suitable for a chain rode. Other sentinels, such as Guardian Marine's Kiwi Anchor Rider, have corkscrew slots molded into them, enabling them to be twisted on or off the rode. A handle on the top facilitates deployment and retrieval. The Kiwi Anchor Rider is manufactured for either a rope rode or chain rode and has internal nylon rollers to reduce friction.



ABI's bronze Anchor Rode Rider, not to be used on chain rode, has an eye for the adjusting line as well as a shackle for attaching the weight.



The Rode Rider sentinel by Ada Leisure Products has a hook at the bottom to allow for temporary storage on the pulpit while an anchor is being set or hauled.

A sentinel can be a complicated patented design or simply a shackle with a weight attached (the weight I use is a cast-iron theater scenery weight coated with epoxy). Whichever type of weight is used, it must ride on the anchor rode without abrading the nylon or rubbing the galvanizing off the chain. Some commercial models have nylon rollers to eliminate chafe and make deployment and retrieving easier.

Even if you don't use such a device every time you anchor, it is a good idea to have an anchor sentinel in your sailor's bag of tricks.

Resources

Anchor Rode Rider
ABI Marine
<http://www.ABImarine.com>
800-422-1301

Kiwi Anchor Rider by Guardian Marine in New Zealand
available in the U.S. from
AB-Marine Inc.
<http://www.ab-marine.com>
401-847-7960

Rode Rider
Ada Leisure Products
<http://www.roderider.com>
800-688-3217

WIND TERMINOLOGY 101

Here are the terms that define the wind

by Don Launer

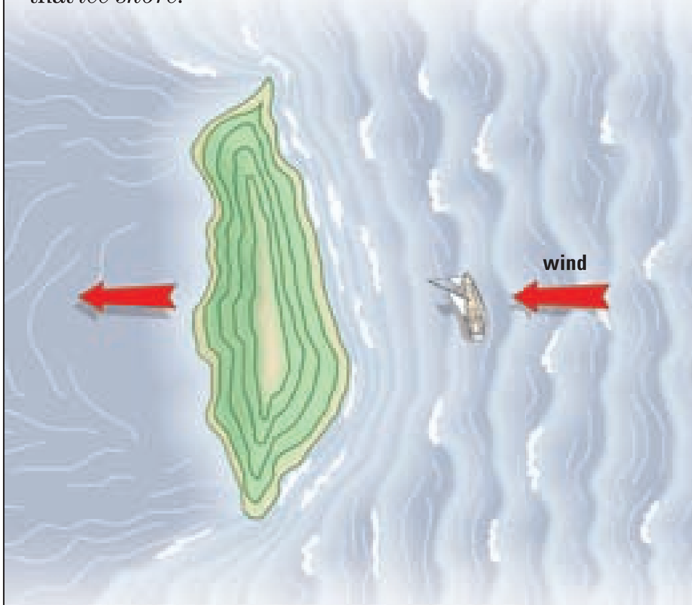
KNOWLEDGE OF THE WIND IS VITAL FOR ALL SAILORS. So is knowledge of the vocabulary of the wind. To understand and talk about the wind, some important terms must be defined.

Wind direction – The direction of a wind is described as the direction *from* which it blows.

Windward – The *windward* side of an object is the side facing the direction from which the wind is blowing.

Leeward – (pronounced LOO-word). The opposite side of that object, the side away from the wind, or downwind.

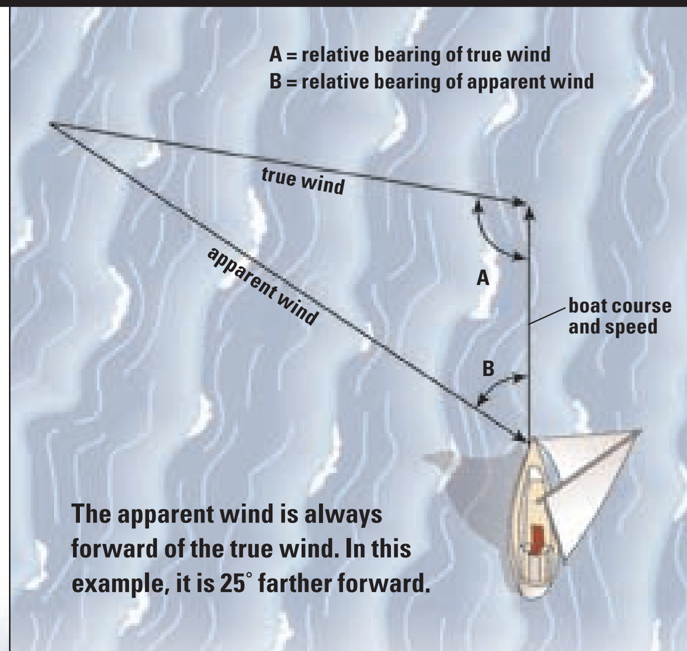
Lee shore – The sailboat in the illustration below is on the *windward* side of the island. The island presents a *lee shore*, since it is to *leeward* of the boat. This is a sailor's worst nightmare in a storm, since if the boat can't claw to windward or maintain its position, it will be driven onto that *lee shore*.



Veering – When a wind *veers*, it shifts direction clockwise. A wind shifting from northerly to northeasterly is a veering wind.

Backing – The opposite of veering. When a wind *backs*, it shifts direction in a counterclockwise direction, such as when it changes from west to southwest.

True wind – The *true wind* is the wind speed and direction as observed from a stationary position, such as a boat at anchor or on land.

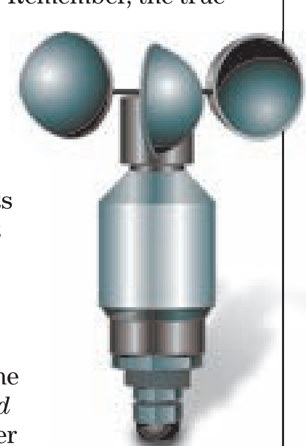


The apparent wind is always forward of the true wind. In this example, it is 25° farther forward.

Apparent wind and relative wind – These terms have the same meaning. They refer to the wind you sense on a moving boat. It is the combination of true wind and the wind made by the motion of the boat. In the vector diagram, the length of a line represents velocity and the angle of the line represents direction. Knowing the boat's vector and the true wind's vector allows us to determine the *apparent wind* by completing the triangle with the third line.

Although the true wind is nearly beam-on to the boat's course in the illustration above, the apparent wind, due to the boat's forward motion, requires that the sails be trimmed in a close-hauled position. Remember, the true wind direction is always aft of the relative wind direction.

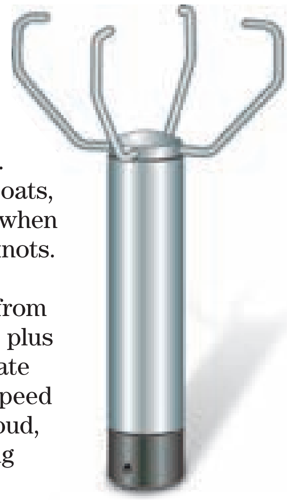
Wind gradient – Friction slows wind down at the surface of the land or water. In average conditions, if the wind velocity is 10 knots at 100 feet above the water, it might be 8 knots at 33 feet and 7 knots at 12 feet. This gradient, combined with the motion of the boat, makes the relative wind at various heights change in velocity and direction. The direction of the upper *relative wind* always lies farther aft than the lower relative wind. This is one of the reasons for inducing twist in the upper part of a sail.



Rotating cups anemometer

Layout and illustrations by Ted Tollefson

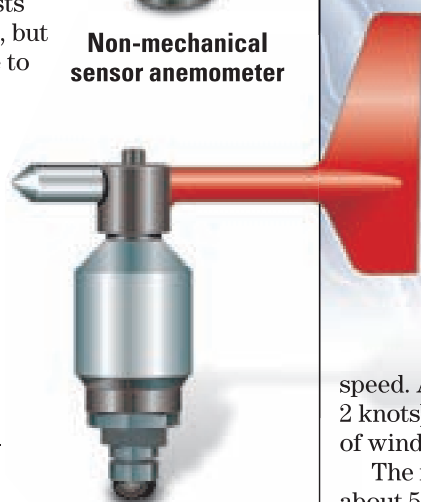
Wind pressure – The pressure the wind creates is proportional to the square of the wind's velocity. If you double the wind speed, the pressure is four times as great. Thus the wind pressure on sails, boats, or buildings is four times as great when the wind increases from 15 to 30 knots.



Non-mechanical sensor anemometer

Anemometer – An anemometer (from the Greek *anemos*, meaning wind, plus *meter*, a measure) is used to indicate wind speed. You can gauge wind speed with a piece of string tied to a shroud, a windsock, or mechanical rotating cups. Professional meteorologists use radar systems and balloons, but these methods are not available to the average sailor.

Recently, an anemometer has come on the market that replaces the rotating cups with a non-mechanical sensor. This sensor is ultrasonic and has no moving parts. It gives wind speed and direction. It is becoming competitively priced, compared with top-of-the-line cups-and-vane mechanical systems, and provides data in icing conditions when the rotating cups-and-vane systems are disabled.

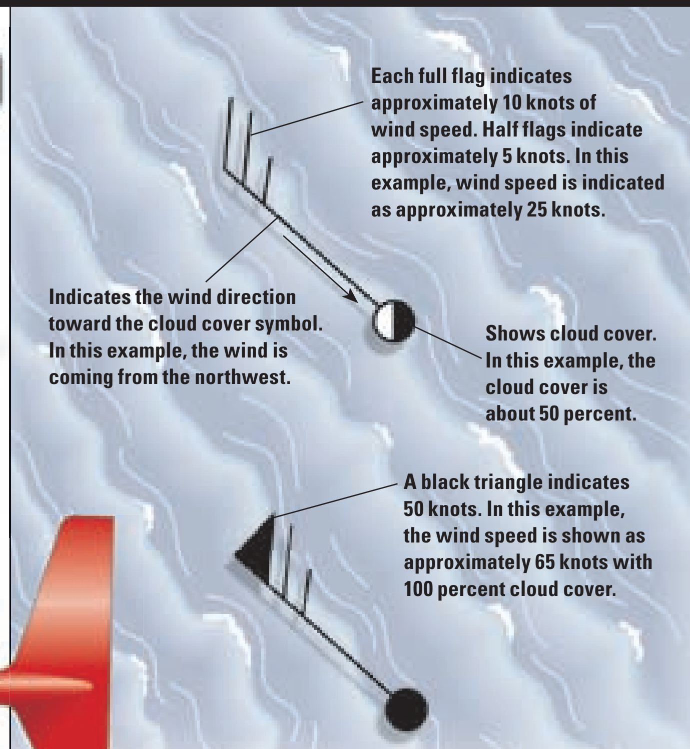


Windvane

Windvane, or weather vane – This is a means of determining wind direction. The *windvane* points into the wind, and the wind direction is measured either in points of the compass or azimuth degrees. When an anemometer and windvane are combined into one unit, the instrument is known as an aerovane.

Weather map symbols – Weather maps have symbols to indicate wind conditions. These symbols, which look like notes on musical scores, indicate the wind speed and direction, as well as the cloud cover for various locations (see *Good Old Boat*, November 2005).

The symbol consists of a circle, which indicates cloud cover, and an arm that points to the circle. This arm indicates the wind direction and is known as the wind barb, or arrow. Think of these arrows as flying with the wind to remember what wind direction they are indicating. The flags, or feathers, at the end of the arrow indicate wind speed. A long feather represents 10 knots of wind (within 2 knots); a short feather represents approximately 5 knots of wind.

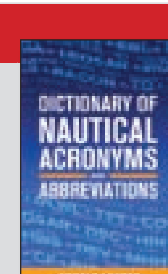


Wind speed and direction symbols as shown on weather maps

The first illustration above shows that the sky has about 50 percent cloud cover and the wind is from the northwest at a speed of 25 knots (10+10+5).

When winds are at or over 50 knots, one or more black triangles are used to indicate each 50-knot wind increment. In the second illustration above, the weather map shows completely overcast skies, with the wind from the northwest at 65 knots (50+10+5).

For further reading . . .



Don Launer's new book, *Dictionary of Nautical Acronyms and Abbreviations*, helps recreational boaters sort through the alphabet soup of abbreviations on nautical charts as well as those in routine use in marine books and articles. This book is available at <http://www.goodoldboat.com/book shelf.html> or by calling 701-952-9433.

What you need and how to use it

by Don Launer

FIRE EXTINGUISHERS ARE CLASSIFIED BY LETTERS AND numbers, depending on the class and size of the fire they are designed to handle. The letter, or letters, indicates the type of fire; the number (usually using Roman numerals) indicates the capacity of the fire extinguisher — the larger the number, the greater the capacity.

You are likely to see fire extinguisher requirements, established by the U.S. Coast Guard, based on vessel length, as shown in the chart on the facing page.

As an example, D-type fires involve chemical materials, such as magnesium, potassium, sodium, and titanium. For the recreational sailor, however, the on-board fires and fire extinguishers are usually the A, B, and C types. A simple mnemonic device for remembering these three most common fires and extinguisher types is:

A = Ash (those fires that produce an ash, such as wood, paper, etc.)
B = Boil (those fires where the combustible source is something that can boil, for example, a liquid, such as oil, kerosene, diesel, gasoline, etc.)
C = Current (electrical fires)

An extinguisher should only be used on the type of fire for which it is rated. For an A-type fire, water can be used as the extinguishing agent. However, this could be disastrous if used on flaming gasoline or on an electrical fire.

Extinguishers used on recreational boats are usually multi-purpose, such as a type BC or an ABC. These may emit a solid, liquid, or gaseous chemical to quench the fire.

Although there is no official standard for the color of fire extinguishers, in the case of A-, B-, and C-class fires red is often the color of the extinguisher. Extinguishers may indicate the fire-extinguisher type with a letter enclosed in a colored geometric symbol and sometimes with a pictogram. For A, B, and C extinguishers these are:

Fire class	Geometric symbol	Pictogram
A	A	
B	B	
C	C	

Extinguishing agents

Water – Water can be used on A-type fires but is unsuitable for B- or C-class fires.

Dry-chemical – The extinguishers that are most commonly seen on recreational boats use a variety of substances and are pressurized with nitrogen. For BC fires, this chemical is most commonly sodium bicarbonate or potassium bicarbonate. ABC-rated extinguishers may use monoammonium phosphate, a yellow powder that leaves a sticky residue. This residue can be damaging to electrical appliances and electronic equipment. Dry chemicals require an immediate, long, and messy cleanup operation but have the advantage that this residue is non-flammable, which can reduce the likelihood of the fire reigniting.

Foam – These extinguishers, usually water-based, are also called *aqueous foam*. They are rated for class A and B fires.

Carbon dioxide – This non-flammable gas is rated for class B and C fires but doesn't work well on class A fires. It extinguishes by displacing oxygen and leaves no harmful residue or cleanup operation, making it ideal for fires in electrical and electronic equipment.

Halon – This gas is a class A, B, and C extinguisher when its capacity is 9 pounds or more; smaller units have a BC rating. Halon is a chlorofluorocarbon that is believed to cause damage to the ozone layer. Due to these concerns, the manufacture of halon extinguishers has ceased, however existing systems may remain in service.

FM-200 – This is an expensive halon replacement. It is a clean, gaseous extinguisher that is safe for occupied spaces. It is oxygen-depleting and non-corrosive to sensitive electronic equipment and has an ABC rating. Although not often seen in stores or catalogs, it is available on special order.

FE-241 – Chlorotetrafluoroethane is another halon replacement agent that is considerably less expensive than FM-200. It leaves no residue. However, it can cause health problems if inhaled. It is approved for unoccupied spaces, such as an engine room, and can be installed for either automatic or manual pull-cable discharge. It is ABC-rated.

FE-227 or HFC-227 – Heptafluoropropane is a halon replacement approved for occupied spaces and has an ABC rating.

Layout and illustrations by Ted Tollefson

Halotron-1 – This is newly approved by the EPA and is safe for electrical and electronic fires. It leaves no residue but can cause immediate and serious health problems if inhaled in concentrations above 2 percent. Ratings are for BC in the smaller units and ABC in larger weights.

Halon substitutes are, across the board, less efficient than halon itself, so the containers are considerably larger than the old halon units for the same capacity. As an example, you would need 50 percent more FM-200 than halon to extinguish a fire.

Whenever you purchase any extinguisher, check to see what class ratings are specified, since the weight of the extinguisher can sometimes be a determining factor in the class rating. The basic steps for using a fire extinguisher on board are:

- If it is a dry powder extinguisher, shake vigorously.
- Pull the pin.
- Stand back several feet and aim at the base of the fire.
- Sweep from side to side.

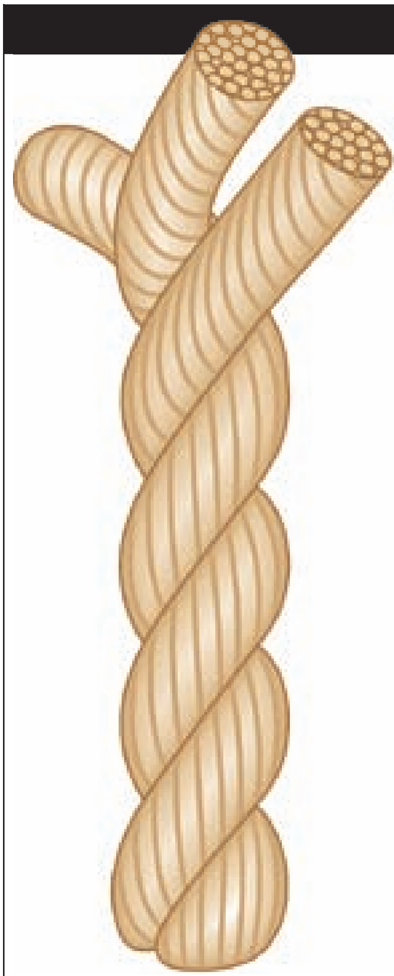
Coast Guard regulations state that all powerboats — and all sailboats with engines — must carry one or more U.S. Coast Guard-approved fire extinguishers.

Vessel length	No fixed system	Approved fixed system
Less than 26 feet	One B-I	0
26 to less than 40 feet	Two B-I or one B-II	One B-I
40 to 65 feet	Three B-I or one B-II and one B-I	Two B-I or one B-II

The pressure and/or weight of your onboard fire extinguishers should be checked regularly — they're not worth having if they won't work. Once you have used a fire extinguisher, either have it recharged (if it is a rechargeable type) or replaced. When purchasing a fire extinguisher for your boat, be sure that it is a U. S. Coast Guard-approved type. Also be sure your extinguisher locations on board are well marked and the extinguishers are easily accessible.

Make sure they stretch and absorb shocks

by Don Launer



Three-strand

Double-braid

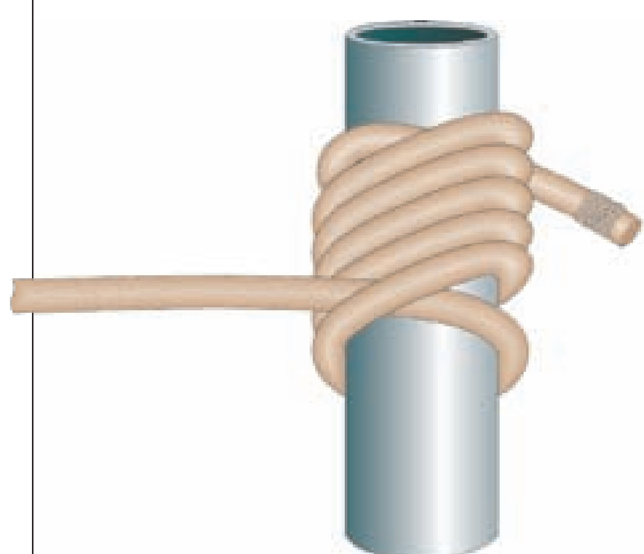
THE MAJORITY OF SAILBOATS SPEND MORE TIME AT THE DOCK than actively sailing. This makes the selection of docklines especially important. Nylon (rather than polyester) is the material of choice for docklines, since it provides strength and enough stretch to absorb shocks and sudden strains. The rule of thumb is that a good-quality nylon line will stretch 25 percent of its length at 50 percent of its breaking strength. At a mere 200 pounds of tension, a ¼-inch line 20 feet long can stretch 4 feet or more. Under the same tension, a ½-inch line 20 feet long will stretch about 1 foot. This stretch helps prevent a dockline from breaking and from putting sudden strains on dock and deck cleats.

Nylon docklines can be either three-stranded or braided. Although double-braided nylon line is 15 percent stronger than three-strand, it stretches less. The advantages of braided line are that it comes in attractive colors, rarely kinks, is easier to coil, and is easy on the hands. The downsides are that it tends to chafe more easily than three-strand, is more expensive, and is difficult to splice. Most chandleries sell braided docklines with eye-splices that have been done by professionals.

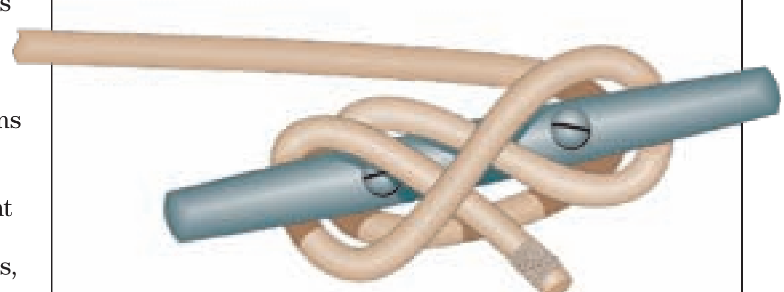
Storm conditions

Docklines terminate in cleats on deck and are connected to pilings, cleats, or bollards on the dock. If possible, in storm conditions, your docklines should be around "permanent" pilings, with the added caveat that these lines should have some method of preventing them from coming off the top of these pilings in a high storm surge. In storm conditions it's a good idea to lead additional docklines around the deck cleat and then fasten them to a keel-stepped mast (if your boat is so equipped), so that if the deck cleat is torn loose, the lines will remain attached to the boat.

Use large-diameter lines when a big blow is moving your way, either in place of or in addition to your normal

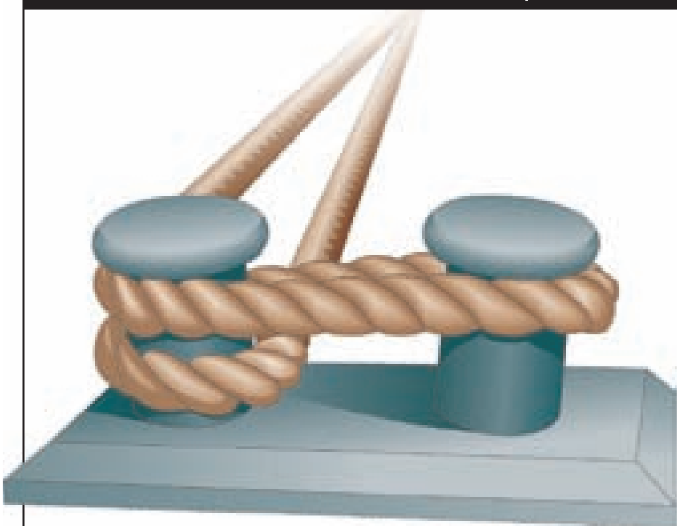


Piling



Cleat

Layout and illustrations by Ted Tollefson

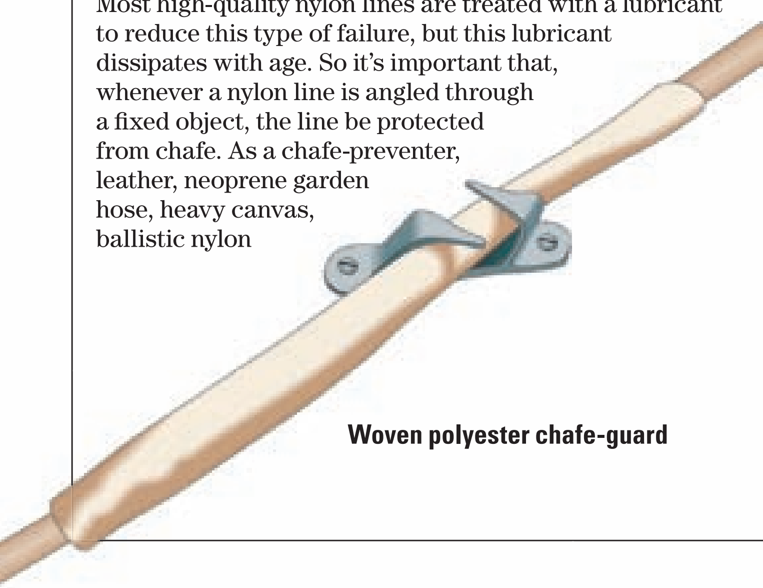


Bollard

lines. But remember, larger diameter offers less stretch. Double the diameter and you cut the stretch by a fourth. (The stretch is inversely proportional to the square of the diameter.) When you are setting up storm lines, you can take advantage of this lower stretch so wind and wave forces won't allow the boat to pound the dock, the pilings, or an adjoining boat. Larger diameter lines are also less likely to fail from chafing.

Chafe prevention

An unexpected finding by the Massachusetts Institute of Technology (MIT) after Hurricane Gloria, which plagued the East Coast in 1985, showed that many nylon lines angled across a chock failed internally when they melted from the friction created by the repeated stretch cycles. Most high-quality nylon lines are treated with a lubricant to reduce this type of failure, but this lubricant dissipates with age. So it's important that, whenever a nylon line is angled through a fixed object, the line be protected from chafe. As a chafe-preventer, leather, neoprene garden hose, heavy canvas, ballistic nylon (Cordura) tubing, or commercial chafe-protectors are often recommended.



Woven polyester chafe-guard

Some suppliers who sell docklines with eye-splices already made offer the option of urethane dips for the eye-splices or on the section of line that will be passing through a chock. Although chafing gear is necessary whenever a dockline goes through a chock, the possibility of melting the nylon through the constant stretching cycles can be increased when some types of chafing gear are used, since they can trap the heat being created and prevent the cooling rain or spray from reaching this critical point. Abrasion-resistant woven polyester sleeves are available from most marine chandleries. These allow the heat to dissipate and let water in to cool the line.

Nylon docklines

Line diameter	Boat length	Breaking strength	Safe working load
⅜ inch	Under 20 feet	4,000 pounds	800 pounds
½ inch	20 to 30 feet	7,000 pounds	1,400 pounds
⅝ inch	30 to 40 feet	11,000 pounds	2,200 pounds
¾ inch	40 to 50 feet	15,000 pounds	3,000 pounds

Characteristics of nylon line

A little-known characteristic of nylon line is that it loses about 15 percent of its strength when wet. The strength returns when the line has dried out. Since we are most concerned with strength during storm conditions — when the line is wet — factor this into the equation when buying larger lines for use in storms. Colored line has slightly less strength than natural, so factor that characteristic in as well.

One last consideration is the question of quality of nylon lines. A wide range of nylon lines is available, with the cheaper nylon stretching more and having considerably less abrasion-resistance and internal lubrication, so don't skimp. Insurance companies estimate that up to half of the boat damage due to Hurricane Andrew, which hit Florida in August 1992, could have been prevented with adequate docklines. It's much cheaper to buy high-quality line than to buy a new boat.

Don Launer is a contributing editor with Good Old Boat *magazine.*

Electronic devices designed to save your life at sea

by Don Launer

EPIRB IS AN ACRONYM FOR EMERGENCY POSITION-INDICATING radio beacon, a device designed to save your life in an emergency by alerting rescue authorities with information about you, your boat, and your location. Early EPIRBs operated on 121.5 MHz, a frequency designed for detection by boats and aircraft before satellites were available. But when satellites took over the search-and-rescue functions, this frequency was not ideal and a newer EPIRB system, operating on 406.025 MHz, became more practical and reliable and included better information about the vessels affected. (For more on this subject, see the January 2001 and July 2007 issues.)

In addition to the 406 MHz signal, the 406 MHz EPIRB transmits a homing signal on the old 121.5 MHz frequency for the purpose of guiding nearby aircraft and vessels to the beacon. While the EPIRBs using only 121.5 MHz will continue to be able to communicate with the search-and-rescue units, their satellite-location properties will be lost over time as this capability is phased out.

A Category-I EPIRB is considered the best and is the most costly. It is a 406/121.5 MHz unit that is housed on deck in a specially designed bracket. It has a hydrostatic release and is activated when it sinks in water to a certain depth. It can also be manually activated.

A Category-II EPIRB is a 406/121.5 MHz unit similar to a Category-I unit except that it can only be manually activated. It is less costly than the Category-I unit.

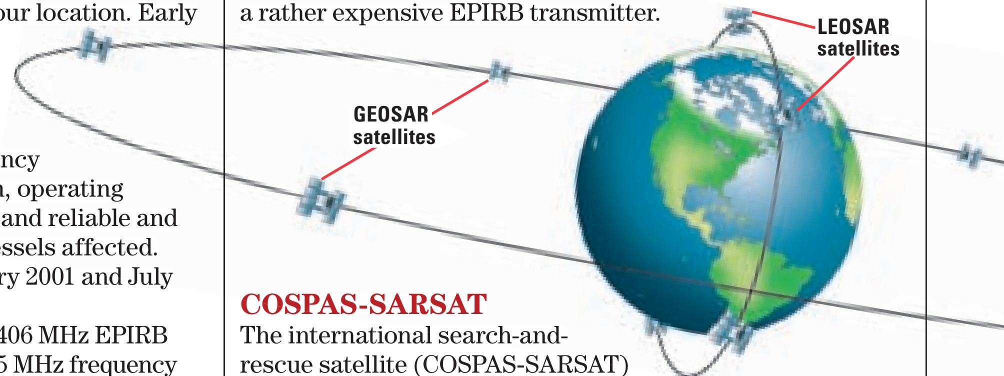
A personal locator beacon (PLB) is a special category of EPIRB designed to be carried by an individual. It operates on 406 MHz but can only be activated manually and, when activated, gives information about that individual as well as the location. This smaller, less expensive unit, can be carried by sailors, hikers, or anyone who will be in a remote area.

Registration

When any new or used EPIRB or PLB is purchased, it is required by law that the new owner must register it with NOAA. Also, if there is a subsequent change in registration information, this information must be updated with NOAA.

This can be done through NOAA's website. Adobe Acrobat Reader is required to view and print these forms. Print from the Adobe Acrobat toolbar to negate any browser incompatibilities. Go to <http://www.sarsat.noaa.gov> and click on "Register Your Beacon." This page gives an overview of the registration procedure. Then click on "Registration Website" for online registration. For any questions pertaining to registration, call 301-817-4515 or 999-212-7283.

NOAA only accepts registrations from the contiguous United States, Alaska, Hawaii, Puerto Rico, U.S. Virgin Islands, Northern Marianas, and American Samoa. The registration of an EPIRB or PLB can also be done through BoatUS. In addition, BoatUS rents EPIRBs to sailors who make infrequent offshore cruises and don't want to invest in a rather expensive EPIRB transmitter.



COSPAS-SARSAT

The international search-and-rescue satellite (COSPAS-SARSAT) system is composed of geostationary search-and-rescue (GEOSAR) satellites that orbit about 22,300 miles above the Earth, and low-Earth-orbit satellites (LEOSAR) that orbit 528 miles above the Earth, with an orbit every 100 minutes.

The GEOSAR satellites are capable of viewing large areas of the Earth and are able to provide immediate alert and

Layout and illustrations by Ted Tollefson

identification of an activated 406 MHz emergency beacon. They are, however, unable to determine the location of that beacon, unless the beacon is transmitting GPS coordinates. If no GPS coordinates are associated with the emergency beacon, then the LEOSAR satellites must determine the beacon's location using Doppler.

This Doppler-location process of the LEOSAR polar-orbiting satellites may take two or more 100-minute orbits to complete. This time could be further extended if the LEOSAR satellite is not in view of a ground station.

Thus, an EPIRB with an integral GPS transmitting the EPIRB's location is of great value. It makes the EPIRB's location known immediately, rather than having a delay of as much as several hours by units using Doppler-shift location of the LEOSAR satellites.

