1 THE LANGUAGE OF BOATING

Nautical words form such a large part of English that few readers will find the language of boating completely new. Everyone knows that "A-1" means highly rated and "making headway" indicates progress is being made. It hardly matters in everyday conversation that these words have a nautical origin. It hardly matters, that is, until you step on board a boat.

In this chapter you will be acquainted with words grouped into general areas of basic boating knowledge. To emphasize their significance as boating terms, these words have been italicized.

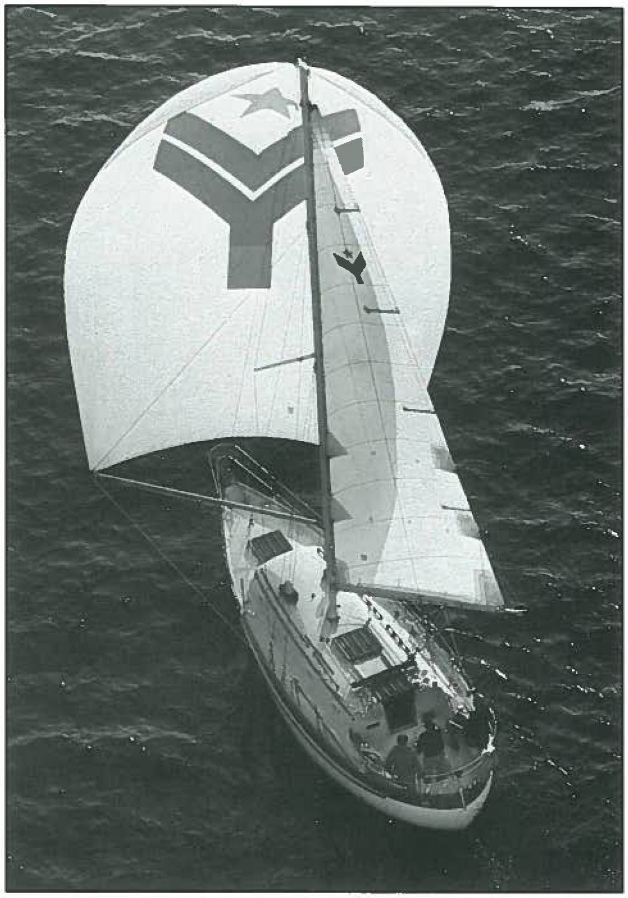
New words introduced in later chapters are not italicized to avoid interfering with your reading. New terms usually are explained within their context, but you may also refer to the Glossary of Nautical Terms in Section 8.

LEARNING THE BASICS

Learning and using proper nautical terms expands the enjoyment of boating. This is true with every style of boating—sail or power, 60-footer or dinghy, racing or cruising, or just "messing about on the water." There's no need for excessively "salty" speech, but there are important reasons for knowing and using the right terms for objects and activities around boats.

Nautical language allows easy communications among the whole crew or with other boaters. Most important, it avoids misunderstandings during emergencies. Critical seconds of valuable time may be saved by using correct, precise terms for needed tools or actions. It takes practice to get into the habit of thinking directly in nautical terms, rather than visualizing "shore" terms and translating them mentally. Most people find it greatly satisfying when nautical language becomes second nature—proof of well honed boating skills.

One chapter cannot include all of the nautical words in common use. And, no two experts would agree on the same list of important words. So, the purpose of this chapter is to prepare you for the various topics covered in *Chapman Piloting*. Later chapters will provide refined definitions or introduce more new words as needed.



An auxiliary sailboat uses sails for propulsion except in calms and for close-quarter maneuvering where power may be used.

What is a boat?

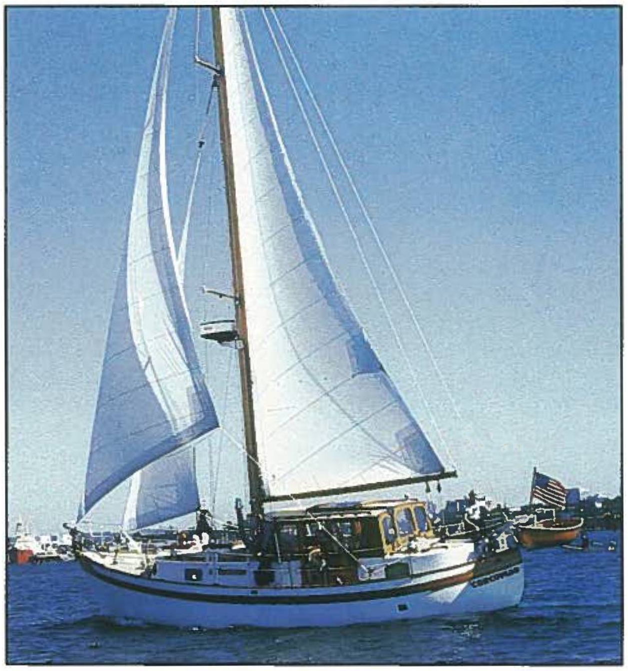
The division between *boat* and *ship* is not precise, although Navigation Rules *(Chapter 7)* make a distinction at 20 meters, or about 65.6 feet. *Craft* and *small craft* usually carry the same meaning as boat. The term *vessel* is used particularly in legal and regulatory contexts without reference to size. *Yacht* deserves special consideration. It often connotes a sail or powerboat over 40 feet (12.2 m) in length with luxurious accommodation. It is also widely used when referring to prestigious government craft such as a presidential or state governor's yacht. In sailboat racing, however, every competing boat is a "yacht" without regard to size or accommodation.

A yacht is a power or sail vessel that is used for recreation and pleasure—as opposed to work. The term is usually reserved for boats 40 feet (12.2 m) or more in length, and is also applied to prestigious government craft.

A boat's primary means of propulsion places it in either the *powerboat* or *sailboat* category. Sailboats are propelled by wind and sails. Most sailboats over roughly 18 feet (5.5 m) long have inboard gasoline or diesel *auxiliary engines;* smaller ones often have an outboard motor. Small, open sailboats are called *day-sailers* and those used primarily for racing may be known as *racing dinghies*, although the word *dinghy* is usually reserved for a very small boat used to ferry crew and supplies.

A boat propelled by machinery is legally a "power-driven vessel." This includes sailboats using auxiliary engines, whether or not they have sails up. *Motorboat* includes craft propelled by gasoline or diesel engines. Some motorboats are now propelled by environmentally friendly electric motors and storage batteries.

A hybrid category exists between pure powerboats and sailboats—*motorsailers*. These have modest sails, but more powerful engines than auxiliary sailboats. Though they share the benefits of both sailing and powerboating, they are relatively inefficient in either mode.



A motorsailer is a sailboat with a large engine that can take advantage of both power and sail, but sacrifices efficiency in both modes of propulsion.

Cruisers—sail or power—carry some form of overnight accommodation. If they are powerboats, they are also described by their method of propulsion. They might be *outboard cruisers*, *inboard cruisers* or even *inboard/outboard (I/O) cruisers*. Powerboats too small to offer overnight accommodation can be *daycruisers*, *runabouts* or *sportboats*. Open boats of this size are sometimes called *utility boats*, and are used for general service applications.

Houseboats are more houselike than boatlike. Many are little more than motorized platforms with living accommodation. *Housecruisers* are a step closer in evolution toward boats. Their hulls are generally better suited to higher speed and may be able to handle small waves on protected waters.

A *hydroplane* is a racing-style powerboat that travels so fast that much of the force supporting its weight is created by air pressure rather than water pressure or buoyancy. *Hydrofoil* boats, on the other hand, have hydrofoils ("water wings") that create lift while immersed, supporting the hull above the water. Until recently, horsepower requirements of hydrofoil boats made engines necessary, but now a few sail-powered boats are also using hydrofoils.

A more common form of high-speed travel under sail is the *sailboard*. The sail on this type of craft is partially supported by the operator who steers by shifting the position of both the sail and his or her weight on the board.

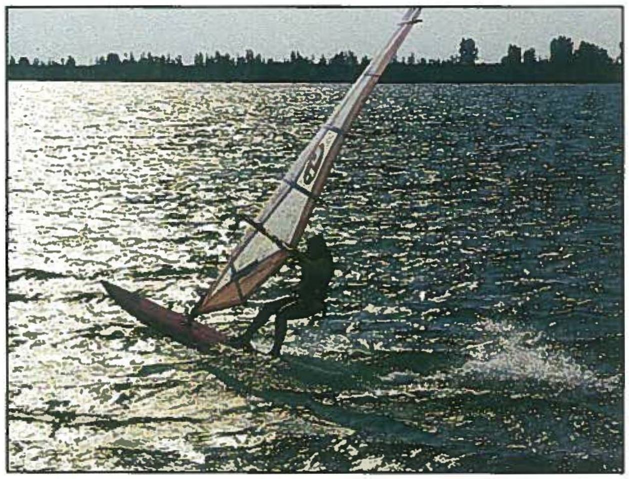
A dinghy can be propelled by *oars* or by a very small motor. If a dinghy is squared-off at both ends, it is called a *pram*. As mentioned earlier, dinghies may be used to ferry crew and supplies. In this case, the dinghy is called a *tender*. Small tenders are sometimes suspended from their parent vessels in *davits*. A *launch* is similar to the tender, but it suggests elegance and a length of at least 20 feet (6.1 m).

Multihulls

Boats with more than one hull are known collectively as *multihulls*. Among multihulls, *catamarans* have two hulls that are either identical or mirror images of each other. *Trimarans* have three hulls, a larger central hull for crew accommodation, and two smaller outer hulls. Although most multihulls are sailing craft, specialized powerboats are sometimes built with more than one hull.

Inflatables

Inflatable boats are usually associated with tenders of less than 10 feet (3 m), but they can be much larger. Inflatables of 25 feet (7.6 m) or longer are occasionally seen. A major



Today, boardsailing is a popular water sport, especially among the young and physically fit.

Rigid-hull inflatable boats, often called RIBs, are constructed both as small tenders and as larger sportboats. They combine the benefits of a conventional hull with inflatable flotation and stability.

advantage of inflatables as tenders is that they can be deflated and stowed in a small space. In this mode they often double as *life rafts* though they lack many of the protective features that are associated with a proper life raft *(Chapter 4)*.

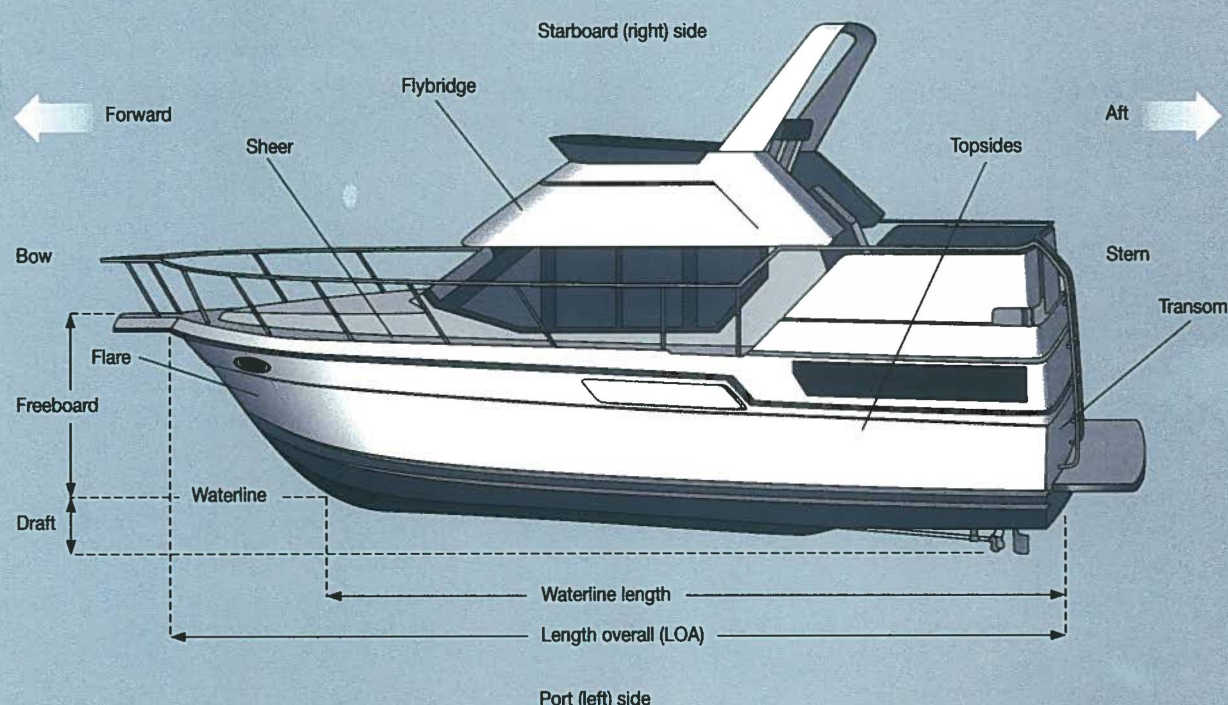
Inflatables provide greater capacity and more stability for the same length as compared to conventional tenders. The soft contours of their inflated tubes spare the finish of the main hull when the tender is alongside. Unfortunately, they can be difficult (if not impossible) to row under windy or choppy conditions, so are usually powered with a small outboard motor.

Primary considerations with inflatables are the quality of the fabric and the gluing process used in their construction. High-quality fabrics that resist abrasion and sunlight and high-strength seams are expensive; consequently, quality boats are more costly than ordinary inflatables of similar size. For safety, any inflatable should have two or more separate air chambers. If damage causes one to deflate, the boat will be kept afloat by the other, undamaged chamber.

A recent development is the combining of inflatable and conventional boat construction in what is called a *rigid inflatable* boat or *RIB*. RIBs are built with a two-part hull: the lower closely resembling the bottom of a high-speed fiberglass powerboat; the upper consisting of inflated tubes. This gives RIBs both the efficient, high-speed performance of a conventional powerboat and the great stability of an inflatable.

ORIENTING YOURSELF ON BOARD

Life afloat is always oriented to the boat, and not to the individual members of the crew. The *port* side, for instance, is always the left side of the boat no matter which way the observer is facing. Likewise, *starboard* always refers to the boat's right side. Anything toward the bow is *forward*, while anything to the stern is *aft*. A position aft of an object is *abaft* of it. (A landmark may be said to be "abaft the beam.") Something is *abeam* when it lies off either side of the boat at right angles to the keel. Parts of the vessel, such as seats or a swim platform, which run across the boat are *athwartships*. Along the vessel's centerline is *fore-and-aft*. Anything in the middle of the boat is *amidships*, whether fore-and-aft or athwartships. *Inboard* is toward the center, *outboard* away from it. Going *below* refers to a person moving from the deck to a lower cabin inside the hull. The reverse is going *above* (decks). The term *aloft* is used for climbing the rigging and masts.



These terms relate to the hull, and directions on board a boat. Note that port and starboard sides remain the same, no matter which way one is facing, and that LOA is figured similarly for sailboats. Refer to Chapter 10 for terms specific to sailboats.

DESCRIBING BOAT TYPES

When yacht designers, or *naval architects*, begin the design of a cruising boat—power or sail—they most often start with the interior layout and work to the outside. Apart from the fundamental assumptions of safe operation, a cruising boat's main function is to accommodate its owner and crew in as much comfort as they can afford.

Though a boat is described primarily by its *length overall (LOA)*, what is often more important is the volume of living space actually available. While living space usually increases with length, the relationship is anything but straightforward. On board cruising sailboats in the range of 25 to 35 feet (7.6 to 10.7 m), important compromises must be struck between living space, aesthetics and performance. Below about 25 feet (7.6 m), these compromises become sacrifices.

Powerboats, unlike sailboats, are well suited to the kind of interior accommodation most people are accustomed to: rooms with basically rectangular shapes. This happy coincidence between the needs of interior layout and powerboat hull shapes is due to the availability of large engines. Cruising powerboats, with some exceptions, are not faced with the need to slide gently through the water driven by low horsepower. Instead, they ride up and over it on large, almost flat surfaces. The shape of a planing hull perfectly suits spacious interiors that are, more or less, rectangular.

