The Rig

The best rig for a given cruising vessel depends on a variety of elements. First is the crew — its number, age, physical capabilities, and experience. Next comes the physical size of the vessel and the sail area required for adequate performance. The part of the world you plan to sail also plays an important part. Performance in light versus heavy airs is a major ingredient, and the final determinant is the form of reefing system to be adopted.

DECISION LOGIC

Before getting into the different sailplans available, let's look at each of the factors to be considered in some detail. Then we can apply them to various types of rigs.

To begin with, there's one absolute truth. Under poor conditions, in heavy weather, shorthanded, you *must* be able to handle the vessel. Any form of modern convenience such as roller furling or roller reefing is just that, a convenience. You must face the fact that it may not be functional when the chips are down. Have an alternate plan.

The size of a rig is not a major factor. Small sails can always be used on large rigs. Assuming that your vessel has a reasonable underwater shape, moderate-to-low wetted surface, and an efficient rig, relatively small working sails, if properly cut, will give a reasonable turn of speed, even in light airs.

So much has to do with the region in which you're cruising. Trade-wind areas rarely surprise you with violent squalls or aberrant long-term weather systems. And while even during the docile months you may encounter some good blows in trades, they come on relatively slowly — you generally have time to change down sails.

Sailing in the higher latitudes is another case entirely. Virtually every high-latitude region has its "bad spots"— Cape Hatteras with its infamous storms that materialize without warning, the Tasman Sea, even the coast of California in winter. Sailing in these areas, you have to use a different approach to your rig and the sails you carry.

As for absolute sail size, look at sailcloth weight versus overall sail size. The problem is not hoisting or sheeting a sail — what causes difficulties for shorthanded crews is getting a sail on and taking it off the headstay or main boom.

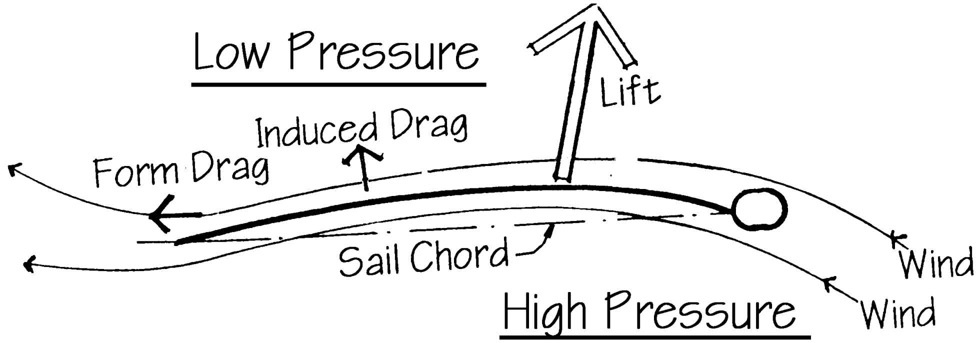
Factoring in your own experience, physical condition, and inclination is a difficult equation. Without the experience to evaluate the situation, you're at the mercy of the "experts." My advice is to remember that you can always use the small sails. Be sure the rig will accept good-size sails, and then as your experience and self-confidence increase, more sail area can be used.

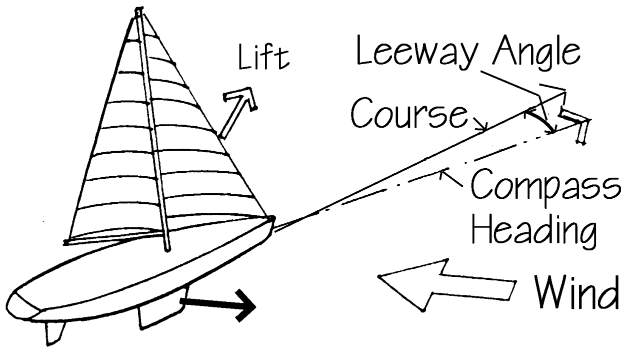
Rig Efficiency

A point to consider in rigs is their relative efficiency. The horsepower per square foot of sail area varies tremendously from one rig type to another. With an efficient rig, you may get away with carrying as much as one-third less area to produce a given speed than a neighbor with an inefficient rig. Efficiency becomes especially important on the wind and as the velocity of the wind increases. You must calculate not only the lift a given sail produces, but also its drag. Once the breeze starts to increase and you're at your normal heel angle, drag becomes the overall concern. A boat with a high-drag rig heels quickly, loads its keel, sideslips more, and requires shortening down much sooner in gusty weather.

In absolute terms you can't do better than a solid airfoil such as is used on some of the C-class catamarans. Next come single-sail rigs as seen on many dinghies and small cats. An una rig of this nature can generate as much as 30 percent more horsepower and/or less drag for a given area than a conventional fore-and-aft rig. In other words, it's less efficient to have more sails.

Rigging and spars contribute enormously to the depowering of sails and increase in drag. Again, comparing a rotating mast or sock sail on a small boat to a full-rigged fixed spar, there can be a 15-to-20-percent difference in drag. Even if you're not that interested in speed, we're now also talking about comfort going uphill or reaching.