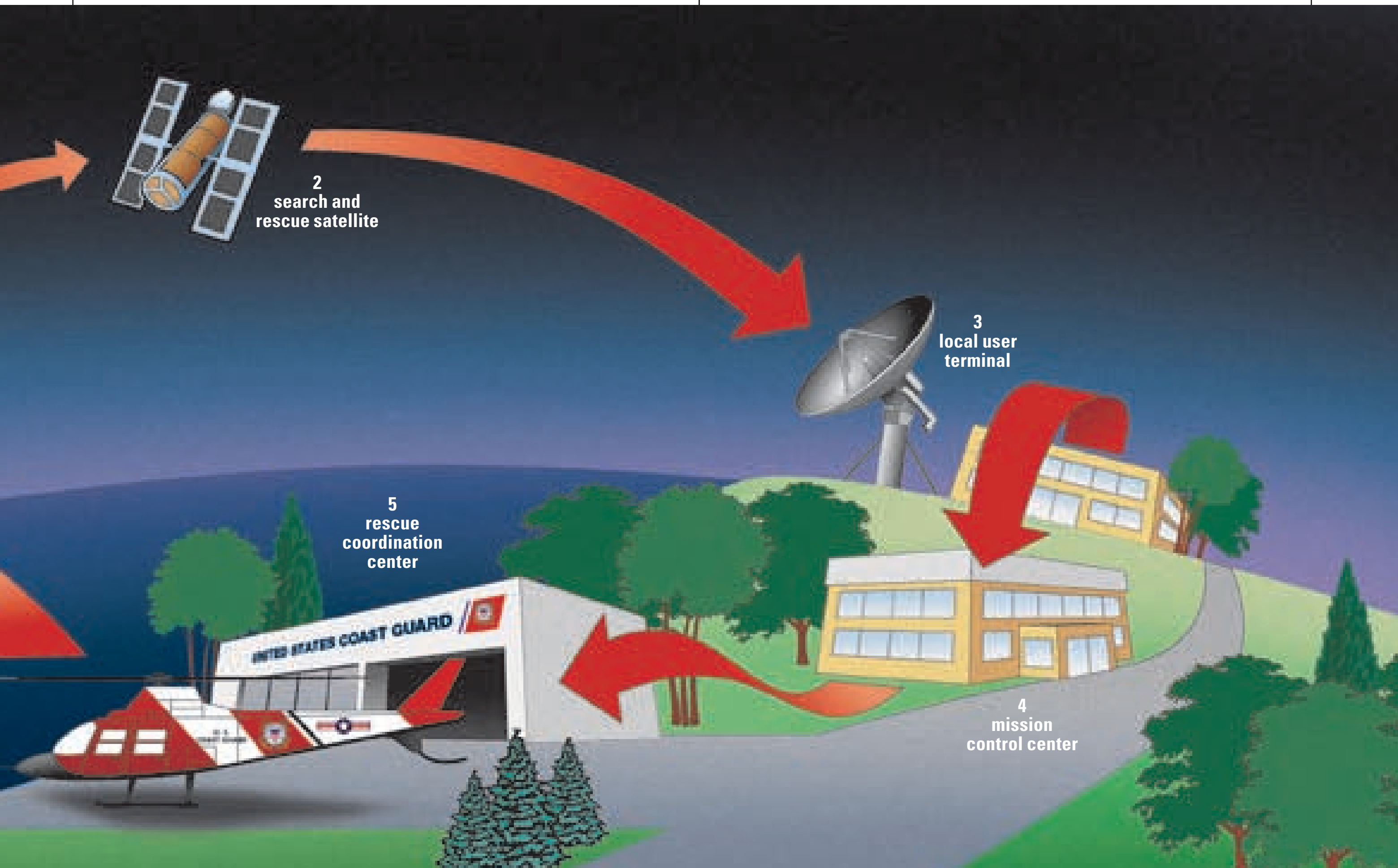
Search and rescue

The EPIRB's or PLB's emergency transmitter sends a unique identification number (UIN) to the COSPAS-SARSAT satellite search-and-rescue (SAR) system. The UIN, which has previously been registered with the Coast Guard, identifies the vessel or, in the case of a PLB, the individual in trouble. This information, along with the vessel's or person's location, is then transmitted and received at a local user terminal (LUT), which is a satellite ground station. The information then goes to a mission control center (MCC) and from there to a rescue coordination center (RCC), from which the physical rescue operation is deployed.

One more useful tool

SART is an acronym for search-and-rescue transponder. This transponder is a battery-powered receiver and transmitter that, when activated, constantly scans the maritime radar frequencies. Upon receipt of a radar signal, the SART transmits a radar-frequency signal that will be received by the searching radar. Since the SART's signal is much stronger than any passive reflected signal from the searching radar's beam, it creates a unique display and greatly enhances the chances of location. If you must abandon ship, the SART should be included in your "ditch bag."

Don Launer is a contributing editor with Good Old Boat *magazine.*



Dealing with potentially lethal gases

by Don Launer

ABOARD SAILBOATS THERE ARE SEVERAL TOXIC OR explosive fumes that are potentially lethal and must be detected for the safety of the crew and boat. The most common dangers are from fuels, smoke, carbon monoxide, and propane or natural gas. The consequences from any of these vapors are serious enough to warrant the small investment in a fume detector.

Fuel-vapor detectors

Fuel-vapor detectors alert boaters to the presence of combustible hydro-carbon vapors. In addition to gasoline vapors, they will also detect gaseous cooking fuels, and hydrogen, as well as some solvents and cleaning compounds. The remote detector type has a tiny detector located at a low point in the engine compartment (gasoline and propane fumes are heavier than air) and an alarm unit located where it will most easily be heard: in the cabin or on deck. Some fuel-vapor detectors have the ability to sound an alarm and also activate the bilge blower automatically.

Carbon monoxide (CO) detectors

Every boat that has a cabin and potential sources of carbon monoxide should be equipped with at least one carbon monoxide detector. The American Boat and Yacht Council standards require a CO detector on every new boat with an inboard gasoline engine or generator. Most sailboats have more than one potential source of carbon monoxide. In addition to the gasoline or diesel engine or generator, most boats also have gas-burning devices for cooking and/or heating.

Carbon monoxide results from incomplete combustion and is present in the exhaust of any internal combustion engine or open flame. Carbon monoxide fumes are lighter than gasoline fumes. The inhalation of this colorless, odorless gas can overcome a person quickly. Carbon monoxide is absorbed into the bloodstream 200 times faster than oxygen. Initial symptoms of CO poisoning are dizziness and nausea, which are often mistaken for seasickness. Carbon monoxide poisoning can be fatal in just minutes; so a CO detector should be aboard all recreational boats.

Fume detectors come in a large variety of sizes and options. Some are wall-mounted and self-contained, while others have a control panel with displays, programming, and remote sensors.

Be sure that your detector is designed for marine use. The marine varieties can operate either from a self-contained battery or from the boat's battery and are calibrated to a significantly different standard from the household variety. Your detector should also be UL-listed and able to compute the time-weighted average of the CO concentration, in order to eliminate false alarms.

Some CO detectors have the ability to shut down the generator when CO is detected.

When the engine or generator is running, there's one place a CO monitor will be of no help. That's when a swimmer is in the water near the exhaust when an engine or generator is running. There should never be anyone in the water next to the boat under these circumstances, especially if it is a gasoline engine.

Propane detectors

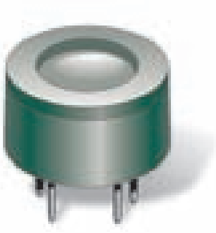
Propane is one of the most convenient and energy-efficient fuels that can be used for cooking or heating aboard. But if there is a leak, it is also one of the most hazardous. Any propane installation should also include a propane detector.

Although self-contained propane detectors are available, it is far better to have a detector of the remote-sensor type. This includes a sensor that is located at a low point within the hull, since propane fumes are heavier than air. Many remote detectors can provide more than one remote sensor and some models, in addition to the alarm, will provide an automatic shutoff at the propane fuel tank.

Natural gas detectors

A small percentage of boaters use compressed natural gas (CNG) for cooking and/or heating. Although more difficult to obtain, it has some inherent safety advantages. Natural gas is primarily methane and, since methane has no odor, an artificial "rotten eggs" odor is added to it to make detecting it easier.

Natural gas is lighter than air and a small leak may go unnoticed, since the gas will escape through hatches or deck vents. However, for those who wish to be on the safe side, and those with diminished smelling ability, a natural-gas detector makes sense.



Sensors for fume detectors measure less than an inch in diameter. They have a limited useful life. That useful lifespan will be shown in the manufacturers' installation/operation instructions. Keep a record of when to replace yours.

Layout and illustrations by Ted Tollefson

Smoke detectors

Just as within a home, a smoke detector is an important warning device that should be located where it can most easily be heard in the sleeping area. Some marine smoke detectors operate on the boat's batteries, while others operate on their own internal 9-volt battery.

Some other types combine more than one fume detector into a single unit, such as a combination smoke and CO detector.

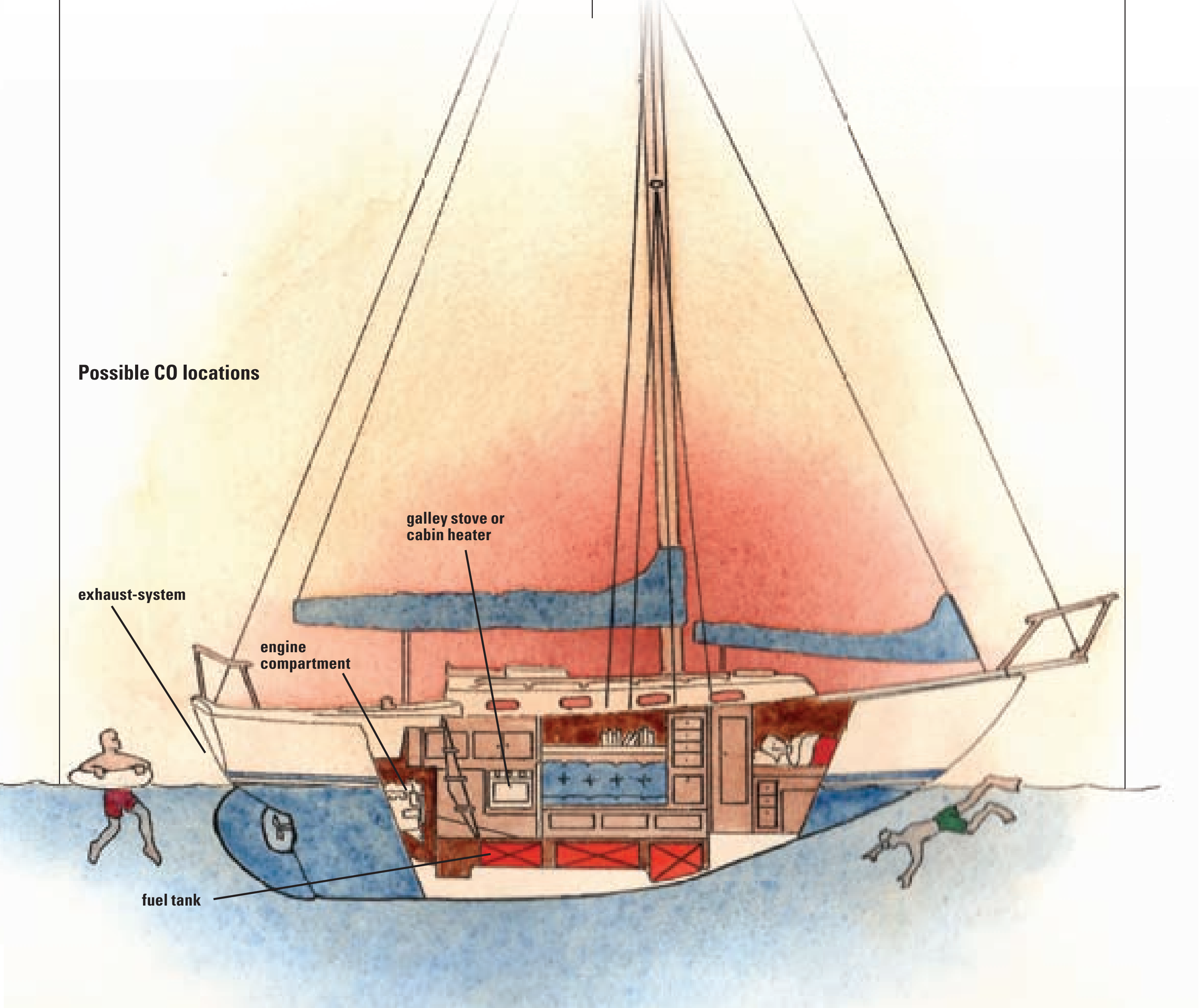
Maintain your system

Just like batteries, the sensors in fume detectors wear out. Some detectors have a warning when this happens, but with others it's up to the owner to keep a record of when the sensor should be replaced.

In case of alarm

Whenever a gasoline, propane, or natural gas detector goes off, vacate the boat immediately. Do not make calls from your belowdecks telephone or radio. Do not plug in or unplug any electrical appliances. Do not turn a light switch on or off and, of course, do not light a match.

Don Launer is a contributing editor with Good Old Boat.



New alerts help prevent loss of life

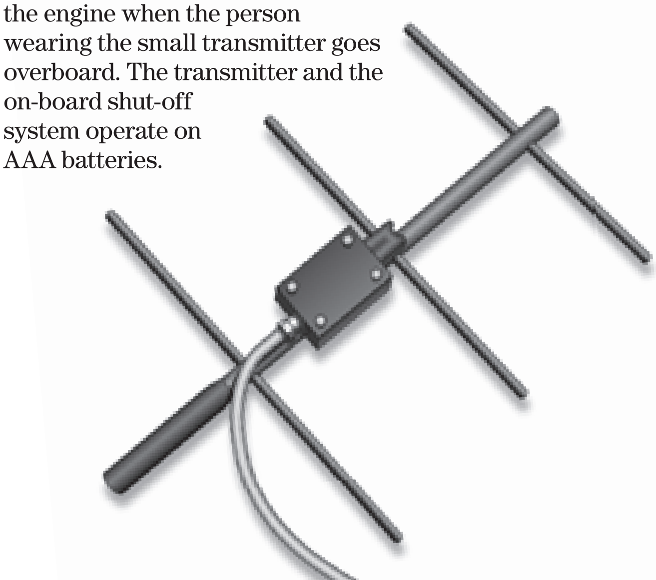
by Don Launer

EVERY YEAR THE ELECTRONICS ABOARD THE OFFSHORE sailboat become more exotic. Among the latest trends in marine safety are man-overboard (MOB) or crew-overboard (COB) electronic alerts. Many manufacturers are now marketing these systems with their own proprietary hardware and software. They are affordable and reliable, and their lifesaving capabilities need no justification. For millennia, sailors have been lost overboard but now these new MOB electronic devices can alert other members of the crew or the government's search-and-rescue responders and help prevent loss of life.

We've come a long way since the only man-overboard devices were a lanyard on the wrist of a small-boat operator (to activate the kill-switch on the motor) and a knotted line towed behind the boat. Although the line towed behind the boat has been touted for years, if the boat is traveling through the water at more than a knot or two, it is nearly impossible for a person in the water to get back to the boat. Even if that feat is accomplished, it is unlikely that he or she will be able to climb aboard.

> **"We've come a long way since the only man-overboard devices were a lanyard on the wrist...and a knotted line towed behind the boat."**

A modern version of the safety lanyard used to kill the engine is an inexpensive device that automatically shuts off the engine when the person wearing the small transmitter goes overboard. The transmitter and the on-board shut-off system operate on AAA batteries.



On-board direction finders, whether automatic or manual (as the one pictured) can point toward an MOB who is wearing an EPIRB, PLB, or other device that sends out the 121.5 MHz emergency signal.

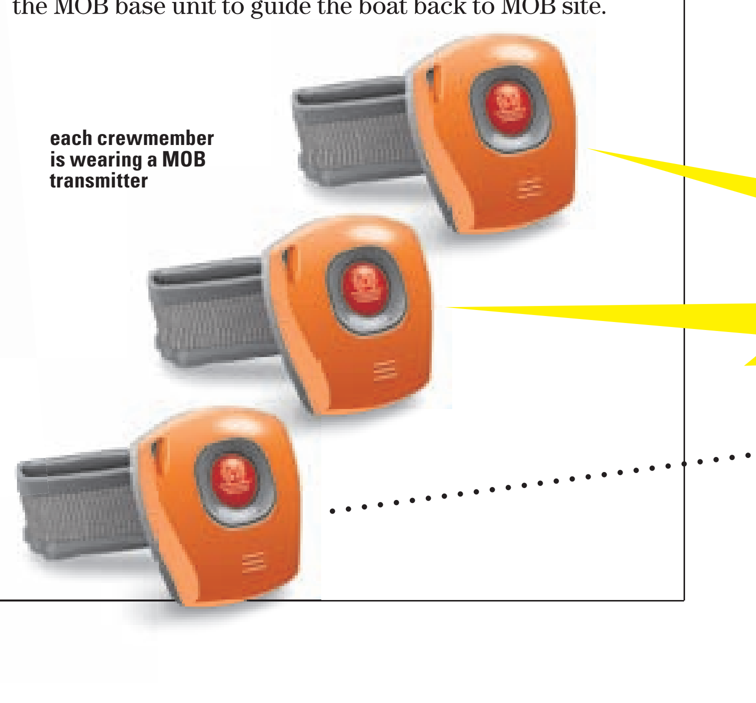
Solo sailors

For the singlehander, a Personal Locator Beacon (PLB) is still the best insurance (see "EPIRBs, PLBs, and SARTs 101" in the January 2008 issue). Most sailboats will round up into the wind when the helm is released. But if the boat is being steered by a windvane or autopilot; if the tiller or wheel is locked into position; or if the boat is under power, it will just continue on its merry way and the solo sailor who has been left behind must rely on the PLB to alert the government's search-and-rescue system.

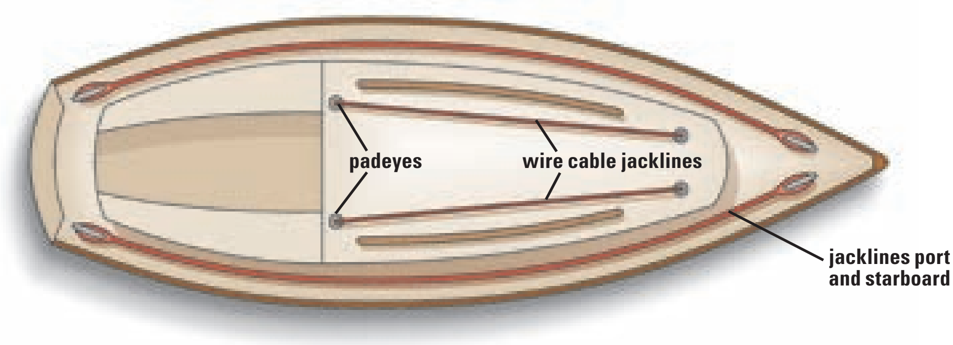
Boats with crews

For boats with more than one person aboard — particularly on boats used for offshore passages — an electronic MOB alert system is a good investment. Through an onboard base station, either the water-activated signal of the MOB unit worn by a crewmember or the interruption of that signal can sound an alarm to alert others who may be sleeping or unaware for any reason.

Some MOB devices can shut down the engine (if engine shutdown is accomplished with an ignition switch). This alert procedure is accomplished either when the transmitter worn by a crewmember is submerged and the signal to the base unit is interrupted or, in other systems, when submersion in the water activates the transmitter. Some MOB onboard displays feature a "track-back screen" that immediately appears on the MOB base unit to guide the boat back to MOB site.



Layout and illustrations by Ted Tollefson



Possible jackline positions. Jacklines on sidedecks may be snugged closer into the cabin sides. These may be made of stainless-steel wire, Dacron line, webbing, or tubing.

Some systems use an automatic electronic or a manual direction finder to pinpoint the location of the MOB, who is wearing a small locator beacon, by using the international emergency frequency, 121.5 MHz. This signal can help pinpoint an MOB and can also be used by sailors on other vessels that join in the search.

Most GPS units and chart plotters have an MOB button which, when pressed, stores the position of the boat at the time the button is pressed and makes it possible to return to that spot.

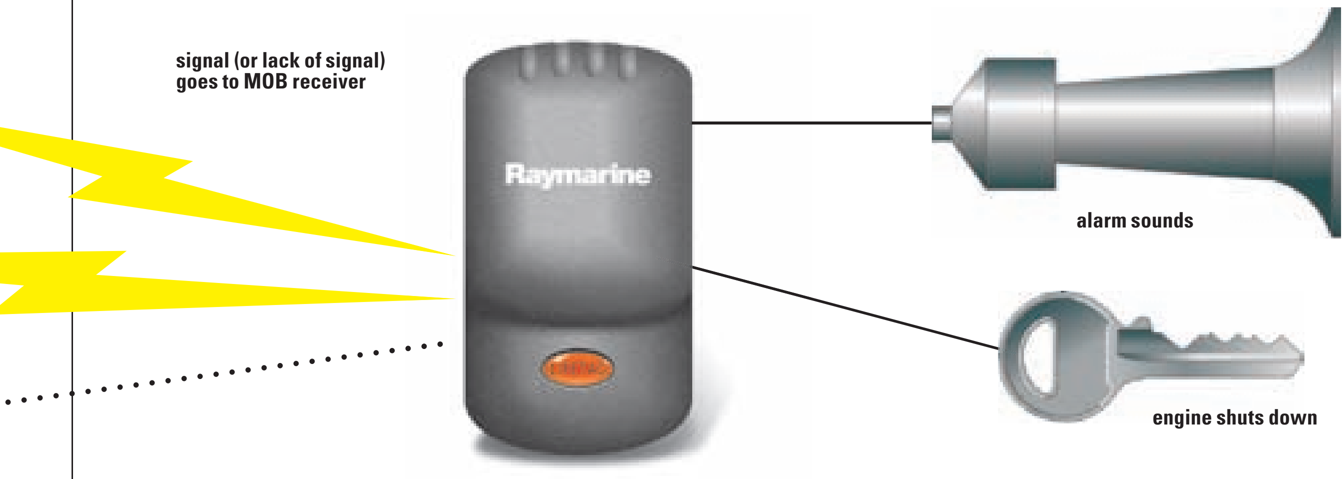
This, of course, can only be done if the boat has a crew of more than one and if someone sees a person fall overboard and presses the button. But there are MOB units available in which the base station aboard the boat will show the MOB position on a compatible GPS or chart plotter through an NMEA connection, while also sounding an alarm and/or shutting down the engine. Many manufacturers provide MOB systems that can be fully integrated into multi-function displays, giving a readout of who went overboard, where, and when.

Prevent falling overboard

Reducing the possibility of having to use an MOB device is an inexpensive requirement. It goes without saying that it is important to wear a safety harness, especially in the case of a singlehander. Many safety harnesses are built into life vests and foul weather gear, but the boat must have suitable fore-and-aft jacklines that can be clipped onto when deckwork must be done.

At night, crewmembers who go on deck should wear a strobe light to facilitate their rescue if they go overboard. Even in the daytime, a strobe light can be helpful, especially in marginal conditions.

Don Launer's complete bio can be found on Page 14.



Schematic of a simple MOB system that provides for an alarm and engine shut-down.

Be careful where you use these similar alloys

by don launer

Brass, primarily an alloy of copper and zinc, is less expensive than bronze and can be used for making items that remain in the cabin, such as clock and barometer cases.

In comparing bronze and brass, it is helpful to define two key terms before pointing out the differences, attributes, and deficiencies of these two materials:

Alloy – When metals combine with each other, along with certain other elements, and fuse together as mixtures, compounds, or solutions, these combinations are known as alloys. The resultant metallic substance often has substantially different properties from any of its individual components. These include strength and corrosion-resistance, which are considerably greater for the alloy than for any of its constituent elements.

Electrolyte – An electrolyte is a nonmetallic electrical conductor in which current is carried by the movement of ions. When two dissimilar metals are immersed in an electrolyte, they create an electrical cell. As current is drawn from this cell, the lesser metal on the galvanic table is sacrificed and goes into solution. Salt water is a strong electrolyte because of all the sodium and chlorine ions in the water. This property of salt water creates a hostile environment for many alloys.

Bronze

Bronze was first created around 3000 B.C. Although it is primarily an alloy of copper and tin, bronze has always included other elements. Modern bronze alloys may contain many other elements, such as phosphorus, aluminum, manganese, iron, or silicon. Within the wide spectrum of alloys that are called bronze, some also contain small percentages of zinc. Since copper and tin are adjacent to each other on the galvanic table, this mixture gives bronze the ability to withstand the harsh marine environment.

This is dramatically demonstrated by bronze artifacts that have been brought up from the depths after hundreds or even thousands of years and show little or no deterioration. Bronze melts at a relatively high temperature and is a very hard metal compared with brass, so it takes a toll on machining tools.

Brass

Brass is primarily an alloy of copper and zinc but may also contain other elements. Copper and zinc, metals widely separated on the galvanic scale, become highly interactive in the presence of an electrolyte such as salt water or in rain containing atmospheric contaminants. Under these conditions the zinc in the alloy becomes a "sacrificial anode" and is eaten up, leaving behind a soft, porous copper sponge. What is left retains the shape of the original part but has little mechanical strength. This process is known as dezincification.

> **"Bronze artifacts . . . have been brought up from the depths after hundreds or even thousands of years and show little or no deterioration."**

Brass deck hardware, even though it is not normally immersed, can deteriorate in this way. Although such hardware is dry most of the time, saltwater splashes leave a residue of salt on the hardware's surface. Then condensation (fog, light rain, or even an extremely humid atmosphere) supplies the water needed to create an electrolyte and subsequent dezincification of the brass. Although it is less common, dezincification can occur in freshwater environments when atmospheric contaminants initiate the process.

LAYOUT AND ILLUSTRATIONS BY TED TOLLEFSON

Since brass melts at a relatively low temperature, is an easy material to cast, machines like butter, and is therefore less expensive to work with, marine manufacturers often choose brass when they should select bronze. It is almost impossible for the consumer to differentiate between bronze alloys and brass alloys, so the reputation of the manufacturer will be the best indicator.

Electrical conductivity

Alloys always have a higher resistance to electrical current than the resistance of the individual metallic elements that have been combined to create them. Copper is the standard conducting material for electrical wiring and bus bars. Unfortunately, however, brass and bronze are sometimes used. Brass has only about 28 percent of the conductivity of copper, and the conductivity of bronze can be as low as 7 percent as that of copper. That means that electrical components made from brass or bronze, such as bus bars, will offer electrical resistance and, when carrying high currents, can become hot enough to be a fire hazard.

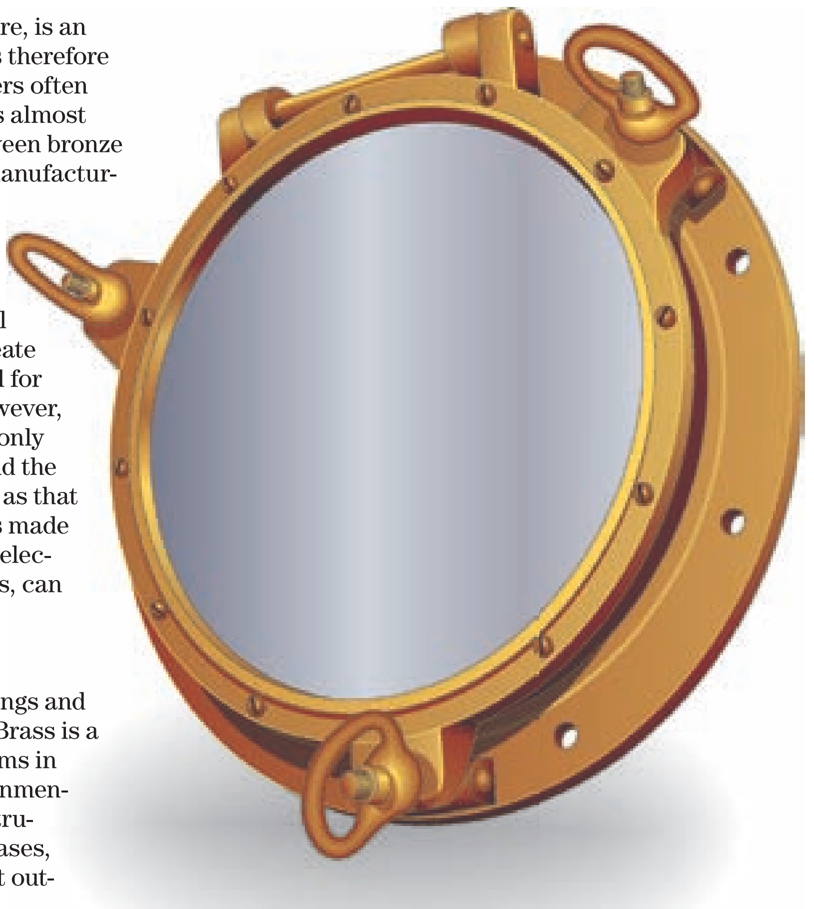
Uses for brass and bronze

Bronze is the clear choice over brass for deck fittings and for anything that will be immersed in salt water. Brass is a practical and relatively inexpensive choice for items in the cabin that do not come in contact with environmental salts: candlesticks, paperweights, musical instruments, barometer and thermometer instrument cases, and cabinet hardware. For the harsh environment outside the cabin, however, bronze is the alloy of choice.

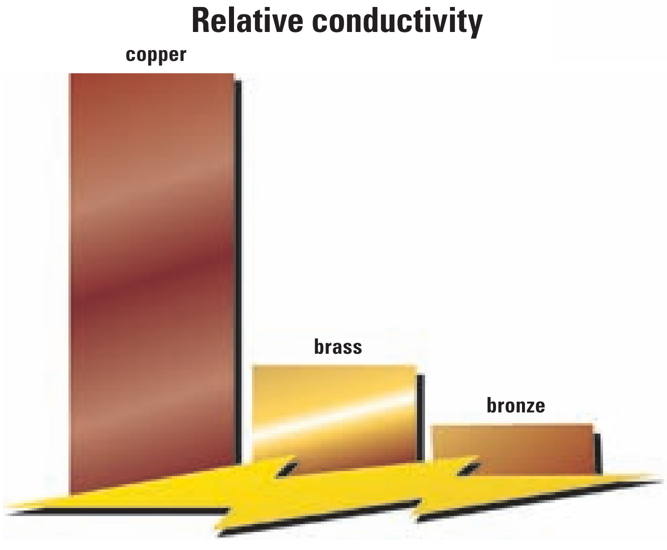
Many "bronze" products come to us from overseas. Even major marine-hardware distributors in the U.S. buy items manufactured outside of this country for economic reasons. Unfortunately, many of these items contain scrap alloys of unknown content, some of which may contain zinc or other unwanted elements.

It would be convenient if we could question the marine-hardware distributors about the content of the so-called bronze they are selling, but they often lack that information themselves. It's up to each buyer to maintain a healthy skepticism and to keep an eye on all bronze in exterior use.

Don Launer, a Good Old Boat *contributing editor, has held a USCG captain's license for more than 20 years. He built his two-masted schooner,* Delphinus, *from a bare hull and sails her on Barnegat Bay in New Jersey.*



Bronze, primarily an alloy of copper and tin, is the clear choice for deck fittings and anything that will be immersed in salt water.

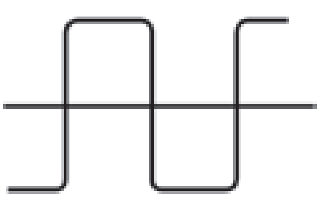


Copper is the standard electrical material for electrical wiring. Brass and bronze are poor substitutes.

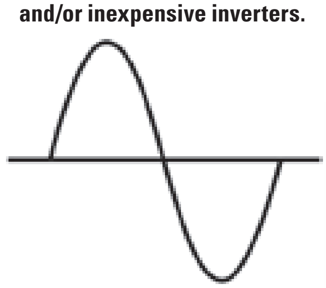
Converting battery power to alternating current

by Don Launer

An inverter is an electronic device that converts direct-current (DC) power (the output of your boat's battery) to alternating-current (AC) power. Although onboard generators (gensets) are necessary for equipment such as refrigerators and air conditioners with high power requirements, the inverter is a good choice for smaller power needs or when high power is used intermittently. There are countless varieties and options available when you're shopping for an inverter. Prices range from less than $30 to thousands of dollars. Although wattage is important, the waveform output of the inverter and what it is going to power can also be deciding factors.



The square wave (left) is the simplest alternating current that can be produced by an inverter. It will operate most appliances, but when used for extended periods with electric motors, these motors may tend to overheat. This is the most common waveform produced by small and/or inexpensive inverters.



The sine wave (right) is the optimum representation of the alternating current (AC) that is supplied by the power company or by an onboard generator. It is the voltage waveform that many appliances are designed for, especially those with electric motors. Some inverters can supply this pure sine wave, although they are the most technically evolved and expensive.