The ruling dimension for designing a cruising boat is the height of the typical male boat buyer: 6 feet. To allow a 6-foot person to stand upright, the boat length must be at least four times this average height, or no less than 24 feet (7.3 m). Women, being on average slightly shorter than men actually have a size advantage with respect to headroom, especially on smaller boats where space is at a premium.

Novice boat buyers typically ask one question, "How many does it sleep?" Builders, anxious to please these buyers, react by giving the maximum number of *berths* (beds), even knowing that most crews will seldom use them all. Sometimes overlooked in the rush to provide berths is the need for privacy. One set of berths should be separated from another by walls called *bulkheads*. Most boats have a *forward cabin* with a *V-berth*—two berths joined at the toe to fit into the bow. Larger boats may have additional mid-cabins and/or aft cabins.

Powerboat types

Powerboat builders use numerous terms to distinguish boat configurations, and they are not always consistent. However, a few basic terms seem to be universal, surviving changes in style. A *runabout* usually seats four or six. Bowrider runabouts have additional seating in the bow accessed via a walk-through windshield. The runabout has no formal sleeping accommodation, but seats may fold down for sunning or napping.

With a slight increase in LOA—to about 20 feet (6.0 m)—the enclosed volume of the bow becomes large enough for a small cabin, or *cuddy*. (The often heard "cuddy cabin" is redundant.) While not luxurious, the cuddy does offer shelter in wet weather and may also enclose a portable toilet.

A marine toilet is traditionally called a *head*; in modern legal parlance, a *marine sanitation device (MSD)*. The head may be connected to a *holding tank*, where sewage is held for discharge—or *pump out*—at shoreside facilities.

Center-consoles, sportboats and daycruisers

The *center-console* boat is popular with anglers because it provides the maximum usable deck space for a boat's LOA.

The walk-around style includes elements of the center-console and the cuddy. A narrow sidedeck allows access to a low foredeck with rails. The cabin provides basic accommodation and storage space. This configuration is well suited to fishing and patrol or rescue work.

Seating is limited to one or two bench or swivel seats. Fishing enthusiasts can handle rods or swing nets around the boat's entire perimeter. The lack of enclosed space, though, makes the boat undesirable for cruising. Center-consoles range in size from less than 15 feet (4.6 m) to about 35 feet (10.7 m).

In the range of 20 to 25 feet (6.1 to 7.6 m), sportboats differ from daycruisers mainly in engine size and styling. However, the basic elements of their layouts are very similar. At this length, sufficient height can be gained to allow a very small cabin with sitting headroom in the bow. The daycruiser cabin will probably have a V-berth, a portable head and a small *galley* (kitchen), consisting of a countertop stove and a basin, as well as a folding table.

Express and sedan cruisers

Above about 25 feet (7.6 m), powerboat styles begin to diverge. Differences in accommodation layout are reflected in sharp differences in their hull and superstructure shapes. *Express cruisers* form one branch of powerboat design while another is made up of *sedan cruisers*, often called *convertibles*.

The express cruiser is a modern, sporty design that enlarges sportboat configuration to include accommodation in the forward cabin and an open raised bridge.

An express cruiser, sometimes referred to as a *sunbridge*, takes the basic sportboat configuration and enlarges it—right up to lengths of 40 feet (12.2 m) and more. The craft's *foredeck* is long and unobstructed, interrupted only by *hatches*—openings that provide access to the enclosed space below. The control station, or *bridge*, is set well aft and a step above the "floor," which is properly called the *sole*, of the *cockpit*. A *radar arch* may provide an excellent mounting position for communication and navigation equipment, including radar sets. Stylish and often high-powered, the express cruiser is also simpler to construct than a sedan or *flybridge* style of comparable size.

A sedan or convertible cruiser puts the main interior space (and possibly a lower control station) on the same level as the cockpit. The interior space is divided into two parts: a main

A power cruiser's flying bridge, usually called a flybridge, is an upper steering position originally intended as a platform to spot game fish.

saloon at the level of the cockpit and the forward cabin below the foredeck. ("Saloon" is the correct nautical word, although "salon" may be seen in advertising copy.) If there is a lower control station, it will be located at the forward end of the main cabin. These controls are often duplicated as a flying bridge on a second level above the main cabin. Smaller sedans and convertibles usually place their galleys within the main cabin. This is known as a "galley-up" layout.

Aft-cabin cruisers

As length increases, it becomes possible to open up sleeping accommodation below the level of the deck at the stern with an *aft cabin*. The engines are moved forward to the middle area of the hull beneath the enclosed saloon, and the resulting style is called a *double-* or *aft-cabin* cruiser. The galley may be located just aft of the *forecabin* on the level below the main cabin (known as a "galley-down" layout).

Sportfishermen

Sportfishing boats can be convertibles that are rigged for fishing or they can be true *sportfish* boats with longer foredecks, shorter main saloons, and larger cockpits than sedan cruisers. Purpose-designed game-fishing boats usually have a *tuna tower* supporting a control station at maximum elevation for spotting fish and shoals. They also will be equipped with outriggers and fighting chairs.

Trawler yachts

Within the commercial fishing community, the word *trawler* has a specific meaning, but in recreational boating the term is used much more loosely. In general, any pleasure craft more than 25 feet (7.6 m) in length that does not carry sufficient horsepower to lift itself out of the water and *plane* at or near the surface is known as a trawler. Since the hull of a trawler rides through (and not over) the water, it is considered as having a displacement hull design—which is described in detail on page 26.

The trawler was originally designed as a low-speed, seaworthy fishing vessel. As a recreational type, trawlers are fuel-efficient and offer many on-board living advantages.

The trawler's hull shape can vary from one with soft bilges to one with hard chines. Practically all trawlers are designed with significant keels. Trawlers now are faster and fitted with twins while single-engine installations were once more common. These boats were popular for traveling at 7 to 8 knots, ideal for waterways where speeds are limited, and well suited for long passages where fuel conservation becomes critical.

Sailboat types

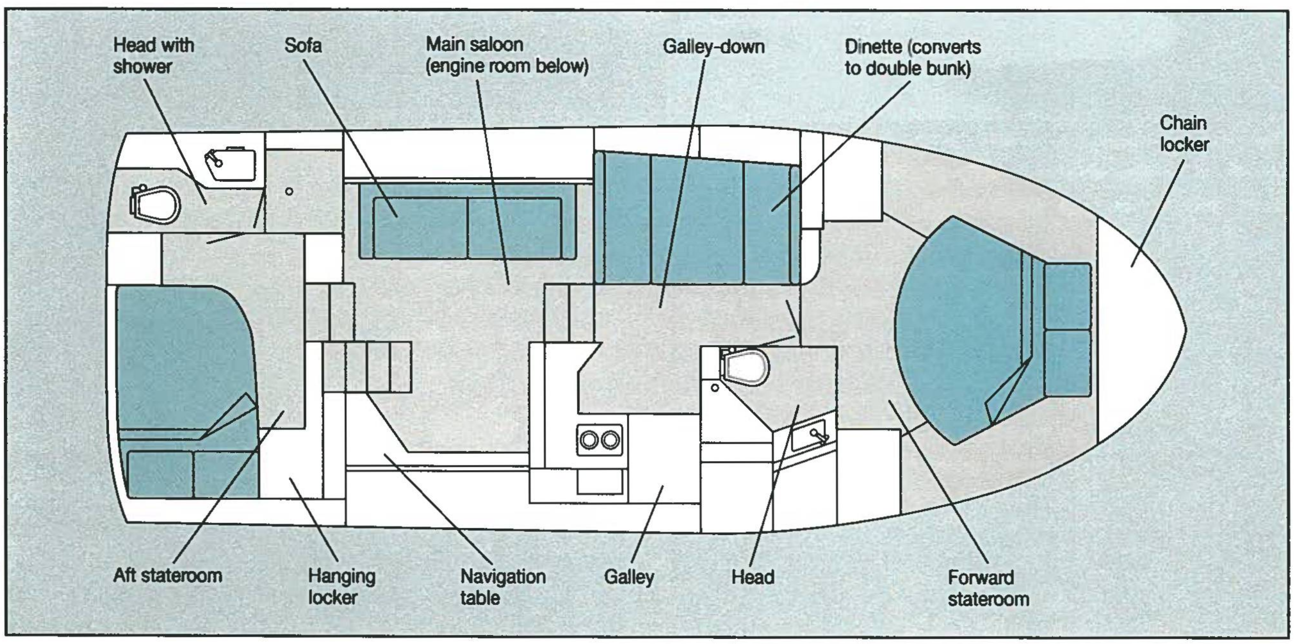
Sailboats are seldom identified according to their cabin layouts—probably because less variety is possible. Instead, sailboats are usually known by their *sail plans*: the number of masts and the position of their sails (described on pages 36 and 37). Sailboats almost always have a *cockpit* placed near or at the *stern*. Interior accommodation is found in a *cabin trunk* forward of the cockpit. While interior space receives the most attention from new boat buyers, it is actually the *cockpit* where most sailors' time is spent.

Center-cockpit sailboats roughly correspond to the aft cabin style in powerboats. With sufficient width at the stern, it becomes possible to build a compact cabin behind or partially under the cockpit. As this cabin grows in size with increasing hull length, the cockpit itself can be moved forward to a more central position. However, to maintain useful space below, it is necessary to raise the cockpit sole to the level of the deck. The result is ungainly in center-cockpit boats of less than about 40 feet (12.2 m) in length.

Sailboat cockpits

Because a cruising sailboat cockpit is both an entertainment and a control center, compromises must be made between access to *halyards* and *sheets* (lines to hoist and trim sails) or to *winches* (devices to increase the pull on such lines) and the comfort of the crew. Typical cockpits have facing bench seats that are close enough together that crew members can brace themselves as the boat tilts—or, in nautical language, *heels*. Cockpit seats sometimes lift open to reveal *seat lockers*, stowage for *sail bags*, an inflatable life raft, dock lines, sheets, winch handles and the accumulated etcetera of life afloat.

A *pedestal* with steering wheel may stand near the aft end of the cockpit. On top may be a *binnacle*, a case that houses a *compass (Chapter 17)*. The pedestal may also support *shift* and *throttle* controls for the auxiliary engine. The *wheel* con-



At about 35 feet (10.7 m) in length, powerboat hulls can have enough freeboard and beam to allow for spacious accommodation with standing headroom. On this boat, the main saloon is raised above the engines amidships, and the galley is "down."

trols the *rudder* that steers the boat. On smaller sailboats, a *tiller* (a handle attached to the top of the *rudder post*) replaces and serves the same function as the wheel.

Regardless of whether a boat uses a wheel or a tiller, the steering controls are called the *helm*. The person (man or woman) handling those controls is traditionally known as the *helmsman*. Over-large steering wheels on many racing sailboats restrict movement in the boat's cockpit, but they allow the helmsman to sit to one side or the other of the cockpit. From there, the helmsman can see the *luff* (forward edge) of the *headsail*. Or, the helmsman may perch on the *coaming*, the raised edge that surrounds all but the leanest and meanest racing cockpits.

Useful for swimming, a swim platform can also be used to board a dinghy. It may also allow an overboard crew member to be brought on board.

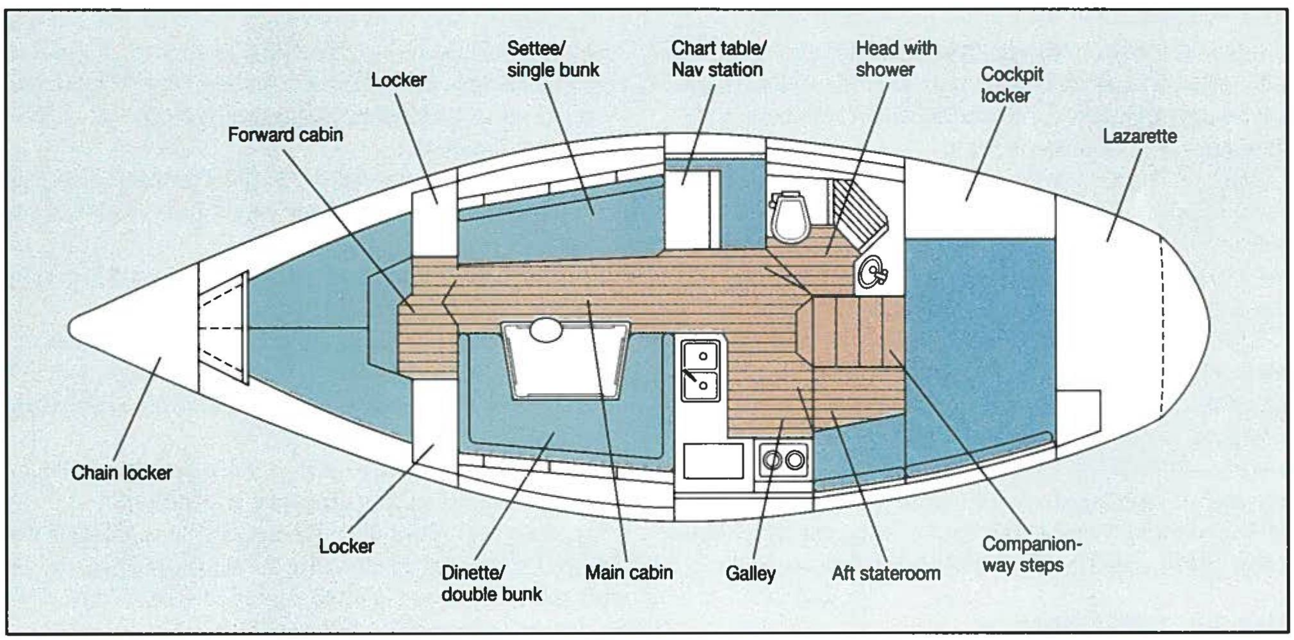
Connecting the sailboat cockpit to the main cabin is a *companionway* consisting of a steep set of ladderlike steps, *grab rails* and a *sliding hatch*. The part of the cockpit that must be stepped over at the top of the companionway is called a *coaming*, an important safety feature. If the cockpit were to fill with water from a large wave, this barrier would prevent it from going down into the interior and collecting in the *bilge*, the hull space under the cabin sole.

Water in the cockpit drains through at least two *scuppers* (drain holes) leading from the lowest point on the cockpit sole through the hull. Of course, the cockpit sole must be at a height above the *load waterline (LWL)* of the hull for these drains to work.

Aft of the cockpit there is often stowage space called a *lazarette*, accessed through a hatch. In more recent designs, the lazarette is giving way to two or three steps leading from the level of the cockpit sole to a small platform near the water. This *swim platform* serves as a "back porch" for swimming and may allow an overboard crew member to be brought back on board.

Powerboat cockpits and bridges

The central element of the small powerboat cockpit is the *control console*. Controls such as the *steering wheel* and *throttle and shift levers* must be placed within easy reach. There must be good sight lines so engine instruments and electronics must be easily viewable. As the length of powerboats increases, it becomes possible to raise the control position above the level of the cockpit sole—where it can more easily be given the traditional name, bridge.



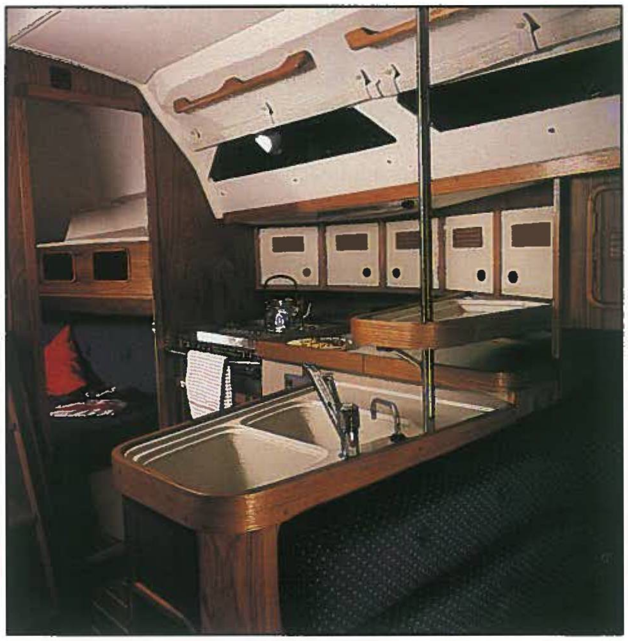
Interior accommodation varies widely, depending on the LOA and beam of the boat. This 34-foot cruising sailboat offers generous cruising accommodations: a double V-berth, a double aft cabin, a U-shaped dinette that converts to another double bed, and a settee across from the dinette that provides a single berth.