In order to make informed decisions on sail design, inventory, and rig type, you need to understand the basics of how the rig and keel interact.

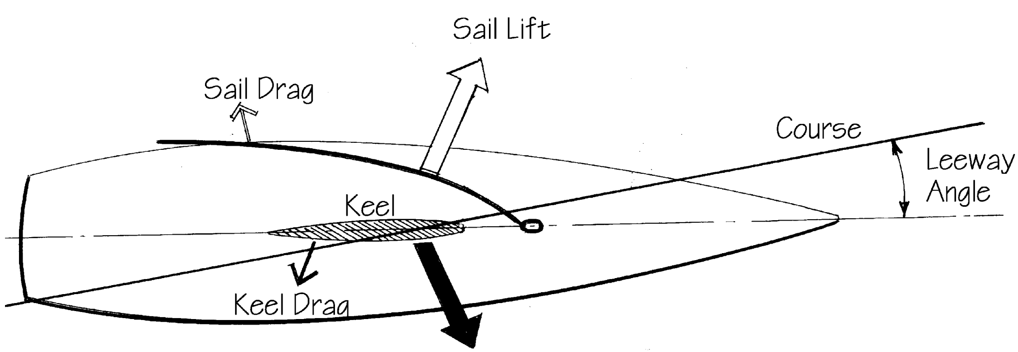
Beating and reaching, the issues are somewhat more complex. Take the mainsail shown in section (top down view) in the top drawing. You have the apparent wind from the starboard side. The shape of the sail causes the wind to accelerate over the longer leeward side of the sail, while it slows slightly on the windward side. This difference in speed creates a pressure drop on the lee side which results in a lifting force.

However, while you are generating lift you are also creating drag. There are three types of drag. Skin friction (when the sail is low); form drag (which is a function of the thickness of the foils, spars and rigging); and induced drag (the largest of all). The angle at which these forces, lift and drags, interact is critical to your success. Form and skin friction drag always pull straight back. Induced drag, angle is a function of the aerodynamic (or hydrodynamic in the case of the keel) forces. Different shapes in different conditions have varying angles. The less aft-facing the induced drag force vector, the less heel and more forward motion you will experience.

In order for a foil to generate lift (and drag) it must have an angle of attack, i.e. it must fly at an angle to the wind (or water in the case of a keel). Lift and drag are proportional to angle of attack, so an oversheeted sail will generate more force. Conversely, if it is eased relative to the apparent wind angle, it will produce less. Visualize the sail in the top drawing being eased out. Both the lift and induced drag forces point more toward the bow, resulting in less heel. Of course, in light airs, speed may drop because you've reduced the lifting forces. However, in stronger winds it is possible to go faster by flattening and easing sails as you reduce drag and lift. Lift can't be used anyway since it overpowers the boat.

The same issue is taking place with the keel and rudder. The angle of attack of the keel comes from leeway. The same issues apply to it as to the sails, only a very small keel can generate a lot of force because it is operating in a much denser medium — water.

The keel should lift in a direction roughly at 90 degrees to that of the rig. The result of these two forces is forward motion.



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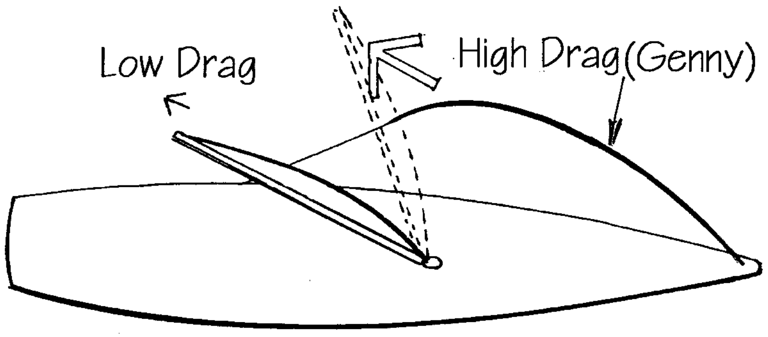


Compare the airfoil shape of the boomed mainsail in this drawing to the headsail that has been eased out for reaching. The headsail has a very thick, high-drag foil shape. The main, with the boom controlling the shape of the sail, is much more aerodynamic. The result is less heeling force and more net forward drive. Going to windward, where the jib's shape is held to a nice flat airfoil by the sheet, this is not the case. However, for cruising we feel you are better off with as much of your total area in boomed sails as is practical.

This relates directly to the number of spars and how much rigging (and, heaven forbid, baggy-wrinkle) is involved.