Inverters' waveforms

Inverters come in two basic varieties. One produces a square wave (or a stepped square wave, sometimes called a modified square wave). The other produces a true sine wave similar to the AC waveform supplied by the power company or a genset.

Some electronic equipment will not work well on a square wave and, because there is no simple way to change that square wave into a sine wave, an inverter with a sine-wave output will be necessary. It is always better to purchase an inverter that puts out a pure sine wave if there are no budgetary constraints, but sine-wave inverters are significantly more expensive than the square-wave-output inverters.

It's easiest and cheapest to create a square wave. A square wave works well for most devices, such as power tools and computers. However, a square-wave inverter will produce horizontal lines on a TV, whereas a sine-wave inverter, which has a waveform for which the TV was designed, will not.

For powering equipment with low-wattage requirements, the small-sized square-wave inverter that plugs into a cigarette lighter outlet works just fine. Since most cigarette lighter sockets are fused at 15 amps, the appliance being powered should not draw more than 150 watts.

For powering equipment with higher wattage drains, such as large-screen TVs and microwave ovens, a larger inverter that is wired directly to the battery is necessary. The

LAYOUT AND ILLUSTRATIONS BY TED TOLLEFSON

The simplest and most inexpensive inverters merely plug into a boat's cigarette lighter outlet. These can supply up to about 150 watts of AC power to low-wattage devices and usually have a square-wave output.

inverter should be close to the battery to eliminate losses in the wiring connecting them.

Battery drain

You can easily determine the current (amps) being drawn from your battery when your inverter is providing power to any 120-volt appliance since:

wattage = volts x amps

Using this formula, you'll note that an appliance rated at 240 watts will draw 20 amps from a 12-volt battery when powered by an inverter:

240 watts = 12 volts x 20 amps

In reality, the amperage will be slightly more than 20 amps; the exact amount is determined by the inverter's efficiency rating. When choosing an inverter, first determine the maximum number of watts you anticipate using and for how long.

The choice of a genset or inverter is not mutually exclusive. Both systems can live aboard together and serve different functions.

Many high-wattage inverters also have a sophisticated control panel that allows you to monitor the number of amp-hours that have been consumed and calls your attention to a low battery with an alarm. But those amp-hours taken out of the battery have to be replaced by the alternator on your engine or by shorepower, a genset, solar panels, or a wind generator.

Frequency concerns

One additional concern is that while the power company supplies an AC frequency of 60 cycles per second (60 Hz), inverters don't necessarily create the exact frequency unless they are crystal-controlled. This could cause problems with appliances that are frequency-sensitive, such as equipment using synchronous motors, as well as some TVs and computers.

There are also units that combine an inverter with a battery charger. Some of these units automatically switch to the battery-charging mode, either when the genset is turned on or when you plug into shorepower.

If you want the AC outlets on board to automatically switch from shorepower to the output of an inverter, this can be accomplished with a double-pole-double-throw (DPDT) relay. With the relay contacts in the "at rest" position, shorepower is connected to the AC outlets on board. But when the inverter is activated, the relay is energized and the onboard outlets are switched to the output of the inverter. Be sure to purchase a marine-grade relay that is made for this type of service.

A 1,000-watt inverter that doubles as a 50-amp battery charger when connected to shorepower is an excellent choice, even for a fairly small good old boat.

Don Launer, a Good Old Boat *contributing editor, has held a USCG captain's license for more than 20 years. He built his two-masted schooner,* Delphinus, *from a bare hull and sails her on Barnegat Bay in New Jersey.*

High-wattage inverters are wired directly to the battery and are capable of an AC output of thousands of watts. Although many supply square-wave outputs, high-end inverters can supply sine-wave output, which rivals or is better than that supplied by the power company. Many of these units have monitoring panels that keep an eye on voltage, battery capacity, and amp-hours.

Anchor Lights 101

Complying with regulations

by Don Launer

It seems that recreational vessels anchored without anchor lights are more the rule than the exception. However, the International Regulations for Avoiding Collisions at Sea (known as COLREGS) require any anchored vessel whose length is between 7 and 50 meters (approximately 23 feet to approximately 164 feet) to show an anchor light visible from 360 degrees for 2 nautical miles in fine conditions.

It is worth noting that both the COLREGS and Inland Rule 30(e) of the U.S. Coast Guard Navigation Rules go on to state, "A vessel of less than 7 meters in length, when at anchor not in or near a narrow channel, fairway, or where other vessels normally navigate, shall not be required" to exhibit an anchor light.

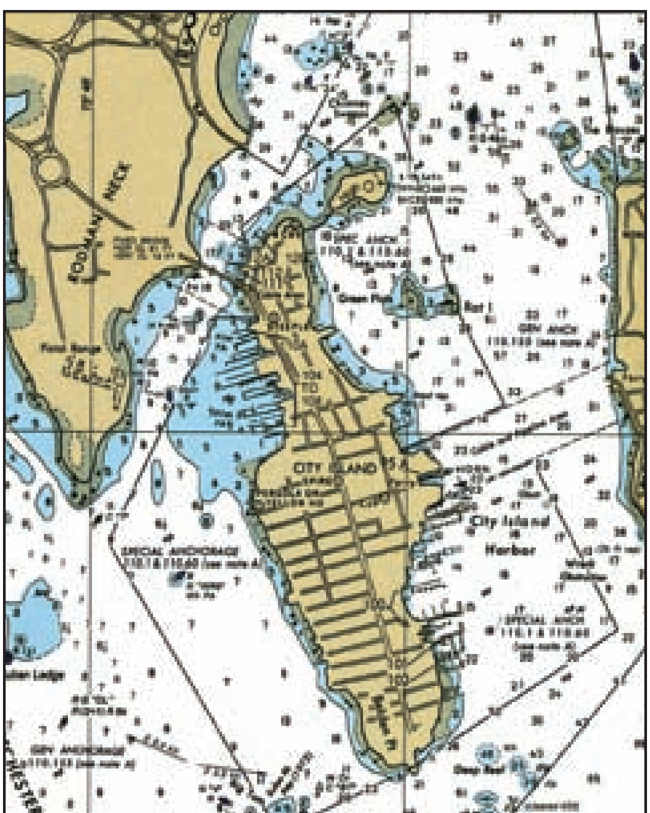


Chart showing several designated special anchorages.

In addition, it is important to know Inland Rule 30(g), which stipulates that a vessel of less than 20 meters in length, when at anchor in a special anchorage area designated by the Secretary of Homeland Security, also is not required to exhibit an anchor light. (A 20-meter vessel is approximately 65½ feet long.) Often these special anchorages are inside busy harbors or close to marinas and are usually, but not always, enclosed by solid magenta lines on the chart with "special anchorage" printed within or just outside that designated area. (The fog signal requirements of Rule 35 for an anchored vessel are similarly waived within these special anchorages.)

So, just because an anchorage exists, is shown on the chart, and may be defined and administered by the state, county, or local government, that anchorage does not automatically become a designated special anchorage, and an anchor light is required.

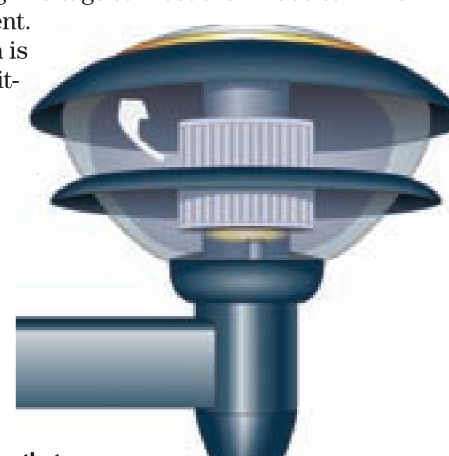
Masthead anchor lights

It takes about 5½ candlepower to make a light visible for 2 nautical miles in fine weather. This candlepower can be obtained either by using a 5-watt incandescent bulb and a Fresnel lens or by using a kerosene (paraffin) light with a ½-inch-wide wick and a Fresnel lens. (Fresnel can be pronounced either as "frez-nel" or with its original French pronunciation, "fray-NEL.")

Both the COLREGS and Inland Rule 30(b) state that when at anchor, "A vessel of less than 50 meters in length may exhibit an all-round white light where it can best be seen . . . " Most sailboats show an anchor light at the masthead. Although this is a convenient location, it is not the optimal spot. Better to have the anchor light near the bow of the boat and low enough so it also illuminates the deck. This is by far the best location, since boaters going through an anchorage are normally looking straight ahead and not up in the sky for anchor lights.

If you do use a masthead light, an incandescent bulb has several drawbacks. One is that it uses more power than other types of bulbs and has a relatively short life. Plus, the long wire up the mast must be of a suitable gauge so the bulb receives enough voltage to meet the 2-nautical-mile visibility requirement.

A better solution is the LED (Light-Emitting Diode) bulb, which has a much



Self-contained solar-powered anchor light. This type of anchor light has a solar panel on top that charges a small internal battery, which then supplies the LEDs when the integral photocell turns the anchor light on from dusk to dawn.

layout and illustrations by Ted Tollefson

longer life (more than 100,000 hours) and uses less electricity. LED bulbs for anchor lights are available as retrofits for many existing anchor-light housings.

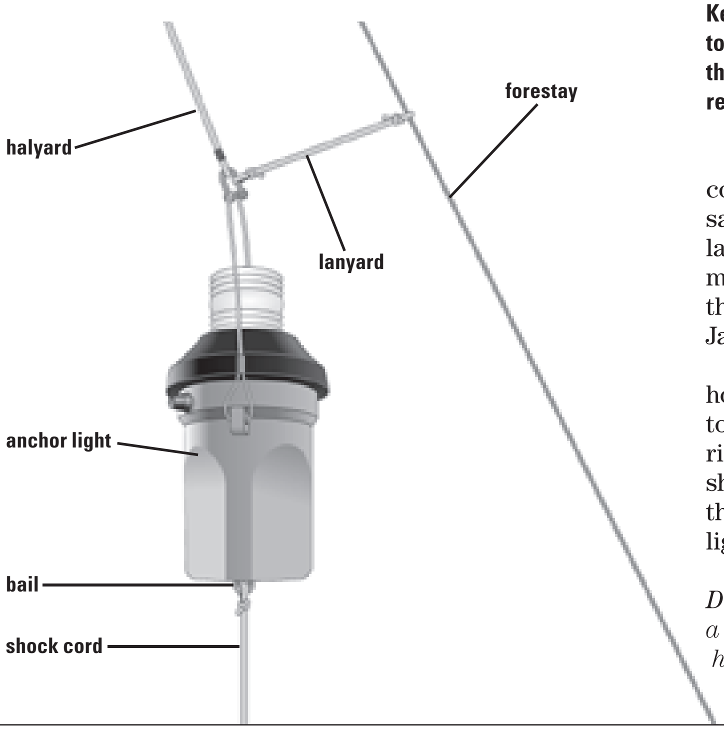
Also, some LED lights have circuits that allow their maximum brilliance to continue down to a supply voltage of 10 volts. And since some are also "bipolar," the polarity of your existing wiring is unimportant. Others have a very rapid pulse-repetition rate, much faster than the eyes' persistence of vision, with duration of the "on" pulse varying with the battery voltage. This conserves battery power while still maintaining the 2-nautical-mile visibility requirement.

Some LED masthead anchor lights have a photocell that turns the anchor light on at dusk and off at dawn, while other LED masthead anchor lights are solar-powered and completely self-contained. These lights have a solar panel mounted on top of the anchor-light housing and a photocell to turn them on and off. Consequently, such lights have no battery drain.

Rigging-hung anchor lights

Although the masthead anchor light is certainly the most convenient way of complying with regulations — just by throwing a switch — many sailors opt for an anchor light hung low in the rigging. This not only provides 360-degree light and 2-nautical-mile visibility, but it also illuminates the deck. This makes the anchored boat even more visible and provides a deck light that can be handy for those unexpected middle-of-the-night deck chores.

Hanging an anchor light in rigging



Kerosene anchor light. This type of anchor light may be attached to the forestay. There is a semicircular bail under the bottom of the anchor light. Usually a shock cord is attached to this bail to reduce the anchor light's swing as the boat rolls.

There are many small electric lights available with self-contained batteries that can handle this job. But many sailors prefer to use a kerosene anchor light. Kerosene lamps burn easily in gale winds, are readily available, are made of solid brass, and have a Fresnel lens that directs the beam horizontally. (See "The Lantern Ritual," in the January 2008 issue.)

Portable electric or kerosene anchor lights can be hoisted using a halyard, with a short lanyard to hold them to the forestay or shrouds. Most have a semicircular metal ring on the bottom (a bail), which is handy for attaching a shock cord to prevent the light from gyrating wildly when the boat rocks. These lights can also be used for interior lighting in an emergency.

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Signaling for Help 101

How to get aid when you really need it

by Don Launer

There are many ways a sailor can signal for help: body movements, sound signals, pyrotechnics, terrestrial radio, and via the search-and-rescue satellite radio system.

Visual signals

Visual signals for help may be as simple as slowly and repeatedly raising and lowering your outstretched arms. This is an officially recognized call for help. No extra equipment is needed. This can be effective any time another vessel is nearby.

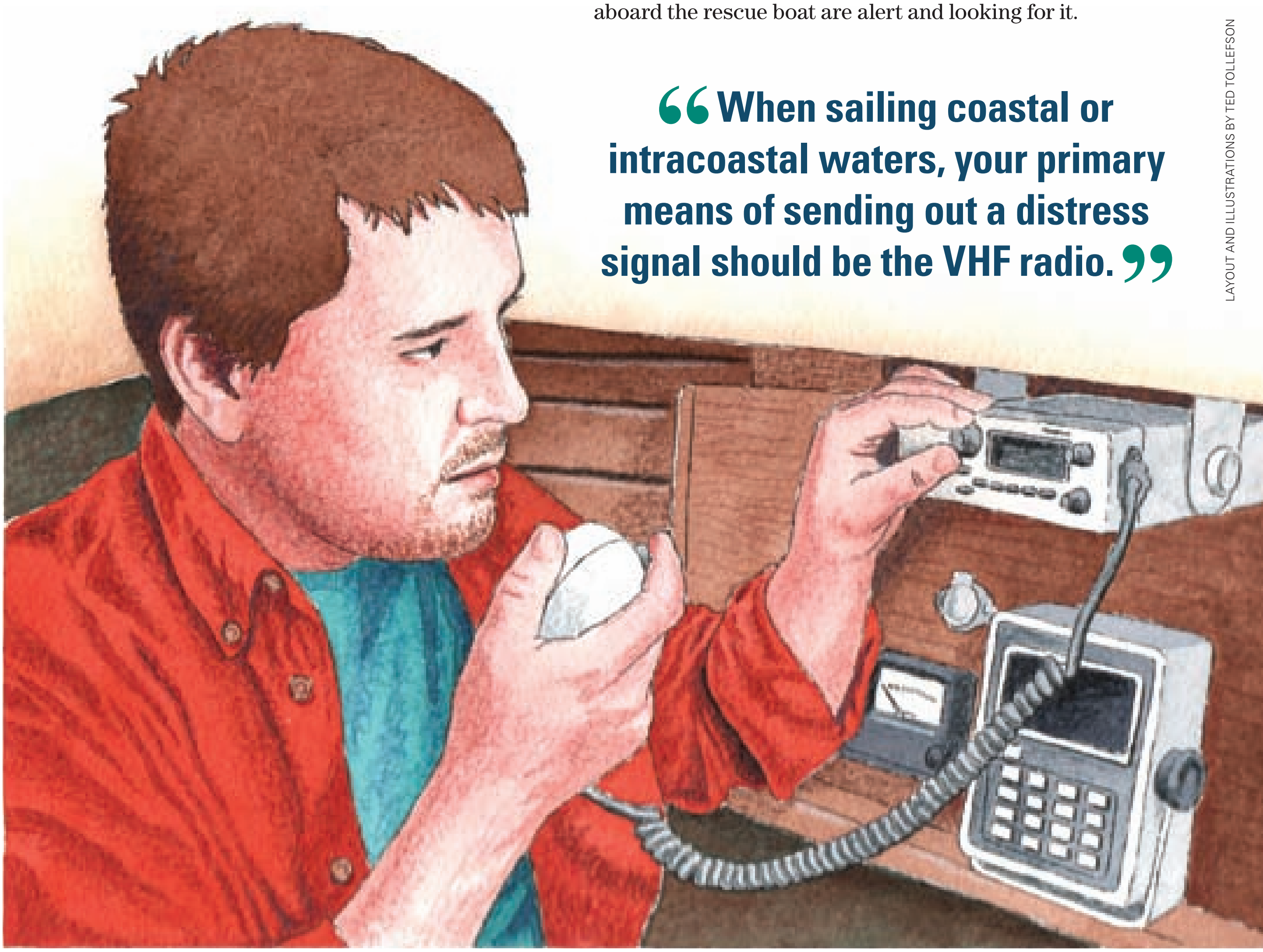
The display of an orange flag with a black ball and square also indicates a call for help. The black ball may be either above or below the black square. This type of flag is included in many emergency flare kits.

Another visual method is by signaling the Morse code "SOS" with a flashlight or searchlight (three short, three long, and three short).

Pyrotechnics is the visual method sailors usually think of first. Red flares can be either hand-held or rocket-propelled. For daytime, a hand-held smoke flare — one that emits large clouds of orange smoke — is very effective at alerting other boats that are too far away to see hand signals and flags, even those just over the horizon. At night, use hand-held flares or rocket-propelled flares.

Rocket-propelled flares may be either the meteor- or parachute-types, with the parachute flare visible longer than the meteor. If you're sure that there are other boats nearby, launch two flares about 30 seconds apart. Very often those on the other boat will think they *may* have seen the first flare. Launch the second flare while the people aboard the rescue boat are alert and looking for it.

> **"When sailing coastal or intracoastal waters, your primary means of sending out a distress signal should be the VHF radio."**



LAYOUT AND ILLUSTRATIONS BY TED TOLLEFSON

Dye markers may also be used but are usually not in the inventory of most recreational vessels.

A white strobe light, flashing at 50 to 70 times per minute, may also be used on inland waters.

Searchlights can be used, provided the searchlight doesn't blind those on another vessel.

Using a signaling mirror to flash sunlight at a specific boat or plane is another method, but it's best to practice this technique before an emergency arises.

Audible signals

Two types of horn signals are recognized. The first is a very long, extended blast of the horn; the second is blowing an SOS — three short, three long, and three short blasts.

Repeatedly firing a gun or producing other types of explosive signals about one minute apart is also recognized as a request for aid but is not often used by recreational sailors.

Terrestrial radio signals

When sailing coastal or intracoastal waters, your primary means of sending out a distress signal should be the VHF radio. This signal can be heard by other boats in your vicinity as well as by the Coast Guard. It's important to learn the procedure for sending out a Mayday distress signal on VHF Channel 16, as well as how and when to use pan-pan and securité signals, even though these aren't distress signals.

If you have upgraded your VHF with Digital Selective Calling (DSC), the DSC distress signals can be transmitted with the press of a button. In association with an integral or remote GPS, this distress signal will also include your position.

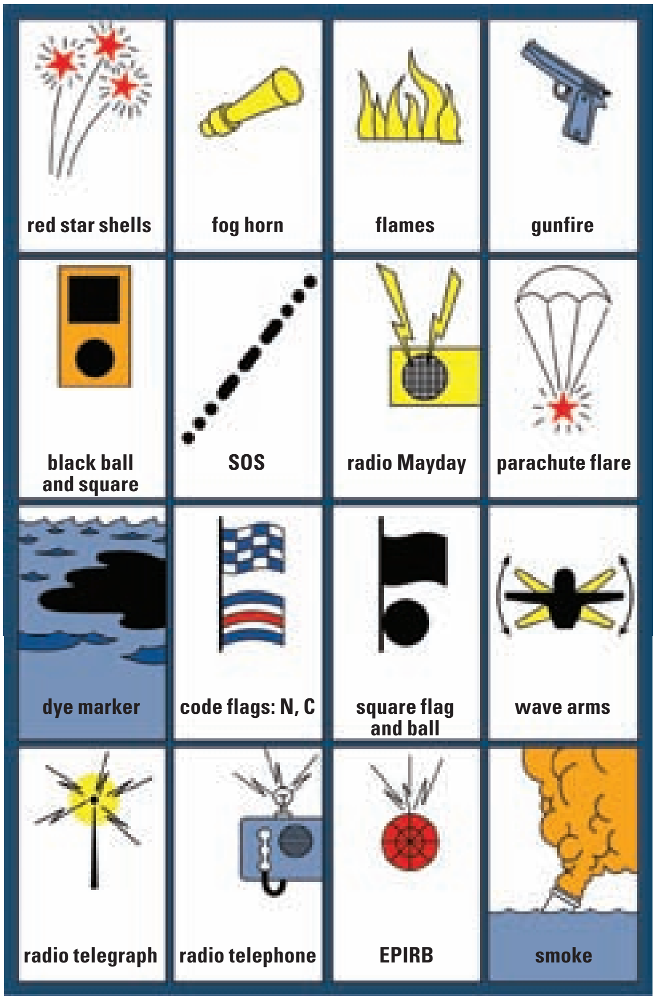
Cell phones should not be your primary way of securing help because, when well offshore, contact with a cell tower may be unreliable. In addition, most cell phones are not water-resistant and 911 operators are not trained to handle emergencies at sea. Furthermore, unlike a VHF radio that can be heard by nearby boats as well as by the Coast Guard, the cell phone provides only person-to-person contact.

For boats well offshore, where VHF is out of range and there are no other boats nearby, radio distress calls can be made using single-sideband radios or the amateur (ham) band.

Satellite search and rescue

The search-and-rescue satellite (SARSAT) system is composed of geostationary (GEOSAR) satellites orbiting about 22,300 miles above the Earth, and low-earth-orbit satellites (LEOSAR), which orbit 528 miles above the Earth, with an orbit every 100 minutes.

GEOSAR satellites are capable of viewing large areas of the Earth and are able to provide an immediate alert for and identification of an activated 406-MHz emergency position-indicating radio beacon (EPIRB). They are, however, unable to determine the location of that beacon, unless the beacon is transmitting GPS coordinates. An EPIRB with an integral GPS is sometimes referred to as GPIRB. If no GPS coordinates are associated with the emergency beacon, then the LEOSAR satellites must determine the beacon's location using the Doppler technique.



This Doppler-location process of the LEOSAR polar-orbiting satellites may take two or more 100-minute orbits to complete, and this time could be further extended if the LEOSAR satellite is not in view of a ground station.

Thus, a GPIRB that transmits a vessel's location is of great value. That's because it avoids the relatively long time involved in using the Doppler-location process of the LEOSAR satellites. (For more on this subject, see "EPIRBs, PLB, and SARTs 101" in the January 2008 issue).

In the absence of any of the above methods of signaling, the U.S. Coast Guard allows any vessel to make any light or sound signals that cannot be mistaken for any other signal.

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Shorepower Adapters 101

A "bag of tricks" has the power to connect you, anywhere

by Don Launer

Cruising is full of surprises, but one you don't need, and can easily avoid, is arriving in a strange marina to find that your shorepower cord doesn't match any of the marina's shorepower receptacles. The answer is to put together a "bag of tricks" so, wherever you go, you can literally pull an adapter to solve any connection puzzle "out of the bag."

Voltage and power options

- Many small sailboats have a simple 15-amp system. This requires little more than a 15-amp 125-volt AC extension cord, similar to an extension cord used in the home but made to marine specifications.
- Mid-sized sailboats, with more AC appliances, use a 30-amp 125-volt shorepower connection. Threaded collars on the shorepower cord provide secure, watertight connections between the shorepower pedestal and the boat. This power is then distributed through the boat by wiring called branch circuits.
- Larger yachts that have one or more air-conditioning units as well as refrigeration need a 50-amp 125-volt system to deliver the high currents those appliances draw.
- Yachts that have large appliances such as electric ranges and clothes dryers need a 50-amp 125/250-volt supply. The matching power cord contains four conductors: the white neutral, the green ground, and red and black conductors that each carry 125 volts.
- Marinas that cater to very large yachts will also provide 100-amp 125/250-volt connections.

The shorepower bag

For safety reasons, each of these systems uses different connectors specifically designed so they cannot be used interchangeably. Thus, if the marina's electrical system is not identical to your boat's electrical system, to plug into shorepower, you will need an adapter.

The prudent cruiser's shorepower bag will contain all the accessories needed to get plugged in at any marina. Along with the shorepower cord, you will want adapters that will connect it into any of the four common shorepower configurations, a telephone cord (unless you use a cell phone), and a cable-TV cord.

Adapters also come in a Y-configuration. The one most often needed is a Y-adapter that plugs into a 50-amp 125/250-volt receptacle, splits the supply, and delivers it to two 30-amp 125-volt receptacles.

Test the supply's polarity

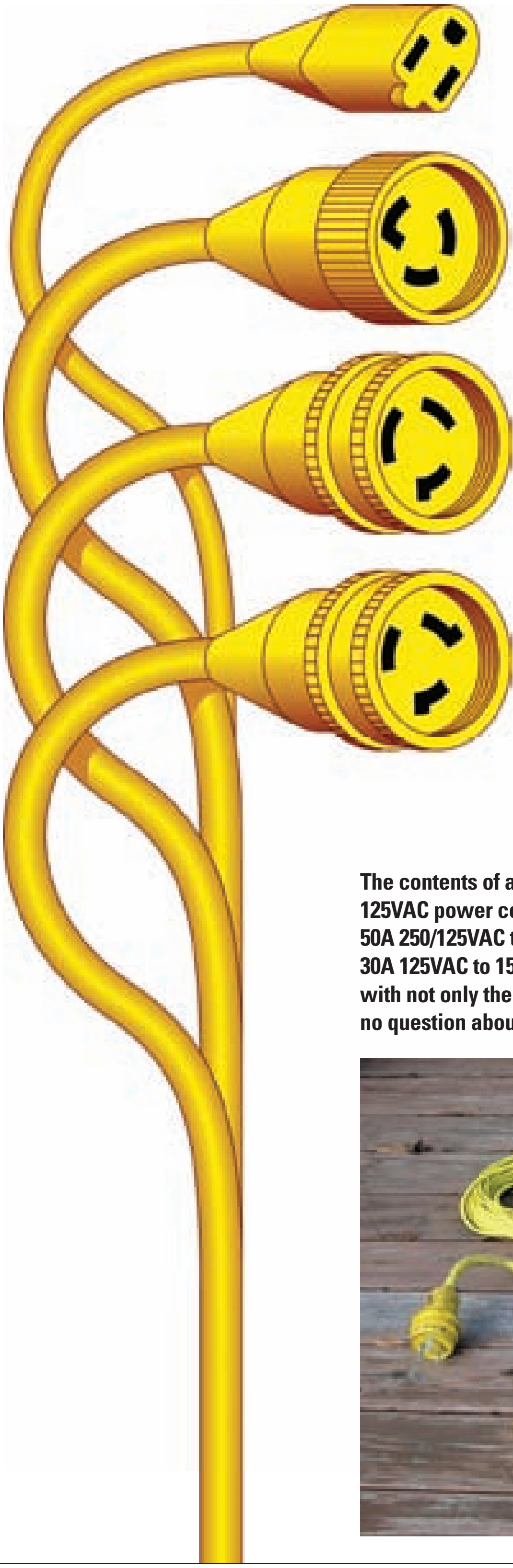
Before turning on any AC circuit in the boat, you should check the polarity of the shorepower supply to ensure that the marina's system is wired correctly. On many sailboats, a reverse-polarity indicator is built into the electrical control panel. To use this indicator, first turn off your main power switch or circuit breaker, then connect your shorepower cable. If your indicator gives the shorepower a clean bill of health, you can turn on the main switch. If it indicates reverse polarity, unplug the shorepower cable and alert the marina's management to the problem.

> **"I couldn't believe my eyes. The hot wire was connected to the ground terminal and vice versa."**

If you have no built-in reverse-polarity indicator, purchase a plug-in type and add it to your shorepower bag. Before you plug in your cord, check the system by plugging the indicator directly into the dockside power pedestal, using an adapter if necessary.

I always check polarity at a marina or yacht club before connecting my shorepower cable. It's a routine. I never expect any problems and had one only once. I took a slip

LAYOUT AND ILLUSTRATIONS BY TED TOLLEFSON



at a yacht club and plugged my polarity checker into the shorepower pedestal. I couldn't believe my eyes. The hot wire was connected to the ground terminal and vice versa — a potentially lethal wiring error. I checked the other outlets on the docks and they were all fine. Mine was the only bad one. I notified the club, and the electrician was there in minutes.

Guard against corrosion

Loose, corroded, or leaking connections are the most common cause of shorepower problems, both at the dock's power pedestal and at your boat's power-input socket. Corrosion, often the result of a non-waterproof connection, causes resistance, and resistance creates heat. This not only leads to a fire hazard, but also ends up destroying the plug on the shorepower cable and the socket on your boat or at the dock pedestal.

The terminals on a shorepower cable should be protected from moisture by vinyl covers and a sealing collar system. The covers protect the plug and connector and the collar system provides both protection from moisture and a mechanical seal between the cordset and the connector.

Don Launer, a Good Old Boat *contributing editor, has held a USCG captain's license for more than 20 years and has sailed the east coast from Canada to the Caribbean. He built his two-masted schooner,* Delphinus, *from a bare hull.*

The contents of a typical shorepower bag, from left to right. Top row: cable-TV cord, telephone cord, 30A 125VAC power cord. Middle row: 30A 125VAC to 15A 125VAC adapter, 50A 125VAC to 30A 125VAC adapter, 50A 250/125VAC to 30A 125VAC adapter. Bottom row: polarity checker, 15A 125VAC to 30A 125VAC adapter, 30A 125VAC to 15A 125VAC adapter, 20A 125VAC to 30A 125VAC adapter. It's a good idea to label the adapter with not only the type of socket it fits, but also with the name of your boat, so that on a marina dock there's no question about who owns the adapter.

Mooring Buoy Pickup 101

Pick up a mooring with grace and élan

by Don Launer

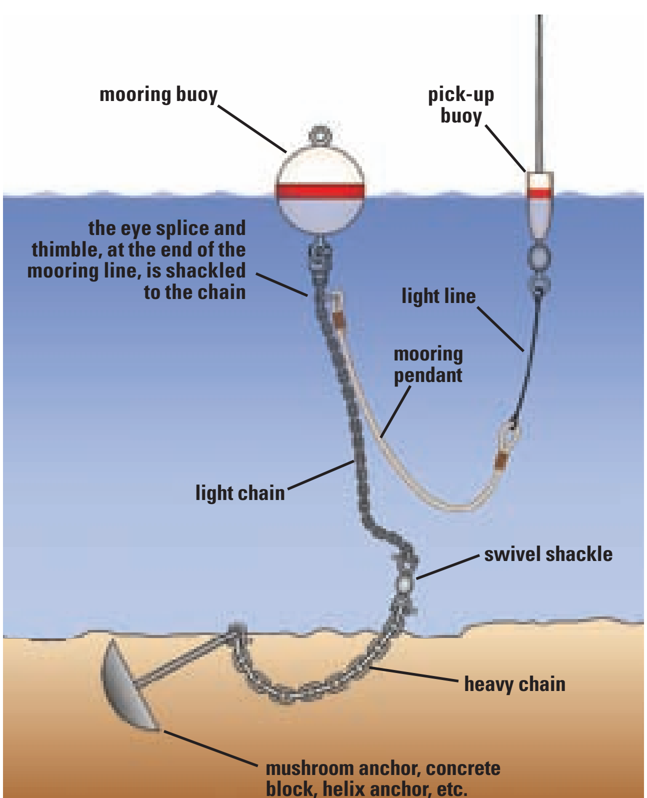
A mooring-and-buoy system consists of an anchor, a length of chain, and a mooring buoy that both holds up the chain and marks the location of the mooring. The anchor may be a mushroom anchor, a block of concrete, a helix anchor, or simply an old engine block. The size of boat the mooring can safely handle depends on the size of the chain as well as the size and type of anchor it's attached to.

The buoy normally has a ring on top so it can be easily picked up with a boathook, but many moorings will also have a rope mooring line, or pendant, attached to the chain, with another small buoy at the end of this line to facilitate snagging it with the boathook. Sometimes this small pick-up buoy will have a vertical fiberglass whip, 4 to 6 feet tall, so the pendant can be brought aboard without the need for a boathook.

Picking up a mooring buoy is not always easy, especially in a strong wind, if a rapid tidal current is flowing, or when you're sailing alone. If you don't catch hold of the mooring on the first try, it's usually not a problem. Ignore the critical gaze of sailors on nearby boats and act as though it were a practice run.