Limited space makes it a challenge to arrange all of the electronics and radio communications equipment on the console in a practical fashion. One common and sometimes overlooked problem is placing the compass in a position that is conspicuous, but which leaves it as free as possible from magnetic influences. Magnets in radio speakers and other electronic equipment can wreak havoc with compass accuracy.

At about 30 feet (9.1 m) of length overall, it becomes possible to provide a flying bridge, usually abbreviated to the term *flybridge*. The flybridge has become popular because it allows more confident control of the boat. Sun and weather protection is often provided by a *bimini top*—a rectangular canvas canopy on a light framework—along with clear plastic side curtains.

Many boats have dual steering stations, one in the cabin and the other on the flybridge. Steering and engine controls are duplicated, as are some electronics. This design allows for a comfortable steering position in any weather.

Powerboats have had swim platforms for years and are now using *gates* through the *transom*, the back of the hull, to permit easier access.



On board both sailboats (as above) and powerboats, the galley is often part of the main cabin. Settees and couches that convert into berths for sleeping are usually included in the cabins.

The main cabin

On board sail and powerboat cruisers, the *main cabin* usually serves multiple uses—living room, kitchen, and sometimes bedroom, too. It may also accommodate a *nav station* for plotting the boat's course on a *chart table*. On most boats, built-in settees serve as couches by day and convert to berths by night. An adjustable dining table may offer extra sleeping space.

Cooking is done in the *galley*, portions of which may also do double duty. Countertop space for food preparation is often also part of the nav station. Somewhere in the layout of the boat's interior, the designer must find space for the toilet room, usually called the *head*—after the nautical name for the actual commode. A wash basin and "telephone-style" shower are also common in heads.

Floor, as a nautical word, applies specifically to structural parts of the boat and not to the surface on which the crew walks. Walking surfaces are more properly called decks, or soles. Don't look up for the ceiling. *Ceiling*, in the nautical sense is the covering—often light planking or slats—that hides the inside surface of the hull. What would be the ceiling in a house is known as the *overhead* or, if made of soft material, the *headliner*.

Lighter and wider shapes for sailboat hulls have allowed designers to improve the *quarter berth*. Formerly a narrow fore-and-aft sleeping space for a crew member on standby duty, modern sailboat quarter berths have become *aft staterooms*, previously the hallmark of luxurious powerboats.

Stowage and lockers

Bunks, galleys and heads serve the crew directly. Additional space must be found for the *gear* (personal baggage) each person brings on board and the *stores* (supplies and food) needed for the voyage. Unfortunately, too many designs give scant attention to the need for *stowage* and *lockers*. At least one *hanging locker* is needed to hold carefully pressed "going ashore" clothing. A separate *wet locker* should be provided for soggy *foul-weather gear* (rain jackets and pants).

Most galleys have only enough food stowage to last a weekend or so. On longer cruises, it becomes necessary to place galley stores at locations throughout the boat. On board a sailboat, the bilge (lowest part of a hull's interior) is ideal for careful stowing of heavy cans and bottles. Paper labels must be removed to avoid clogging the *limber holes* that ensure bilge water drainage.

Improperly planned stowage can affect the boat's handling and perhaps its safety in stormy conditions. The following points are worth considering:

- Keep the boat's center of gravity low. Heavy items generally should be stowed low in the hull and light items high.
- Heavy gear is best stowed amidships, freeing the ends for light gear and stores. Too much weight in the ends, particularly the bow, adversely affects the performance of both powerboats and sailboats.
- Light items that must be kept dry are best stowed high, carefully wrapped in zipper-top food storage bags.
- Especially for long cruises, storage of food is practically a science. Perishables are stowed in the icebox, which on boats with sufficient power is often equipped with electrical or mechanical refrigeration *(Chapter 23)*.
- In some boats, a stowage plan is necessary for safety reasons—to ensure quick access to emergency equipment or tools, for example.

DESCRIBING HULLS

A vessel floats because water exerts a buoyant force on it. This force exactly equals the weight of the water that is displaced by the hull. To benefit from the force, the vessel must weigh no more than the volume of the displaced water. If the boat should weigh more than the water it displaces, any buoyant force would be inadequate and it would sink.

Floating in salt water is different than in fresh water. Since salt water is heavier and thus more dense, a hull needs to displace a smaller volume of salt water than of fresh. That's why the draft of a boat decreases when it goes from a fresh water river into the salty ocean. As a boat settles into the water—imagine it lowered in *slings* by a crane—it reaches a level of equilibrium where the weight of the displaced water equals that of the boat. This level is the *waterline* and is often marked by a *boot-top*, a contrasting horizontal band painted around the hull just above the waterline. Below the waterline, *anti-fouling* paint is applied to reduce marine growth.

If vessels were required merely to float, hulls would all look much the same. The only variations would be overall size and the materials used to build them. But boats must do more than just float. They must also move through the water. And once they begin to move, the complex laws of physics inspire an extraordinary diversity of hull shapes. Over the years, this diversity has fostered a vocabulary to describe both hull shapes and specific locations on those hulls.

Parts of the hull

The words "bow" and "stern" refer to the front and back ends of a boat respectively; they also can be used to indicate larger areas of the hull without distinct limits. In the middle is the *midships*. The transom is the hull's back vertical surface. Planing-hull powerboats have wide transoms. Displacement-hull sailboats usually have smaller, narrower sterns. If the transom does not reach the waterline, there is a *counter stern*. A transom angled forward is a *reverse transom*. On some displacement hulls, the transom disappears; such a hull is *double ended* and may be described as having a *canoe stern*.

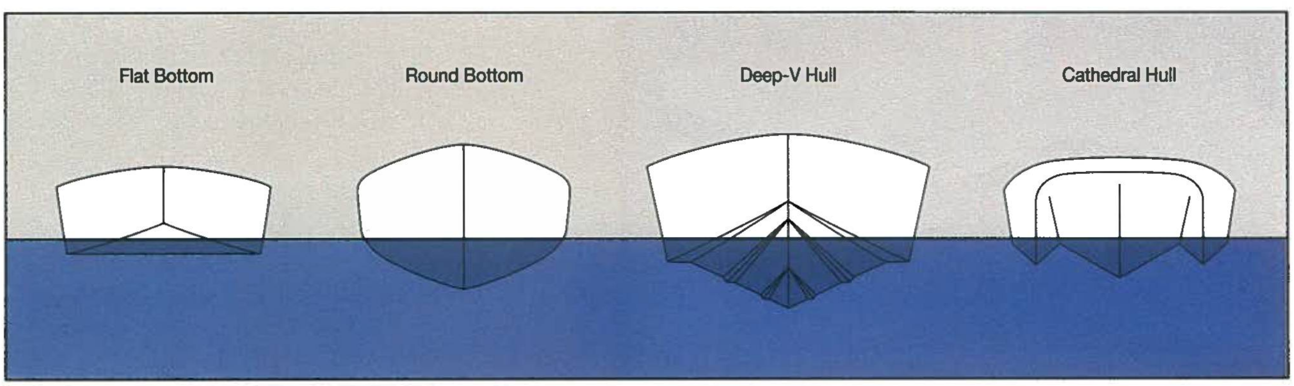
The extreme forward part of the bow is the *stem*, a word left over from a time when there was actually a structural wooden piece in that position. A boat with a stem that is straight and nearly vertical has a *plumb bow*. If the stem leans forward, it is *raked*. If the sides at the bow curve outward (typical of a powerboat), the boat is said to have *flare*. A *spoon bow* (typical of a sailboat) has convex sides.

The length overall, often abbreviated LOA, refers to the distance from stem to stern. It does not include bowsprits or swim platforms unless they are integral to the hull. Thus, a boat with an LOA of 35 feet (10.7 m) might have a total length of 42 feet (12.8 m) when these appurtenances are considered.

The *gunwale* (pronounced "gun'l") is the structural element at the upper edge of the hull and its shape strongly affects the boat's appearance. The often subtle curve of the gunwale when viewed from the side is the *sheer*. Yacht designers pay considerable attention to the sheer because it strongly influences a boat's aesthetic appeal. Traditional sheers curve upward toward the bow. Today a *reverse sheer* is common, especially to increase the interior space of a powerboat or to emphasize the pointiness of a sportboat's bow. A sheer that is not irregular and has no distortion is described as *fair*.

A *fine* hull is narrow as opposed to *beamy*, or wide. A beamy boat usually will have a *bluff bow*, while a fine boat will have a fine bow. The *entry* is the place where water flow comes under the influence of the hull shape. The flow leaves the hull as it passes under the *aft run*. In general, the aft run is wide and straight for fast hulls, narrow and curved for slow ones. *Freeboard* is the vertical distance from the waterline to the gunwale. Freeboard is higher at the bow than at the stern, at least in North American and European boats. The surface of the hull from the waterline to the gunwale, with the exception of the transom, is the *topsides* and not even the popular shoe bearing that name will allow you to walk on it.

From the boat's waterline to the bottom of the hull is known, not surprisingly, as the *bottom*. The distance from the waterline to the deepest part of the boat is called the *draft*. (This term also refers to the minimum amount of water in which a boat will float; a boat is said to "draw" a certain amount of water.) On a sailboat or displacement powerboat, the lowest point is usually the bottom of the keel; for planing-hull power-



A flat-bottomed boat is inexpensive to build, but pounds; a round bottom provides a soft ride at displacement speeds. The deep-V hull is used on high-speed offshore craft; cathedral hulls have good stability.

boats, it normally is the propeller tips. Single-screw displacement powerboats often have a *skeg* that protects both the rudder and the propeller by being the boat's deepest part.

The word *section* normally means a cross section of the hull cut at right angles to the keel. In boat building, a *section mold* is one of the forms used to create the hull's shape.

Boat hulls are divided into two broad categories: *displacement* and *planing*. A displacement hull gets all of its support from buoyancy. Planing hulls obtain dynamic lift from a combination of hull shape and the speed at which they move through the water. In addition, there are also two small but increasingly important subcategories: hulls that achieve lift through air pressure (*tunnel hull* hydroplanes) and hydrofoil boats that "fly" on small, immersed wings.

Displacement hulls

All cruising sailboats and large, low-speed powerboats (such as trawlers) use the low power demands of displacement hulls to advantage. Little driving force is needed to move one of these boats until hull speed is reached. Then, no reasonable amount of increased power results in any efficient increase in speed. A close approximation of any vessel's hull speed in knots can be found by multiplying the square root of its waterline length (in feet) by the constant 1.3. A boat with a 25-foot (7.6 m) waterline has a theoretical hull speed of 6.5 knots: $\sqrt{25} \times 1.3 = 5 \times 1.3 = 6.5$.

The need for an easily driven hull is obvious in a sailboat. In a powerboat, a displacement hull allows long-range cruising with minimal expenditures on fuel. Cruising ranges in hundreds of *nautical miles*—6,076 feet (1,852 m) or 1.15 statute (land) miles—are not uncommon, especially for a trawler-style boat with a single diesel engine. Another advantage of a displacement hull is the ability to carry heavy loads with little penalty in overall performance.

Trawler-style hulls are often rounded and would be termed *round-bottom hulls*. A round-bottom powerboat hull has little or no discontinuity in the curve of its section between the gunwale and the keel. Put another way, the *turn of the bilge* is slack. Occasionally, a displacement hull will be *flat bottomed*, but this design is for ease of construction rather than for reasons of efficiency.

Hydrodynamic force lifts a planing hull partially out of the water, reducing drag and wave-making resistance. This makes high speeds possible.

Flat-bottomed hulls have defined "corners," called *chines*, where the sides of the hull meet the bottom. Some trawler-style hulls combine round-bottom sections forward and flat-bottom sections in the aft run. Pushed above hull speed, this design operates as a semi-displacement hull. The higher speeds come at the expense of increased fuel consumption.

Planing hulls

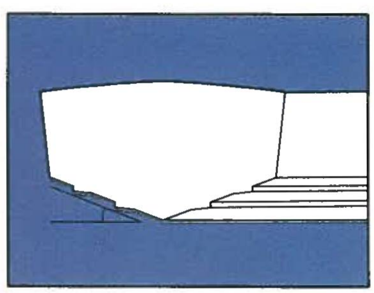
Hydrodynamic forces are used to lift a planing hull almost out of the water. This greatly reduces drag and wave-making resistance, allowing relatively high speeds. Nearly all modern powerboats have planing hulls. Small, light sailboats with large sail plans can reach planing speeds in ideal conditions.

A planing hull is characterized by a flat aft run that meets the transom at a sharp angle. This angle allows water flowing under the hull to "break away" cleanly from the transom. Hydrodynamic forces on the flat aft run lift the boat until only a small portion of its bottom is in the water. Distinct chines aid in speed and directional control as speed increases.

It takes lots of horsepower to achieve planing speeds and that means higher fuel bills. As a result, the cruising range of a planing hull is generally much less than that of a displacement boat carrying the same amount of fuel. Of course, the planing hull gets to its destination a lot sooner!

The V-hull

Pounding inevitably occurs when any boat is driven through rough water at high speeds. It is accentuated by the broad, flat sections required of an efficient planing hull. Slowing down eliminates the problem, but many planing hulls become much more difficult to maneuver at slow speeds. The need to compromise between planing speeds and *sea-keeping* qualities has led to the almost universal acceptance of the *V-hull*, a design developed in the mid-1950s. A steep *deadrise* (the angle formed at the transom by the V) provides acceptable wave-riding qualities along with sufficient planing ability to achieve high speed. Many variations in hull design have been tried, but almost all of them fall within the *modified-V* type, typically considered to include boats with deadrise of approximately 16 to 19 degrees.



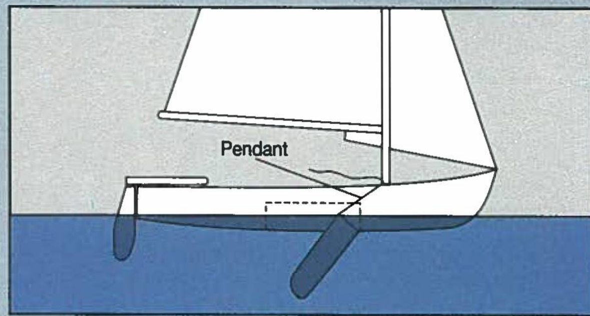
Hulls with deadrise angles of 16° to 19° are considered to be modified-V types. Steeper angles, as high as 23°, are considered deep-V types.

SAILBOAT HULLS

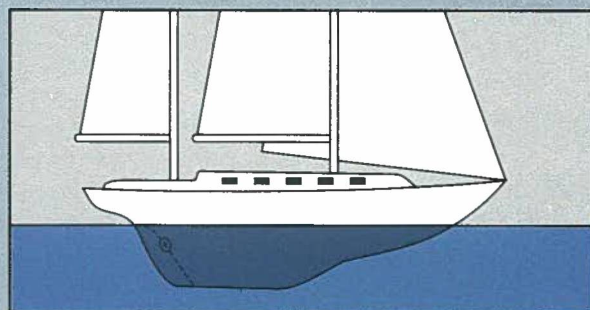
Unlike any other type of boat, a sailboat needs a hull with a large amount of *lateral resistance*. Without this resistance it would blow sideways instead of sailing forward. Small, unballasted sailboats use movable appendages called *centerboards* or *dagger boards* to provide lateral resistance. A centerboard is hinged and swings down out of a *centerboard trunk*, while a dagger board goes down vertically and can be completely removed from the boat. An older method of obtaining lateral resistance is through *leeboards*, which look like centerboards, attached to both gunwales.