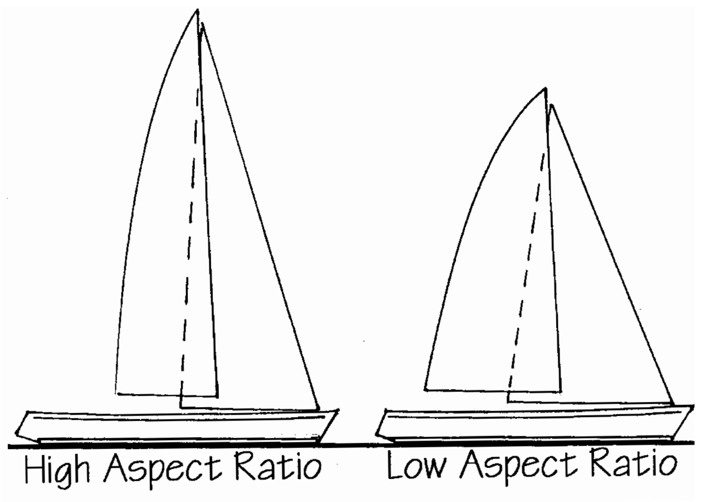
Within the context of a conservative structural system, the less rigging you have waving around in the breeze the better off you will be. This applies to standing rigging, roller-furled sails, mast size, and the spars themselves.

Boomed Sails

Generally speaking, boomed sails are more efficient across a wider spectrum of wind angles than headsails are. When reaching or running, the boom keeps the sail in an optimal airfoil shape as opposed to the heavily cambered shape that a jib forms when sailing free.

Boomed sails also tend to last longer than headsails, especially now that full battens are prevalent.

Finally, you can reef a boomed sail, maintaining an efficient shape in the process. Reefing head-sails are possible, but their shape always suffers.



Aspect ratio is a tricky concept. In theory, a taller, skinnier rig is more efficient. Certainly, in light airs this is the case. But as the breeze builds, heeling forces come into play and sail loads increase dramatically with the longer leech of the high-aspect-ratio sail. So, like everything with cruising yachts, there are a lot of trade-offs to consider. In general, our feeling is that moderate-aspect ratio rigs, like that shown to the right and above, are more cruiser-friendly.

Aspect Ratio

Aspect ratio is the height-to-width relationship of the sail. The taller it is for a given width, the higher the aspect ratio. The higher the aspect ratio of a given airfoil, the lower the induced drag. In fact, induced drag goes down with the square of the increase in aspect ratio.

With this in mind you might say that sails with huge aspect ratios are good. This is only true to a point. The problem comes with sheeting the sails, steering, trimming them, and making them last. As aspect ratio goes up — i.e., as a sail gets taller and skinnier — the loads on the

Most folks think of the cutter (left) in a traditional context — a small main set well back in the boat, and a large forward triangle broken up into a staysail and yankee. If the yankee tacks to a bowsprit, well, that's what we expect to see. However, when it starts to blow, and that bowsprit begins to poke itself through oncoming seas, it will not be a favorite place from which to reduce sail. (Port Townsend Sails)

At the other extreme, most of the newer BOC racers (right) would be considered cutters. They have large mains set well aft (sometimes dead in the middle of the boat), and use a small staysail (more like a staysail-proportioned genoa) for going upwind in any sort of breeze.

The headstay is there primarily for large, light headsails used upwind in very light conditions, and mainly for reaching. (North Sails RI)

leech and clue rise dramatically. This forces you to go to heavier weight cloth and/or take a hit on the life of the sail. In addition, the sheeting angles are more critical. They can be sheeted efficiently to windward, but when reaching it becomes very difficult to get an efficient shape in the sail. Finally, they are more difficult to steer for helmsman, vane, or pilot.

Our own experience is that anything much above 3.2-to-1 will be a problem. Whenever possible we prefer to keep our aspect ratio for headsails at under 3-to-1, and the main at no more than 3.3-to-1.

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A nice shot of a Deerfoot 63 (left) powering along in New Zealand during sea trials. The forward triangle is about 44 percent of the total area on the boat. The headstay is set well back from the bow, and the mainmast is somewhat farther aft than is the norm.

I feel that these rig proportions offer some of the advantages of the cutter — ease of working on the headsail set back from the bow, and wider staying base for the mast — while retaining the performance advantages of the sloop. Of course, there is a removable staysail stay for storm canvas.

A more traditionally proportioned sloop (right) has the mast somewhat further forward, as you can see in this Frers 44. She is set up for a single-handed transatlantic race. Note the heavier jib on the second roller furler set aft of the bow. (North Northeast photo)

Headsail Area

Nothing is less efficient than a headsail that is too big and eased to spill some air. The drag created by such a sail, as opposed to a correctly sized sail, is enormous. That drag makes it difficult to sail upwind and uncomfortable when reaching. For offshore work, if you have to make a choice, it is better to head toward smaller sails. On the other hand, in light airs nothing will heat up your performance quite as fast as a large, light headsail. The answer is to have several sizes of headsails, for light and moderate airs.

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Overlap

Once a headsail begins to overlap the shrouds, the increased area quickly loses efficiency. At 10 percent of overlap you are probably at close to 100 percent of power. But at 25 percent, the extra area is probably not producing half of what the front of the sail does, and at 50 percent the numbers have tapered off to just a few percent. The harder the wind blows, the less the efficiency, until at some point it begins to generate so much drag that you are better off with a much smaller sail.