If you plan to pick up a mooring in an unfamiliar location, first check with the yacht club, marina, or harbormaster to be sure that the mooring is adequate for your boat. You don't want to pull an undersized mooring out of the bottom. Sometimes the maximum boat size will be marked on the buoy itself.

Well-managed mooring buoys are pulled up and inspected annually and worn or corroded parts are replaced. The frequency of inspection required in salt water is much greater than in fresh water. If weed growth on a mooring buoy appears excessive, it's a good indication that the mooring hasn't been serviced in a long time.



Anatomy of a mooring with mooring pendant and pick-up buoy.

> "If the mooring buoy has no mooring line attached, you should have a mooring line already fastened to a bow cleat."

Picking up a mooring

The most basic method of picking up a mooring is by using a boathook to either pick up the mooring line or, if there is no mooring line or pendant, to snag the ring on top of the buoy. In all but the smallest of boats, you should know when you're doing the pickup not to try to hang on to the mooring ring with the boathook if the boat is swept away from the buoy. When this happens, you'll probably be unable to release the hook from the buoy and the boathook will either break or be ripped from your hands.

If the mooring buoy has no mooring line attached, you should have a mooring line already fastened to a bow cleat and be prepared to connect this line as quickly as possible to the buoy's ring.

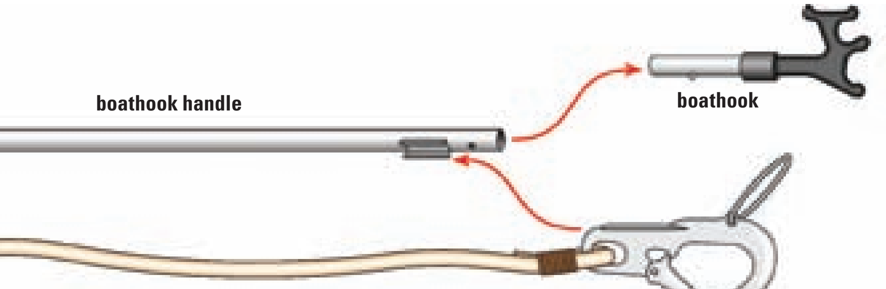
Communicate with signals

During the last stages of the approach the buoy will be lost from the view of the helmsman, so the pick-up crew should use signals to guide the helmsman's actions. It's of vital importance that the boat not run over the buoy's pick-up line. To prevent an unfortunate incident with propeller and mooring line, the pick-up crew must be able to communicate with the helmsman.

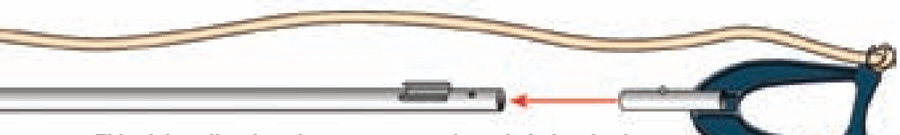
Hand signals are much more effective than shouting. Every crew that works together seems to develop its own set of signals. Whatever those signals are on your boat, all aboard should understand and use them.

After the buoy becomes invisible to the helmsman, the pick-up crew should point at it with an outstretched arm so the helmsman will know where it is and can maneuver accordingly. When it's time for the helmsman to put the boat's transmission in neutral, the pick-up crew should give him a specific signal. This might be a slashing motion across the

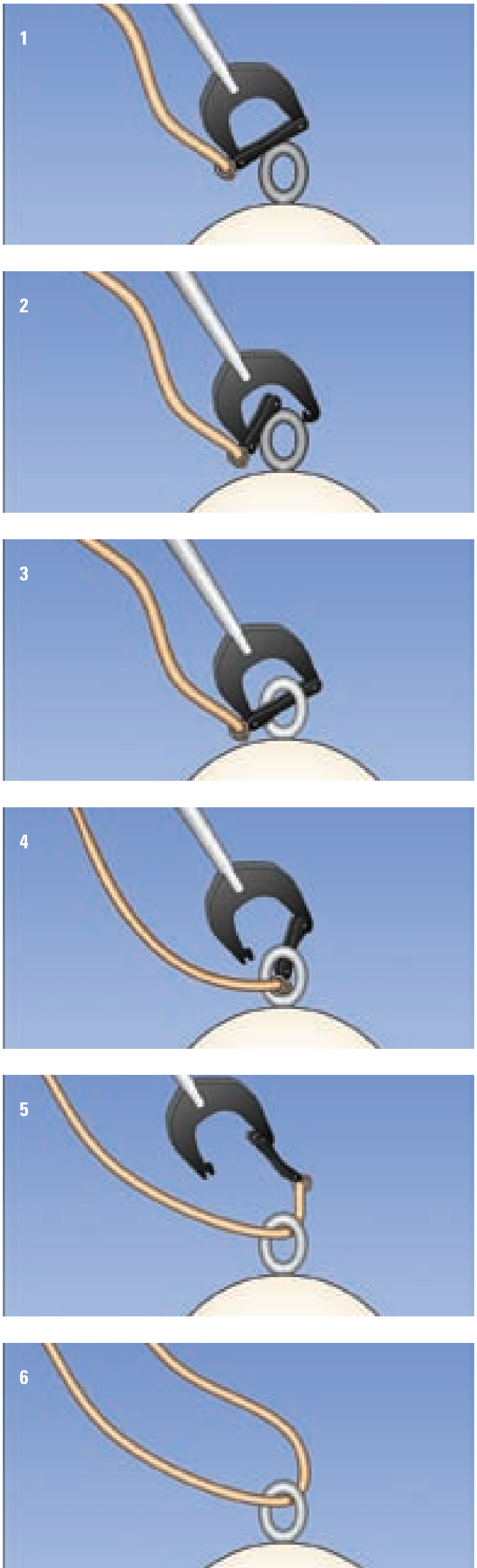
LAYOUT AND ILLUSTRATIONS BY TED TOLLEFSON



pick-up hook attached to a slide on the end of the boathook handle



This pick-up line threader can mount on the end of a boathook as an attachment, or on the end of its own pole, if used often.



To use the pick-up line threader, right, first fasten one end of the line to a bow cleat and the other to the threader. Push the flat surface of the threader against the ring on the buoy and withdraw. Pull the pick-up line aboard and cleat it off on board.

throat indicating, "Cut," or a raised clenched fist, as used by the military, police, and heavy-equipment operators. A palm held backward often means, "Go into reverse."

The solo sailor

Picking up a mooring presents special problems when you're single-handed. It's usually impractical to pick up the mooring from the bow because you lose sight of the buoy from the helm during the final approach. By the time you reach the bow, the boat will have fallen off, leaving the mooring out of reach. A far better way for the solo sailor is to fasten a long mooring line to a bow cleat and lead it back to the cockpit, outside of the shrouds and the lifelines. Now you can complete the pickup without making a mad dash to the bow. Once the boat is attached to the mooring, you can shorten the pick-up line and properly fasten it to the mooring chain.

Special equipment

Things are a bit more difficult when there is no mooring pendant or pick-up buoy. Fortunately, several handy inventions are available to assist in the pickup. These are especially useful for the solo sailor or when sailing with a novice crew.

In one method, a snap hook at the end of a mooring line attaches to a slide at the end of the boathook. When the hook is snapped onto the mooring buoy's ring, the hook and mooring line slide off the boathook track and the boathook handle can be pulled away smoothly.

Another ingenious device actually threads the mooring line through the ring at the top of the mooring buoy with one simple motion, pushing the line through one side of the ring and retrieving it on the other side. When leaving the mooring later, you can let go one end of the line and pull it through the ring, thus eliminating the need to pull up the mooring buoy.

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The Ditch Bag 101

The equipment you hope you never have to use

by Don Launer

LAYOUT AND ILLUSTRATIONS BY TED TOLLEFSON

Among the most important pieces of equipment on board our boats are some we've spent good money for but hope we never have to use. Fire extinguishers are one example and the ditch bag is another.

If your boat is foundering and you're forced to take to the life raft, you'll need to take with you several items to assure your comfort and aid in your rescue. These should be stored in a ditch bag that's easy to find and retrieve in an emergency.

The ditch bag is sometimes referred to as a rapid-ditch bag, a ditch kit, a grab bag, a flee bag, or an abandon-ship bag. What you stow in the ditch bag depends on the kind of sailing you do and where you sail. A ditch bag suitable for bluewater cruising with a large crew in cold climates is very different from one needed when sailing in coastal or intracoastal waters.

> "Think about things you need to keep you warm and dry, protect your skin from exposure to the sun, keep you hydrated and nourished, maintain your health, signal for help, and navigate toward land."

The container

No matter what its contents, the ditch bag should be able to float when packed and should be designed so items inside the bag can be fastened to it with individual lanyards. The bag itself should be brightly colored and sport reflective strips. It should also be identified with a large label stating "Ditch Bag," or something similar, so there will be no mistake as to which bag to grab amid the stress and confusion of abandoning ship.

Boating supply stores sell a great variety of ditch bags. Some bags have a Velcro bulkhead mount so they can be located in plain sight and easily removed in an emergency. Many bags claim high flotation loads, but unless the bag is completely waterproof (and most are not), the weight of the equipment inside can send the bag to the bottom. The shoreside weight of the contents can be misleading. If the bag contains a number of heavy water bottles, for example, they will provide their own flotation when the bag is submerged in salt water, since fresh water is less dense than salt water. Metal objects are an entirely different matter. The only real way to know if your bag will float is to immerse it when it's loaded with all the requisite gear and see for yourself.

You can supplement flotation by storing many of the items in the bag — medications, first-aid gear, and so on — in sealable plastic bags that trap a substantial amount of air. A completely waterproof bag is another solution, but they are not easy to find. If you locate one, it should be able to keep your heavy contents dry while staying afloat.

The contents

What goes into a ditch bag is a matter of personal choice and will depend on where you sail. Here is a selection of items, some of them essential and all of them useful. (A) folding, plastic 5-gallon water jug (B) signaling mirror (C) waterproof flashlight (D) stainless-steel multi-tool (E) fishhooks and line (F) waterproof strobe light (G) waterproof VHF-FM marine-band radio (H) waterproof matches and match-holder (I) stainless-steel knife (J) plastic spoons (K) pop-top food cans (L) water bottles (M) folding plastic bucket (N) lightweight foul-weather gear and hats

Whatever else you decide to put in the bag, the most important items are those that can alert rescuers to your status as soon as possible. These include electronic systems such as an EPIRB and PLB (see "EPIRBs, PLBs, and SARTs 101" in the January 2008 issue) as well as a VHF radio that is either waterproof or in a waterproof bag. Your kit should also contain visual distress signals. These could include a strobe light, hand-held and rocket flares, and smoke signals. Although they are stored out of sight in the ditch bag, don't forget to check the expiration dates of pyrotechnic devices and replace them when appropriate. A signaling mirror can also be very effective in attracting attention but requires a sunny day (see "Reflect on This" in the January 2005 issue and "Signaling for Help 101" in the January 2009 issue).

Solar blankets can protect you from the sun or cold and can be used to catch rainwater. Include bottled water and some form of nourishment. If that nourishment is in cans, you'll need a can opener unless the cans have pull-tab tops. If you're making a long ocean crossing, a solar still or hand-operated reverse-osmosis desalinator should be part of your emergency equipment, as should simple fishing gear. A basic medical kit is important too. Don't forget any medication that you or a crewmember can't live without, and sunscreen.

> "Whatever else you decide to put in the bag, the most important items are those that can alert rescuers to your status as soon as possible."

Spare glasses and a pencil and pad of paper could be helpful; a knife is essential. Inflatable life rafts should have patch kits and a supply of short lanyards to make sure nothing is lost overboard, such as the bailer or the knife.

There are no hard-and-fast rules about the contents of a ditch bag. Sailors must evaluate their own requirements. Think about things you'll need to keep you warm and dry, protect your skin from exposure to the sun, keep you hydrated and nourished, maintain your health, signal for help, and navigate toward land.

If your sailing lifestyle will never put you in a situation where a ditch bag would be necessary, assembling one will not be a high priority. But if there is a chance, however remote, you might need it, the ditch bag should be one of those items you spend time and money on and then hope you never have the occasion to use.

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Lazy-Jacks 101

An extra hand for short-handed cruising sailors

by Don Launer

Lazy-jacks provide a simple way to control a sail when you lower it. By holding the sail above the boom and preventing it from falling on the deck, they also make it easier to furl the sail. They can be used on Marconi rigs, gaff rigs, and even on club-footed jibs. There is no one definitive way to rig lazy-jacks; almost as many variations exist as there are installations.

Lazy-jack installation

A basic component of any lazy-jack system is a pair of upper support lines, one on the port side of the mast and one on the starboard side. These hold up a lower set of lines that actually contain the sail, which is raised and lowered between them.

The upper support lines are usually attached to eye straps about half to two-thirds the way up the mast. With this type of installation, the tension in the lazy-jacks can be controlled by adjusting the lower lazy-jack lines at the forward end of the boom. Alternatively, instead of being fixed to eye straps, the upper support lines can lead over small blocks and down to the base of the mast, where they can be adjusted to tension or loosen the lazy-jacks.

Regardless of which system you use, the lower ends of the upper support lines terminate in an eye-splice around a thimble. When making this eye-splice, be careful to ensure no sharp ends of melted strands protrude from the eye-splice as they will chafe the sail.

Two-leg lazy-jacks

In a two-leg lazy-jack, the lower lazy-jack line is one continuous line. One end is fastened to an eye strap on one side of the forward end of the boom. It leads up to and through the thimble eye of the upper support line on the same side of the boom, down around the boom through an eye strap, back up to the other upper support-line thimble eye, then down to a cleat at the forward end of the boom, where its tension can be adjusted.

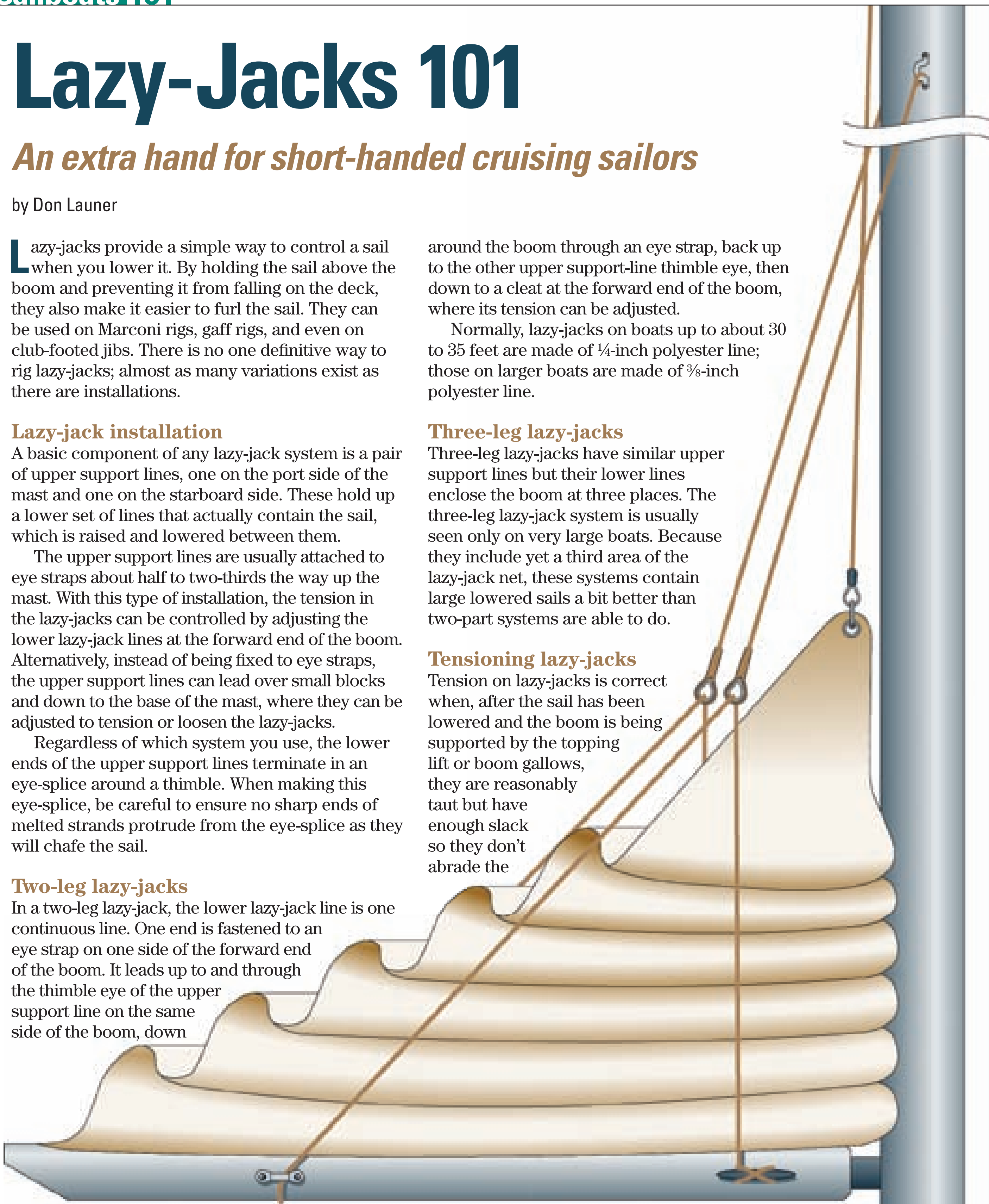
Normally, lazy-jacks on boats up to about 30 to 35 feet are made of ¼-inch polyester line; those on larger boats are made of ⅜-inch polyester line.

Three-leg lazy-jacks

Three-leg lazy-jacks have similar upper support lines but their lower lines enclose the boom at three places. The three-leg lazy-jack system is usually seen only on very large boats. Because they include yet a third area of the lazy-jack net, these systems contain large lowered sails a bit better than two-part systems are able to do.

Tensioning lazy-jacks

Tension on lazy-jacks is correct when, after the sail has been lowered and the boom is being supported by the topping lift or boom gallows, they are reasonably taut but have enough slack so they don't abrade the



Two-leg lazy-jacks can be as simple as the arrangement shown here, where the tension of the whole is adjusted at the single cleat on the boom. According to preference, each side could be set up separately and the upper support lines could be brought down to cleats on the mast, as shown on the opposite page.

LAYOUT AND ILLUSTRATIONS BY TED TOLLEFSON

Depending on the amount of control desired, the upper legs of the lazy-jack can terminate on the mast aloft (opposite page) or, as shown here, lead through blocks and down to cleats or other adjustment devices at deck level.

sail. They should be slack enough so you have room to install the sail covers easily. As a matter of fact, it's somewhat easier to install a sail cover when the lazy-jacks are properly tensioned, because the sail cover can be laid out along the boom and will stay in place.

Batten fouling

The most common complaint sailors make about lazy-jacks is that the boat must be pointed directly into the wind when the crew raises the sail. On a boat with a Marconi main, raising sail off the wind will cause the aft ends of the sail battens to be blown outside the lazy-jack lines and catch there. Boats with full battens usually don't have this problem. One way to solve the dilemma is to slack off the lazy-jacks before hoisting the sail; another is to make sure the boom is directly downwind. Once the mainsail is part-way up, and the battens are clear of the lazy-jacks, there is no further problem.

A way to prevent the battens from snagging the lazy-jacks is to slack off both lazy-jacks, or even just the leeward one, and bring them forward to the mast when hoisting sail. Once the sail is raised, the lazy-jacks can remain in the forward position or be moved back to their normal position in readiness for the next time the sail will be lowered. For many, this extra maneuver may negate the inherent advantage of using lazy-jacks: making things simple.

One side benefit of fitting lazy-jacks is that they provide an emergency backup for the topping lift, since the lazy-jacks will prevent the boom from crashing down on the craniums of the crew if the topping lift fails. It's tempting, if you have lazy-jacks, to do away with the topping lift entirely, but this makes it more difficult to reef or furl the sail when the lazy-jacks are supporting the weight of the boom at the same time.

Naturally, lazy-jacks add a bit more windage and a small amount of weight aloft, so they're not often seen on racing sailboats, where every hundredth of a knot is important. But for the cruising sailor they are a great asset, especially when sailing solo or short-handed.

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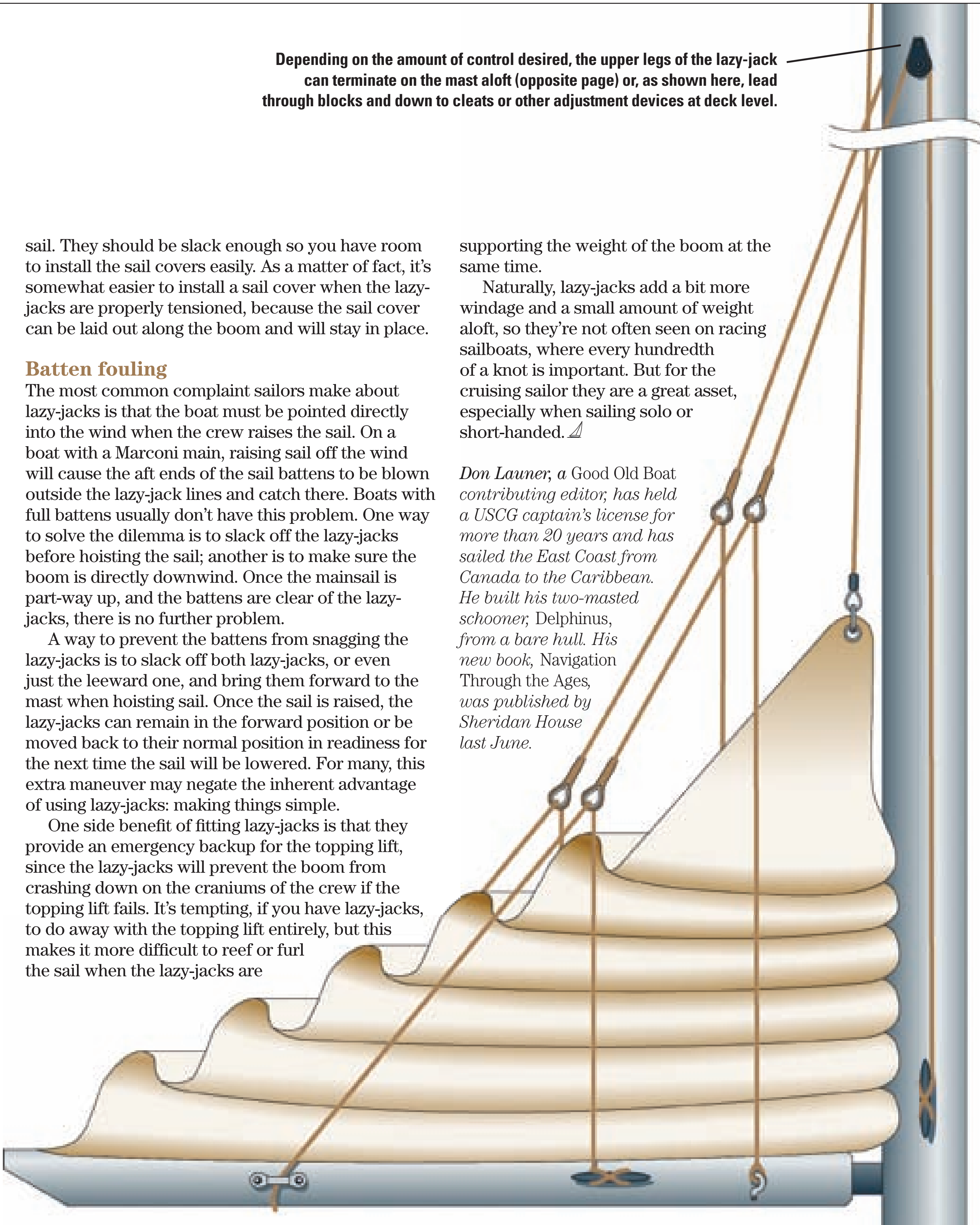
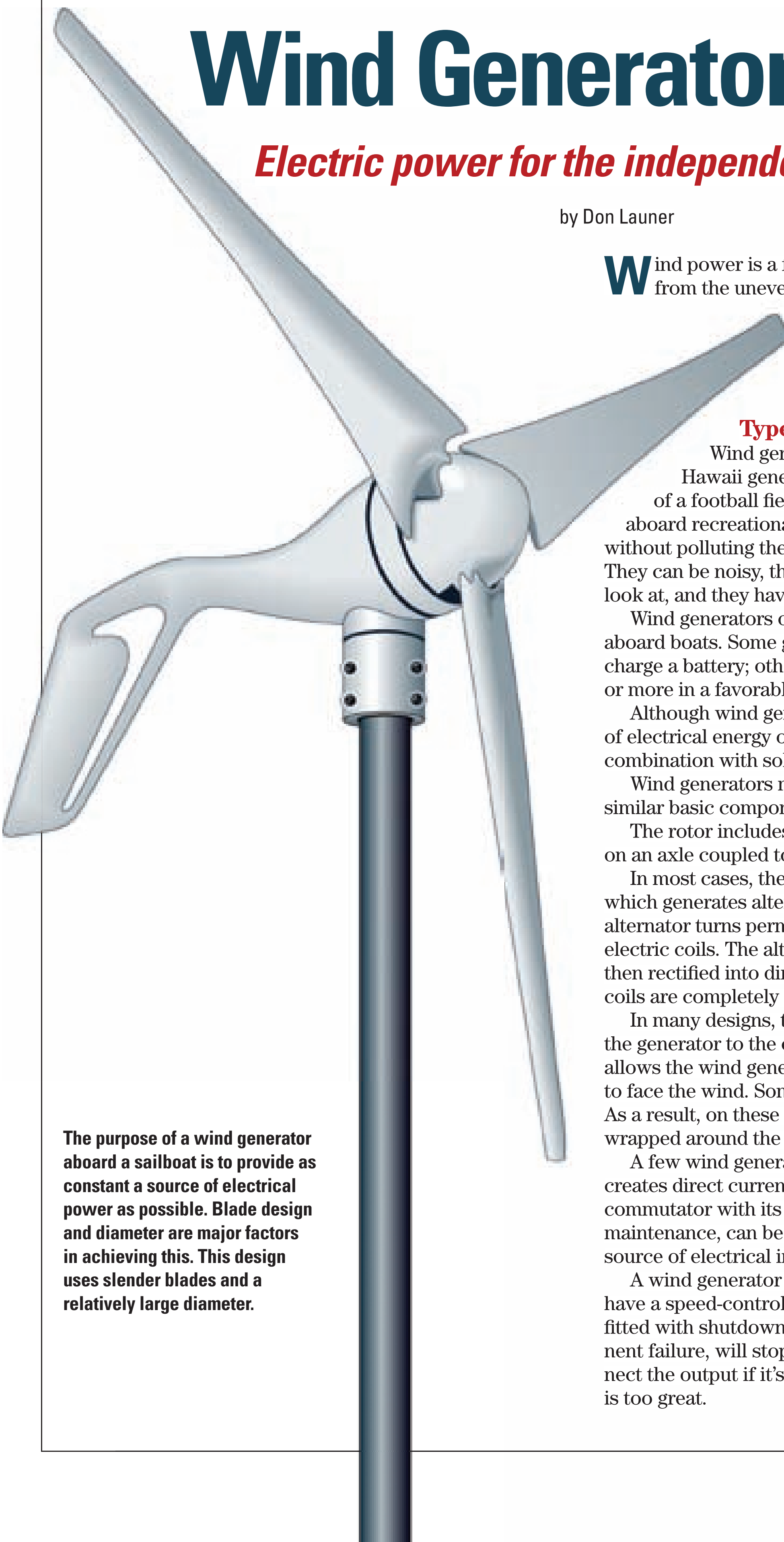


A three-leg lazy-jack system can hold a larger sail more securely and, just like the two-leg, can be as simple or elaborate as the situation demands. Someone who often sails singlehanded might even lead the upper-leg control lines to the cockpit.

Wind Generators 101

Electric power for the independent sailor

by Don Launer



The purpose of a wind generator aboard a sailboat is to provide as constant a source of electrical power as possible. Blade design and diameter are major factors in achieving this. This design uses slender blades and a relatively large diameter.

Wind power is a form of solar energy — winds result from the uneven heating of the atmosphere by the sun. To generate electricity, a wind generator converts the kinetic energy of the wind into mechanical energy and then into electrical energy.

Types of wind generators

Wind generators vary in size from the 20-story Hawaii generator, with a blade diameter the length of a football field, to the relatively small ones used aboard recreational sailboats. They all deliver electricity without polluting the air but do have some disadvantages. They can be noisy, they are not always thought of as pretty to look at, and they have the slight potential to kill birds.

Wind generators of many different designs are used aboard boats. Some generate only enough power to trickle-charge a battery; others are capable of generating 100 watts or more in a favorable wind.

Although wind generators can be used as the sole source of electrical energy on sailboats, they are most often used in combination with solar panels and the engine's alternator.

Wind generators may vary in appearance but they all have similar basic components.

The rotor includes the rotating blades, which are mounted on an axle coupled to an electric generator.

In most cases, the electric generator is an alternator, which generates alternating current. The driveshaft of the alternator turns permanent magnets inside a housing of electric coils. The alternating current generated in the coils is then rectified into direct current. In better generators, these coils are completely encapsulated to reduce corrosion.

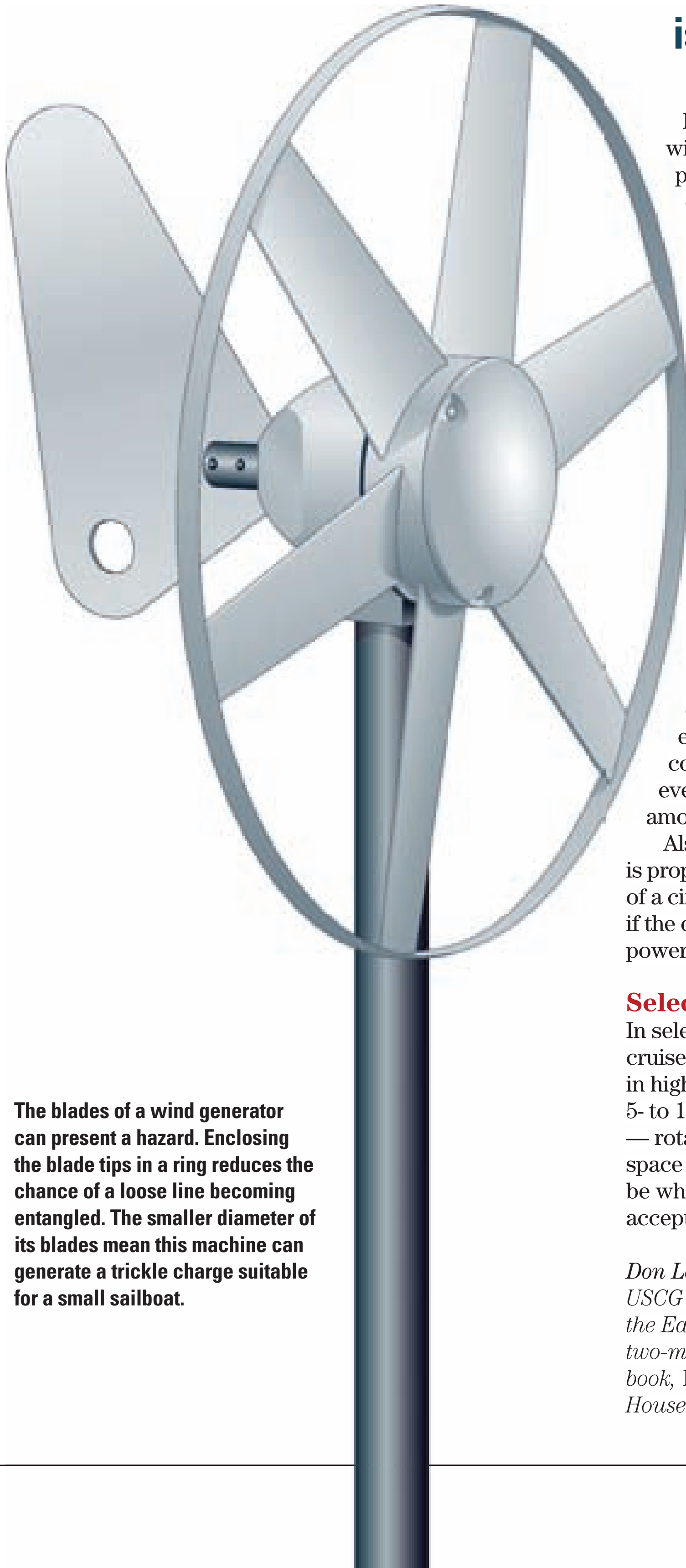
In many designs, the electrical current is transferred from the generator to the output cable via slip rings, a feature that allows the wind generator to rotate through a full 360 degrees to face the wind. Some wind generators don't use slip rings. As a result, on these models, the output cable can become wrapped around the support mast.