Larger sailboats have permanently attached *fixed keels* designed to provide lateral resistance. Older designs have a *full keel* that starts near the bow and continues aft until it joins the rudder. In recent years, *fin keels* have become popular because they allow greater maneuverability and improved upwind performance. The rudder of a fin keel boat may be attached to a small *skeg* for protection, or it may be a separate appendage known as a *spade rudder*.

Both full and fin keels also serve as the boat's fixed ballast. Modern practice is to form these keels out of lead or cast iron so the ballast is outside and below the hull where it has maximum anti-heel effect. Ballast has no effect until the boat begins to heel. As the angle of the heel increases, the ballast exerts an increasing force to right the boat. A ballasted sailboat typically will heel rather easily at first, then "stiffen" as the ballast takes effect. Each sailboat has an angle of heel where the hull achieves maximum performance.



A centerboard is raised or lowered in its trunk by a *pendant* (pronounced "pennant") to permit adjustment according to the point of sail or for shallow water.



A full keel is usually found on larger boats. It may have internal ballast or exterior ballast bolted onto the hull—which also acts as a *grounding shoe.*

Deep-V and modified-V hulls are very sensitive to trim tab adjustment and to small changes in the angle of propeller thrust. Trim tabs are rectangular control flaps that project parallel to the water's surface at the transom when the hull is planing. Adjusting the tabs down changes the boat's trim by pushing the stern up and the bow down. The angle of propeller thrust is fixed on a conventional inboard boat, but is adjustable with an outboard motor or inboard/outboard drive.

Ballasted hulls

A sailboat must be able to resist the *heeling force* created by the sails. This force acts high above the deck where it has maximum impact on stability. The boat can fight the heeling force with hull shape and *ballast* (weight put on board specifically for this job). Heeling is the tipping of a boat caused by wind in the sails. (This is in contrast to *listing*, which is tipping caused by improper weight distribution.) A flat-bottom hull presents immediate and strong resistance to heeling, but will ultimately give up with a sudden *capsize*, turning bottom up. At the other extreme, a round hull required for efficient sailing offers little initial resistance to heeling. Likewise, a fine hull offers less resistance to heeling than a beamy one.

The force exerted by the wind on the sails creates a heeling effect, which causes a sailboat to lean away from the wind.

BOAT CONSTRUCTION

Recreational boat building underwent a revolution about 40 years ago. Until the late 1950s, the principal material used in boat building was wood. A major change started when polyester resins and glass fiber became accepted as durable and economical materials. Within a few years, almost the entire small craft industry switched to molded plastic construction, which continues today to be the standard method.

Wooden construction placed severe limitations on the designer. On the other hand, it allowed the *boatwright* (the craftsman boat builder) wide latitude to express his taste and expertise by manipulating the material. *Fiberglass* (fiber-reinforced plastic) molding has created exactly the opposite situation. Molding allows designers unprecedented freedom to express their ideas in both structure and style, but it requires minimal skill on the part of the workers. The leveling effect on the craft of boat building was soon apparent.

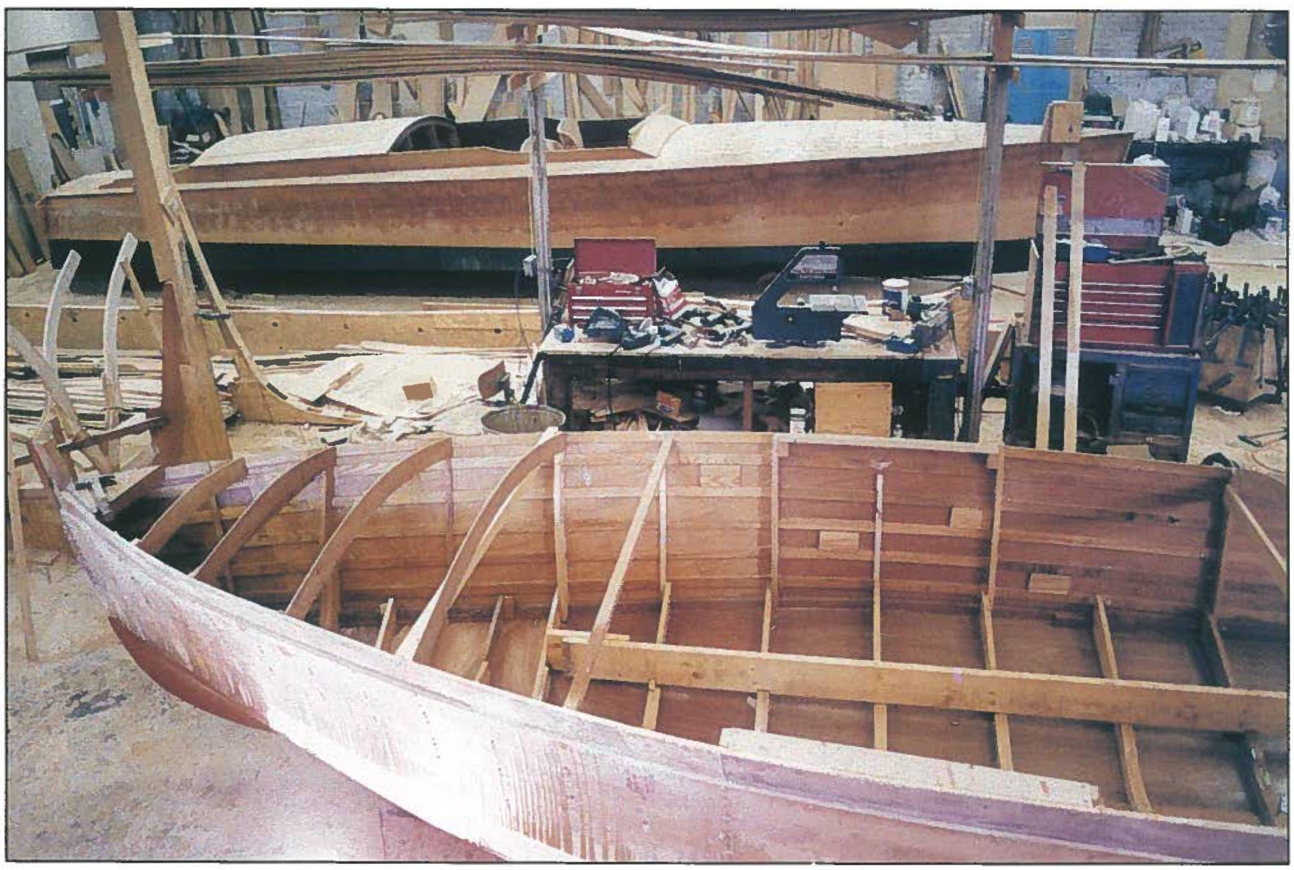
This effect is also apparent in the losses to our boat-building vocabulary. Words such as "carlin" and "bearding line," for example, no longer have meaning in the context of boat construction except among wooden boat aficionados. However, there are enough wooden boat enthusiasts and enough wooden boats that many novice boaters may someday find themselves experiencing the unique pleasures of replacing a rotted plank or varnishing a vast expanse of *brightwork*—a boat's wooden trim. For that reason alone, the language of wooden boat construction is worth preserving. However, there is also a practical side: The terminology of wooden boat building helps to provide a more thorough understanding of the much newer vocabulary of fiberglass construction.

Wooden boat terms

Larger wooden yachts built in North America before World War II were built in *carvel* construction. Separate planks were fitted to the *frames*, or ribs, of the boat. Each plank was butted flush with its neighbors to form a smooth outer surface. Slight gaps between planks were sealed by *caulking* with a fiber and tar compound called *oakum*. After the boat was launched, the planks would swell, tightening the seams.

At the same time, a large number of mostly small craft were produced using a Scandinavian method of overlapping the planks. Called *lapstrake* construction, this method yields a boat with a noticeable "step" at each lap. A *strake* in the context of these wooden boats is a continuous line of planking. Planks were held together with copper clench nails, giving rise to the term *clinker built* as an alternative description of this construction.

Factories built large numbers of boats up to about 30 feet in length upside-down on *jigs*. A jig is a dimensionally correct



On wooden boats, frames (also called ribs) are set into the keel at right angles, then covered with planking. These boats are carvel-planked runabouts. Each continuous line of planking along the hull from bow to stern is called a strake.

framework that holds the parts in position until the hull is strong enough on its own to be rolled over and completed. Extremely well-defined series production methods allowed pre-war boat builders to turn out a consistent, cost-controlled product for a large market.

Larger yachts, particularly those built as a one-off contract, would be built right side up in *stocks*. The keel would be laid, then the frames erected on it. Planks would be attached starting simultaneously at the gunwale with the *sheer plank* and at the keel with the *garboard*. Each plank might have been *rabbeted*, given a shoulder along both edges to allow a more secure fit and a gap wide enough for caulking. The last plank, usually installed near the turn of the bilge, was known as the *shutter plank*.

Joints where frames met on the keel were reinforced with roughly triangular pieces called *floors* or *floor timbers*. In a ballasted sailboat, floor timbers supported the long *keel bolts* holding the exterior ballast keel in position. A substantial and carefully fitted timber at the bow, the *stem*, accepted the plank ends and tied them together. The stem was usually reinforced to the frames by another triangular piece called a *breasthook*.

The deck was formed by *beams* with a slight convexity known as *camber*. Fore-and-aft stiffness was provided to the deck by *carlins* which might also accept the bolts holding important deck *fittings* such as a *mooring bitt*. The deck itself might be planked and caulked, or made of plywood covered with canvas waterproofed with paint.

From planking to plywood

In the late 1920s wooden boat building began to see some influence from aircraft construction, which was then also executed largely in wood. In fact, many early airplane builders began their trade by crafting lightweight, high-performance racing boats. Improved glues resulted in plywood receiving respect as a secondary boat building material. But it was not until after World War II that *cold molding* became accepted in the marine world.

Cold molding involves thin, flat strips of wood that are laid diagonally over a male mold. Additional layers are applied at about right angles to previous layers until the desired thickness is achieved. Each layer is set in waterproof glue, resulting in a strong, lightweight *stressed-skin* hull that has little need of interior framing. In recent years this process has been further improved through the use of epoxy glues.

World War II brought large-scale use of sheet plywood in boat construction that was quickly adopted for civilian craft. Plywood was inexpensive, strong for its weight and easy to use. Its major drawback is that it can be curved in only one physical plane; it can be formed into a cylinder, but not a sphere.

Hard-chined hulls

Fortunately, the switch to plywood coincided with the availability of cheap, powerful engines. The shaping limitations of plywood forced the creation of hulls with boxlike *hard chines*, but these proved ideal for high-speed planing performance. The nation's waterways quickly filled with amateur-built boats brought to life from the pages of *Motor Boating, Rudder, Popular Mechanics* and other do-it-yourself magazines of the late 1940s and 1950s.

Hard-chined designs are equally easy to build in steel or aluminum. Both of these metals are used extensively in larger yacht construction. Modern epoxy coatings enable the steel or aluminum to be encapsulated to prevent *electrolysis* or corrosion. With notable exceptions, few production builders have chosen to mass produce metal boats. Steel and aluminum generally have been reserved for the serious amateur or for custom, one-off construction.

A chine—the sharp angle at which the sides of a boat's hull meet the bottom—provides this deep-V powerboat with better control and a dry ride at planing speeds.

The shift to plastic

Then came the chemists. With several drums of *thermosetting* resin, a few cans of *catalyst* (a curing agent), some bolts of white glass-fiber cloth and a mold, just about anybody could get into the boat-building business. Early molded boats were fairly timid imitations of carvel planked wooden hulls. Since no one was really sure how strong fiberglass was or how long it would last, most builders erred on the side of safety. The result, as we know today, was overly heavy hulls that were almost indestructible. Current fiberglass hulls are much lighter in weight and much less likely to suffer cosmetic deterioration, yet still appear to be as indestructible as their overbuilt predecessors.

The principal advances in molded construction—at least for boats on long production runs—involve the use of rigid foams or *balsawood* cores. Fiberglass is strong, but heavy and not very stiff. Sufficient panel stiffness can be achieved by separating two layers of glass with a light but compression-resistant core. *Cored construction*—also called *composite*

Fiberglass construction allows multiple hulls, superstructures and other components to be made economically from reusable molds. Surfaces can be of any desired compound curvature. In addition, plastic hulls resist attack by marine organisms—but they do require anti-fouling paint.

construction—is now almost universally used in many areas of hulls and decks. The structure might also be stiffened by the use of box sections called *high-hat sections* forming a grid or running longitudinally inside the hull or deck.

Other advances have been made in *gel coat* formulation to provide a glossier and more color-retentive surface. Gel coats and barriers have also been formulated to prevent *osmosis*, the movement of water through the gel coat that eventually produces blisters.

A typical *mold schedule*, or list of layers, consists of a gel coat; possibly an osmosis barrier; alternating layers of *mat* (cloth made of irregular short fibers), regular fiberglass cloth and *roving* (stiff, coarse woven cloth); and, occasionally, chopped strand sprayed onto the surface by means of a pneumatic gun. This series of layers might be followed by the core material and further interior layers. Each layer is *laid up*, or hand-rolled into place against the highly polished surface of a female mold.

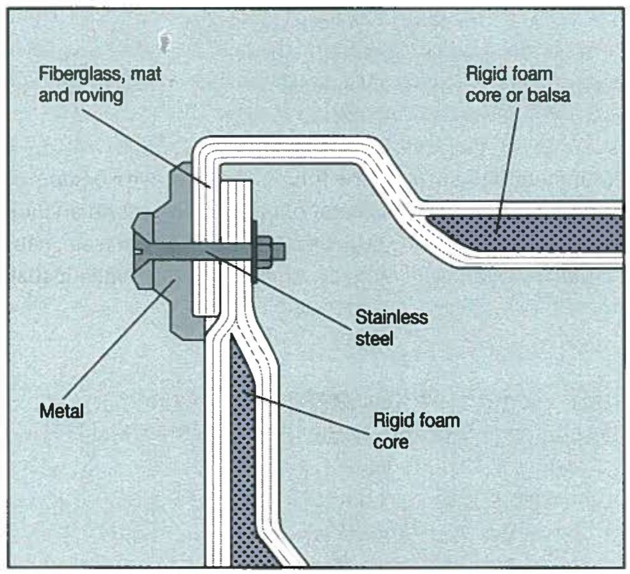
Secondary parts of the boat are also molded out of fiberglass, usually with a simpler schedule than is used for the hull. The major parts are lifted from their molds to receive various fittings and equipment (such as cleats, winches, hatches, rails, windlasses, tanks and electrical harnesses) before they are assembled into a boat.

The hull-deck joint

The chief engineering problem, once the molding is complete, is how best to attach the deck to the hull. Theories abound, but in general the best *hull-deck joints* offer large surfaces for *bedding compound* or other sealers and adhesives. Thick wood or metal bearing plates for through-bolt attachments and a box-shaped section for stiffness are also requirements. Finally, there must be provision for *rub rails* and *stanchion bases*.

Molded construction is also used for one-off, high-performance racing boats—both power and sail. While the methods used are similar to production boats, one-off projects make more use of better materials such as *unidirectional*, *biaxial* and even more specialized glass cloths. Epoxy resins often replace the polyester resins used in conventional boats. And reinforcing materials other than glass fiber, such as *Kevlar* and *carbon fiber*, are used.

In terms of industrial design, today's molded boat can be considered a great success. An extremely durable, strong and safe product, it costs far less than the equivalent vessel built of wood. And it has brought to boating a much larger group of owners than was ever contemplated in the days of the boatyard craftsman.



Hull-deck joints must be rigid and watertight. Most are molded box-sections that are liberally caulked with adhesive sealants. Stainless steel through-bolts provide additional security. This hull-deck joint is appropriate for a small powerboat.

Sailboat masts and spars

While carbon fiber is also used in the construction of sophisticated racing sailboat masts, the majority of modern sailboat *spars* are made of extruded aluminum alloy. Most *masts* and *booms* (the horizontal spar at the base of what is usually the *mainsail*) are simple tubes. When more efficient shapes are required, they can be fabricated by cutting and rewelding basic extrusions.