In addition, sails with less overlap tend to set better in very light airs and are, of course, much easier to tack. A 105-percent lapper can be just about hand-trimmed all the way in, if there is no cutter stay. Even in moderate breezes, all that is usually required on the average cruising boat is a quick turn of the winch for final sheeting, and you are done. Contrast this to what happens with a large overlap, when you have to struggle to get the sail drawing properly. If you happen to be short-tacking, the headsail overlap can make the difference between success and disaster.

TYPES OF RIGS

All sorts of rig configurations are used on cruising boats. Almost any of them will get you where you are going. The differences really come into play with ease of handling and performance. And while you might think these two desirable traits are mutually exclusive, this is not at all the case.

The Cutter

Properly set up, a cutter will have the sail-reduction capability of a ketch without the attendant cost, complexity, or aerodynamic inefficiency of two spars. A good-size mainsail that can be used when set full with a staysail, jib, or with both headsails at once makes a powerful, easily handled rig. Additionally, a cutter should be able to sail under just her staysail in really heavy winds, even when going to weather. Add to this a storm trysail, and you can take just about anything without ever changing the headsails on their stays.

A cutter rigged with twin headstays can use either of two sizes of jibs — or both, when broad reaching or running — and then shorten down to one jib and a staysail, then to a staysail alone. The inner stay, or forestay, is ideal for carrying a storm headsail; it's easier to work around, since it's placed well abaft the stemhead, and if you're going upwind its sail is less likely to blow the bow off in heavier conditions or when you're cresting the tops of high seas.

Another advantage of the cutter is in her spars. The size of a yacht's spar is determined by the compression load, and this is a direct function of shroud angle (among other things). Since the spar is farther aft than on other rigs, where there is more beam for chainplate attachment, the shroud angles are not so extreme. As a result, rigging and spar sections can be lighter for a given amount of stability. This saves weight aloft, which in turn makes for a stiffer vessel.

The negative in all of this is the fact that the mainsail is quite small relative to forward triangle. And the overall efficiency of the rig is not as high as on a sloop.

Sloops

The most common rig is the masthead-rigged sloop. It's initially cheaper than a cutter, because it eliminates the running backstays, inner forestay, and related chainplates necessary on the cutter. But it can carry only one headsail at a time, and under extreme conditions a small jib on the bow *must* be balanced by a storm trysail. Contrast this with the cutter's ability to sail upwind under just a staysail. Running, with their larger mains and single large headsails, sloops are faster than any of the other rigs. Sloops often set a staysail under a spinnaker or even with a jib in moderate conditions, without using running backstays. But this is only a way to develop more sail area — do not attempt this when the going gets rough.

If you're buying a used boat, you'll find more sloops available than anything else. If you already own or plan to buy a sloop, consider adding an inner forestay and running backstays to increase versatility and heavy-weather capability.

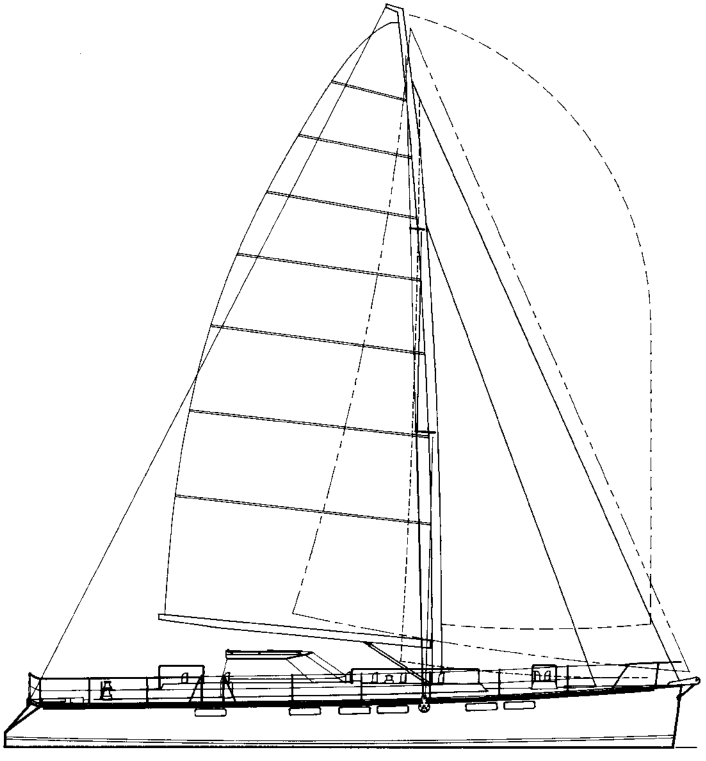
A removable inner forestay allows the efficiency of the sloop rig, while maintaining the heavy weather capability of the cutter — the best of both worlds.