A few wind generators turn a motor-type generator that creates direct current. However, in such a generator, the commutator with its brushes and springs requires more maintenance, can be subject to corrosion, and is a potential source of electrical interference.

A wind generator needs a mounting tower and also must have a speed-control system. Some wind generators are also fitted with shutdown systems that, in the case of a component failure, will stop the blades from rotating and disconnect the output if it's too high or if the heat being generated is too great.

LAYOUT AND ILLUSTRATIONS BY TED TOLLEFSON

“If the wind speed doubles, the theoretical potential power available is eight times as great.”



The blades of a wind generator can present a hazard. Enclosing the blade tips in a ring reduces the chance of a loose line becoming entangled. The smaller diameter of its blades mean this machine can generate a trickle charge suitable for a small sailboat.

Multi-purpose generators exist that can be driven by wind blades or, with the wind blades removed, by a water propeller towed from the stern of the boat. In the right conditions, a water propeller may provide enough electricity while under sail to power an electric autopilot or an electronic navigation system.

The necessity: wind

The major problem with wind power is the intermittent nature of the wind, which varies greatly with location and time of day. Since the wind may come from any direction, the horizontal-axis wind generator must be able to rotate so it faces into the wind. This usually requires that a wind generator be mounted on a tower, a very sturdy pole or, in the case of very small units, hoisted on a halyard. These precautions keep the blades out of the way of wayward lines, hands, and heads. Some wind generators have an outside ring around the tips of the blades to reduce the possibility of fouling or injury.

The power available from the wind varies as the cube of the wind speed. Thus, if the wind speed doubles, the theoretical potential power available is eight times as great. If this energy can be efficiently converted by the wind generator, strong wind conditions, even for a brief time, can therefore supply a considerable amount of electricity.

Also, for horizontal-axis wind blades, the power generated is proportional to the area swept by the blades. Since the area of a circle is directly proportional to the square of its diameter, if the diameter of the blades is doubled, the theoretical electric power available is four times as great.

Selecting a wind generator

In selecting a wind generator, the primary interest for most cruisers should not be the highest current output available in high wind conditions but the current output in the normal 5- to 15-knot wind range. The physical size of the generator — rotating blades and all — as well as the available mounting space is also of prime importance. Other deciding factors will be whether the vibration and noise at high wind speeds are acceptable and the reputation of a device’s manufacturer.

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Travelers 101

Primary tools for controlling sail shape

by Don Launer

On a sailboat, the sheet that controls the mainsail boom can be adjusted through a block or blocks that are attached directly to the deck. A more common configuration is to connect the sheet to a traveler.

A traveler is a system in which a sheet block is attached to a car that runs along a track. The car's position can be adjusted, thereby providing a means to fine-tune the shape of the mainsail. A traveler is indispensable to the racing sailor and is also very useful to the cruising sailor who appreciates proper sail shape.

Travelers may be used on jibs and foresails but are seen most often on mainsails.

> "The traveler can be used to increase twist in the sail without changing its angle of attack."

Travelers and twist

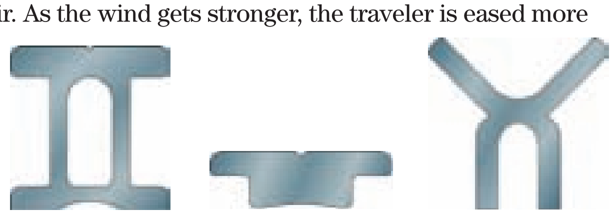
Both the traveler and the mainsheet control the position of the boom and the amount of twist in the mainsail, but the sail responds differently to these two controls.

On a beat or close reach, where the boom is well inboard, adjusting the mainsheet will always change both the horizontal and the vertical position of the boom end. Thus, easing the mainsheet will always reduce the angle of attack of the sail and also increase sail twist (see "Doing the twist" on page 20). The mainsail responds differently to the traveler. Easing the traveler will allow the boom to fall off to leeward, but the boom end will not rise, so the angle of attack of the sail will be reduced, but the twist will not increase.

The traveler can also be used to increase twist in the sail without changing its angle of attack. In light air, the traveler can be hauled more to windward while the mainsheet is eased. When the controls are used together in this way, the boom's horizontal angle is held constant but its end is allowed to rise, increasing twist.

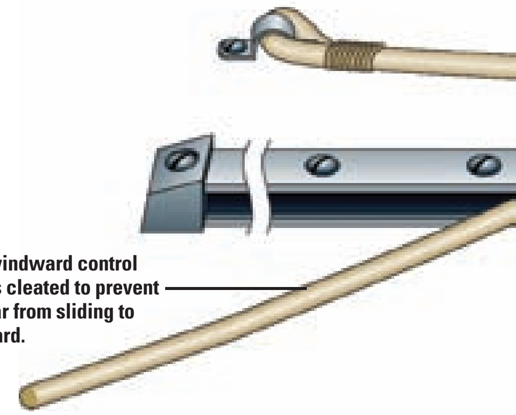
Usually, less twist is desired in the mainsail in heavier air. As the wind gets stronger, the traveler is eased more and more to leeward and the mainsheet tightened a corresponding amount. This effectively decreases the angle of attack and also decreases twist as the pull of the mainsheet becomes more vertical. This is the opposite of what happens if a mainsheet is used with no traveler.

When beating to windward, the car should be readjusted on each change of tack.



I-beam T-beam X-beam

Traveler tracks are made in a variety of cross-sectional shapes.



The windward control line is cleated to prevent the car from sliding to leeward.

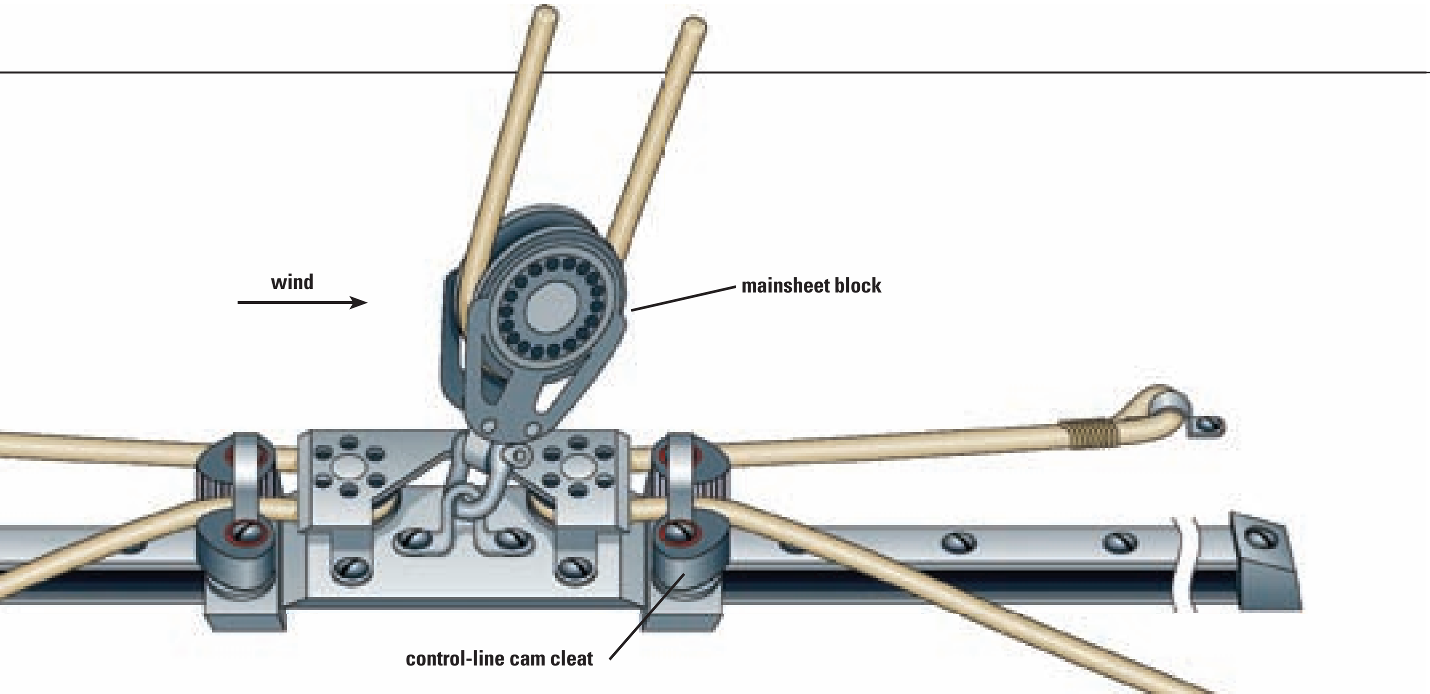
The old-style travelers used a T-track, sometimes with port and starboard adjustable stops and sometimes with a stop incorporated in the car, as here. The cars did not run on ball bearings and were difficult or even impossible to adjust when under load from the mainsheet. This type of track and car is not used in new mainsheet systems but is still used for adjusting the leads for headsails.

Traveler technology

Early travelers consisted of a simple T-shaped track with moveable stops, port and starboard, and a car with no ball bearings. These systems were inefficient because the car tended to bind under load and could not be moved easily.

In modern traveler systems, the car is adjusted athwartships by lines that can pull it to port or starboard. These lines are typically secured with cam cleats. Ball bearings in the car allow it to run smoothly along the track even under high tension. On small-boat travelers, these bearings are usually made of black or white Delrin. On large boats, where the loads are very high, the bearings in the cars are generally made of Torlon, which is greenish-brown.

Traveler tracks are manufactured in a variety of cross sections and each type and size of track must be matched



The traveler control lines can be configured in a great many ways. In this simple example, cam cleats for the port and starboard control lines are incorporated into the car.

LAYOUT AND ILLUSTRATIONS BY TED TOLLEFSON

with a specifically designed traveler car. The most common tracks come in T-, X-, or I-beam cross sections. The top of the cross section, which bears the upward load, must be sturdily constructed and, since the load on the track can be very heavy, the track must be strongly bolted in place with a backing plate to distribute the stress.

Tracks attached to the deck can be custom-bent to the shape of the deck contour; they may also be on bridges that span gaps or other deck gear.

A long traveler track allows the boom to be pulled down hard to remove twist even when it's quite far off center. The same length track used with a mid-boom mainsheet results in a greater range of control than one on an end-boom mainsheet. However, the mid-boom location also means the sheet, traveler, and boom will be more heavily loaded and more power will be required to trim the sail. The location of the sheet on the boom ultimately depends on the boat's design and purpose and can be anywhere from forward of the companionway to the end of the boom.

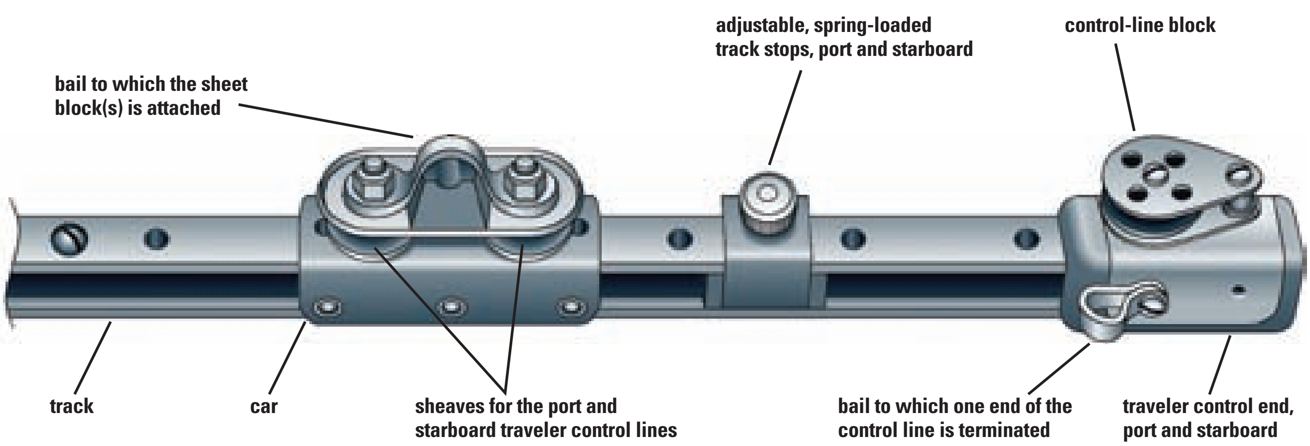
Traveler maintenance

Travelers with ball-bearing cars should never be sprayed with a lubricant. This can cause the ball bearings to slide instead of roll and they will wear unevenly. Some lubricants will attract dirt and dust and accelerate the deterioration of the ball bearings. Instead, the traveler track and car should be flushed frequently with fresh water, especially in a saltwater environment. It's also a good idea to occasionally squirt a solution of water and detergent into the car, run it back and forth on the track to distribute the solution, then flush it with fresh water.

If the car doesn't run smoothly on the track, inspect the track for corrosion. If the track doesn't show corrosion, it probably needs a good soap and freshwater cleaning.

Don Launer, a Good Old Boat *contributing editor, has held a USCG captain's license for more than 20 years and has sailed the East Coast from Canada to the Caribbean. His newest book is* The Galley: How Things Work.

Parts of a traveler

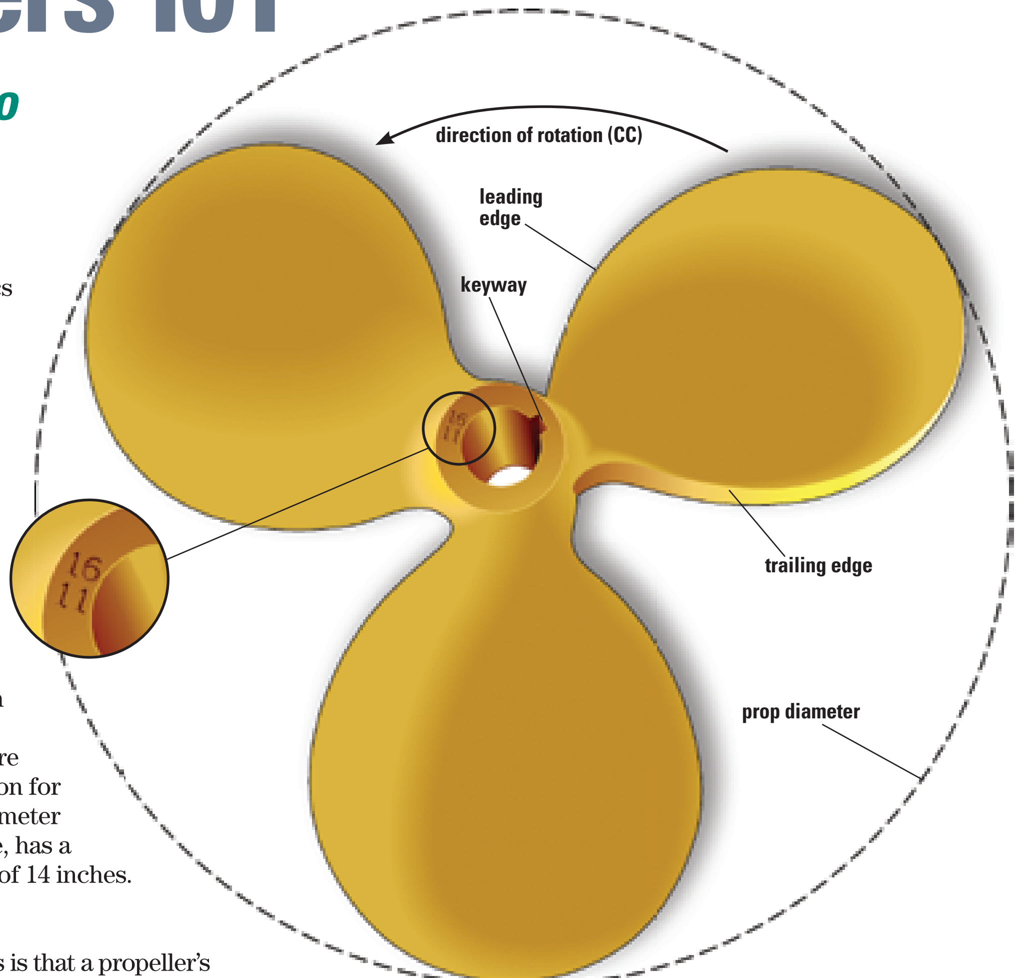


Propellers 101

Basic insights into how they work

by Don Launer

Much complicated mathematics lies behind the deceptively simple appearance of a boat's propeller, but it can be described and specified with a few simple numbers and terms.



Viewed from astern, this propeller rotates counterclockwise with the engine in forward gear, making it a left-handed prop. The numbers stamped on the hub indicate that it has a diameter of 16 inches and a pitch of 11 inches.

LAYOUT AND ILLUSTRATIONS BY TED TOLLEFSON

Diameter and pitch

The diameter of a propeller is the diameter of the circle described by the tips of its blades when it rotates.

The pitch of a propeller is the theoretical distance it would screw its way through a solid with each complete revolution.

In the U.S., these dimensions are stated in inches, and the convention for specifying a propeller lists the diameter first. A 16 x 14 propeller, therefore, has a diameter of 16 inches and a pitch of 14 inches.

Number of blades

This is obvious. What's not obvious is that a propeller's efficiency decreases as the number of blades increases. Although a two-bladed prop is more efficient, the two blades enter the disturbed water flowing either side of the boat's keel at the same time. On full-keeled boats, this often causes vibration or humming in parts of the boat. A prop with more blades provides smoother propulsion with less vibration.

A three-bladed prop is a good compromise for an auxiliary cruising sailboat with a full keel, since each of the blades enters this disturbed water at a different time. However, the three-bladed propeller will induce more drag under sail, whereas the two-bladed prop, when stopped and aligned vertically — at least on a full-keeled boat — is hidden by the keel, reducing its drag.

Shaft size

This is the diameter of the propeller shaft, exclusive of the tapered end to which the propeller is fitted.

Key and keyway

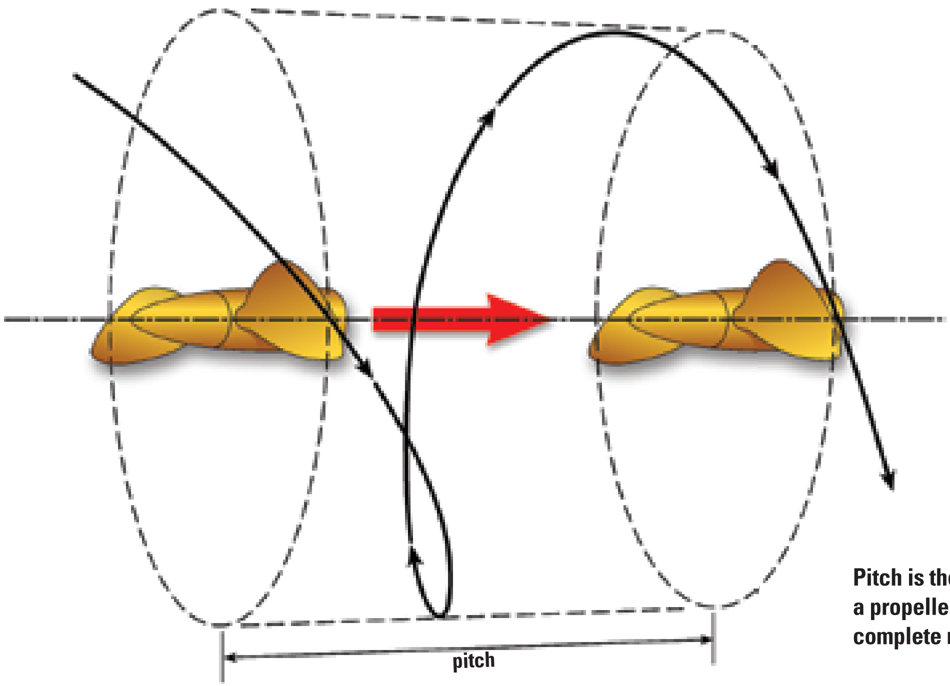
The keyway is a slot machined into the propeller shaft and into the hub of the propeller. A key fitted into the keyway prevents the propeller from turning on the shaft. This key usually has a square cross-section. In the U.S., the side of that square is designated in inches, so a ¼-inch key is used in a ¼-inch keyway.

Rotation

The direction in which a propeller rotates depends on the particular engine and transmission. If, with the engine in forward gear, the prop rotates clockwise when viewed from the stern, it is described as right-handed. If, with the engine in forward gear, the prop turns counterclockwise when viewed from the stern, it's left-handed. On a boat fitted with twin shafts and props, the props will generally rotate in opposite directions, so one prop will be a right-handed prop and other a left-handed prop. Because of their opposite pitches, the props cannot be interchanged.

Thickness

Ideally, propeller blades should be as thin as possible, since more power is wasted turning a thicker blade. As an example, because stainless steel is about five times stronger than aluminum, a prop made of stainless steel can have thinner blades than one made of aluminum, and will therefore be more efficient.



Pitch is the theoretical distance a propeller would travel in one complete revolution.

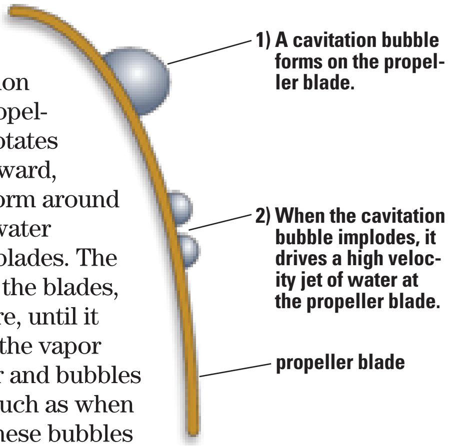
Slip

When propelling a boat, a propeller, because it's working in a fluid and not a solid, actually moves forward a lesser distance per revolution than its manufactured pitch. Thus a prop listed as having a 14-inch pitch, may only move the boat forward 7 inches for each revolution. The difference between the theoretical pitch and the actual forward movement is termed slip. Many factors contribute to slip, including hull resistance, wind and wave conditions, and the weight of the boat.

Thrust

The propeller propels the boat forward by generating thrust, which in the U.S. is measured in pounds. The propeller on the typical auxiliary creates thrust in the neighborhood of 8 pounds per square inch (psi) of blade area. The power used by the propeller's blades to create thrust is provided by the engine. A typical propeller only converts about 50 percent of the engine's power into thrust.

Cavitation



Cavitation is an unwanted phenomenon that accompanies propellers. As a propeller rotates and drives a boat forward, low-pressure areas form around the propeller as the water accelerates past the blades. The faster the rotation of the blades, the lower the pressure, until it becomes lower than the vapor pressure of the water and bubbles of gas are formed (much as when water boils). When these bubbles subsequently collapse under the higher pressure of the surrounding water, they do so violently, creating high-pressure implosions and microscopic high temperatures (thousands of degrees). When the bubbles implode on the surface of a propeller they create explosive noise. What's more, these implosions and instantaneous microscopic high temperatures also cause pitting of the propeller's surface. This pitting is higher on propellers made of softer metals. Cavitational pitting can dramatically shorten a propeller's efficiency and life.

Propeller variants

Folding or feathering propellers and variable-pitch propellers address the problem of drag when sailing. Racing sailors often choose folding props because they are thought to cause the lowest drag. Their drawback is that they do not work in reverse as well as other designs. Feathering propellers create a little more drag than folding propellers but have excellent thrust in reverse. Variable-pitch propellers have about the same drag as feathering propellers but adjust their pitch automatically to maximize efficiency. These propellers have been found to maintain higher efficiency over a wide range of boat speed and engine loading.

Propeller selection

Choosing a propeller's specifications is a complicated process. In general, you want to start with the largest diameter that will allow adequate clearance between the blade tips and the hull or aperture, use the smallest number of blades that will do the job, and choose the pitch last. *(**Note:** See articles in* Good Old Boat *by Aussie Bray, March 2003, and Rebecca Burg, March 2008. **–Eds.**)* You can also find guidance in selecting a prop in books and through programs on the Internet.

Don Launer, a Good Old Boat *contributing editor, has held a USCG captain's license for more than 20 years and has sailed the East Coast from Canada to the Caribbean. He built his two-masted schooner,* Delphinus, *from a bare hull. His newest book is* The Galley: How Things Work.

Lifelines 101

Ensure your first line of safety really is safe

by Don Launer

Lifelines are designed to reduce the chances of your going overboard. On many boats, however, these systems are poorly designed and installed and receive little maintenance. They're the most overlooked and least inspected hardware on deck.

The lifeline system consists of the lifelines themselves, terminal fittings, stanchions, stanchion bases, and the bow and stern pulpits or deck pad-eyes to which the lifelines connect.

Lifeline material

Lifelines on cruising boats are most commonly made of 1 x 19 wire rope (the same type used for standing rigging) covered by a vinyl coating, although you might find 7 x 7 or 7 x 19 wire rope in some installations. The wire inside the vinyl coating is usually 302/304 stainless steel. Although vinyl-coated stainless-steel wire looks and feels nice, the coating can foster corrosion in the wire by trapping moisture inside and eliminating the oxygen that keeps stainless steel stainless. What's more, the coating hides the corrosion.

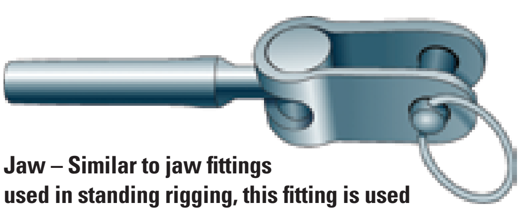
To be on the safe side, saltwater sailors should replace vinyl-coated lifelines every five years. When doing so, it is far better to use a larger-diameter uncoated wire as it will be stronger, last longer, and simplify inspection. For uncoated lifelines, 302 or 304 stainless steel offers adequate corrosion resistance. For a brighter, less corrosion-prone lifeline, 316 is a good choice, but it is considerably more expensive. Also, it is not quite as strong as 302/304 stainless steel, so an increase in diameter is indicated.

Swaged and swageless fittings

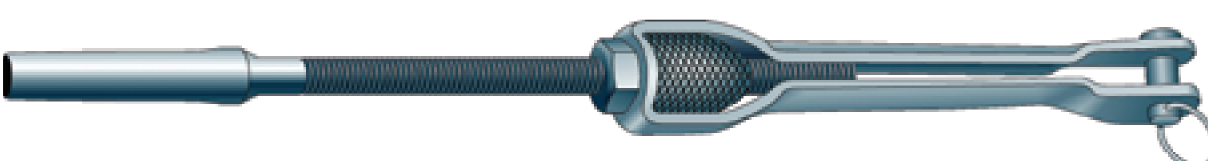
Swaged fittings, such as those used on the standing rigging of most sailboats, are pressed onto wire rope by machine and make a strong terminal connection. Many sailboat lifelines have terminal fittings that are similar in appearance to machine-swaged fittings but are in fact hand-crimped onto the wire rope with a special tool.

Inspect your fittings to see what type they are. The sleeves of hand-crimped fittings have thinner walls than those of machine-swaged fittings and are longer. They are usually crimped in three places, leaving three indentations on the sleeve. A swaging machine, on the other hand, presses the sleeve uniformly along its entire length.

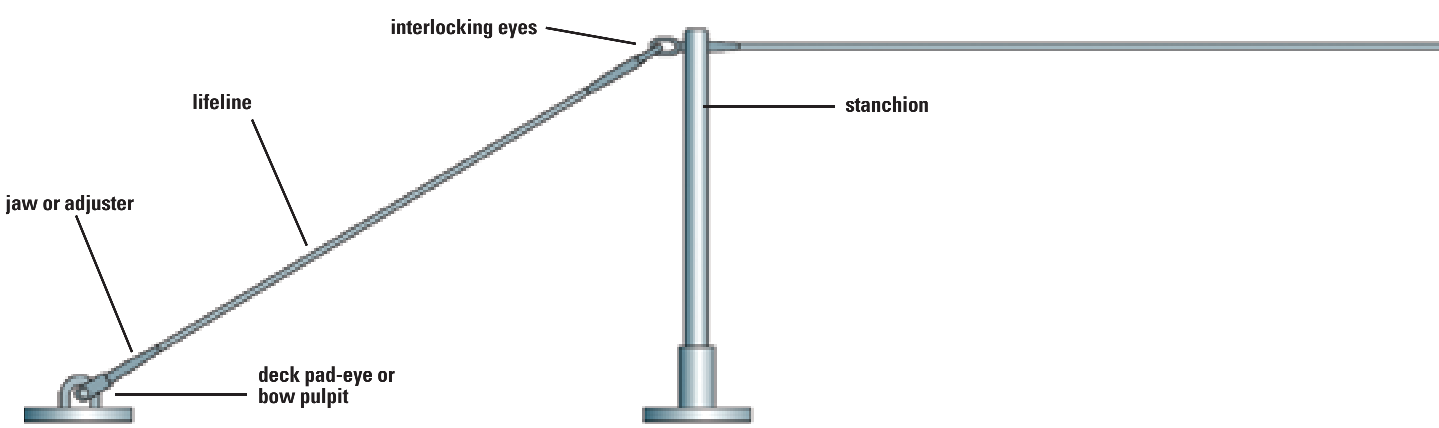
Due to their lesser strength, hand-crimped fittings should *not* be used in high-load applications, such as standing rigging, and I have strong reservations about using them for lifelines also.



Jaw – Similar to jaw fittings used in standing rigging, this fitting is used to connect a lifeline to a bail on a pulpit or stanchion. It may be combined with an adjuster.



Adjuster – This is a terminal wire fitting that allows lifeline tension to be adjusted.



LAYOUT AND ILLUSTRATIONS BY TED TOLLEFSON

“The stanchions that support the lifelines must be very strong and their bases must be very securely fastened to the deck.”

Swageless fittings have become the standard standing-rigging fitting on world cruisers because of their higher strength and greater longevity than swaged fittings and because they can be reused. They are now available in all the terminal configurations used in lifeline systems and offer the do-it-yourselfer a means of creating a stronger lifeline system when the time comes to replace the old lifelines. Swageless terminals are easy to assemble using simple hand tools.

Lifeline height

Currently, the minimum height for lifelines recommended by the American Boat & Yacht Council (ABYC) is 24 inches, but there is an industry move to raise that to 28 inches. If the height is greater than 24 inches, ABYC recommends a second lifeline be fitted at mid-height. This may prevent an adult from rolling underneath but will not stop children or pets from going overboard; for them, it’s necessary to install lifeline netting to fill the gap. The Offshore Racing Council (ORC) requires a minimum height of 24 inches and double lifelines on sailboats over 28 feet in length.

Stanchions and bases

The stanchions that support the lifelines must be very strong and their bases must be very securely fastened to the deck. The higher the stanchion, the stronger it and its base need to be to withstand the longer lever action created by a load on the upper lifeline.

To distribute this load, stanchion bases must be through-bolted to large backing plates. These backing plates are normally 1/8-inch stainless steel or aluminum or 3/16- to 1/4-inch fiberglass. On sandwich decks, the core material should be dug out and replaced with epoxy to prevent the deck from being crushed.

The combination of a stainless-steel stanchion and an aluminum base is a disaster waiting to happen because the initial strength of the base is less and the inevitable corrosion between the dissimilar metals will lead to early failure.