Aluminum is strong, so mast failures are rare except on board hard-pressed racing boats. Its main advantage, however, is the material's light weight, which keeps the boat's center of gravity low and improves sailing performance. Many replicas of older ships now carry aluminum spars that are dressed to look like either steel or wood.

DECKS, FITTINGS AND LINES

The deck is an important structural part of the boat, its design dictated as much for strength as by aesthetics. This is particularly true of sailboats with deck-stepped masts that are supported entirely by the deck. Fortunately, the nature of molded fiberglass construction allows naval architects to achieve strength through the shape—curves and angles—of the deck, as well as through the materials used. Beauty can be functional, too.

In wooden boat construction, decks are horizontal while *superstructures* such as a *deckhouse* or *trunk cabin* are vertical. Everything is separate pieces held together by fasteners and caulk. Fiberglass construction allows deck and superstructure to be blended into one seamless part.

A trunk cabin seldom projects more than 18 to 24 inches above the surrounding deck. A small *doghouse*, or raised section, may be added to provide standing headroom inside. This combination is typical of many sailboat designs of the 1950s and '60s. A true deckhouse, common on sportfish and convertible power cruisers, provides full standup headroom and is large enough to enclose the main saloon.

The open expanse of deck forward of the superstructure is known as the *foredeck*. This is where anchor handling equipment will normally be found, together with a *samson post*, a stout wooden or metal *bitt* around which an anchor rode or tow line can be attached. If the boat has a trunk cabin, *side decks* will lead aft to the cockpit. Safety demands that the walking areas of all exterior decks be treated with nonskid material.

Fittings and equipment

The fittings and equipment that the novice boater must learn to use depend on the nature of the boat. This can be illustrated by two modern boat types: the high-powered sport runabout; and the high-performance racing sailboat.

The sport runabout is almost bereft of anything that might be called deck "hardware." Its deck is a gleaming sweep of plastic with hardly any indication that the boat might ever be tied to a pier. A close look will likely reveal a couple of *cleats* (fittings with outward curving arms, or horns) designed to accept a mooring line or loop of a *lanyard* tied to a *fender* (a pneumatic cylindrical cushion that protects the boat's side when docked).

The racing sailboat, on the other hand, can seem to have no other purpose than to carry hardware. Like a display in a well-stocked marine supplies store, it has a bewildering variety of *blocks*, *clamcleats*, *linestoppers* and *snapshackles*.

The difference between the two boats is that, in the case of the sport runabout, the engine is self-contained and normally hidden from view. Open the motor box and the complexity of this type of boat is immediately apparent. The racing sailboat, by contrast, is a kind of "wind engine" entirely open to view. The complexity of this boat is on deck, not hidden below. In both cases, the hardware is linked to its means of propulsion and appropriate to the boat's intended purpose.

Making fast

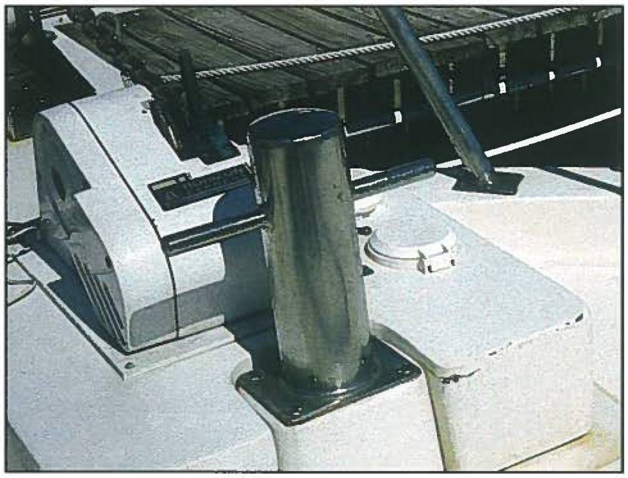
Making fast is the nautical term for securing a *line*—rope cut for a specific purpose—to a cleat or other fitting. Most often, it is the proper term to describe tying the boat to a pier, a wharf or even a tree on shore. With a small rowboat this can be as simple as taking a *painter* ashore and looping it over a bollard. (A painter is a light line usually permanently fixed to a ring bolt at a small boat's bow.) Painters are adequate for making fast small craft like dinghies. Making fast a boat only slightly larger and heavier presents challenges. *Dock lines* must be carefully placed, even for a stay of only a few minutes.

Starting with the smallest auxiliary sailboat or outboard runabout, every vessel needs well-made hardware properly placed for the purpose of making fast to a pier. Deck cleats must be substantial and through-bolted with a backing plate under the deck. A single large cleat is often installed near the center of the foredeck of small cruisers. It serves as both a docking cleat and a fitting to secure the anchor line.

Most builders install two cleats near the stern, one on each side. The one closest to the pier normally gets the work. Additional cleats are often placed along both gunwales about one-third and two-thirds of the boat's length from the bow. These cleats are useful for *spring lines* (also called "springs") that control the boat's lateral movement along the pier.

While a good quality, well-installed deck cleat is adequate for making fast in a dock, it is not intended for towing—which puts considerably more strain on hardware than making fast to shore. Larger and heavier boats are often fitted with a forward samson post, the best of which extend through the deck and are attached to the keel, becoming an integral part of the structure; if one does not go down to the keel and is bolted to the deck, a strong *backing plate* must be used on the under side. A horizontal *norman pin* goes through the samson post to prevent a line from coming up and off the post.

The foredeck should provide a secure pulpit, strong stanchions and lifelines, and a toe rail to brace against. Cleats on a boat not equipped with a samson post must be strong enough for anchoring and for any towing. Fittings on this racing sailboat have been chosen for their light weight and not their strength.



The samson post, a strong fitting on the foredeck, secures the anchor rode or docking lines. The norman pin, which passes through it, keeps lines from riding up and off the post.

Staying on deck

Rails are installed around the sides and ends of the deck to prevent crew members from falling overboard; they may be of metal tubing or plastic-covered stainless steel wire. These are supported by *stanchions* along the gunwales. Sailboats and some powerboats will have *pulpits* made of metal tubing on the bow and sometimes at the stern. Handrails on trunk cabins and at other locations aid in moving about safely.

A solid barrier at the deck edge on larger boats is a *bulwark*, usually topped by a *cap rail*. At the stern, such a rail is a *taffrail*. Smaller craft that cannot support bulwarks often have *toe rails* to keep an errant foot from slipping. Toe rails may be made of teak or special aluminum extrusions. Sailboats often use slotted toe rails as attachment points for hardware.

Some sailboats have special eye bolts installed at various locations around the deck where crew members can secure the *tethers* of their *life harnesses*. A life harness keeps the wearer attached to the boat even during an accidental slip overboard. An alternative to eye bolts is a plastic-coated stainless steel wire running from bow to stern at the middle of the deck. Known as a *jackline*, it allows the crew free movement fore-and-aft without the need to unclip their tethers.

Other deck fittings

A variety of equipment in addition to fittings for making fast or adjusting rigging is found on boats. Other deck items range from hatches and windows to ventilators and windlasses.

A boat more than 30 to 35 feet (9.1 to 10.7 m) long, especially if frequently at anchor, is generally fitted with a special type of rotating-drum winch called a *windlass*. This device handles the heavy work of retrieving an anchor and a long *rode* (anchor line). A windlass is usually powered by hand or an electric motor, although some larger units use hydraulics.

Fenders are essential to protect the topsides against damage when securing to a pier or *rafting* alongside other boats. (They are always "fenders," never "bumpers.") Fenders are rigged from the gunwale or lifelines on lanyards. Setting them properly is a skill that must be acquired, even though most boats are equipped with a *rub rail*, a protective metal strip (often with a metal cap or vinyl insert) along the gunwale, or lower on the topsides on a *rubbing strake*.

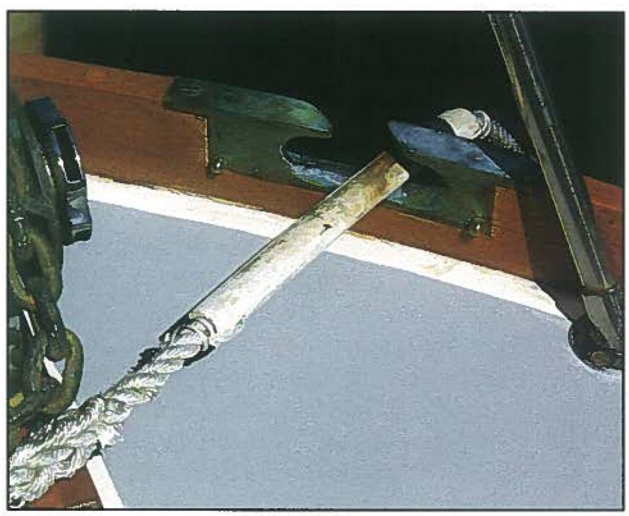
Because of a boat's small space and constant dampness, ventilation is an issue: Air must be let in, but water kept out. One of the best solutions is a Dorade vent (named after a famous racing sailboat). A Dorade has a cowl atop a two-part box—a box with a barrier in the middle. Air flows over the barrier, but water is trapped and allowed to drain back out.

Smaller nautical windows are called *deadlights* when they cannot be opened and *portlights* (often called just "ports") when they can. Some portlights have metal covers to keep water out should the glass break. Larger windows are too large to be called portlights; they are just *windows*.

Protecting lines from chafe

Mooring lines should be protected from *chafe* (wear) whenever they run across the edge of a deck. Metal *rubbing strakes* do this while still allowing the rope freedom to move fore-and-aft along the gunwale. In some cases, such as with an anchor rode, movement of the rope along the rail is not acceptable. Then, the line is kept in place by a special fitting called a *chock*. The smooth surface of this metal fitting lessens chafe while its horns force the line to remain in position.

Chafe can be a problem despite chocks or rubbing strakes. Boats are always moving, even when made fast to a pier, and this motion causes ropes to wear. Protective *chafing gear* is often fitted to mooring lines where they pass through a chock or over an obstruction. Chafing gear might consist of plastic hose split to slip over the rope and bound to it, or heavy canvas wrapped around the rope where chafe might occur.



Chafe guards should be used on any lines that pass over an abrasive surface. They may be a purchased item, as above, but can be home-made by using slit garden hose or special tape.

MECHANICAL PROPULSION AND STEERING

Except for sailboats under sail, most recreational boats are driven through the water by propellers. Directional control—steering—is through a rudder or, in the case of outboard and inboard/outboard powerboats, *vectored thrust*. Unlike cars, there is no standard number of engines for a boat. Many power cruisers have two engines, propellers and rudders; a small number have three engines, some even have four.

Propeller basics

A *propeller* is a rotating, helical device that changes the rotational power of the engine into either forward or reverse thrust. In the early days, propellers were thought to pull themselves through the water much like a wood screw pulls itself into a plank. That gave rise to the term *screw* as a synonym for propeller. A *twin-screw* vessel is one that has two propellers. In nautical slang, propellers are also sometimes known as "props or "wheels."

Propellers are usually classed by the number of blades, their direction of rotation, their diameter and their pitch. For example, a three-blade right-hand 13" x 19" turns clockwise (in forward gear); is 13 inches in diameter; and theoretically travels forward 19 inches in one rotation. Therefore, the pitch of the propeller is 19 inches. However, some forward distance is always lost to *slip*.

In order to create useful force, or thrust, a propeller must have a slip angle because the tip of each blade travels a larger circle than the root near the propeller *hub*. This means that the tip is moving at a much faster rate than the root, so it must have a smaller angle to achieve the same amount of forward motion. That's why the blade of a propeller is twisted from its root at the hub to its tip—to create the required slip angle.

A propeller blade in cross section is shaped to act as a *foil*—a curved surface that creates a force by moving through water or air. Other foils on boats are sails, keels and rudders.

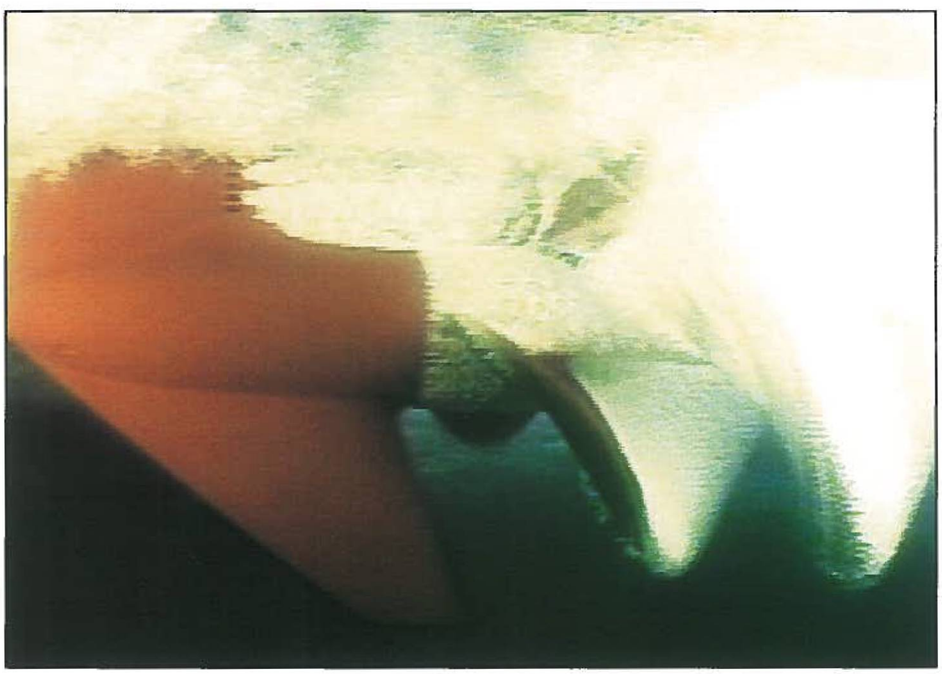
Propeller efficiency

Sailors constantly *trim* their sails to match boat speed and wind conditions. Trimming involves changing the angle of the sail relative to the wind and changing the actual curve of the sail. In theory, the same sort of trimming should be done with a propeller blade to match the amount of thrust needed. In fact, *variable-pitch* and *adjustable-pitch* propellers have been developed, but most of the propellers in use are *fixed-pitch*.

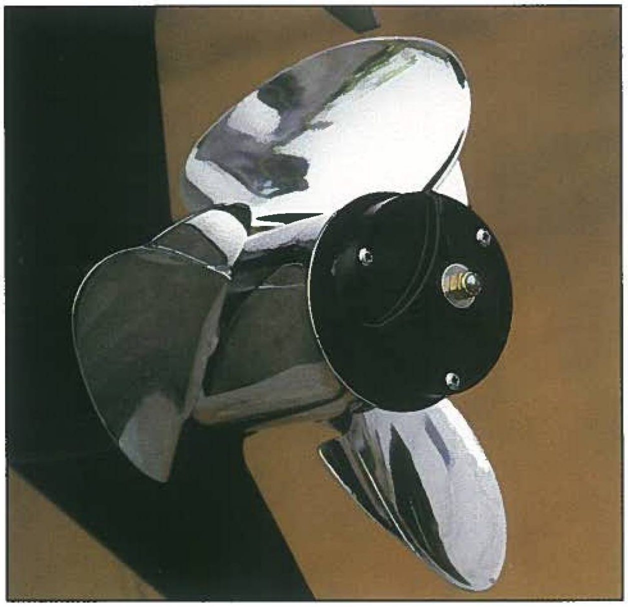
Variable-pitch propellers are designed with blades that can be pivoted by the operator to change their pitch during operation. These are expensive, complicated and seldom seen on boats. Adjustable-pitch propellers are similar, but the pitch cannot be changed by the operator while underway. A fixed-pitch propeller has a factory-installed pitch that is not changed to meet operational demands. Instead, a pitch is chosen that allows the engine to reach maximum safe revolutions per minute (rpm) under the anticipated load.

Blade area is directly related to the amount of horsepower that a propeller can handle. In general, the more horsepower available per pound of boat, the greater the required blade area and pitch. If additional horsepower needs to be applied, the diameter and blade area are usually increased, and the *shaft speed* (rotation) is reduced.