Fractional Rigs

In smaller sloops, fractional rigs also have a lot to offer. They provide the flexibility of mainsail draft control that is available with the “bendy” spar inherent in this rig, and also allow smaller headsails that are easier to handle. The large main of a fractionally rigged sloop will drive the boat well without a jib, making it very handy for maneuvering under sail in close quarters. In addition, that large main does a great job of blanketing the foredeck when the time comes to change headsails. The smaller spinnaker that comes with this rig is also easier to control than on a masthead cruising boat.

But there is one drawback. The fractional rig usually depends upon running backstays to keep the headstay tight when going to windward. That's an acceptable compromise, as long as a mistake with the runners doesn't cost you the mast. A conservative spar system is recommended for cruising.

Bruce Farr has been putting fractional rigs on cruising boats since the late 1970s.. *Beach Party*, a Kiwi-built 46-foot (14.2m) yacht, has typical proportions for one of his boats. Note how far forward the main mast is, and how large the main is relative to the jib.



We used a conservative fractional rig on three of the Sundeer 64s. The working jib is just 650 square feet (61 square meters) — very small for a vessel of this size and power.

The main is 1,021 square feet (97 square meters) which might seem a bit on the large size. However, it is easily handled within the lazyjack system.

A halyard to the masthead could be used for a spinnaker or reacher. The reacher was tacked to the end of the anchor sprit.

When the breeze started to come up, the first reef was taken in the main. Next came another reef, after which you went to work on headsail size.

The main was designed to overlap the backstay a couple of feet (0.6 m). In anything over 4 knots of apparent wind, it would pop right through.

However, when short-tacking in light airs, a reef is necessary to get the sail to clear easily.

These rigs were not runner dependent. In fact, headstay tension was achieved by adjusting the backstay.

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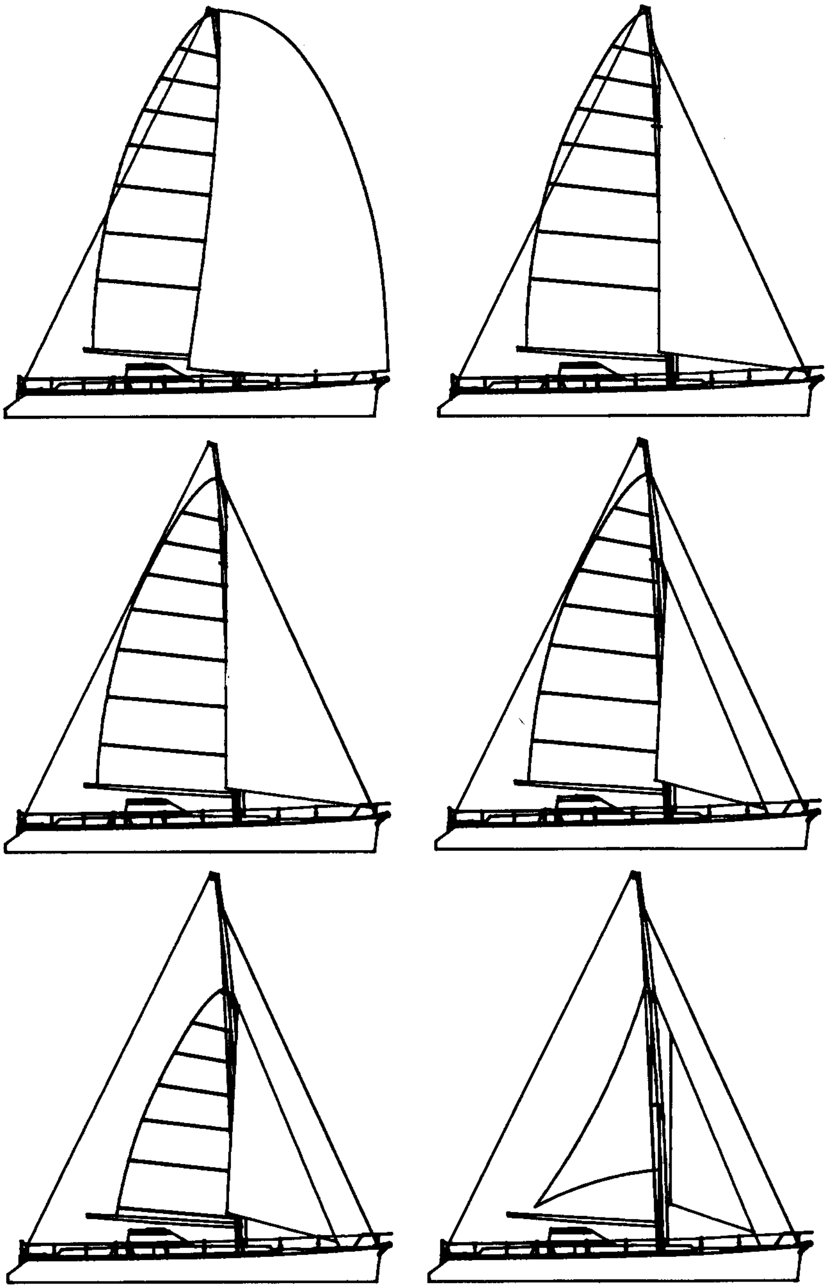
Of course, if the main has its first deep reef at a point where the head of the sail is below the runner tangs, then both runners can be permanently set up after a reef. At this point you're just as secure as with a masthead rig. Some racing boats use cut-down mains, in effect reefed to the headstay, to make life easier on the crew during deliveries. The need for runners can be reduced or eliminated by using aft-swept spreaders. By stiffening the mast section you can also accomplish the same goal.