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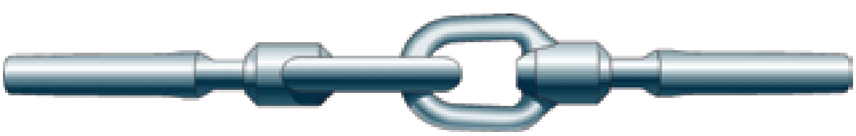
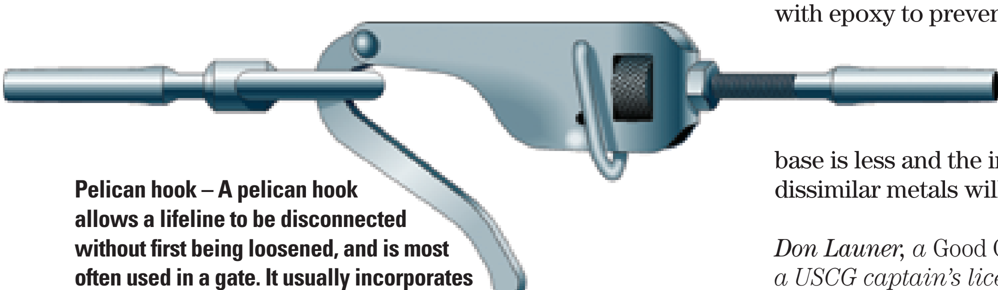
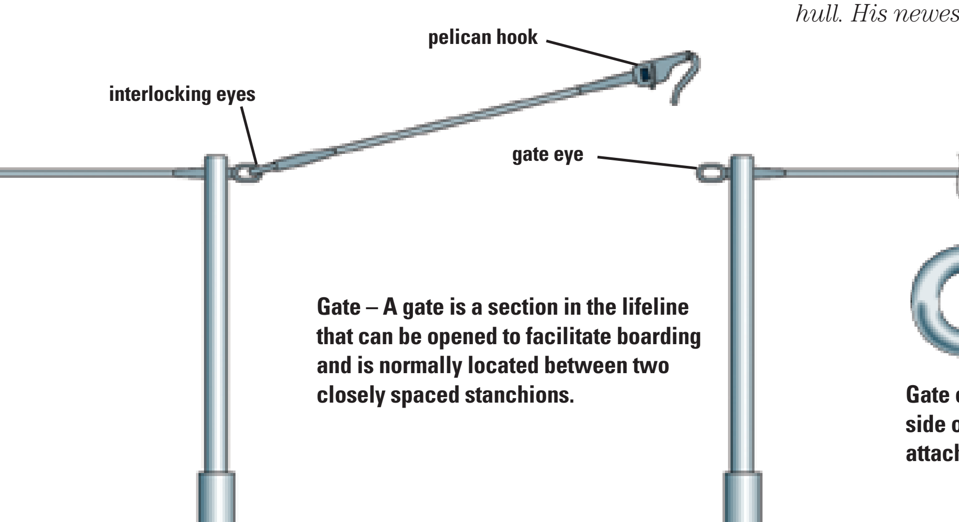


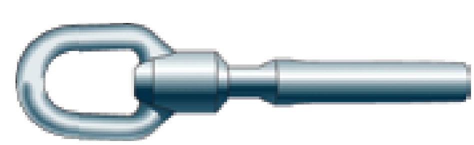
Interlocking eyes – These eyes are used wherever a lifeline makes a sharp bend and at the opposite side of the gate from the pelican hook.



Pelican hook – A pelican hook allows a lifeline to be disconnected without first being loosened, and is most often used in a gate. It usually incorporates a lifeline tension adjuster and locknut.



Gate – A gate is a section in the lifeline that can be opened to facilitate boarding and is normally located between two closely spaced stanchions.

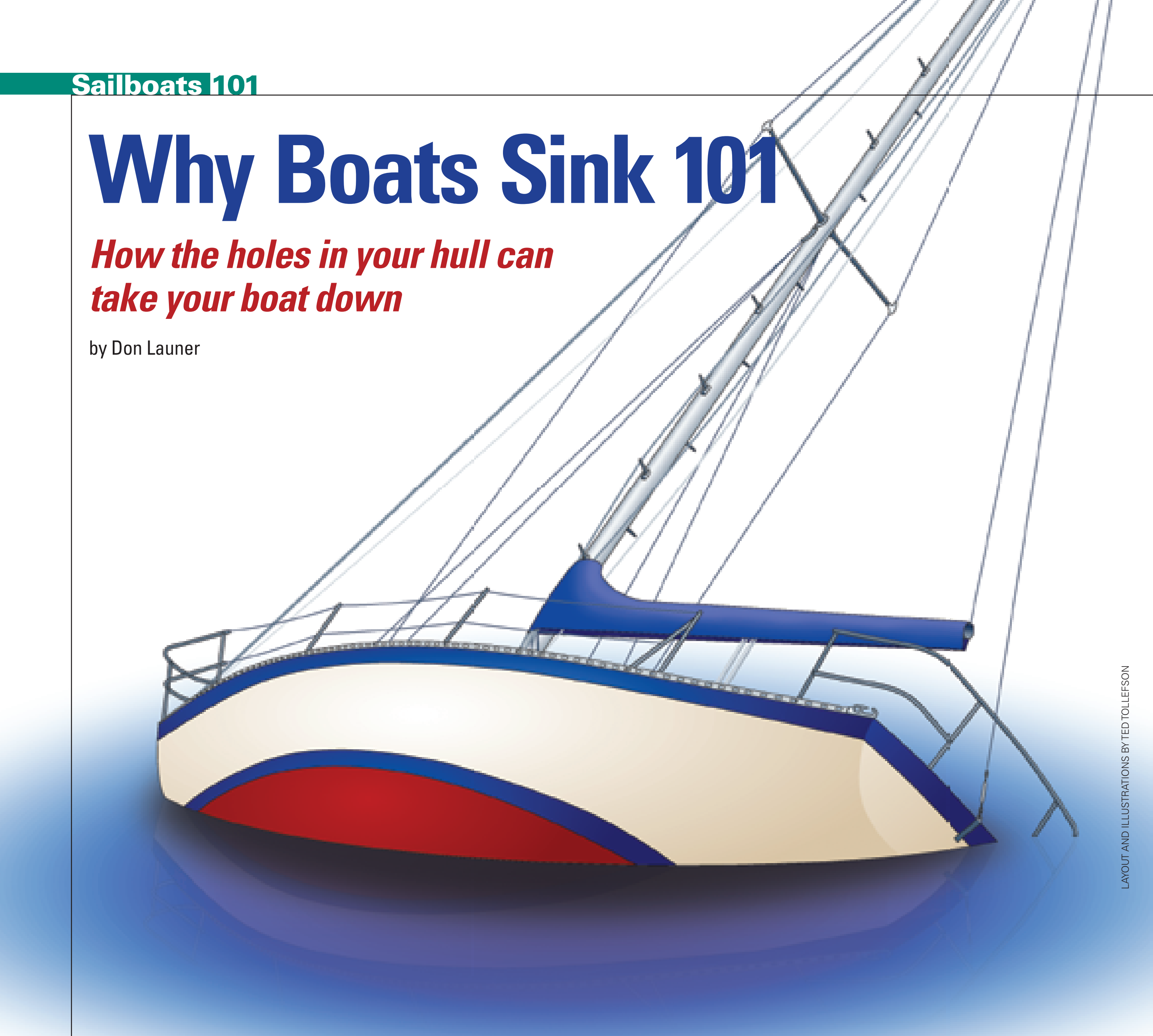


Gate eye – This terminal fitting is used on the side of a gate to which the pelican hook is attached. It can be a fixed eye or a swivel.

Why Boats Sink 101

How the holes in your hull can take your boat down

by Don Launer



LAYOUT AND ILLUSTRATIONS BY TED TOLLEFSON

Although fiberglass, steel, and aluminum are not naturally buoyant, they can be fabricated into a shape like a boat hull that will float . . . until it's punctured. In spite of that truth, we deliberately puncture our hulls to install raw-water intakes (for heads and engines) and discharges (for the same heads and engines plus galley sinks, cockpit drains, and more).

The legendary naval architect L. Francis Herreshoff thought putting holes in the bottom of a boat was such a bad idea that he advocated the use of a cedar bucket instead of a plumbed marine head.

Don't bet on the bilge pump

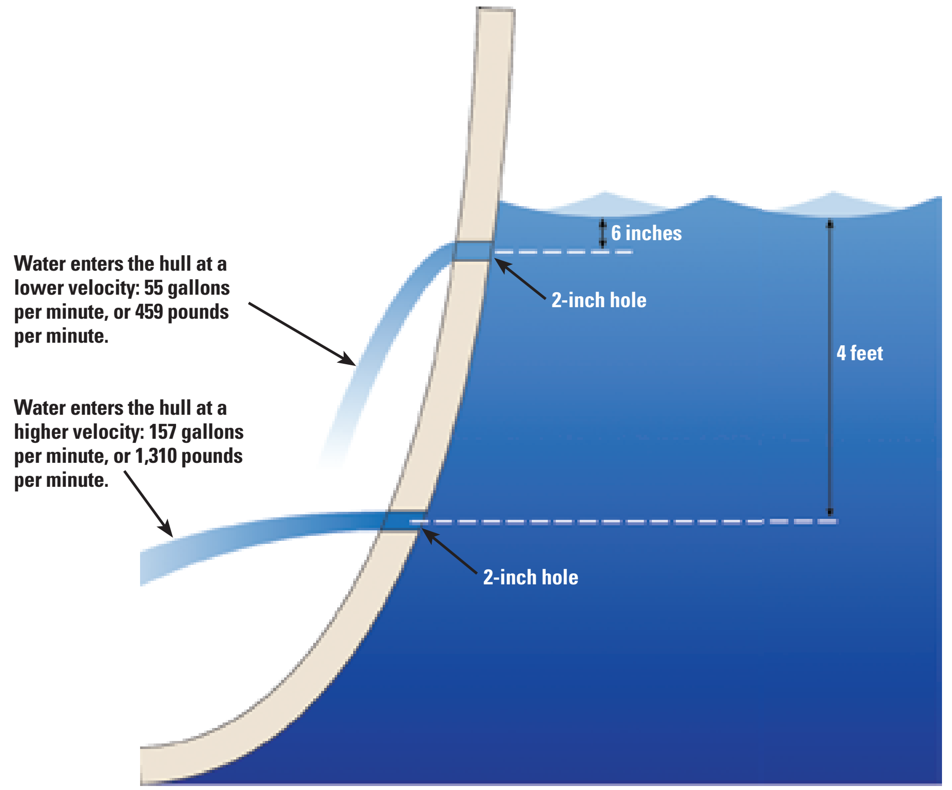
Some small boats, such as center-console outboards, have double hulls filled with foam to make them buoyant even when swamped. But larger boats (and most sailboat hulls) will not float after the hull has been punctured unless the bilge pumps can keep up with the leak.

It would be nice to think your bilge pump *could* handle the task, but a 1-inch hole 2 feet below water level will allow water into the hull at a rate of 28 gallons per minute. That's 1,680 gallons per hour — 14,000 pounds. Doubling the diameter of the hole quadruples the flow, since the area of a hole is proportional to the square of its diameter.

As weight is added to the boat it will settle lower in the water and the flooding rate will increase.

Can the average boat's bilge pump handle this? Only if it's very large *and* the battery remains charged *and* the automatic bilgewater-level switch works properly *and* the bilge pump's switch is in the automatic position *and* the pump is wired directly to the battery rather than through a battery-selector switch that *might* be turned *off*.

It's also sobering to realize that the gallons-per-hour (gph) rating of your bilge pump is not at all realistic, since that figure is determined by how many gallons it will pump with zero "head" (the distance it must raise the water). Friction



Under the laws of hydrodynamics (the study of liquids in motion), the velocity at which water flows through a hole is equal to the velocity that a falling object would have if it fell through a distance equal to the distance the hole is below the surface of the water. Given that and the hole's diameter, it's possible to calculate the rate of flow through the hole.

in the pump's hose adds to the head, with the result that the effective head decreases the actual rate at which the pump will operate to about 40 percent of its quoted rating.

Where is the leak?

The location of the leak very often determines whether a boat can be saved or is doomed. Is it at a point in the hull that cannot be reached? At what depth below the waterline is the leak? The farther below the waterline, the faster water will come into the boat and the more difficult it will be to stem the flow. Whenever possible, any through-hull added below a boat's waterline should be as close to the surface as is practical for the particular application.

Sinkings by the numbers

Bob Adriance, editor of the BoatU.S. publication *Seaworthy*, describes some of the common causes of sinking as: leaks at through-hulls and hoses (18 percent); leaks in the engine's cooling system (12 percent); damage due to grounding (10 percent); and striking a submerged object (4 percent).

Failure to close through-hulls is a major cause of winter-related sinkings. Many of these sinkings are caused by ice lifting the hose off the through-hull. Most of these off-season sinkings could be prevented if the hoses were fastened to the through-hull fittings with two opposed all-stainless-steel hose clamps or, better yet, if the through-hull seacocks are closed.

Many boats also sink at the dock due to leaky stuffing boxes. On most sailboats, unfortunately, stuffing boxes are difficult to reach and don't get inspected or adjusted regularly. Inspecting for deteriorated hoses and broken raw-water strainers is also often difficult. Water left in a strainer over the winter can freeze and crack the strainer's glass and the damage can go unnoticed during spring commissioning.

Another cause of sinking is water siphoning back into a marine toilet located below the waterline and connected for direct discharge (which is only legal well offshore). Frequently, this is caused by the air-valve at the top of a vented loop becoming corroded so it cannot open and break the back-siphon. To prevent the head discharge from coming in contact with the air valve and causing corrosion, it's a good idea to mount the air valve at the end of a short tube and screw the tube into the vent fitting on the loop.

A damage-control kit

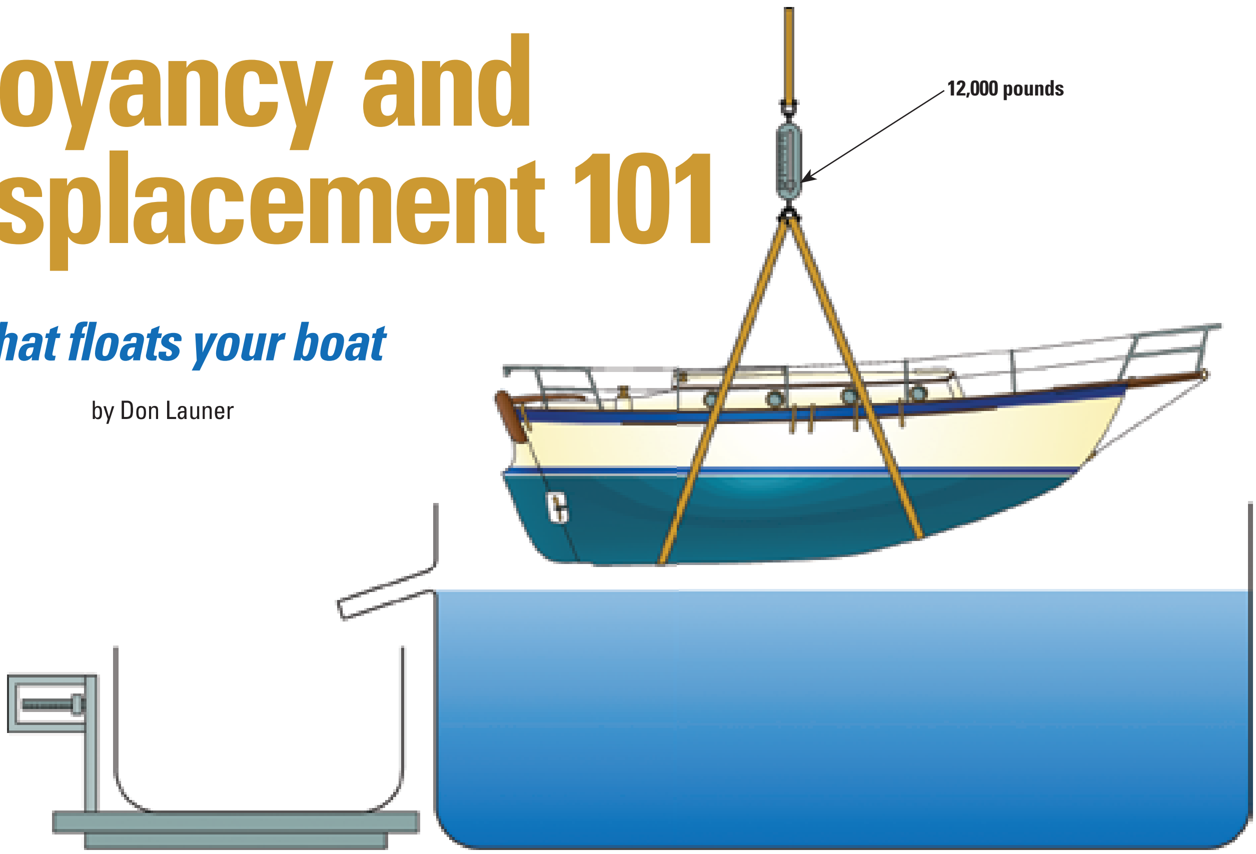
Since the United States Coast Guard does not have any regulations concerning the equipment that should be on board to prevent flooding and sinking, it's up to individual boatowners to create their own damage-control kits. A good starter collection for this bag should include a selection of tapered softwood plugs that can be pounded into place and a mallet with which to pound them; rubber balls in various sizes; small sheets of flexible metal, along with pieces of wood of different lengths for wedging them in place; and underwater two-part epoxy putty.

Don Launer, a Good Old Boat *contributing editor, has held a USCG captain's license for more than 33 years and has sailed the East Coast from Canada to the Caribbean. He has been a lifelong student of the history and arts of navigation and frequently gives talks on the subject.*

Buoyancy and Displacement 101

What floats your boat

by Don Launer



Boats are designed to float. This might seem to be an unnatural act, especially for hulls that are made of aluminum, steel, concrete, or fiberglass. These materials are denser than water and might be expected to sink. Even wooden boats, loaded with gear, ballast, an auxiliary engine, and miscellaneous equipment would head for Davey Jones' locker if it weren't for a physical force that causes buoyancy.

In physics, buoyancy is defined as the upward force on an object exerted by the surrounding liquid or gas in which it is fully or partially immersed.

A solid object will sink in a fluid if its density is greater than the fluid's density, and it will float if its density is less. Both the floating object and the submerged object experience a buoyant force. In the case of the floating object, the buoyant force is equal to that object's weight.

We don't ponder this phenomenon often, but why do boats made of materials denser than water float?

If material that is denser than water is formed into a shape — ceramic into a bowl or steel into a ship — with an aggregate density less than that of water, it will float in water. As long as a sufficient proportion of the vessel (bowl or ship) below the surface of the water is less dense than water, then the effective aggregate density of the entire vessel can be less than that of water, regardless of the material of which it's made.

Archimedes' principle

Archimedes' principle is named after Archimedes of Syracuse, Sicily, (287-212 B.C.) who discovered this law of physics while taking a bath. He subsequently published a two-volume work, *On Floating Objects*, in which he stated the law named for him:

> *Any object wholly or partly immersed in a fluid is buoyed up by a force equal to the weight of the fluid displaced by the object.*

But what does this mean to sailors? Well, the word "displaced" should ring a bell.

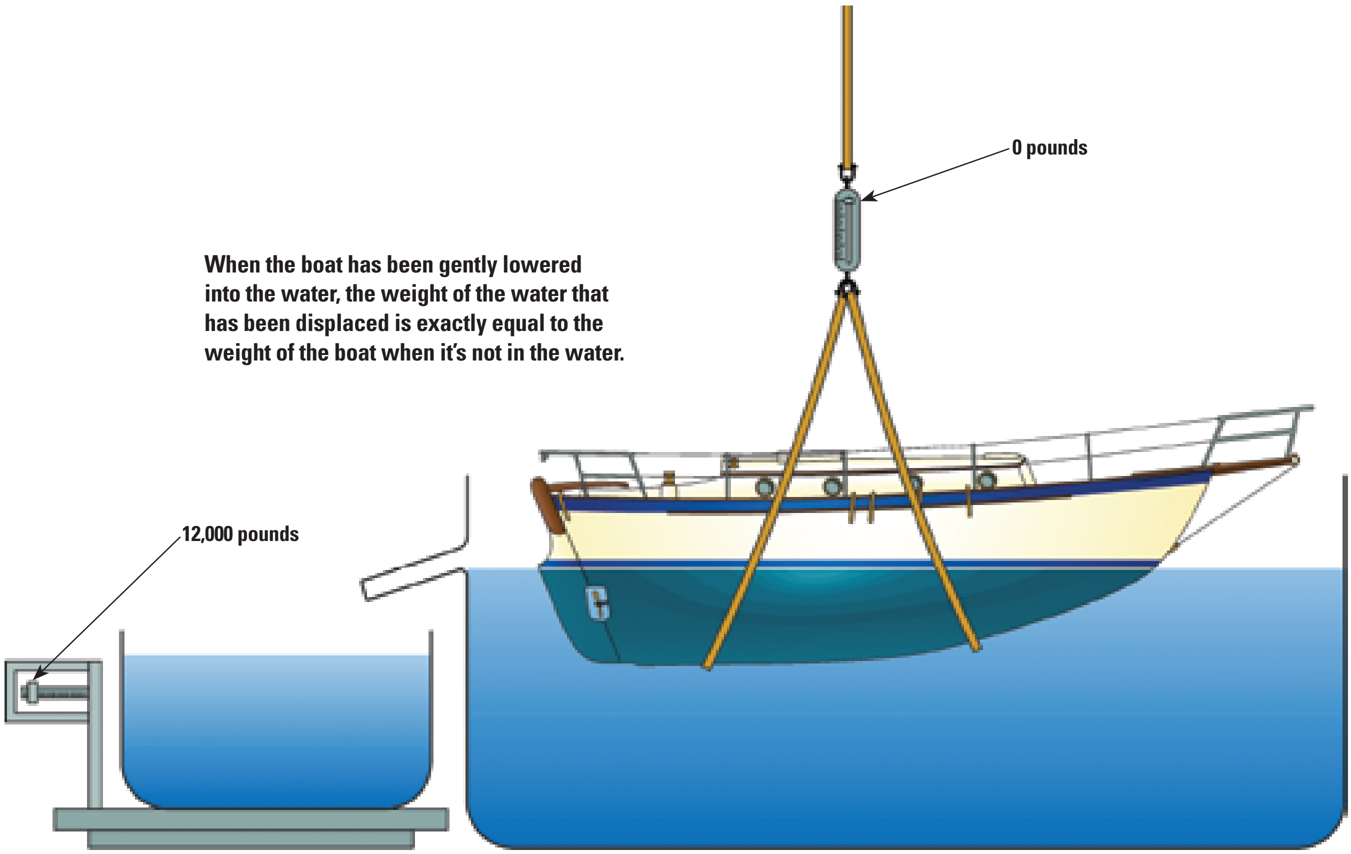
Displacement

The buoyancy of a boat is locked in tightly with its displacement.

In the illustration above, our test hull is being lowered into a tank of water. As the boat is lowered, water will be displaced and will overflow into the weighing tank until the boat is floating, on facing page. When we weigh the displaced water in the weighing tank, we'll see that its weight is exactly equal to that of the boat when it was suspended above the tank. The displacement weight (the weight of the water) is the boat's weight, just as Archimedes said.

In the U.S., this displacement may be expressed in pounds, in long tons (2,240 pounds), or in cubic feet of water (35 cubic feet of seawater at 64 pounds per cubic foot equals one long ton).

Let's perform another test with our boat (but don't try this at home!). We'll fill our test boat with concrete. Now the boat's hull will be denser than water and will sink (as we would expect). But it still experiences buoyancy; the boat weighs less submerged than it did when suspended in the air. And, lo and behold, if we weigh the displaced water in the weighing tank, we will find that its weight exactly equals the weight the boat has lost when submerged. Once again, Archimedes hit the nail on the head.



LAYOUT AND ILLUSTRATIONS BY TED TOLLEFSON

Buoyancy and displacement work equally well in fresh or salt water but, because fresh water is less dense than salt water, the boat will have to sink lower in fresh water than in salt water for the weight of the displaced water to equal the boat's weight. So, a boat on one of the Great Lakes floats deeper in the water than it would if it were equipped identically and heading for Hawaii.

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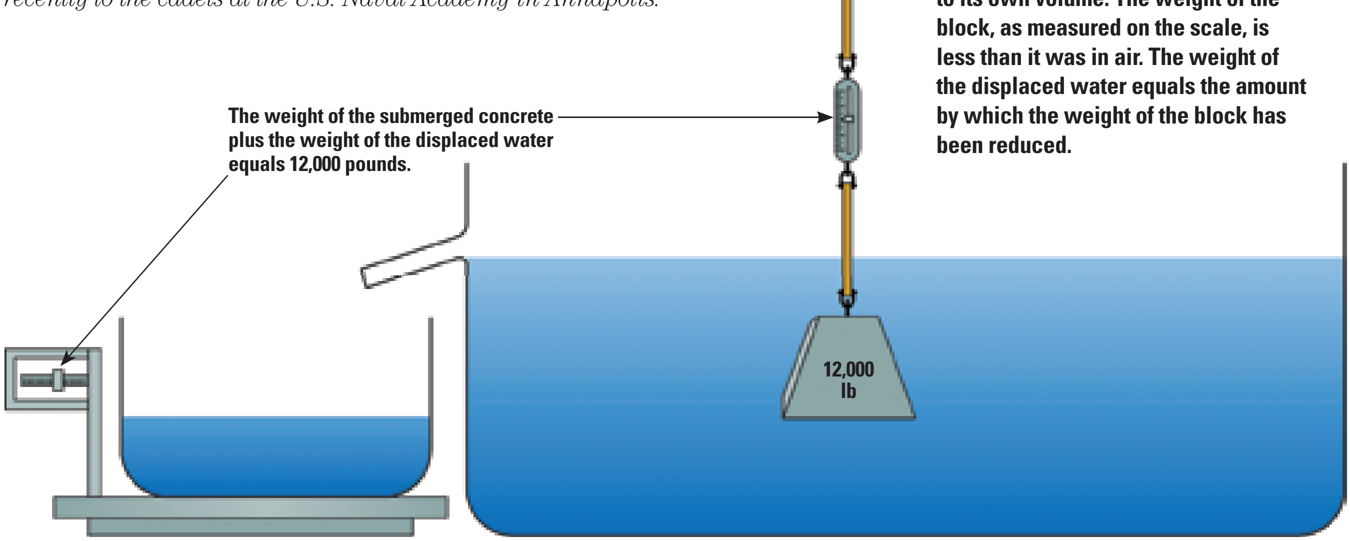
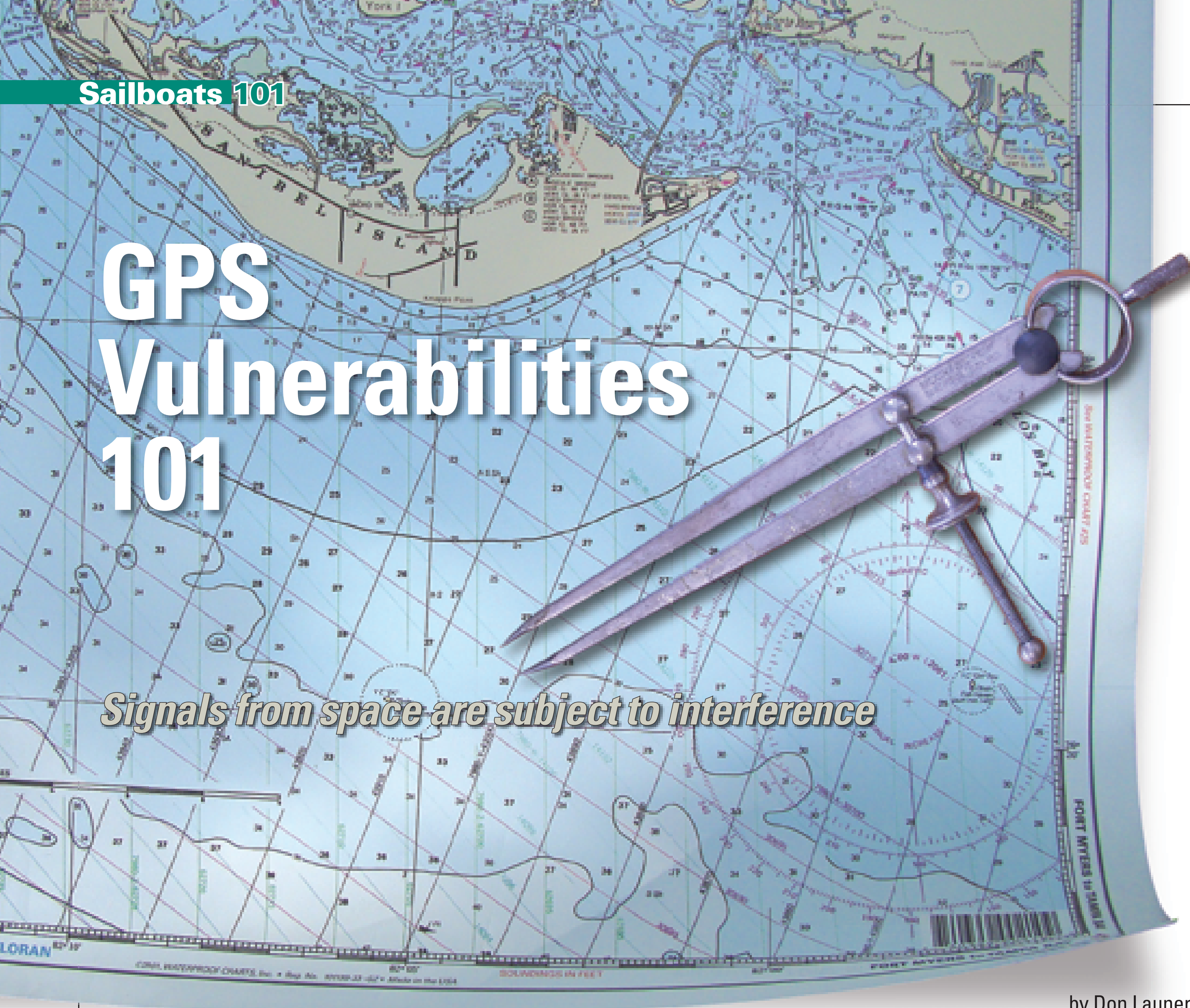
If we submerge a block of concrete, which is denser than water, it displaces a volume of water equal to its own volume. The weight of the block, as measured on the scale, is less than it was in air. The weight of the displaced water equals the amount by which the weight of the block has been reduced.





GPS Vulnerabilities 101

Signals from space are subject to interference

LAYOUT AND ILLUSTRATIONS BY TED TOLLEFSON

by Don Launer

The satellite-based Global Positioning System (GPS) provides very accurate navigational information, but everyone who uses it should be aware that it has vulnerabilities. These include susceptibility to radiation caused by solar storms, sunspots, and solar flares and to human interference by hacking and jamming. Individual satellites occasionally malfunction and some older GPS receivers have compatability problems when newer satellites with more modern programs are inserted into orbit. Users of GPS receivers can also introduce errors that result in inaccurate data being displayed.

Solar interference

Earth's magnetic field protects its surface from most of the harmful radiation emanating from the sun, but GPS satellites orbit thousands of miles beyond it where they are exposed to the solar wind — protons and electrons streaming from the sun at close to the speed of light. They are also vulnerable to the the sun's magnetic storms, a powerful one of which could disrupt, or even wipe out, the electric power-grid systems on earth.

During periods of increased sunspot activity, the solar wind can become so intense as to disrupt a satellite's signals. If the solar event is too violent, control stations on the ground can shut down the satellites to protect them from damage.

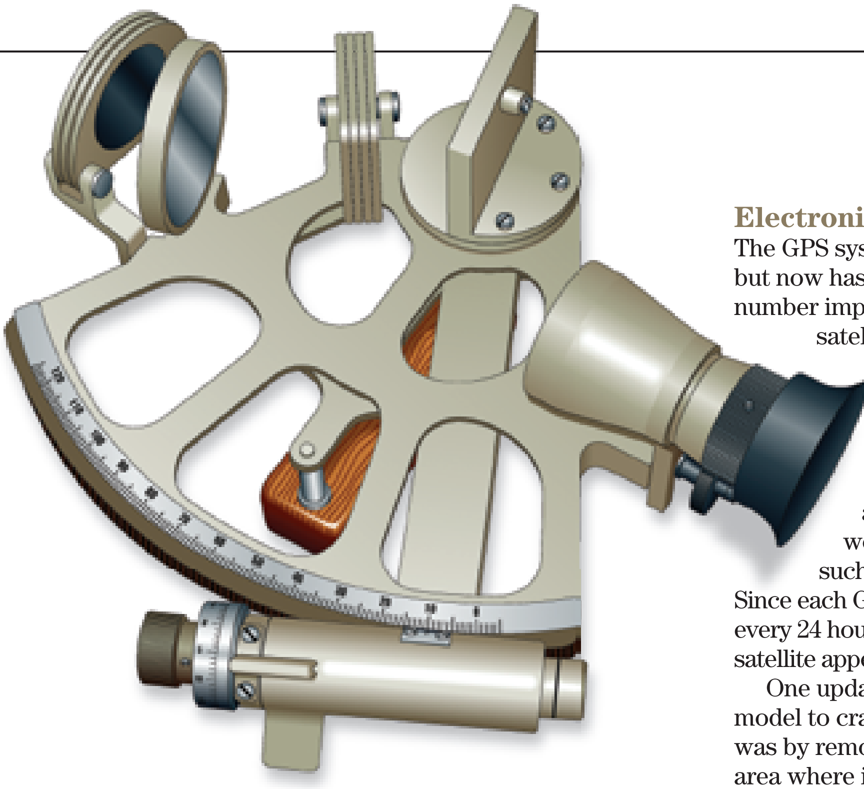
Solar flares are fierce explosions on the sun that release enormous amounts of energy. They emit radiation across the entire electromagnetic spectrum that can seriously affect radio communications on earth as well as GPS satellites. When the sun is active, at the height of the 11-year sunspot cycle, several solar flares may be erupting simultaneously; when it's quiet, a week may go by without a single one. One solar storm wiped out GPS reception on the sunny side of the earth for 14 hours, and many shorter failures have been caused by solar activity.