If the blade tips spin too fast, the propeller will begin to *cavitate*. Tiny, low-pressure bubbles in the water collapse against the tips with enough force to actually pull metal out of the blade. If it continues long enough, cavitation will destroy the blade tips. Reducing shaft speed by increasing pitch and blade



Propellers move a boat in the water using much the same principle as sails in the wind. Curved "foils" (the blades) create a pressure difference: low pressure on the forward surface and high on the aft. The foil shape is intended for forward rotation, one reason propellers are less efficient in reverse.



The adjustable-pitch propeller answers the need for greater efficiency through a wide range of speeds.

area is the usual fix for this problem. *Ventilation* is a different condition that is often confused with cavitation. It results from the propeller running too close to the surface of the water. When a propeller "ventilates," the engine races while forward thrust is lost.

Power from the engine is transmitted through a *transmission* and *propeller shaft* similar to those in a car. The transmission has a clutch mechanism, forward and reverse gears, and may have *reduction gears* to reduce the speed of the propeller shaft without slowing the engine. The shaft exits the boat through a *shaft log* which keeps water out while still allowing rotation.

Propwalk

Propellers must be either *right-* or *left-handed.* The direction of rotation would be unimportant except that the blades act unevenly as they swing through a full turn. The blade at the bottom of the circle moves through deeper water at higher pressure and creates both more thrust and more transverse force than at the top of the circle. Another factor is the downward angle of the shaft, which causes the effective propeller pitch to be greater on one side than the other. The imbalance in transverse forces pushes the shaft slightly sideways, producing *propwalk*—a tendency for the stern to move sideways.

Propwalk is most apparent with single-screw boats at low speeds, particularly in reverse when the curve of the propeller blades is "backward" and extremely inefficient. At higher speeds, both the rudder and the propeller blades act with greater efficiency, so the effect of propwalk is negligible.

Propwalk can be canceled out with two propellers. The props of twin-screw vessels rotate in opposite directions for this reason. Normally, the port propeller will rotate counterclockwise and the starboard turns clockwise. (Both engines turn in the same direction; reversal of one shaft is done in the transmission.) Twin-screw vessels are much easier to handle at low speeds partly because they don't walk, but mainly because each prop can be shifted independently of the other. A twin-screw boat can be pivoted in its own length by putting one propeller in forward and the other in reverse. See Chapter 9 for more details on boat handling under power.

Another way to reduce propwalk is to put two propellers of opposite rotation on what appears to be a single shaft. Counterrotating props cancel out each other's transverse pressure and the boat tracks straight ahead.

An inboard-outboard's "outdrive" or "lower unit" permits the coupling of a powerful inboard engine with a steerable and trimmable propeller shaft. This configuration has become popular for powerboats from 18 to 28 feet (5.5 to 17.7 m).

Engine and drive types

There are three primary ways of powering recreational boats: outboard motor, inboard/outboard and conventional inboard. Each method has unique advantages.

■ **Outboard.** Engines featuring integral drivetrains that are attached to the vessel's transom are *outboard motors.* These generally produce relatively high horsepower for their weight, and are somewhat more convenient to fit and service than built-in engines. The engine's propeller axis is easily trimmed so that it remains parallel to the surface (unlike the props on inboard installations that angle slightly downward) at varying loads and speeds. Outboards are the power of choice for inflatables, dinghies and other small craft including smaller

Counterrotating propellers—two mounted on the same shaft—cancel out each other's transverse pressure, and allow the boat to track straight ahead. By tuning each propeller to the other, engine horsepower can be transmitted to the water more efficiently as well.

sailboats. Larger horsepower engine models are suitable for use on boats into the 30 foot (9.1 m) range.

▪ **Inboard/Outboard (I/O).** Most medium-sized powerboats built in North America today are equipped with inboard/outboard drivetrains. *I/Os*, as they are more commonly called, provide the dual advantages of an outboard propeller and an inboard engine. The outboard drive allows for a steerable propeller with easy trim adjustment, just like an outboard motor. The inboard engine can be more powerful than an outboard because it is based on an automotive block.

▪ **Inboard.** An engine installed entirely *inboard* (within the hull) must drive its propeller through a *stuffing box* (or shaft log) that keeps water from entering where the propeller shaft passes through the hull. The position of the engine inside the boat often forces the shaft to cross the hull at a slight downward angle which, unlike an outboard, cannot be changed.

Cooling water for either an I/O or an inboard engine is supplied through a *sea cock*, a heavy metal or plastic *through-hull fitting* with a shutoff valve. *Raw water-cooled* engines circulate sea water directly through the block. *Closed system cooling* uses automotive coolant in the block which is cooled by sea water in a *heat exchanger*. Raw-water cooling is acceptable for boats used exclusively in fresh water. The corrosive effects of salt water make closed cooling the best choice for boats operating on brackish water or the ocean.

The layout of a boat's accommodation may require that the engine be located in the extreme aft end of the hull. This is the ideal location of an I/O installation. When a conventional inboard drivetrain is desired, power must be transmitted through a *V-drive*. The engine faces "backward," which adds a level of mechanical complexity.

Steering by rudder

Most boats are steered by rudders or with vectored thrust. Rudders are used on inboard powerboats and sailboats while outboard motors and I/Os vector their thrust.

A *rudder* is a flat plane of metal, fiberglass or wood that is hinged at or near its forward end or pivots vertically beneath the boat's hull. Steering is accomplished by putting the rudder over to one side or the other. The hull of the boat responds by pivoting the bow toward the side to which the rudder has been turned.

To be effective, there must be a flow of water past the rudder. Putting the rudder over has no effect on the boat's heading if the boat is sitting still. Since the flow of water is greatest in the discharge current directly behind a propeller, this is the most efficient location for a rudder. Single-screw vessels have one rudder while twin-screw boats have two. A larger rudder will provide more rapid response and a tighter turning circle. Sailboats that seldom exceed speeds of 10 knots have relatively large rudders for this reason. Powerboat rudders are smaller because they always benefit from propeller discharge currents. Also, a large rudder on a high-speed powerboat might result in oversteering and loss of control. (This is because as speeds increase, the effectiveness of the rudder also increases.)

The rudder stock enters the hull of the boat through a *rudder port*, a fitting much like a shaft log. It allows the stock to rotate freely without allowing water to seep into the boat. Smaller sailboats have a *tiller* (a horizontal lever for steering) attached directly to the stock. On larger sailboats and powerboats, this is replaced by a smaller *tiller arm* that is actuated by mechanical steering.

Tiller steering is often confusing to novices. The tiller extends forward of the stock in the same plane as the rudder. Putting the tiller to the starboard side causes the rudder to turn to port and the bow to rotate to port. Fortunately, on wheel-steered boats, turning the wheel to the right causes the bow to pivot right. Whether the boat has a tiller or a wheel, the entire steering apparatus is known as the *helm*.

Vectored thrust steering

Outboard motors and I/Os do not use rudders to steer. Instead, the lower unit is turned to port or starboard as desired. This causes the discharge current, or thrust, to be vectored at an angle to the boat's keel. *Vectored thrust* steering of this type is extremely effective since the full power of the engine is used. Outboard and I/O boats are favorites with novice boaters because they are the most maneuverable of single-screw powerboats. A tiller arm is used to steer smaller outboard motors; larger outboards and all I/Os have conventional steering wheels.

HARNESSING THE WIND

A sailboat is propelled by harnessing the wind through the use of sails, which are broadly divided into two categories: *fore-and-aft* sails and *square* sails. Fore-and-aft sails include Marconi *(jib-headed)* or *gaff-rigged mainsails* and *headsails* flown from the headstay in front of the mast. Square sails were used on clipper ships, but are seldom seen on modern recreational craft. Within these broad categories are sails with colorful specific names such as "gollywobbler" and "blooper."

Sailboats are described by the number of masts they carry and their arrangement of sails, or *sail plan*. A boat with one mast and one jib is a *sloop*; if it carries two jibs, it may be a *cutter*. Some one-masted sailboats, *catboats*, have no jib. Two-masted sailboats are usually *ketches* or *yawls*, although a few may be *schooners*.

As sailcloth, rigging wire and metal masts have improved in strength, it has become possible to extend the height of *rigs* (spars, standing rigging—the gear that supports sails—and sails) without increasing weight. Greater height allows more sail area, or the same area in a more efficient shape. Reduction in rigging weight, more stable hulls and better deck equipment have gradually made possible simpler sail plans.

Standing rigging

The wire cables and fiber ropes that support the mast and spars, and control sails are known as the *rigging*. Further division separates parts that only support the mast into *standing rigging*; lines that hoist and control sails are *running rigging*.

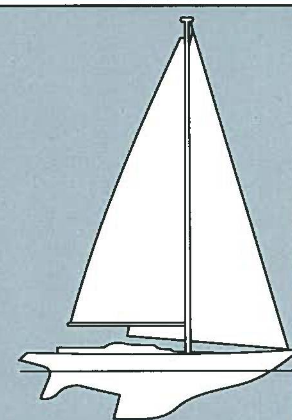
Of the standing rigging, *shrouds* support the mast from the sides. They attach to the gunwales at metal fittings called *chainplates*. A single set of shrouds goes to the *masthead fitting*. If there are two sets, the upper shrouds go to the top; about halfway up they are held out from the mast by *spreaders* that provide extra support. Lower shrouds go about

A winch revolves in only one direction, resisting the strain of sheets and providing extra power for trimming sails. Self-tailing winches like this one allow one person to do the work of two.

SAIL PLANS, HISTORICAL AND NEW

The sloop

The most popular sail plan is the sloop, which has one mast forward of midships and two sails. The forward sail is the *jib* or *headsail* and the aft one is the *mainsail*, also called the *main*. A sail's leading edge is its *luff*; its after edge is the *leech* and its bottom edge is the *foot*. The jib is attached to the *headstay* with *hanks*, strong hooks with spring-loaded closures. An alternative design uses a semiflexible track, or *foil*, on the stay that accepts a *bolt rope* sewn along the sail's luff. Such tracks offer better air flow over the luff, making the sail more efficient; this also allows *roller furling*.



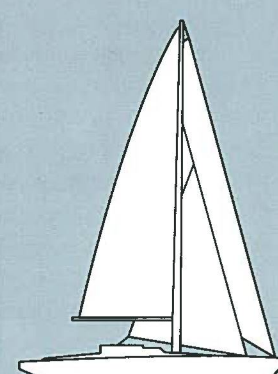
Headsails can have many names, depending on their size, weight and shape. The smallest is a *storm jib*, followed by a *heavy-weather jib* and a *working jib*. A *genoa*, reaching well past the mast, has greater surface area than the main and comes in a number of sizes.

When a sloop's jib is hoisted from a stay running to the top of the mast, it is a *masthead sloop*. If the jib is hoisted to a lower point, the sloop is a *fractional rig*. The headsail of this type of rig occupies only a fraction of the height of the mast—typically three-quarters or seven-eighths.

The foot of a working jib may be attached to a small spar called a *club*. This arrangement allows the sail to be *self-tending* because it can be controlled by one *sheet* rather than two. A *club-footed jib* can be *tacked* (turning the boat so the wind blows on the other side) without releasing one sheet and hauling the other. A self-tending jib is much easier for one person to handle.

The cutter

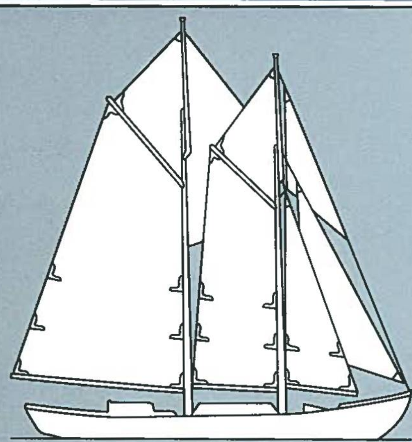
A single-masted sailboat similar to the sloop, the *cutter* has its mast nearly midships, leaving room for a larger *fore-triangle* filled by two headsails. The upper headsail is the jib, while the lower is a *staysail*. A cutter rig has two advantages. First, it divides sail area among smaller sails that are more easily handled. Second, it provides more sail reduction options in rough going than does a sloop. And when sail is reduced, the remaining area is closer to the mast, giving added safety in a seaway. This rig has been a longtime favorite among cruising sailors who prefer a one-mast rig.

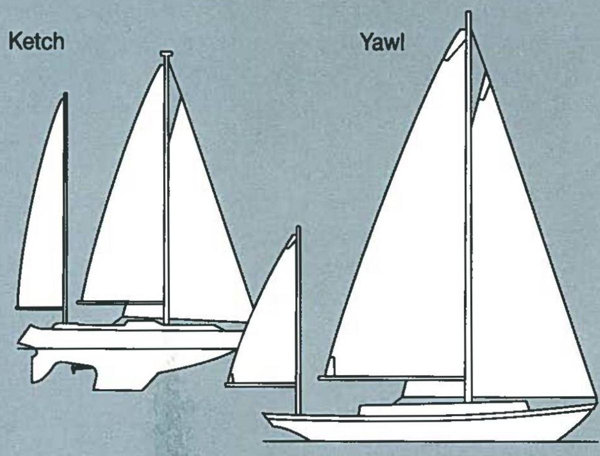


The ketch and yawl

The *ketch* and *yawl* look somewhat alike. Both have a tall *mainmast* and a shorter *mizzen mast* (smaller mast aft of the mainmast) that flies a *mizzen sail*. The distinction between a ketch and yawl is a common topic of debate among sailors. Traditionally, the governing rule is the location of the mizzen mast: If it is ahead of the rudder post, the boat is a ketch; however, if it is behind the rudder post, the boat is a yawl.

Ketches and yawls are *divided rigs*, meaning the sail area is divided between two masts. Either craft may have a masthead or a fractional rig forward of the mainmast with one or more headsails. Individual sails are manageable in size and more easily handled by a small crew. Both may fly a large jib-like sail between the masts called a *mizzen staysail*. Because of the extra rigging and mast surface area exposed to the wind, these rigs have more *windage*. They are less effective on smaller boats where windage is relatively more important. The ketch and yawl rigs are popular among cruising sailors for long-distance voyages. Mizzen masts are a practical location for mounting electronic antennas.





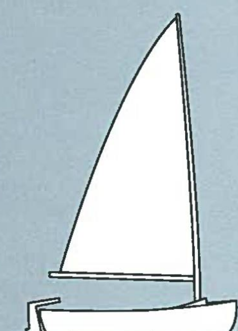
The schooner

The *schooner* is a vessel with at least two masts (in the last century, some carried up to seven). On two-masted schooners, the *mainmast* is aft, and is at least as tall or taller than the forward mast, or *foremast*. Most schooners used multiple headsail combinations including—from top down—the flying jib, the jib, and the forestaysail. The number of headsails and their names varied with the location and the time period.

Schooners were originally work boats, mainly fishing vessels. Equipped with tall, powerful rigs, they raced back home from the Grand Banks to get top dollar for their catches. These were some of the first sailing competitions in the United States. Schooners were originally *gaff rigged* with four-sided sails on the mainmast and foremast supported by a spar—the *gaff*—at their top edges. Often, a triangular *topsail* was flown above both the main and foresails. For extra power, a sail called a *fisherman* was set between the masts. These complex rigs required more deck hands than are standard today. The modern schooner rig may carry a *Marconi* or *jib-headed* main and foresails (triangular like the mainsail on a sloop). The foresail may be *loose-footed*, or not fitted with a boom, and there may only be one headsail.