The fractional rig offers several big advantages for cruising. First, the headsail is quite small and therefore easy to handle. Next, with most of the sail area in the main, it's much simpler to reduce sail as the wind increases. If you add a cutter stay, as shown here, the only headsail you ever need to change down to is a storm staysail.

The Yawl

I can think of a few good things to say about yawls. They tend to be good-looking. Also, the mizzen is a great place to rig an awning, and makes a wonderful handhold and an excellent radar platform. Some people tout the yawl's mizzen as a steering rudder when maneuvering under sail in crowded conditions. But if the boat is designed correctly in the first place, that shouldn't be required. The mizzen is so small relative to the rest of the rig ahead of it that it frequently operates in a substantial amount of back wind. It does, however, provide a good riding sail at anchor. And, in heavy weather, you can sail jib and jigger.

If you get a free mizzen on the back end of a boat, and if it looks nice to your eye, you might as well leave it back there. But I wouldn't pay extra for one!

With the helm aft of the mizzen, some would argue that this is a ketch rather than a yawl. However, we've always felt that it was the relationship of sail areas rather than the location of the wheel that determines rig type.

These rig proportions were very popular for a while during the later 1960s through the mid-1970s.

Close-reaching like this, the small mizzen will generate some horsepower. But this boat would be much better off with a slightly taller mainmast and no mizzen. She'd be easier to sail, less expensive to build and maintain, and would probably behave better in anything other than light airs.

But the second spar does add a bit of charm to the overall look of the boat.

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Chiriqui was a 60-foot (18.5m) John Alden–designed ketch that my family owned during the mid-1950s. Her rig proportions were those of the classic CCA ketch. While the mizzen added a bit of drive off the wind, the main purpose was to balance the staysail when sailing in strong winds with main and furled yankee. With today's modern materials, *Chiriqui* would be much easier to handle, not to mention faster, if she had a single stick.

A small yacht like this looks saucy with its mizzen, and the proportions of the sails are not too bad. However, in this size of yacht a single-stick rig would be far easier to sail and less expensive to build and own. (Port Townsend Sails photo)

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The Ketch

In recent times a substantial percentage of sailors have thought of the ketch rig as something that looked cute on a Colin Archer double-ender, but not on a modern offshore cruising yacht. And racers haven't considered a split rig since *Kialoa III* and *Windward Passage* discarded their mizzens in the early stages of last decade's maxi wars.

Well, times change, materials improve, technology creates new possibilities. And the split rig, reincarnated in the form of a high-performance ketch, is making its comeback.

What are these new elements? First, stronger sailcloth and better sail-construction techniques mean mizzens can maintain their shape over a wider range of conditions, a factor that is even more critical in a split rig than in a single-sticker. Second, conservative spar bending to control mizzen draft makes possible a range of sail-draft ratios, from flat to full. This allows the mizzen to be an effective sail to windward and a powerhouse when reaching, as opposed to the old days when most mizzens were furled upwind. Third, acceptance of full battens has improved the versatility of the mizzen. When the design proportions are right, the resulting ketch is almost as fast as a single-sticker uphill and substantially quicker off the wind, with a series of handling benefits thrown in, too.

That the single-sticker is potentially closer-winded is a given. However, cruising yachts typically have shallow-draft keels that aren't efficient enough to sail at tight-tacking angles. When passaging offshore, sea conditions and comfort requirements usually make footing (sailing free) a better option than pinching. So the potential advantage of the sloop or cutter is minimized in the offshore and/or shoal-water scenarios.

Crack your sheets a bit and watch out. The ketch rig takes off. With more sail area, the ability to generate higher lift coefficients when reaching, and a lower center of effort, the ketch will simply create more usable propulsive force.

Locura, a Deerfoot 72 (left), has close to optimal proportions between main and mizzen. The mizzen is such an integral part of this rig that it acts like a trailing edge flap on an airplane. By adjusting the mizzen you can see a difference in flow over the jib.

When sailing off the wind, the mizzen is typically overtrimmed a bit, to increase lift on the forward part of the rig. The same holds true in light airs upwind. However, once the breeze starts to build, the mizzen quickly flattens out and is eased down on the traveler — not because of helm pressure, but to reduce drag on the entire rig (since with increased wind pressure, less lift and therefore less drag is required.

This is similar to the way the wing on a high-performance glider is used. Positive flaps are used when a glider takes off, lands, or flies slowly in thermals. In order to cover territory fast and reduce drag to a minimum, the flap angle is reduced — just like easing the mizzen.