The 11-year sunspot cycle will peak during 2011 and GPS failures are expected to increase.

Terrestrial jamming

The signal strength of a GPS radio wave is extremely small — one ten-billionth that of a cell phone signal. This makes the GPS signal very vulnerable to jamming.

Unintentional jamming can occur if a signal or noise masks the GPS signal. Not long ago, it was discovered that a popular brand of onboard TV antenna emitted a signal that could wipe out GPS reception for boats within a half-mile radius.



Even while the sun is disrupting GPS, you can still find your position from it if you have a sextant.

Governments unfriendly to the U.S. have systems that can be used to intentionally jam signals. U.S. military testing can also disrupt GPS. Furthermore, a hacker using a simple one-watt jammer can wipe out GPS reception for thousands of square miles, as happened during the 1997 Moscow air show.

GPS receivers may not be equipped to sense or indicate when the signal is being jammed and may continue to display a position, but one that is wildly inaccurate.

Not only does your compass tell you where you are heading, you can also use it to take bearings to establish your position.

Electronic anomalies

The GPS system was originally created with 24 satellites but now has more than 32 in operation. The greater number improves accuracy and availability, but the new satellites inserted into the GPS constellation can cause problems with receivers.

Several models of GPS receiver give erroneous readings when they see more than the original 24 satellites. They show a speed over the ground (SOG) of up to 800 knots and produce random erroneous fixes. If a boat were being steered by an autopilot that accessed such a GPS receiver, the result could be disastrous. Since each GPS satellite is above the horizon for about 8 of every 24 hours, the error introduced by a high-numbered satellite appeared to be intermittent.

One updated WAAS satellite caused a popular GPS model to crash. The only way it could be turned back on was by removing the battery, moving the device into an area where it could not access a WAAS signal, reinserting the battery, and reprogramming the GPS.

Recently, aircraft and ships in the North Atlantic found that GPS was placing them about 75 miles from where they thought they were. This was due to an atomic clock failure in a GPS satellite. The offending satellite was finally shut down by the ground control station.

The need for reliable backup aboard was dramatically illustrated on July 17, 2004, when all units of a particular model of GPS chartplotter crashed simultaneously. Engineers at the parent company were stumped. It took a month to solve the problem and every affected unit had to be returned for an upgrade. Boaters using this particular chartplotter who had no other backup system were forced to go back to basics.

User errors

Most GPS users are unaware that a hundred or more different chart datums are available within a GPS receiver. Most units default to the geodetic datum WGS84/NAD83, which is the datum used for all current U.S. charts. However, when navigating in foreign waters and using foreign charts, be sure to set your GPS to the datum to which the chart is referenced. If you don't, your indicated position could be miles off.

Carry alternatives

Because of the very real potential for loss of GPS signals due to solar activity, jamming, or electronic problems, every sailor should have one or more alternative ways of navigating.

Don Launer, a Good Old Boat *contributing editor, has held a USCG captain's license for more than 33 years and has sailed the East Coast from Canada to the Caribbean. In recognition of his lifetime achievements as a sailor, and as an author and lecturer on maritime topics, he was recently inducted into the Barnegat Bay Sailing Hall of Fame.*

Displacement Hull Speed 101

As fast as physics allows

by Don Launer

Although it's somewhat of a misnomer, the term "displacement hull" is used in reference to a boat whose displacement at speed is the same as its displacement at rest. All hulls displace their own weight at rest (see "Buoyancy and Displacement 101," September), but some hulls, when driven fast enough, are able to climb up and plane on the surface of the water. These hulls, called planing hulls, displace considerably less water when at speed than at rest. The loss in buoyancy is made up for by dynamic lift. Most large monohull sailboats have displacement hulls.

Making waves

When a boat travels through the water, it creates a wave that moves at the same speed as the boat. There is a direct relationship between the speed of a wave and the length of that wave. (In fluids, the length of a wave, its wavelength, is usually, but not necessarily, measured from crest to crest.) The faster the speed of a wave, the longer its length. As an example, a tsunami wave often will travel in the open ocean at speeds of hundreds of miles per hour. The wavelength (from crest to crest) is also very long — 20 miles or more — which explains why boats in open water don't notice when a tsunami wave passes beneath them. (For the purposes of this discussion we will ignore how very shallow water and variations in the density of water affect the behavior of waves.)

A boat moving slowly creates a slow-moving wave with a short wavelength. In calm seas, the resulting series of waves can be seen along the hull.

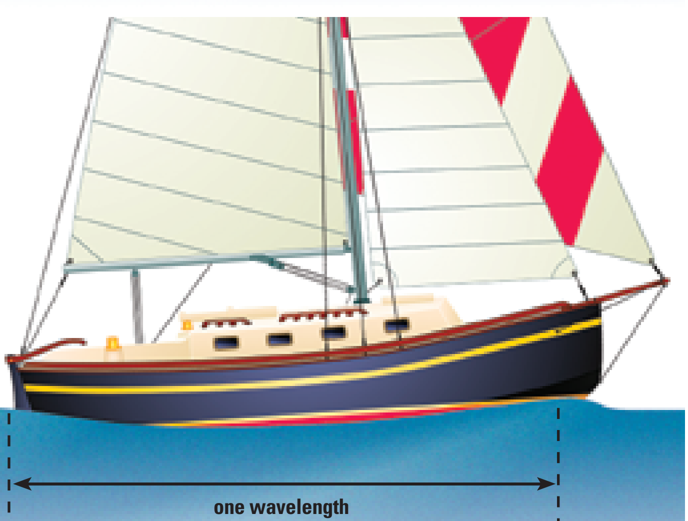
Speed limit

Because the length of a wave is proportional to its speed, as the boat moves faster, the wavelength becomes longer until the point arrives where the length of the wave that the boat is creating is the same as the length of the boat's waterline. If the boat tries to go faster than this, the wave it creates will be longer than the waterline of the boat.

At slow speeds, a boat creates a wave with a short wavelength.

LAYOUT AND ILLUSTRATIONS BY TED TOLLEFSON

As a boat increases its speed, the wave, too, travels faster and its wavelength is longer. When the wavelength reaches the length of the boat's waterline, the boat has reached its "displacement hull speed."



When a boat attempts to go faster than its displacement hull speed, it creates a faster wave with a wavelength longer than the boat's waterline. In effect, it is trying to go uphill on the face of the wave that it has created, resulting in the familiar squat of the stern.

> **"The top speed of a displacement hull is limited by the length of its waterline."**

We've all experienced the phenomenon when a boat "squats down" in the stern. This happens because the hull is in the trough of the wave it's creating while the bow is on the crest. The boat is now attempting to go uphill on the face of the wave it's creating. This holds true for all displacement hulls, whether they are a 30-foot sailboat or the QE2.

To make a heavy boat go uphill takes a tremendous amount of power — more than most displacement hulls have available — and to attempt to do so would be extremely wasteful of fuel for a negligible result. So effectively, the top speed of a displacement hull, often referred to as its "hull speed," is limited by the length of its waterline or, in other words, by the length of the wave it's creating.

Many of us have seen this condition when towing a dinghy. When the towing speed exceeds the dinghy's displacement hull speed, we see the dinghy squat down at the stern as its bow rises on the face of the wave it's creating. This puts great tension on the towline and considerably reduces the speed of the towing vessel.

Calculating hull speed

For most good old boats, hull speed can be calculated using the formula $S = 1.34\sqrt{L}$, where S is the hull speed in knots and L is the waterline length in feet. The number 1.34 is a constant. The number 1.4 would more accurately represent the speed of a wave whose length was L, but many naval architects use the lower number because the effects of achieving maximum hull speed are usually observed *before* the wavelength reaches L.

As the formula shows, maximum hull speed is proportional to the *square root* of the waterline length, which explains why a boat with a 40-foot waterline doesn't sail twice as fast as a boat with a 20-foot waterline.

Rule breakers

Waterline length is not the speed-limiting factor for all hulls. Long slender hulls, such as those of multihulls, incur relatively low wave drag (drag due to creating waves) compared to the wetted-surface drag, or viscous drag. The notion of limited hull speed does not apply to these hulls.

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Watermakers 101

Pressing pure water out of the sea

by Don Launer

Osmosis is a natural process in which molecules of a liquid spontaneously pass through a semi-permeable membrane. The direction of flow across the membrane is from a liquid with a low concentration of dissolved substances (solutes) to one with a high concentration. The process can generate very high pressure, called osmotic pressure, on the side of the membrane occupied by the liquid with the high concentration of solutes.

Osmosis can be reversed when pressure higher than the osmotic pressure is applied to the liquid high in solutes. When high enough pressure is applied to salt water, for example, water molecules, but not the salt molecules, pass through the membrane to the low-pressure side. This principle is used in reverse-osmosis (RO) watermakers to desalinate seawater.

Reverse osmosis is similar to a membrane filtration system but with several differences.

Reverse-osmosis watermakers

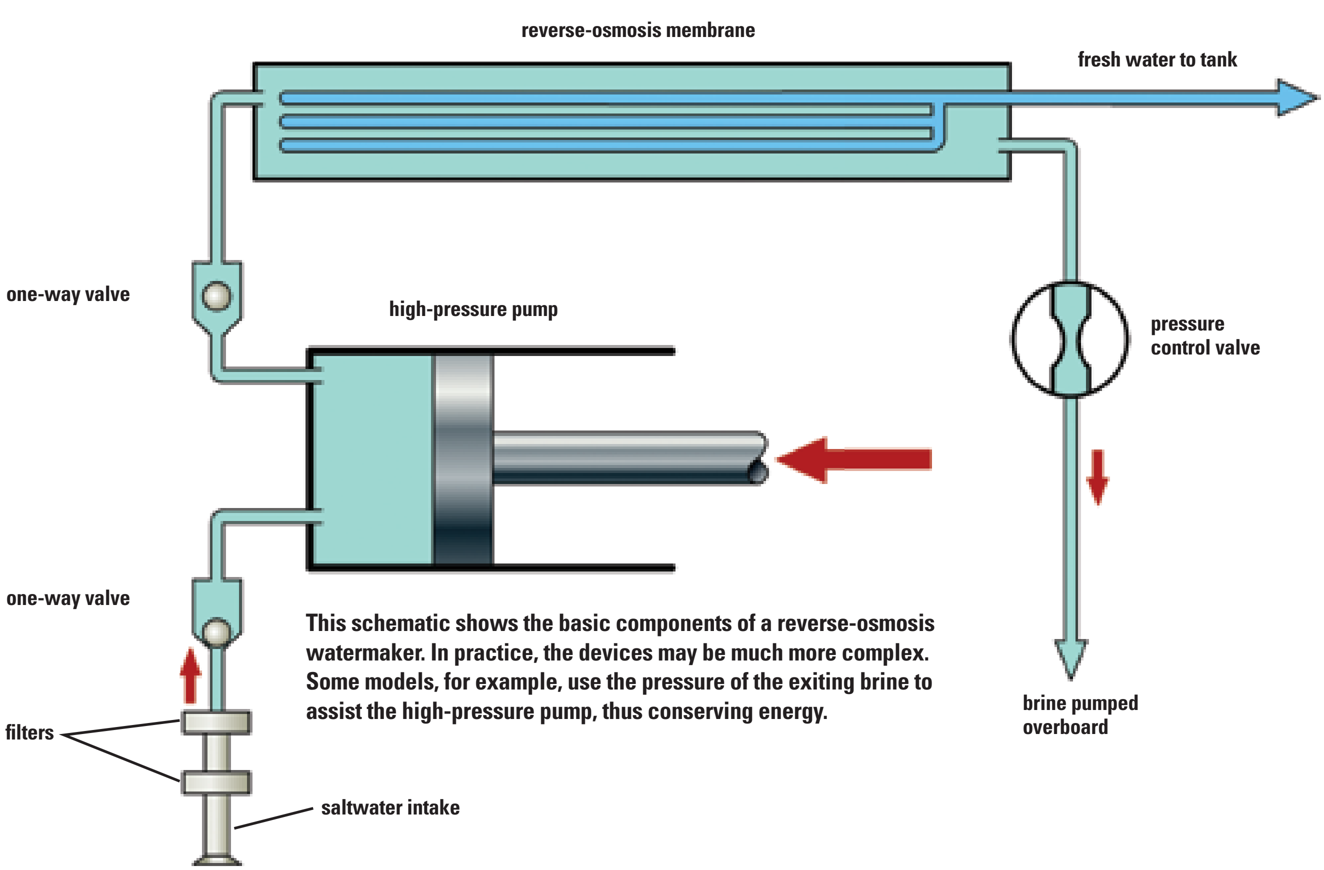
The primary function of an RO watermaker aboard a boat is to make potable water by removing salt from seawater. This is done by pressurizing salt water to 800 or more pounds per square inch (psi) and forcing water molecules through the semi-permeable membrane. The desalinated water is collected for storage and the salt water (now more concentrated) is discharged overboard.

In recent years, the cost, complexity, size, and power requirements of RO watermakers have been reduced to the point where even a small boat can take advantage of the technology. RO watermakers vary in size and capacity from small manually operated ones for use aboard a life raft to huge units weighing hundreds of pounds.

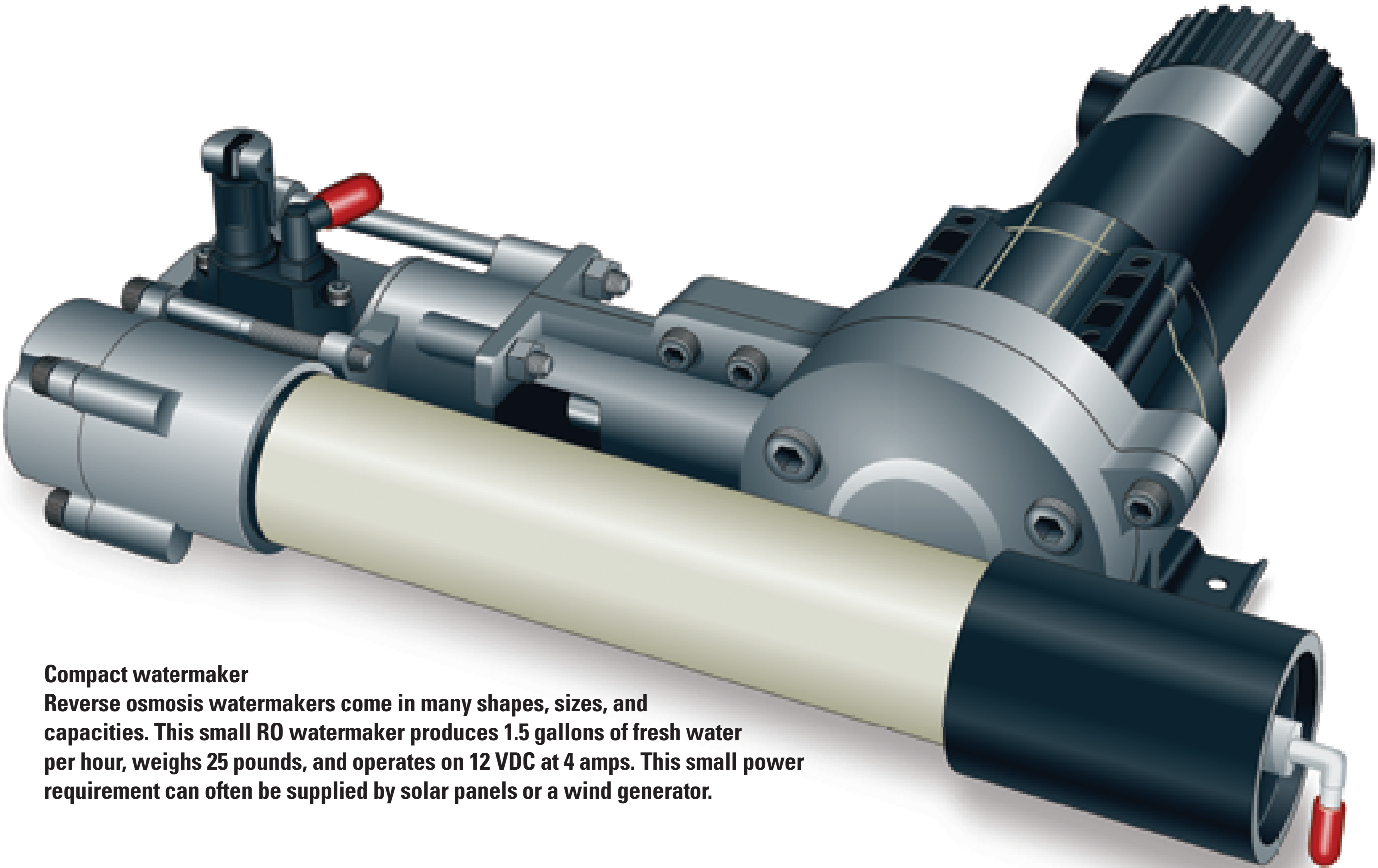
Watermakers are wonderful devices for offshore passage-makers. With the capability of making water, long-distance cruisers don't need large water tanks aboard. Reverse osmosis can have an added advantage for those who cruise abroad, where the quality of the water at some marinas may be in question and the price high. Coastal cruisers equipped with watermakers can eliminate trips to marinas for water.

Ocean water contains approximately 30 to 32 parts per thousand (ppt) of dissolved salt. An RO watermaker can reduce salt content by 150:1. The resulting drinking water will have 0.2 ppt of dissolved salt, a salt content that can't be tasted and is medically safe.

LAYOUT AND ILLUSTRATIONS BY TED TOLLEFSON



This schematic shows the basic components of a reverse-osmosis watermaker. In practice, the devices may be much more complex. Some models, for example, use the pressure of the exiting brine to assist the high-pressure pump, thus conserving energy.



Compact watermaker
Reverse osmosis watermakers come in many shapes, sizes, and capacities. This small RO watermaker produces 1.5 gallons of fresh water per hour, weighs 25 pounds, and operates on 12 VDC at 4 amps. This small power requirement can often be supplied by solar panels or a wind generator.

RO watermakers should not be used in harbors where pollution, oil, or chemicals might be in the water. Oil and chemicals will clog the primary filters and some chemicals, such as chlorine, may also destroy the membrane, requiring an expensive replacement. In addition, some viruses in polluted water are small enough to pass through the membrane into the drinking-water supply. If the watermaker might be used where the possibility exists of germs passing through the membrane, an ultra-violet sterilizer is a logical addition to the system (and is a good option to choose in any case).

The stated production rates for RO watermakers are usually given for 70°F water. When the water is colder, the watermaker's output will be reduced.

Installation and maintenance

Installation of an RO watermaker requires two extra through-hulls to be fitted. One through-hull will be below the waterline, for the saltwater intake, and the second will be above the waterline, for the saltwater discharge. The intake through-hull should have an external strainer and the water going to the watermaker should then pass through two progressively finer filters. These filters require regular cleaning.

Some RO watermakers are available in modular form, which makes it easier to install the various components in available unused spaces aboard.

“Some RO watermakers are available in modular form, which makes it easier to install various components.”

A key component of a watermaker is a high-pressure pump. This can be belt-driven by the engine or, if it's a smaller unit, powered by the boat's batteries. If the boat has a generator, the pump can run off 120 volts AC.

All RO watermakers require a strict maintenance schedule and operate at their best when used daily. If a watermaker is not used for several days, special maintenance procedures are necessary to protect the membrane, which means a watermaker is probably not practical for the weekend sailor.

During an extended passage, the watermaker's pre-filters must be cleaned about once a week and replaced periodically. Also, the watermaker's O-rings and check valves should be replaced after 1,000 hours of use and the equipment should be cleaned annually. In addition, it's a good idea to periodically check the fresh-water output with a Total Dissolved Solids (TDS) meter to assure the unit is operating properly.

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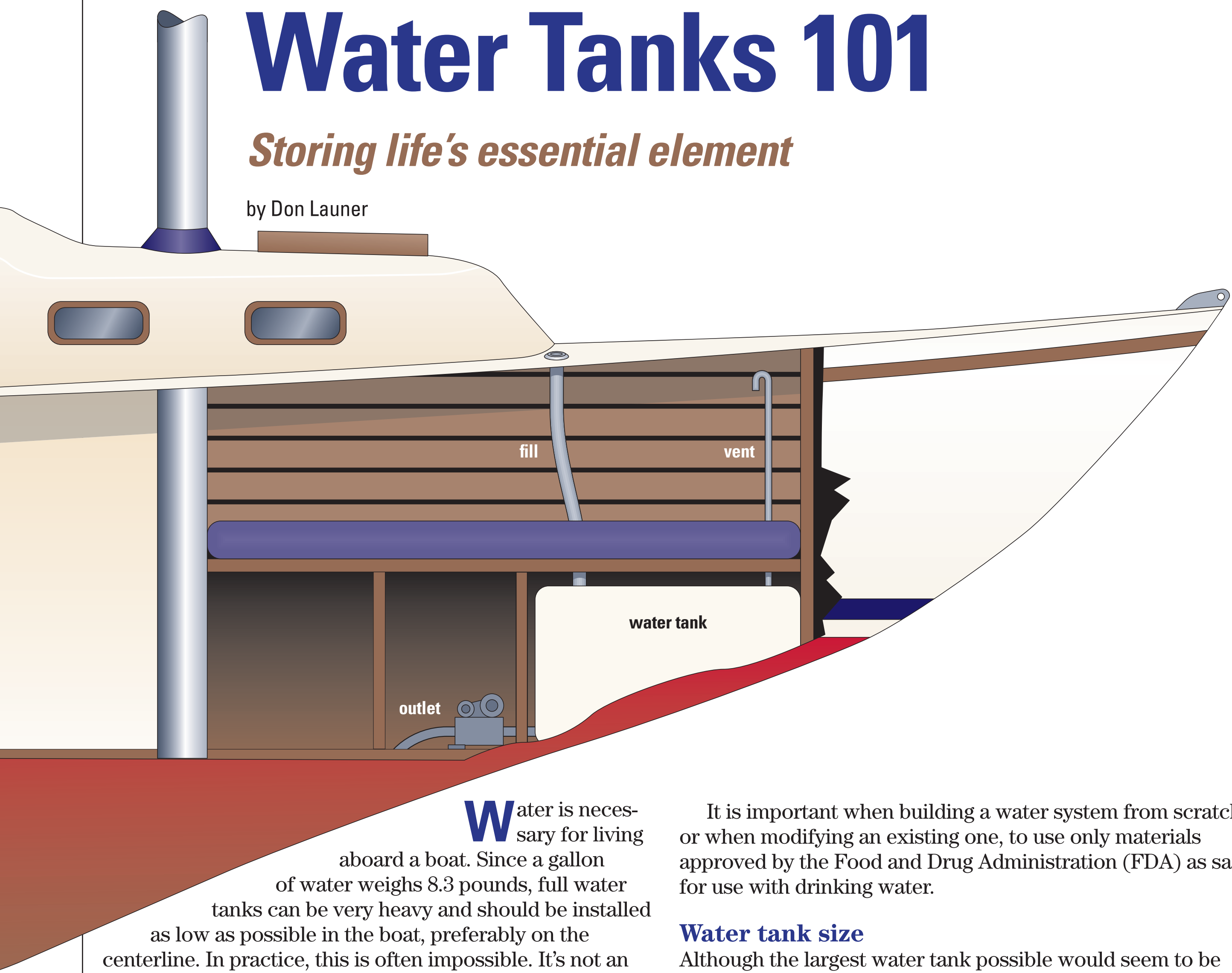
Water Tanks 101

Storing life's essential element

by Don Launer



LAYOUT AND ILLUSTRATIONS BY TED TOLLEFSON

Water is necessary for living aboard a boat. Since a gallon of water weighs 8.3 pounds, full water tanks can be very heavy and should be installed as low as possible in the boat, preferably on the centerline. In practice, this is often impossible. It's not an option in most small boats or in boats with shallow bilges. Alternative locations are beneath the V-berth, which is on the centerline, or under saloon settees or quarter berths. If tanks must be located far from the centerline — such as under settees or quarter berths — a good solution is to fit a tank on each side of the boat to maintain trim. The weight of an off-centerline tank might also be balanced by the galley or by heavy stores, such as canned goods, on the opposite side of the boat.

Water tank materials

Water tanks can be made of many materials including stainless steel, aluminum, Monel, fiberglass, polypropylene, polyethylene, high-density polyethylene (HDPE), and polyvinyl chloride (PVC). Each has its advantages and disadvantages. Tanks are available in many shapes and sizes and they can be made to order to fit oddly shaped spaces.

Plastic water tanks are considerably lighter (about 40 percent) than metal tanks, and have the added advantages of being seamless and corrosion-free. They also cost considerably less than metal or fiberglass tanks of comparable size.

It is important when building a water system from scratch, or when modifying an existing one, to use only materials approved by the Food and Drug Administration (FDA) as safe for use with drinking water.

Water tank size

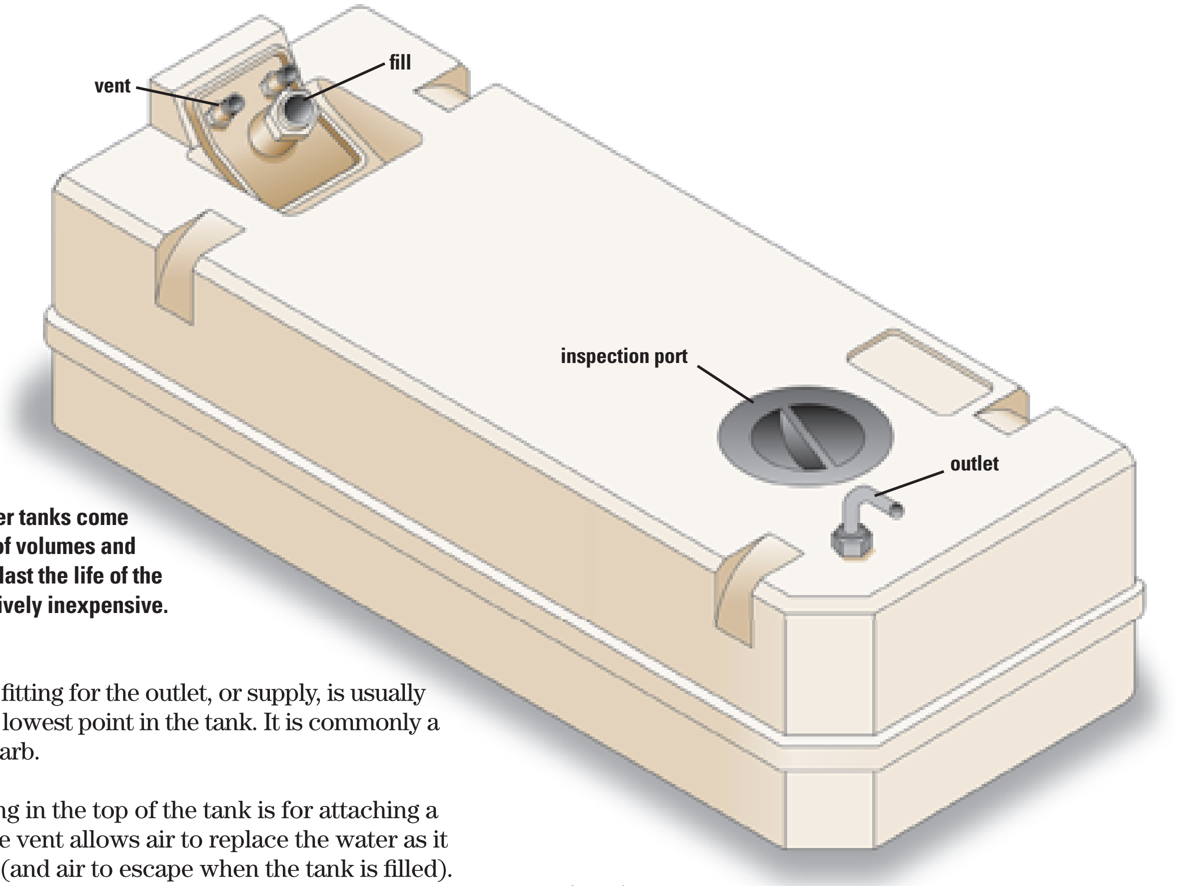
Although the largest water tank possible would seem to be ideal, this is not necessarily so. The weekend sailor who uses his boat only one or two days a week, and takes showers ashore at a yacht club or marina, might find that the water in a too-large tank will become stale before it can be used up or replaced. Under these circumstances, a smaller tank, or more than one small tank, will be more practical.

Hundreds of pounds of water surging back and forth as the boat pitches or rolls can put undue strain on the water tank and its mounts. It's important, therefore, for large-capacity tanks, whether rigid or flexible, to be fitted with baffles to restrict the water's movement.

Water tank fittings

The typical rigid water tank has four openings.

- ***Fill*** – Most boats are fitted with fill plates on deck. A large-diameter hose connects the deck plate to the fill fitting on the water tank. Often this hose has a Y-valve for directing the water to either of two tanks. The deck fill should be prominently marked "WATER" and preferably be located as far as possible from the fuel-fill deck plate so there's no chance of confusing the two.



Polyethylene water tanks come in a wide variety of volumes and shapes. They can last the life of the boat and are relatively inexpensive.

- ***Outlet*** – The fitting for the outlet, or supply, is usually located at the lowest point in the tank. It is commonly a ½-inch hose barb.

- ***Vent*** – A fitting in the top of the tank is for attaching a vent hose. The vent allows air to replace the water as it is withdrawn (and air to escape when the tank is filled). The vent line is routed to a high point inside the boat. Avoid leading the vent to a fitting on the outside of the hull, since outside water could come in when the boat is heeled or when waves strike the hull. An air vent is not necessary with flexible (bladder) tanks.

- ***Inspection port*** – A large screw-type hatch at the top of the tank (usually 3 inches or larger in diameter) makes it possible to inspect and clean the tank (not all tanks have this fitting). This is also where an internal water-level sensor can be mounted. (External tank-level sensors are also available). A large tank with baffles might have more than one large access port.

Doing it yourself

If you have to replace a tank that was installed when the boat was manufactured, chances are you're in for a very messy and frustrating job that could entail tearing up the cabin sole or interior furniture. Installing a new tank in place of the old one is usually a major undertaking.