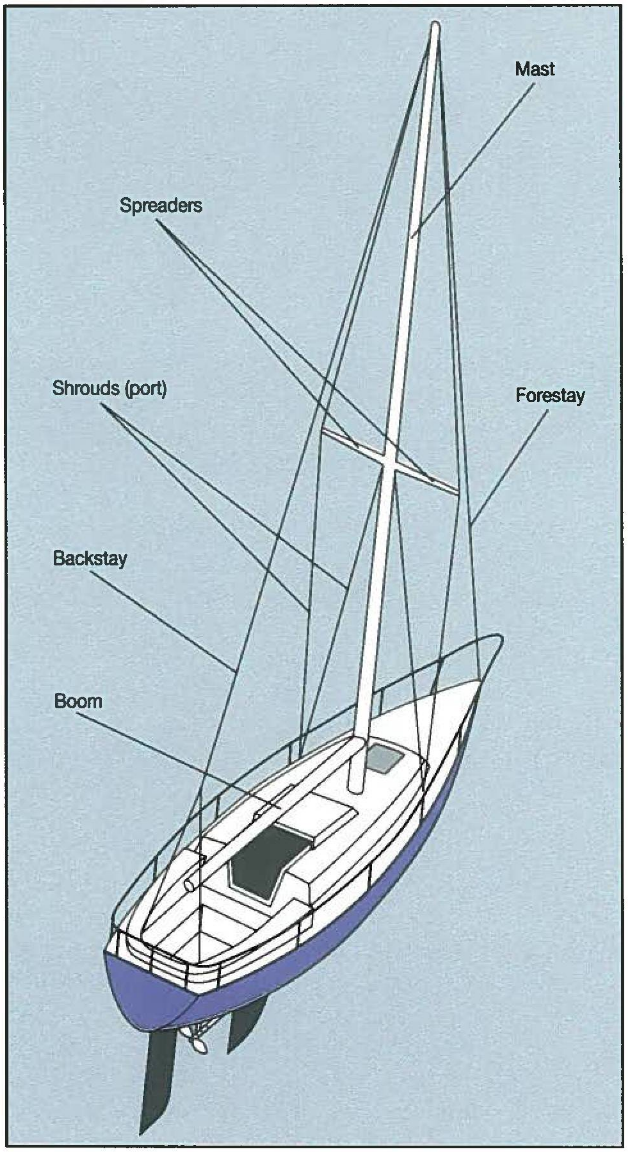
Schooners are most comfortable in steady trade winds on long ocean passages. Although they do not go to windward as well as other rigs, they make up for it when the wind is on or aft of the beam.

The catboat



A boat that features only one mast set far forward and only a mainsail is known as a *catboat*. Traditionally, these were small, inshore boats. (Lack of redundancy in the rig was an issue when rigs were considerably less reliable.) The catboat was a very useful and practical design for coastal fishermen because there was less rigging to get in the way when handling nets on the water or unloading the catch ashore. Also, the boat's single sail was easier for one person to handle.

Recent cat-rigged designs make use of *unstayed* masts (masts that have no standing rigging, but are supported only by the deck). With less windage and high, narrow sail plans, modern catboats often can perform as well as sloop rigs. This type of rig is found on both racing and cruising boats. Experimental catboats with sails that look much like those found on sailboards are a new development. Some record-breaking boats even use two cat sails side by side. As to what these rigs might be called, some future edition of *Chapman Piloting* will have to be consulted.



Standing rigging supports the mast against the tremendous strains imposed by wind on the sails. This sailboat has upper and lower shrouds, a single forestay and a split backstay.

halfway up the mast to the *spreader bases*. *Stays* support the mast fore-and-aft. Any stay that runs forward from the mast is a *forestay*, but the one from the masthead is the *headstay*. The *backstay* runs from the masthead fitting to the stern. Most boats have only one backstay because the mainsail boom must swing inside this stay.

Getting power from the wind

Sails extract power from the wind by dividing a stream of air into two paths, shaping both along a curve, then letting them rejoin smoothly. The flow across the sail's concave, or *windward*, side reaches a higher pressure than the flow on the opposite, convex, or *leeward* (pronounced "loow'rd") side. This difference in pressure, called *lift*, is used to propel the hull *(Chapter 10)*. Such aerodynamic lift is the primary force propelling the boat. Maximum lift is achieved when sailing with the wind on the beam or slightly ahead of abeam. (It is a common error to think sailboats are driven by wind blowing onto the sails. In fact, this condition only occurs when the boat is *running* dead downwind, its slowest *point of sail*.) When the wind is behind the beam, sloops and other fore- and-aft sailboats can fly additional *reaching* or *downwind* sails. The most familiar of these is the large and colorful *spinnaker*.

Controlling the sails

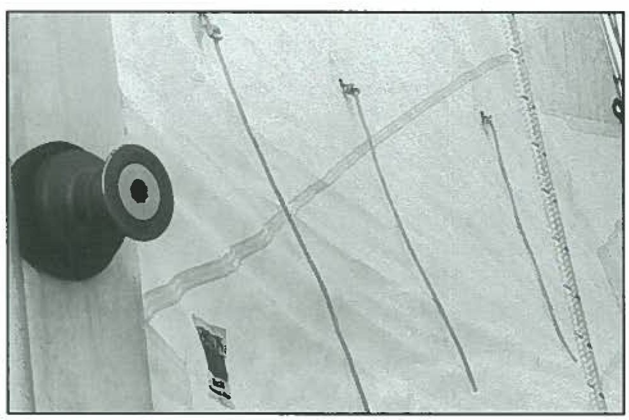
Sails are hoisted using special lines called *halyards* that run through *sheaves* (pulley wheels) at the top of the mast. Hauling is done by hand initially for speed, but final tension is applied by use of *halyard winches* that are often mounted on the mast.

The shape and position of the sails is controlled by ropes called *sheets* that attach to the boom of each mast or the aft, lower corner (*clew*) of each sail. The mainsheet is generally rigged as a *block and tackle* for mechanical advantage in overcoming the mainsail's force. Each headsail has two sheets, one on the port and one on the starboard side of the boat.

Halyard and sheet winches today are usually *self-tailing*—special drum mechanisms secure the line, allowing operation by one person. An ordinary winch must be *tailed*—line pulled off the drum under tension—by one person while another turns the winch with a crank known as a *winch handle*.

Shortening sail

The power generated by sails increases with wind speed; at a certain point, it is more than the hull can control and reducing sail area is in order. The normal first reduction on a sloop is to exchange a large headsail (usually a *genoa*) for a smaller jib. If additional reduction is needed, the mainsail can be *reefed*. Sloops may have *jiffy reefing*—a system of lines attached to the sail for the purpose. Mainsails have one or two horizontal rows of ties, known as *reef points*, that allow the reefed portion of the sail to be secured to the boom.



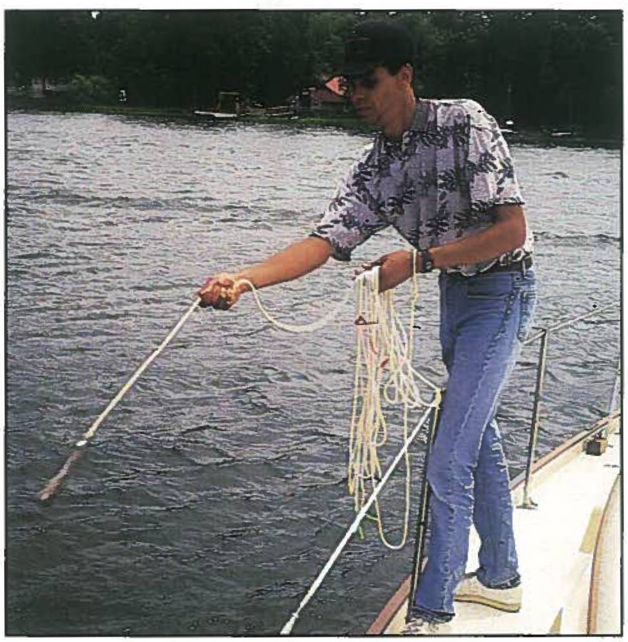
When the wind blows too strongly for comfort or safety, it is time to take a reef in the mainsail by tying the reef points (shown above) under the foot of the sail, as described in Chapter 10.

Knowing where you are, where you want to go, and how to get there safely are the three fundamentals of navigation. Whether fishing on a small lake, cruising along a river or crossing an ocean, as skipper you have both a moral and a legal responsibility to know how to navigate. While this responsibility weighs heavily on every boat owner, the ability to navigate also brings great rewards.

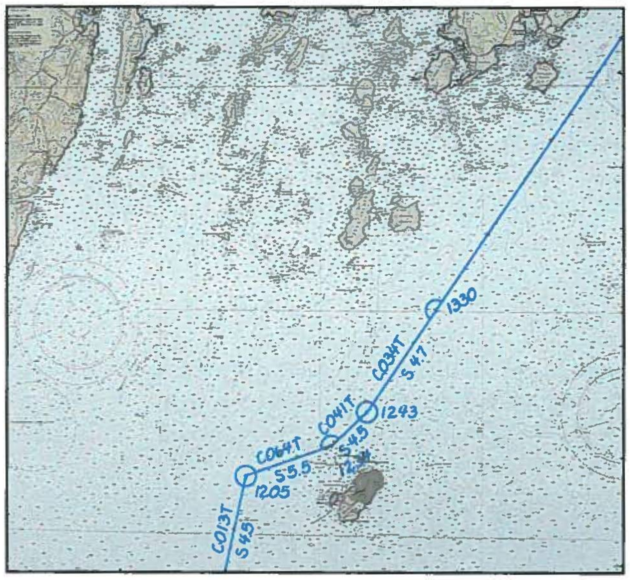
Tremendous pleasure can be taken from successfully navigating a craft. Piloting and chartwork offer an intellectual challenge that can be matched by a satisfying sense of accomplishment—in terms of both rational calculation and the intuition of a practiced eye. A major part of navigation is the technique of basic piloting and position determination. Much of this book, particularly the chapters in Section 5, is devoted to these subjects.

The basic tools of piloting are the *chart* (a nautical map), the *magnetic compass* and a *log* (a marine speedometer) to measure speed. Most boats also carry an electronic *depth sounder* or a *lead line*, its traditional predecessor. A lead line is a weight fastened to a light rope that is marked to indicate various depths. The lead line is "swung" forward of the boat and allowed to settle to the bottom. The depth is read as the line comes "up and down" next to the boat.

Binoculars have a special place on board a boat, of course, especially because they help to improve distance vision. A *hand bearing compass* makes taking magnetic bearings quick and easy. Many boats are now also equipped with a *barometer*, which measures atmospheric pressure. Changes in this pressure are reliable indicators of changing weather.



Considered "old fashioned" by some, a lead line is handy as a backup to an electronic depth sounder and for determining the nature of the bottom. In an emergency, it can also be used for checking depths all around a boat that has gone aground.



A careful skipper plots courses on a chart, and notes the time of significant events, especially course changes. Chapter 20 covers important procedures for determining position.

Charts and chartwork

The nautical chart offers a wealth of information for interpretation by a knowledgeable reader. Every chart is a representation of a water area overlaid with a grid system. The lines of the grid system are, of course, latitudes and longitudes. Lines of latitude are termed *parallels* because they run parallel to the equator. Latitude is measured from 0° at the equator to 90° either North or South at the respective geographic pole. Lines of longitude are *meridians* that run through the geographic north and south poles. Longitude is measured from 0° at the prime meridian (Greenwich, England) to 180° East or 180° West, which is the same line—the International Dateline follows this meridian with some deviations.

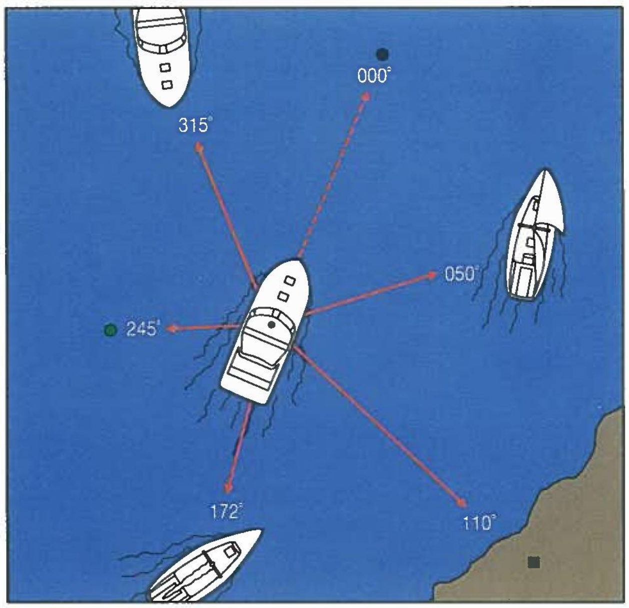
The majority of coastal charts are *Mercator projections* that show lines of latitude and longitude intersecting at right angles. A *nautical mile* on a Mercator chart is the equivalent of one minute of latitude. It is sufficiently accurate to say that one degree of latitude equals 60 nautical miles. This means that the latitude scale on the east and west sides of most charts can be used reliably to measure distance. Nautical miles are about 15 percent longer than *statute miles*, the standard measure of distance most often used on land, as well as on inland lakes and rivers and the Intracoastal Waterways.

Where distances are measured in nautical miles, speeds are measured in *knots*, or "nautical miles per hour." Speeds on inland waters, as on land, are commonly measured in statute miles per hour. (In countries such as Canada where the metric system has been adopted, the standard measure of speed is kilometers per hour.) Depths may be measured in feet, *fathoms* (1 fathom equals 6 feet) or meters. It is important for the navigator to always confirm from the chart which units of measure are being used.

True and magnetic courses and bearings

A *course* is the direction in which it is intended that the boat travel, and a *true course* is one referenced to *true north*, or geographic north. *Magnetic north* is the direction a compass would point if it were not subject to any local interference. A *magnetic course* is referenced to magnetic north. *Variation* is the angular difference between magnetic and true north at any particular location on earth. It is important to know that variation changes from place to place, so it must be checked on every chart and factored into any calculation of direction that relies on a compass reading.

Deviation describes the error in a magnetic reading due to local influences such as the magnetic properties of metals in and around the boat, particularly within a range of 2 or 3 feet of the compass. Deviation is devious. It changes with the boat's heading and might even change on the same heading from one boating season to another. The combination of variation and deviation produces what is called *compass error.*



Relative bearings can be measured as angles from dead ahead clockwise around the boat. Directions are always shown as three digits, using leading zeros if necessary (050, not 50).

A *bearing* is the direction of an object from the boat to that object expressed as either "true" or, if variation and deviation are taken into account, as "compass." Bearings are *plotted* on a chart in order to determine a *fix*, or known position. Chapters 19 and 20 explain in detail several ways to obtain a fix, which is the spot where the navigator's *dead reckoning* plot always begins.

Not all of the information required by the navigator can be printed on the chart. *Coast Pilot* books give detailed descriptions of harbors, including the locations of marinas, hoists and repair facilities. *Light Lists* contain expanded information on lights, buoys and other aids to navigation.

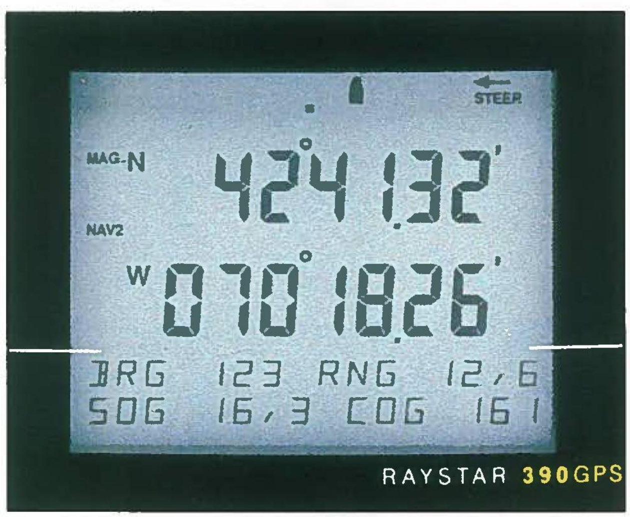
Aids to navigation

Aids to navigation are established by various government authorities or private parties to indicate safe and unsafe waters. *Buoys* are floating objects that mark channels or other significant locations. They may be lighted and may carry audible signals such as bells, gongs or whistles. Buoys are painted according to a particular color scheme *(Chapter 22).*

Lights, as their name implies, are lighted aids with characteristic flashing patterns and colors; for daytime use, most also have distinctive signs, or *dayboards*, painted in a color scheme that matches buoys. An important difference from buoys is that lights are not floating, but fixed in position so that they can be precisely located on charts. *Daybeacons* are also fixed aids, but have only dayboards, no lights. *Ranges* are special combinations of dayboards and lights that guide vessels in narrow channels.