In keeping with what we learned with *Locura* (above and right) and the Sundeer 67, when the time came to develop a ketch rig for the Sundeer 64 (below) we put more area into the main and mizzen and less into the forward triangle than what we had done previously.

The rig on the 64 turned out to be as powerful as we had hoped. This made for a boat that was fast and easily handled when beating or reaching, especially when you consider the shallow draft (6.5 feet/2 m).

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Mizzen Aerodynamics

There are a lot of misconceptions about just what the mizzen does. Most folks think that it acts on its own, and not very well at that, since it's sitting in the backwind of the main and jib. But the reality of a ketch rig is something substantially different. We've found that if you're sailing a properly proportioned ketch to windward and everything is trimmed just right, with the jib telltales a little nervous, the jib will start to luff when you ease the mizzen sheet! That's the flap effect of the mizzen. Its main function is to improve the pressure distribution of the sails ahead of it.

If you go back a few years to study the aeronautical literature on biplanes, quite a bit of data is available. Of course, applying this in the sailing world is something else again. Theory dictates that the ratio of mizzen area to forward sail area should be proportional to the square of the luff lengths. This means that if mizzen luff length is 75 percent of the mainmast height, the mizzen's sail area should be about 50 percent of the main and foretriangle. But the forward spar has both mainsail and jib areas, so it's difficult to get near the ideal. In the end, it's best to fit the biggest mizzen practical.

The Sundeer 67 (above) with all her downwind finery.

Notice the difference in the proportions of this rig and that of *Locura* on the preceding page. The mizzen on *Sundeer* is about 10 percent larger in scale that of *Locura*, and she was much faster for it. Since she had a better length-to-beam ratio and more efficient fins than *Locura*, helm balance was not an issue. She could carry a full mizzen long after *Locura* would be starting to reef.

Sundeer is trimmed up for broad reaching in light winds. True wind is about 11 knots, from about 140 degrees. The mizzen is just off-center, with the mizzen spinnaker sheeted in quite tightly. She would pull her apparent wind forward so quickly that even at these deep downwind angles it was difficult to keep the mizzen chute drawing. Once the breeze came up, however, the mizzen spinnaker would become very stable.

Locura is sailing in similar conditions. Since she is not quite as fast, her apparent wind is further aft. She is flying a mizzen reacher rather than a spinnaker — an easier sail to trim in light airs. (Jeri Conser photo)

Mizzen Headsails

Another advantage of the high-performance ketch and its tall mast is a big mizzen staysail. Mizzen staysails can generate enormous amounts of drive in light or moderate conditions. When this power is coupled with the somewhat smaller spinnaker a ketch carries, the total usable driving force off the wind is substantially greater than on a single-sticker. When the breeze begins to pick up, you can easily douse the mizzen staysail, leaving the smaller spinnaker up through a higher wind range than would otherwise have been possible on a sloop or cutter.

A critical factor in using the mizzen staysail is the tack and sheet position. It's most important to keep the slot between the mainsail and the mizzen staysail open. This is achieved by moving the tack position somewhat aft and toward the toerail. The ideal location will be found only by experimentation. Be aware, though, that slight changes in tack position can have an enormous impact on the total drive of the rig! The same factors apply between the mizzen and staysail leeches. Once again, you don't want to close the slot between these sails. This means sheeting the staysail to the end of the mizzen boom when sailing free. Closer on the wind, the tack will move

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toward the center of the boat, while the sheet will go to the stern quarter.

For ease of handling, the mizzen staysail can be built with a snuffer, or sewn on a wire or Vectran rope luff and used with a roller-furling drum at the bottom.

On most boats you'll find that the mizzen staysail only begins to be valuable at about 85 degrees apparent-wind angle. Once you get to 135 degrees, it starts to blanket the main, so while it does generate a lot of power, the wind angles in which this can be done are somewhat circumscribed.

With high-roach sail design it is much easier to develop optimal mizzen-sail areas. And when you get the proportions right, it makes a huge difference in boat speed. A ketch rig like this on the Sundeer 64 will generate as much power in the mizzen as the mainsail. When the time comes to reef, you typically shorten down the main first, and then the mizzen. This gets you ever closer to the optimal relationship between the mizzen as a flap and the main/jib combination as the wing. (Billy Black photo.)

Mizzen Rigging

The rigging of the mizzen mast offers a number of opportunities for enhancing cruising safety and comfort. Mizzen stays should be totally independent of the mainmast. This may require a very flat mizzen headstay angle, but since this is lightly loaded, tight angles are feasible.

If the mizzen cap shrouds are taken right out to the deck edge (which reduces loading on the spar and rigging), an extra-high lifeline can be rigged between main and mizzen mast.

Cruising in the tropics? The mizzen mast makes an ideal aft-end tie-down point for the main deck awning.

If you intend to mount a radar on the mizzen, consider oversizing the bracket just a little. With a few handholds or steps, you can have an ideal perch aloft to watch for low-lying landfalls or coral heads.