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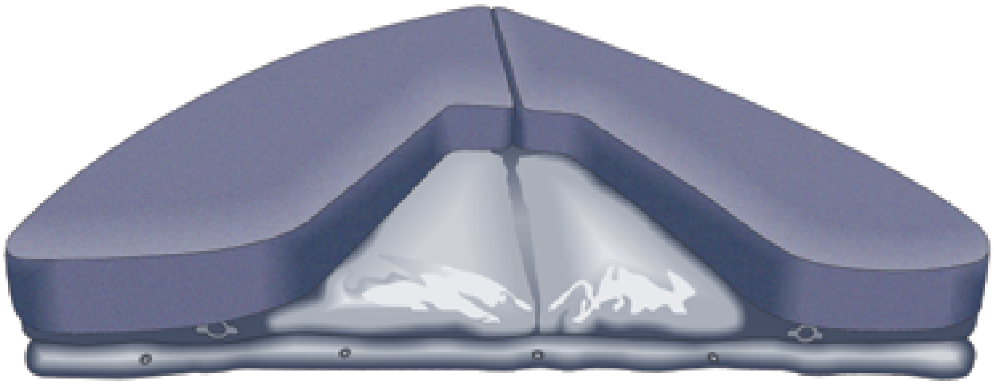
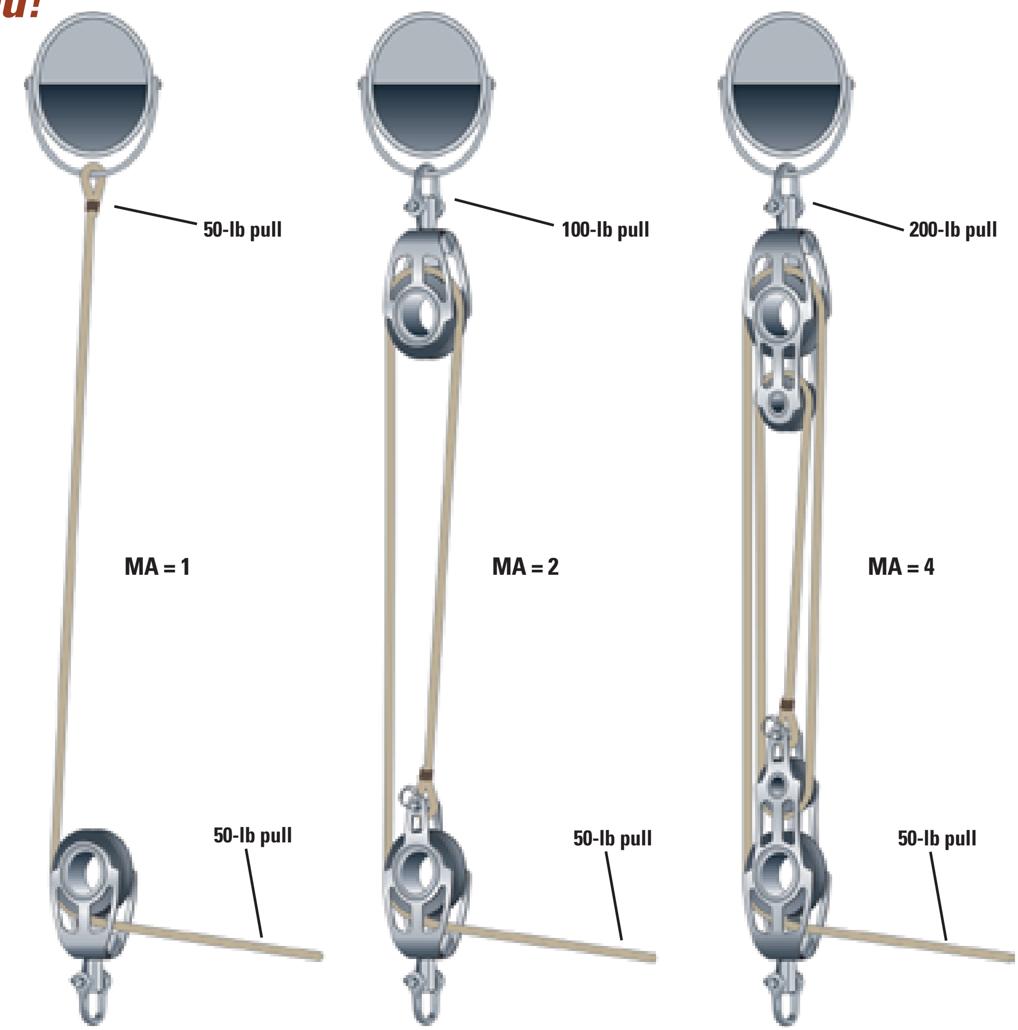


The flexible tank can fit into a space in which a hard tank would be difficult or impossible to install. An innovative idea, especially useful on small boats where space is at a premium, is a combination water tank and water bed. This illustration shows how a water bed/water tank works. The center berth cushion has been left out for clarity.

Mechanical Advantage 101

More power to you!

by Don Launer



The forces we have to contend with when sailing a boat are greater than we can handle with our unaided physical strength. To cope with them, we make use of a physical principle known as mechanical advantage. This is the factor by which a mechanism multiplies the force applied to it.

Mechanical advantage is often necessary when managing centerboards and swing keels and when adjusting traveler cars, boom vangs, halyards, and sheets.

The great mathematician and engineer Archimedes, who was born in 287 BC, first demonstrated and quantified the principle of mechanical advantage by using a multiple-part block and tackle to move a heavy ship to the water for launching.

Calculating MA

The theoretical mechanical advantage (MA) of any system can be found by comparing the distance the effort moves (the hand pulling the mainsheet, for example) to the distance the load moves (the boom).

- MA = distance the effort moves/distance the load moves

  The mechanical advantage can also be found by comparing the force applied to the load to the force applied by the effort.

- MA = force applied to the load/force applied by the effort

  For a system in which the mechanical advantage is 4, the ratio would be written:

- MA = 4:1

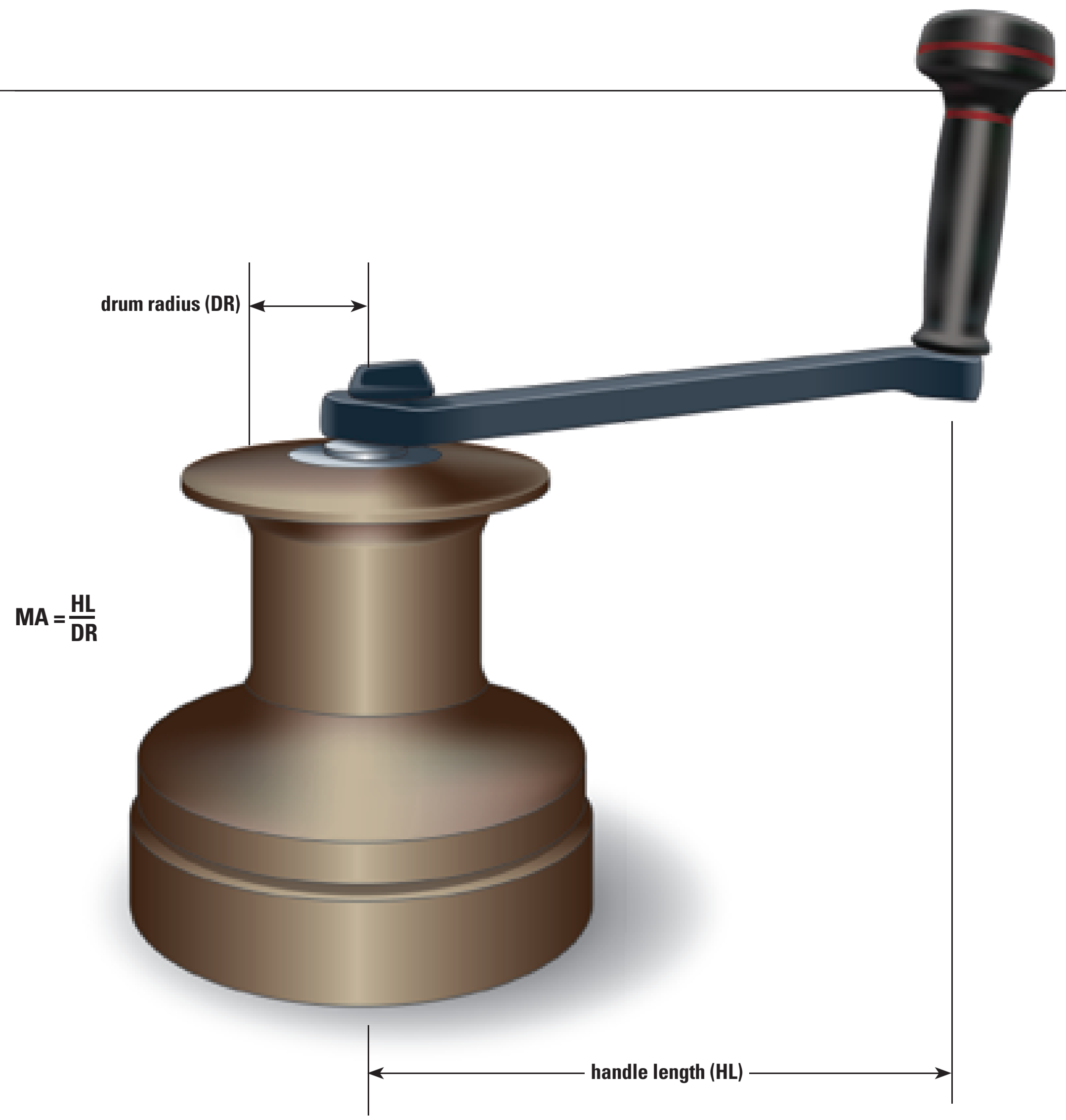
This theoretical, or ideal mechanical advantage (often abbreviated as IMA), neglects friction and other factors, such as the weight of the blocks when using a block and tackle. To overcome friction and weight, more force is needed than would be required for the ideal mechanical advantage. This extra force must be accounted for to determine the true or actual mechanical advantage (AMA).

MA through a block and tackle

The old Gloucester fishing schooners had no winches on board (except for the windlass) and the huge forces on the sails were controlled with multiple-part block-and-tackle arrangements. A block and tackle provides an easy way to create mechanical advantage and nearly every small to medium-sized sailboat still uses one to control the boom.

As stated above, to produce an increase in force using a simple machine, the applied force must move through a proportionately greater distance. This principle leads to the main disadvantage of the multiple-part block and tackle, which is the long length of line involved and the problem of stowing that line.

On my 32-foot schooner, the block and tackle for the mainsheet has an MA of 4. Although the end of the boom, to which



LAYOUT AND ILLUSTRATIONS BY TED TOLLEFSON

the mainsheet is attached, only travels a distance of 15 feet when the mainsail is swung out on a run, the sheet itself is about 60 feet long. When the boom is amidships, we have to contend with about 50 feet of extra line in the cockpit. To solve this problem, I installed a belaying pin rack on the boom-gallows stanchion. It's not for belaying, but rather to serve as a handy spot to store the coiled-up mainsheet.

Just as the sailors on the Gloucester fishing schooners did, I use block-and-tackle systems on the main boom, the fores'l boom, the gaff halyards, and the boom on our club-footed jib.

MA through a winch

A small winch enables us to exert great force on a line. It does this by means of a long winch handle turning a small-diameter winch drum while a ratchet mechanism prevents the drum from reversing direction when the force on the handle is released. Larger winches gain even greater mechanical advantage through internal reduction gears. Some operate at multiple gear ratios (or speeds), which are usually engaged by changing the direction of rotation of the handle.

The average sailor can exert about a 30- or 40-pound horizontal pull on a line. On larger boats this is just not enough — sheet forces in the thousands of pounds are common on large cruising or racing yachts. By means of leverage (a long winch handle turning a small-radius drum) and reduction gears (the number of revolutions of the handle that turn the drum through one revolution), high mechanical advantage or "power ratios" can be developed.

This power ratio is simple to calculate: it's the handle-to-drum ratio multiplied by the gear ratio.

If you have a 10-inch handle and a 5-inch-diameter drum, then the handle-to-drum ratio is 10/2.5 (2.5 being the radius of the drum), and the mechanical advantage is 4.

If, in addition, the winch has a 5:1 gear ratio, the handle-to-drum MA multiplied by the gear ratio (5) gives a power ratio of 4 x 5, or 20:1.

Winches are given numbers that approximate this power ratio, so a #8 winch has a mechanical advantage of 8:1. This 8:1 figure is, of course, a theoretical figure — the ideal mechanical advantage — since friction between the internal winch parts will reduce this ideal number somewhat. With small winches that have no internal gearing, the power ratio, or ideal mechanical advantage, is simply the handle-to-drum ratio.

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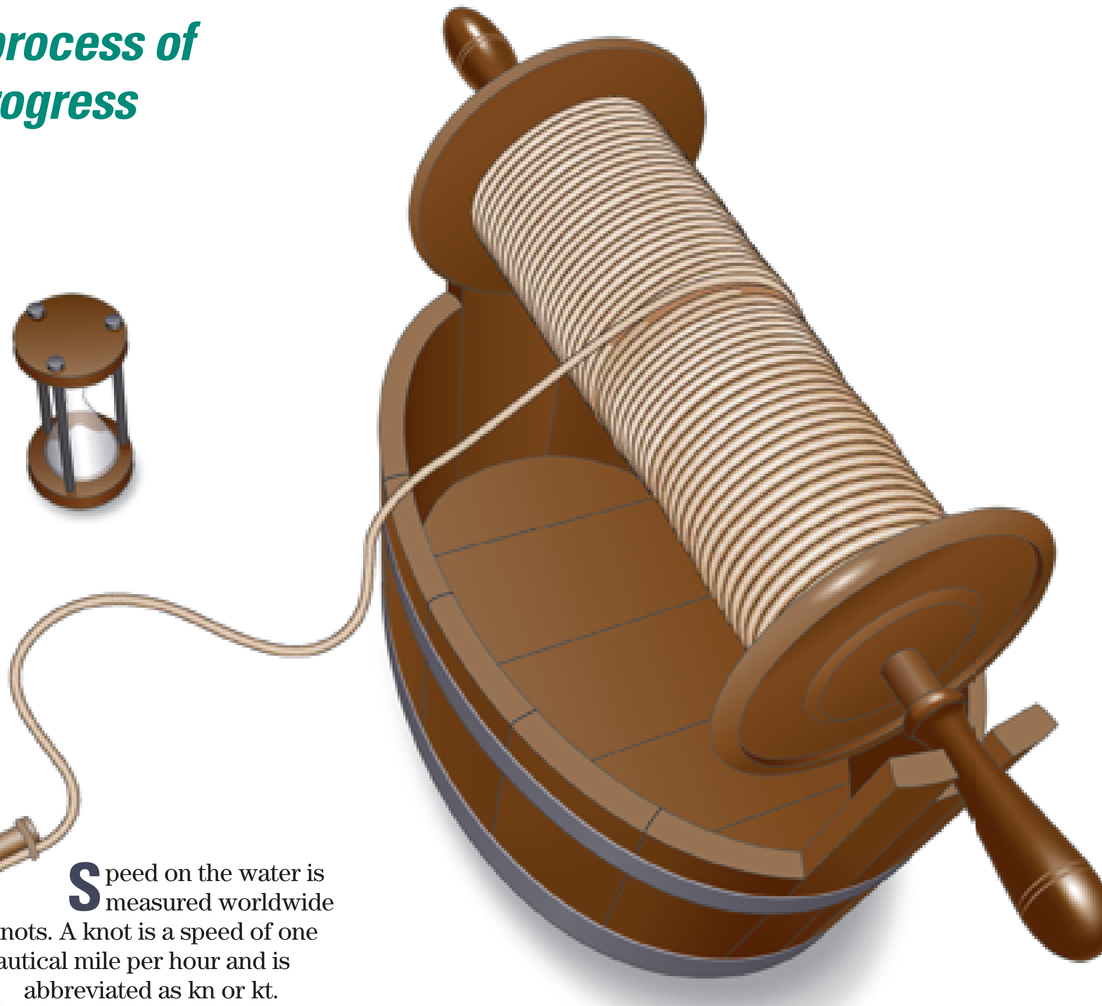
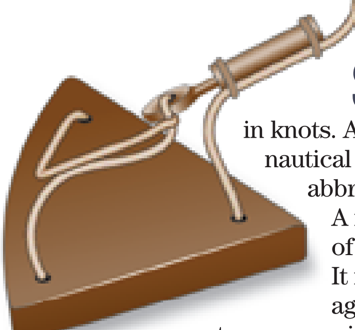
Measuring Boat Speed 101

Steps in the process of measuring progress

by Don Launer





On ships, the reel of line on a chip log was immense, about 3 feet across, and was held by two men, one holding the handle on each side of the reel.

LAYOUT AND ILLUSTRATIONS BY TED TOLLEFSON

Speed on the water is measured worldwide in knots. A knot is a speed of one nautical mile per hour and is abbreviated as kn or kt.

A nautical mile is the length of one minute of latitude. It is defined by international agreement as 1.852 kilometers, approximately 1.151 statute miles.

It begins with a log

In the early days of exploration, the most common method of measuring speed, and consequently distance, was called the Dutchman's Log.

On the sailing ships of that period, a large supply of firewood was carried aboard to fuel the galley stove. To determine how fast a ship was sailing, sailors threw a firewood log into the water at the bow of the ship and counted the time it took to reach the stern. Since speed is distance divided by time, and the distance was known (the length of the ship), the boat's speed could be calculated.

A chip off the old log

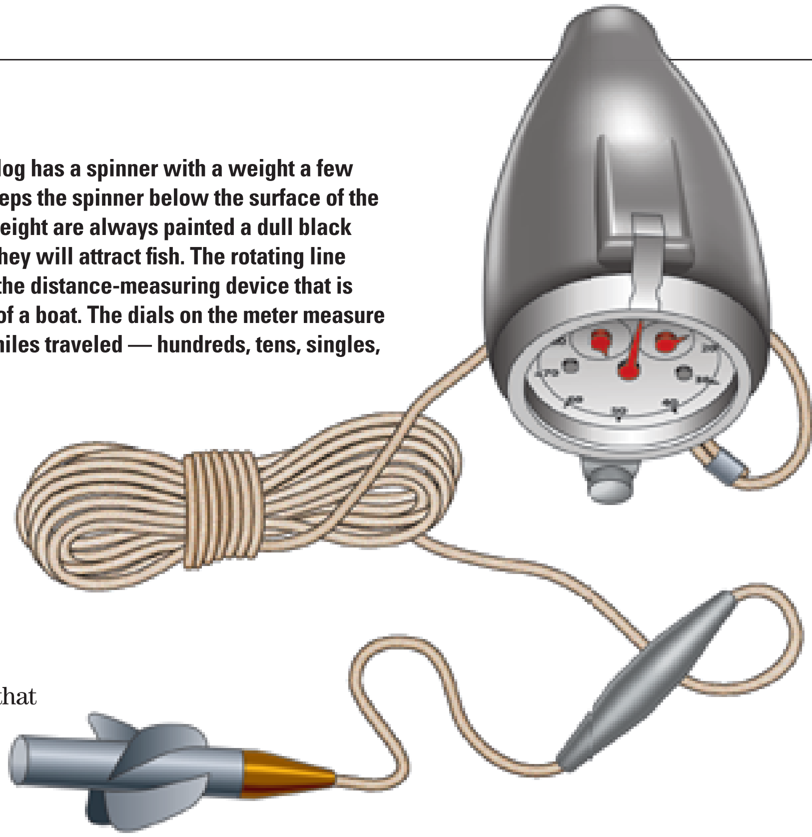
By 1600, speed through the water was measured more accurately with a device known as a chip log. It consisted of a piece of wood, usually in the shape of a quarter circle or half circle, weighted on the curved side so it floated vertically to create the greatest resistance to the water. A string bridle fastened at three points was led to a single line that had knots tied into it at equal intervals.

To measure speed, the chip was thrown into the water and the line allowed to run out through a sailor's hand. The sailor counted the number of knots that passed through his hand during the period measured by a sand timer. Each knot tied in the line represented 1 nautical mile per hour. Thus, when the sailor called out, "Eight knots," the ship was traveling 8 nautical miles per hour. Eventually the term "knots" (the actual knots on the chip log's line) became synonymous with a boat's speed through the water.

Revolutionary counter

In the late 1700s, more accurate measurement of speed and distance was obtained by use of the Walker, patent, or taffrail log (the taffrail is the stern rail on a boat). This was a spinner that was towed behind the boat. It measured distance traveled by counting revolutions of the spinner, either directly

This 100-year-old taffrail log has a spinner with a weight a few inches up the line that keeps the spinner below the surface of the water. The spinner and weight are always painted a dull black to reduce the likelihood they will attract fish. The rotating line is attached to the rear of the distance-measuring device that is fastened to the stern rail of a boat. The dials on the meter measure the distance in nautical miles traveled — hundreds, tens, singles, and fractions.



on the spinner itself or on a gauge fastened to the taffrail. To make it less attractive to fish, the spinner was painted a dull black.

Electronic logs

A method of measuring speed through the water that has become common in modern times employs a small paddle wheel that projects from the bottom of the boat's hull. Magnets on the blades of the paddle wheel pass a coil of wire inside the hub of the device, inducing a voltage that depends on the rotational speed of the paddle wheel. For many years, the voltage was registered by an analog-meter display calibrated in knots. These days, the displays are almost exclusively digital.

A diversity of devices

Many other methods are used for measuring speed through the water. One type of speed sensor uses ultrasonic sound and measures the Doppler shift in frequency resulting from the speed of the passing water. Other devices measure the resistance of an object that's towed through the water, usually using a spring.

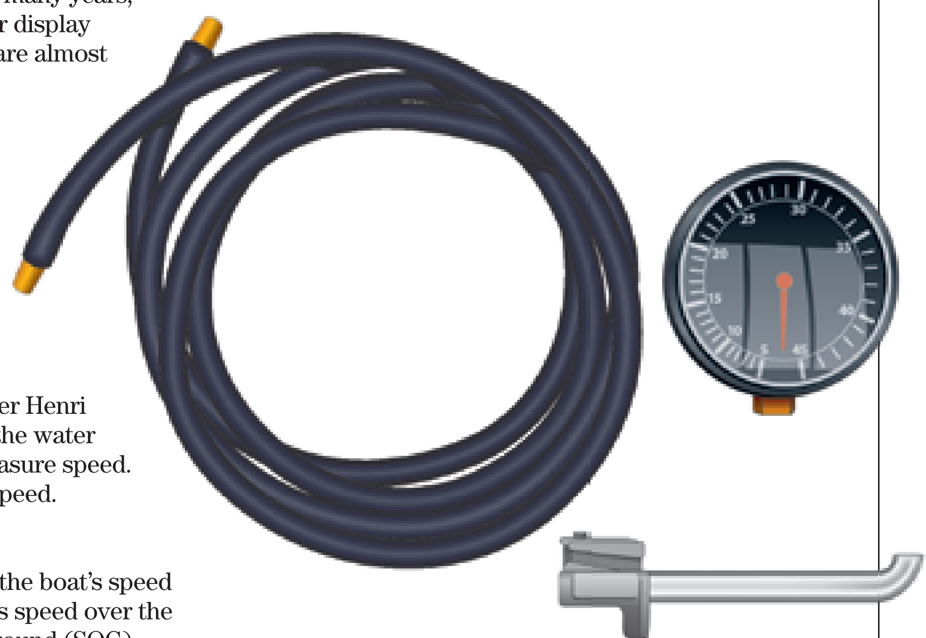
The Pitot tube, invented by French engineer Henri Pitot in the early 1700s, uses the pressure of the water arising from the boat's forward motion to measure speed. It is widely used on airplanes to measure airspeed.

Speed over ground

All of the methods described above measure the boat's speed through the water, which is not necessarily its speed over the surface of the earth, also called speed over ground (SOG).

If a boat were heading south through the Florida Straits between Florida and the Bahamas, it might be doing 3 knots through the water, but due to the north-flowing Gulf Stream it could be going backward or standing still relative to the earth's surface.

It wasn't until the electronic age that speed across the face of the earth could be measured directly. Loran-C did this, and GPS still does, by determining a boat's terrestrial position at frequent intervals and calculating how fast the boat must have been traveling to get from one point to the next. This is the most commonly used means to determine speed on recreational sailboats today.



A Pitot speed-measuring system is comprised of the Pitot tube, the speedometer dial, and the pressure tube that connects the two together.

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Icebox Insulation 101

Keeping out the heat

by Don Launer

LAYOUT AND ILLUSTRATIONS BY TED TOLLEFSON

Whether your icebox holds ice or houses a refrigeration evaporator, to be efficient it must be very well insulated. To achieve this, the box should have a minimum of 2 inches of high-R-value foam for insulation. Four inches is better and on our schooner we have 6 inches.

The function of icebox insulation is to slow down the movement of heat from the outside to the inside. This heat transfer can take place in three ways: radiation, convection, and conduction.

Radiation, the electromagnetic transfer of heat, is how our Sun warms the Earth. Radiation contributes the least amount of heat transfer into an icebox or refrigerator — only a couple of percent.

Convection is the transfer of heat by the movement of a gas or a liquid. An open drain at the bottom of an icebox combined with a leaking door gasket can cause a large amount of heat to be transferred by convection as cold air flows out the drain hose and is replaced with warm air entering through the poor door seal.

Conduction is the transfer of heat in a solid or a fluid due to molecular interaction. The majority of heat transferred from the outside to the inside of an icebox or refrigerator is due to convection and conduction.

Radiation, convection, and conduction from outside the icebox are not the only sources of heat. Filling the box with room-temperature food introduces a significant amount of heat, so a box filled with food will have a higher heat load on it than an empty box. This heat load is less when frozen food is placed in the box.

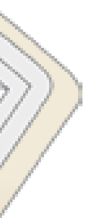
R-value and K-factor

An insulating material's R-value is a measure of its resistance to heat flow. The R-value is derived from the thermal conductivity factor, or K-factor, which in the U.S. is defined as the number of BTUs that will pass in one hour through 1 square foot of insulation 1 inch thick with a temperature difference of 1 degree F between the two sides. The higher a material's K-factor, the poorer its insulating quality. The R-value of a material is its thickness divided by the material's K-factor, so the higher the R-value, the better it insulates. This R-value varies with the temperature of the insulating material.

Icebox construction

An icebox should be top-loading, not only because it is more efficient in maintaining a cold temperature inside, but also because it eliminates the possibility of everything spilling out of the front if a door is flung open by a violent motion of the boat.

Even a top-loading icebox should have a means of locking the door against its opening in the event of a knockdown. In fact this is often a requirement for sailboats taking part in offshore-racing events.



When constructing an icebox within a designated space, you face a trade-off: the more you increase the thickness of the insulation to make your icebox more efficient, the smaller the potential storage volume inside the box.

Some advocates insist that closed-cell foam is the best insulation, but the problem is not that simple. Two-part polyurethane foam suffers the disadvantage that it absorbs water and its R-Value decreases over time. Other materials sharing this problem include polyisocyanurate and expanded polystyrene.

Extruded polystyrene is the best type of foam insulation since it doesn't absorb water and will maintain its R-value indefinitely. These foams go under the commercial names of Styrofoam Brand Square Edge Insulation (also known as blue board) and Insulpink-Z.

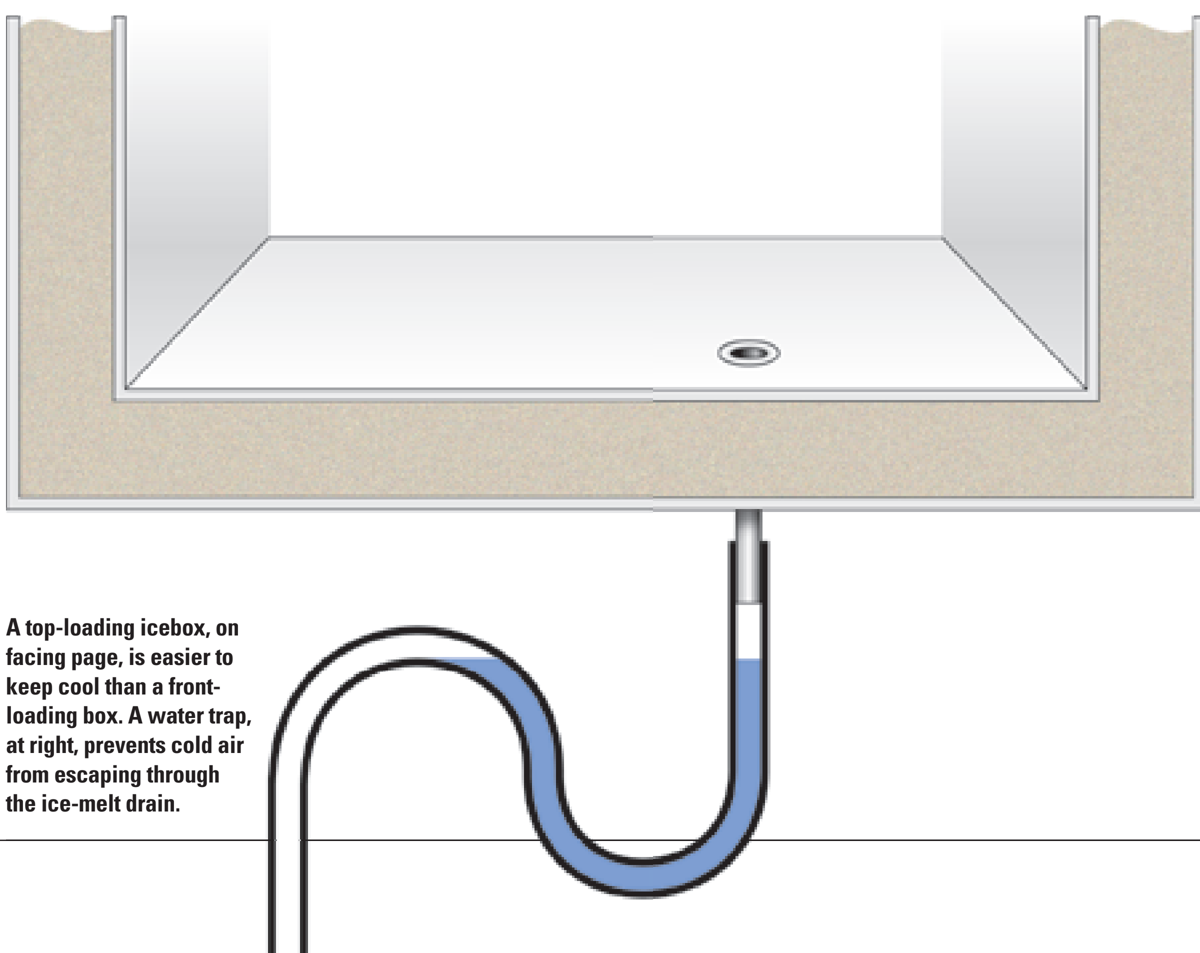
But what are the recommended R-values for a boat's icebox? This depends largely on the climate where the boat is being sailed. For warm climates, R-20 is recommended for an icebox or refrigerator and R-30 for a freezer. Extruded polystyrene has an R-value of 5 per inch of thickness, so it would take 4 inches of thickness to achieve the recommended R-value for the refrigerator and 6 inches for a freezer.

An alternative to foam insulation is a technology called vacuum insulation panels (VIP) which, although more expensive, can have an R-value of 50 at 1 inch of thickness. VIPs can deliver a high R-value while also increasing the available interior size of the box. Panels for this type of insulation have to be custom-built for a particular application.

Meltwater drain

Although not required for refrigerators, an icebox that uses block ice for cooling will need a drain in the bottom for the melting ice. This bottom drain should include a trap, similar to the trap used in home sinks and tubs, to prevent the cold air inside the box from flowing out and being replaced with warm, outside air. If the drain tube can also be insulated, it will help maintain the low temperature of the icebox and eliminate condensation drips. The icebox drain should not discharge directly into the bilge, where it will promote an unpleasant rotting-food smell that's hard to eliminate, but into a container in the bilge. This container of meltwater must be manually emptied at least once a day, depending on its size. Alternatively, it can be emptied with a pump, such as a small automatic bilge pump, that discharges through a through-hull.

Don Launer, a Good Old Boat *contributing editor, built his two-masted schooner,* Delphinus, *from a bare hull and has held a USCG captain's license for more than 36 years. He has written five books, including* The Galley: How Things Work *and* Navigation Through the Ages, *and frequently gives talks on the history of navigation.*



A top-loading icebox, on facing page, is easier to keep cool than a front-loading box. A water trap, at right, prevents cold air from escaping through the ice-melt drain.

Donald Launer has held a US Coast Guard captain's license for over 35 years and has written more than 300 magazine articles and five books on boating. For 15 years he was field editor for the yearly *Waterway Guide* and he is currently a contributing editor for *Good Old Boat Magazine*. He holds a pilot's license for both land-planes and sea-planes and has won two Emmy Awards for his work as technical director of TV coverage at the Olympics.

Captain Launer has lectured on navigation at the United States Naval Academy in Annapolis, Maryland, as well as to hundreds of other organizations throughout the northeast and in 2010 was inducted into the Sailing Hall of Fame.

He is a member of the BoatUS Speakers Bureau, the Boating Writers International Speakers Bureau, and Mensa.

Ted Tollefson was born and raised in Brainerd, Minnesota. After high school, Ted spent four years in the Navy aboard the aircraft carrier USS *Hancock*, then studied graphic design and went to work for his art teacher. Ted worked as an artist for a short time then worked for a decade as a welder on the iron range in northeastern Minnesota. In 1984, his love of creating art called him back to Brainerd and since then has worked as an illustrator/graphic designer.

Beyond *Good Old Boat,* Ted has been published in the *In-Fisherman, Lake Country Journal* and *IQ* magazines, several books, and the 1991, 1997, and 2007 Minnesota State fire convention.

Ted's artwork can be seen at his website; www.thoughtsillustrated.com. In his spare time, Ted enjoys sailing, camping, canoeing, and cross-country skiing.