While the focus here is piloting, another branch of navigation allows determination of position by reference to the sun, moon, planets and stars. Known as *celestial navigation*, this type of position determination requires a *sextant* (a precision navigating instrument for measuring angles) as well as a *nautical almanac*, a set of *sight reduction tables*, and a chronometer or watch and radio signals to obtain accurate time.

Piloting and navigation are going through revolutionary changes, some of which are outlined in Chapter 25. Electronic radio receivers and on-board computers now make it possible to obtain positions from signals transmitted from shore stations or orbiting satellites. *Loran C* and the *Global Positioning System (GPS)* allow automatic computation of the boat's location, heading and speed. Like other electronic tools or devices, however, these systems are prone to unexpected failure. The prudent navigator still uses conventional paper charts and plotting to doublecheck the results provided by electronics.



The Global Positioning System (GPS) is steadily replacing the older Loran-C system of electronic navigation. GPS is now available in compact units such as this one, which combines an antenna, receiver and processor.

WEATHER, CURRENT AND TIDES

Weather is an important factor in safe, pleasant boating. Every skipper should develop a good "weather eye," the ability to judge local weather conditions. It's also prudent to routinely monitor weather broadcasts and forecasts for advance warning of weather changes.

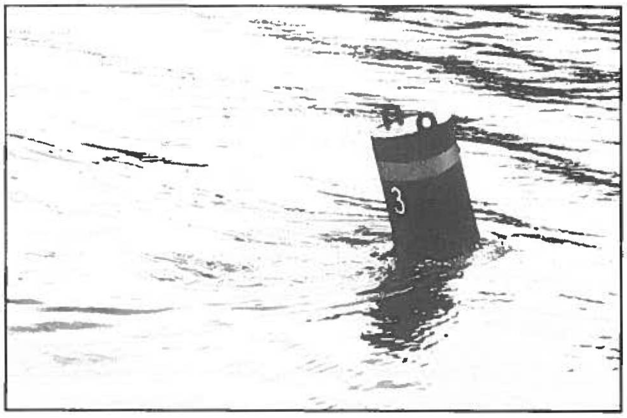
Storms and their associated wind and waves do not "come out of nowhere." Whether it's a local rain shower or full-blown hurricane, a storm has a definite life cycle that can be tracked and, in a general sense, predicted.

Water movement and sea conditions

Large ocean undulations, generated by distant storms and unrelated to local causes, are called *swells*. The surface of a swell may be perfectly calm, but it is usually textured by the wind into groups of tiny ripples called *catspaws*. The ripples gradually build into *waves*. Each *crest* reaches higher above its *trough* as the waves travel faster over a longer *fetch*—the distance free of obstructions. Increasing wind tears at the wave tops, revealing *whitecaps* and throwing off *spume*. When this heavy *sea* encounters shallow water, its energy can no longer be absorbed by circular movement of water within each wave. The crests rise and *break*. *Surf* crashes ashore.

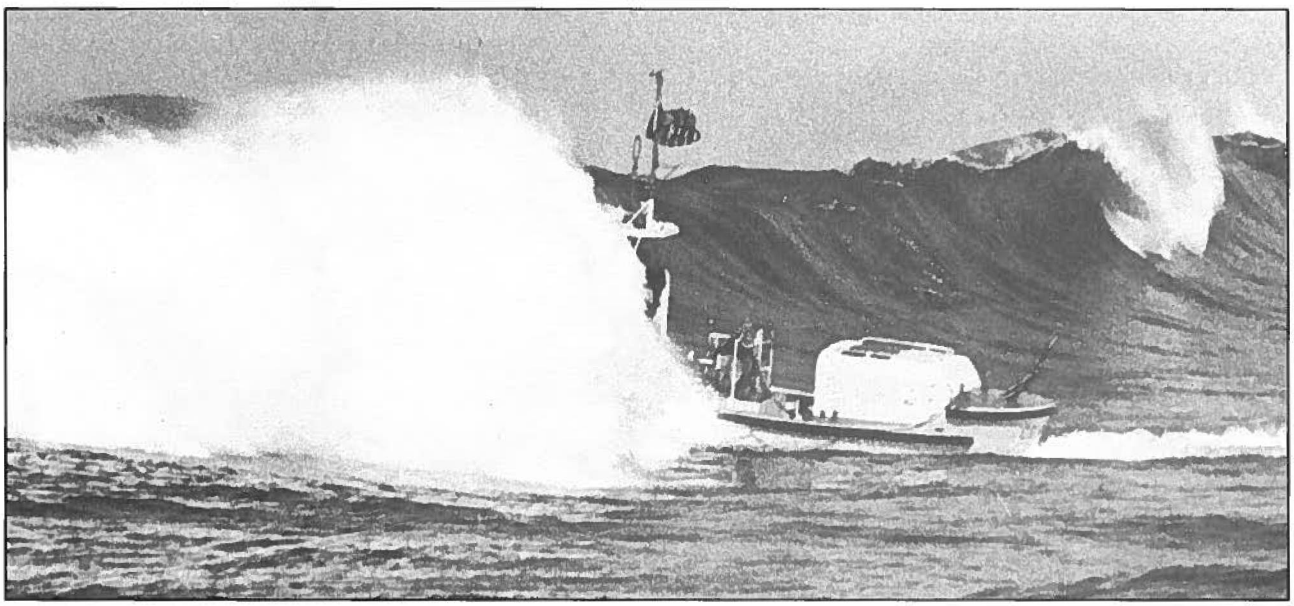
The same sea, meeting a *current* (explained in Chapter 15) will rear up, creating a *rip*, sometimes amplified by the narrowing funnel of an *inlet*. Over long fetches of shallow water strong winds may create waves of moderate height, but viciously steep and short—a *chop*—even more dangerous than ocean waves of greater size. Lake Erie and Delaware Bay, for example, are two bodies of water renowned for choppy conditions.

Coastal and inland boaters are familiar with currents, the horizontal flow of water in a downstream direction. Currents are also found in open water where they range from huge, persistent ocean movements, such as the Gulf Stream or the California Current, to the strong but short-lived *undertow*, or *rip current*, of a beach where surf finds its way back offshore. Ocean, lake and river currents respond to the push of *prevailing winds*. In addition, ocean currents are affected by variations in water density resulting from different levels of salinity and temperatures.



Current is the horizontal flow of water. A buoy's leaning is often an indication of the speed at which the water is moving. In coastal areas, currents result from changes in tide levels.

The largest currents are part of the world's five *gyres*—giant circular oceanic currents. There are two gyres in the northern hemisphere that travel in a clockwise direction: one circling the North Atlantic; the other, the North Pacific. Three gyres in the southern hemisphere circle the South Atlantic, the South Pacific and the Indian Ocean in a counterclockwise direction. While the gyres are surface currents, there are other equally important countervailing, deep currents.



Waves result from local wind action on the water surface, but may travel great distances as swells. They crest over and become breakers as they move into shallower waters. Dangerous waves form over bars, such as at this one off a Pacific Coast inlet.

Marinas provide a sheltered harbor for yachts and small boats. Piers extend into the water and finger piers project from them. Each boat's space is called a slip. A self-propelled sling lift *(center)* hauls boats out of the water and a gin pole helps with unstepping masts. Powerboats less than about 25 feet (7.6 m) long are often stacked in dry storage *(background)* with a large forklift truck. They are taken off the rack and launched for each outing.

Regular, intermittent currents that respond to movement of the sun and moon are called *tidal currents*. *Tides* (discussed in Chapter 15) are the actual rise and fall in local water level as tidal currents force masses of water alternately against and away from shore. Incoming tidal currents *flood*, then *ebb* as they retreat. The strongest are associated with *spring tides* during new and full moons, when the moon and sun pull in parallel directions. Tidal currents flow more gently as *neap tides* that occur at the quarter moon.

Every current, regardless of its origin, has a *set* (direction) and a *drift* (speed). Set is the true direction toward which a current flows; drift is its speed. The speed of tidal currents and the height of the tides are so important to coastal navigation that annual *tide tables* and *tidal current tables* are published under governmental supervision.

Shaping the coast and shoreline

Wave action, the movement of currents, and the rise and fall of tides all play a part in sculpting river beds, lake shorelines and coastal shallows of oceans. *Hazards to navigation* are often created by this sculpting. *Bars* form across the mouths of rivers despite efforts to *dredge* clear channels. Important harbors are protected by *breakwaters* built parallel to the shore to absorb the energy of incoming seas; *jetties* built parallel to channels serve much the same purpose. *Groins* are built perpendicularly to beaches to limit erosion caused by currents along the shoreline. *Riprap*—large chunks of concrete, for example—is sometimes laid down to limit erosion.

Harbors and docks

The layout of slips, quays and piers in a harbor defines a *fairway* leading to a channel and possibly to a *roadstead* where vessels may safely anchor while waiting to make fast at a wharf. Some people may say they are "standing on the dock," but it's quite unlikely that they are—the *dock* is actually the area of water in which a vessel lies when made fast. These speakers are probably standing on a *pier*, or—if the structure is parallel to shore—a *wharf* or *quay*. (A good pronunciation of quay is "kay," but in salty company "key" is safer.)

In a marina (yacht basin) or small-craft harbor, the boat is often made fast to a *finger pier* and the water space it occupies may be a *slip* or *berth*. The pier might be supported by heavy wooden or steel piles or pilings driven vertically into the harbor bottom. Two or three piles bound together become a *dolphin*.

A vessel *hauled out* for maintenance or winter storage may be carried up the *ways* on a *marine railway*. These days it is more likely to be hauled in slings by a self-propelled *straddle crane* (often called a "Travel Lift" after one brand). The boat is blocked in its cradle or on stands built for the purpose.

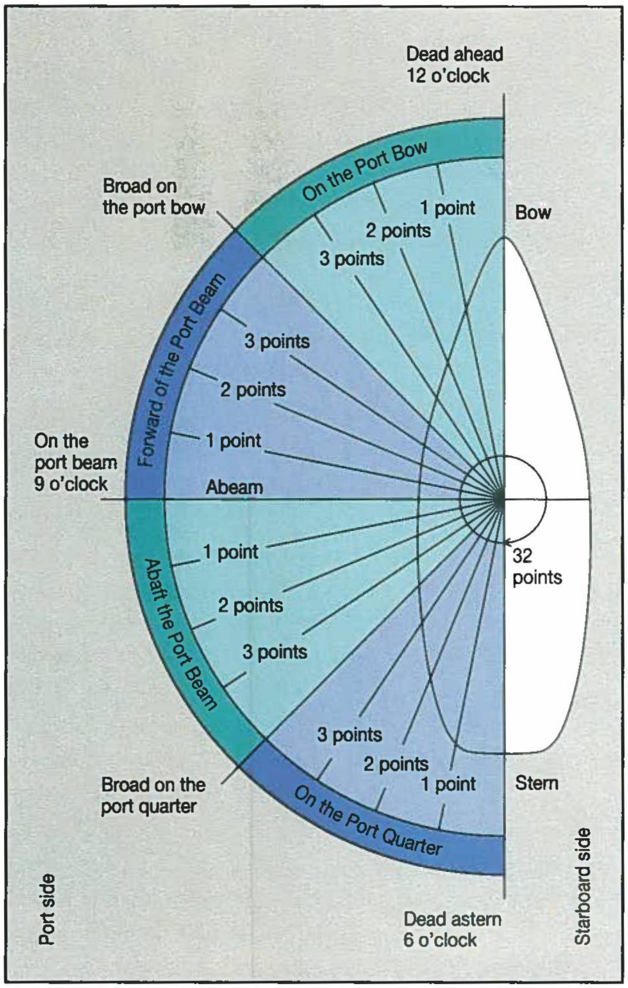
Powerboats less than 25 feet (7.6 m) in length are often stacked by a forklift truck in dry rack storage. Fully rigged racing sailboats may be stored on shore—*drysailed*—between races and launched with a *derrick*. ("Drysailing" is one of boating's most confusing misnomers. Such boats are anything but dry when actually sailing.) If a mast or other spar must be removed, it is done with a light crane called a *gin pole*.

OTHER BOATING TERMS

A boat is *underway* when not *anchored*, *aground* or *made fast* to shore. If getting underway from a *dock*, the mooring lines are *cast off*. Or, the anchor is *aweigh* when it has been broken out of the bottom and lifted clear—called *weighing anchor*. If the boat has been attached to a *mooring buoy*, the *pendant* (often pronounced "pen'ant") is *slipped* to get underway.

Even though it is underway, a boat can be sitting still in the water, or *not making way*. When the boat moves under its own power, it begins to *make way*. If it goes forward, it makes *headway*. If it backs up, it makes *sternway*. And if it moves sideways under the influence of the wind or currents, it is making *leeway*. Under many conditions, the boat makes both headway and leeway simultaneously. When the boat builds up enough speed for the rudder to be effective, it begins to make *steerageway*. Water that is disturbed by the passage of the boat is the *wake*. If the boat is going too fast, the wake becomes a *wash*, which can threaten to erode the shoreline.

Other boats or objects directly in front of the boat are said to be *dead ahead*, while those behind the boat are *dead astern*. Anything that is at 90 degrees to the vessel's bow is *abeam* to port or starboard, respectively. Objects at 45 degrees to the bow are said to be *broad off* the appropriate bow. Likewise, objects that are at 45 degrees to the stern are broad off the appropriate *quarter*.



A more accurate method of describing surrounding objects is through *relative bearings*, which are related to the bow of the boat rather than true or magnetic north. The traditional 32-point system divides the circle in which the boat is centered into divisions of 11¼ degrees each (360° ÷ 32 = 11.25°). A system that's easier to remember relies on familiarity with an analog clock face. An object may be described as "at 8 o'clock" instead of "3 points abaft the port beam."

Underway in a sea, the hull experiences five separate motions in addition to headway. *Pitch* is a fore-and-aft rocking motion, while *roll* is a rotational movement to either side. The bow may *yaw*, or swing to port or starboard off course. Wave action can lift the boat vertically, a motion called *heave*, or cause it to *sway* with sideways horizontal motion. Yawing is often caused by a *following sea* when the waves come up behind the boat. If a yaw gets out of hand, the boat may *broach* and swing wildly parallel to the waves.

If the wind increases to Force 8 or 9—measurements of wind strength by the *Beaufort Wind Scale (Chapter 14)*—it may be time to *heave to* (retain a slight forward motion, just enough to allow control). When a sailboat heaves to, it has the steadying effect of the sails but would certainly have taken at least one *reef* (sail reduction). A powerboat might be headed into the wind and its speed reduced to bare steerageway.

A *sea anchor*, a cone of heavy canvas that acts somewhat like a parachute, could be set to hold the boat's bow up to the wind and seas. (A *drogue* is a similar device towed astern to slow forward movement and hold the stern to following seas.) In this situation, the navigator would wonder about the quality of the last *fix*, a position determined through landmarks or aids to navigation. The *dead reckoning track* based on the boat's course and speed would be double-checked.

The most dangerous place to be in heavy weather is off a *lee shore*. The term refers to a shore that is in the lee—*downwind*—of the boat. In this situation, wind and waves can push the boat ashore. It's much better to be off a *weather shore*, one that is *upwind* from the boat. A weather shore provides protection from high seas and gusty winds.

On rare occasion it becomes necessary to call for help using the *VHF* (very high frequency) ship-to-shore radio. Once in contact, the boat's position must be accurately reported. Chapter 19 describes how to report a *relative position*, one in relation to a charted aid to navigation or landmark, and a *geographic position*, one related to the geographic coordinates of *longitude* and *latitude*.

In the traditional 32 point system of relative bearings, the circle in which the boat is centered is divided into eighths. These eighths start at dead ahead and continue on each side through on the bow, forward of the beam, abaft the beam, and on the quarter to dead astern. Each of these pie-shaped sections is further divided into four points, each of which has 11¼° of arc.