There are some other aspects to consider. If you have an aft cockpit, designing a dodger will conflict to some degree with the mizzen vang. The mizzen sheet has to be rigged so that chances of entangling the helmsman while jibeing are minimized. Coamings have to be designed with thought given to the lower mizzen shrouds, and to being able to walk down the deck without too much interference.

There are a whole series of possible sail combinations with the high-performance ketch rig.

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Shortening Down

Ideally you start reducing sail with the main and jib first. This gets you closer to the ideal ratio between the forward and aft spars. Contrary to what you may think, sailing with an unreefed mizzen while sail area is reduced forward won't necessarily increase weather helm. Reducing heel angle makes the biggest difference.

The most efficient way to shorten down is to reef the main, go to a smaller jib, and then start to reef the mizzen. Another approach is to drop the main entirely and sail with only mizzen and jib. We do this quite a bit aboard *Sundeer.* Since the main is the biggest sail aboard, and easy to put away, it frequently is the first sail down when the breeze starts to increase. While logic would indicate that the large separation between the two sails would reduce efficiency, a ketch sailed in this manner can be very, very fast, while maintaining moderate heel angles, especially to windward.

Ketch Rig and Boat Size

How small a yacht makes a good platform for the ketch rig? The answer really depends on deck and interior layout. The mizzen mast creates difficulties in these areas. And just sticking a spar on the back end of a sloop where it's out of the way won't satisfy the aerodynamic requirements enough to justify the problems associated with the split rig.

Ideally, the mizzen mast will be keel-stepped to increase its inherent strength and to reduce weight aloft (since a smaller mast section can be used with a keel-stepped spar). But this interferes with the interior layout.

Unless the mizzen is of substantial size, it is really not worth the trouble. From my experience, the mizzen should represent at least 25 percent of the total measured sail area, and preferably 35 percent or more.

Bear in mind that a ketch rig is more complicated to sail than a single-sticker. Not only is there a third working sail to deal with, but efficient use of the ketch rig means all the sails are interacting, so trimming complexity is greatly increased.

When we bought *Intermezzo,* she was yawl-rigged with a small mizzen well aft. It was in reality a CCA "racing rule" sail. The mizzen was a waste of weight, windage, and money. But it came to us free and it looked nice, so we left it there. Then came the opportunity to change the back end of the boat and we moved the mast forward, allowing a much larger sail. It began to pay its way. Still, if I were starting from scratch on a boat that size, I would not have used a mizzen.

When we did *Intermezzo II* we looked carefully at a split rig, but in the end opted for the cutter configuration. We saved substantial money, and it simplified deck layout. But I felt after a lot of sea miles that we were approaching the size limit a couple would feel comfortable with in a single-sticker.

In the years that followed we had the opportunity to do several more ketch rigs. Both *Wakaroa* and *Locura* proved to be substantially more efficient sailing upwind and reaching than we had anticipated. This was in spite of the fact that the mizzen staysail seemed to be used less than we thought it would be.

When the time came to decide on a rig for *Sundeer,* we carefully reviewed all the options. At 67 feet we felt she was a little big for a single-stick rig, although we could have managed with a large, full-batten mainsail. The true deciding factor was that we wanted a clear aft deck for dink stowage and in-port lounging. The ketch rig lent itself well to this scheme.

Using George Hazen's velocity-prediction software we did extensive performance analysis on split-rig sail-area ratios and ketch-against-cutter speeds. Adjusting sail areas and rig weights in each case so that in a given wind the two computerized boats would have the same heel angle, we were surprised to find that the ketch was only a few percent slower when beating. The expected performance advantage off the wind was very apparent.

Computer prediction is one thing. The real world is something else. In trials against some of the larger cutters we've sailed, *Sundeer*'s ketch rig has actually proven to be somewhat faster. Compared to my dad's 74-foot *Deerfoot II,* we are faster upwind in all conditions. Not that I would ever rub it in, mind you.

Does the ketch rig make sense for you? Obviously, that depends upon a lot of factors — size of boat, what you feel about handling, aesthetics, and the type of sailing you will be doing. For most, the answer will be no. Certainly, on vessels under 55 feet or so, the trade-offs don't add up.

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The 76-foot (23.4m) John Alden schooner *Constellation* was the archetype of the fishing schooner reoriented toward cruising. My dad bought her after World War II. In 1948 we left Michigan, sailed down the St. Lawrence River (before the seaway), down the East Coast, and on to California via the Panama Canal. *Connie* was lovely to look at but a bear to handle. My dad always had four crewmembers aboard in addition to our family.

Schooners

We started by saying that a single sail was the most efficient way to get horsepower from a given amount of sail area. Well, you can imagine how I feel about schooners (even though I grew up on them) — two expensive spars and sets of rigging, and a whole bunch of postage-stamp–size sails. They look great and go like hell on a broad reach if a spinnaker and gollywobbler are used. But we cruise shorthanded, and no shorthanded schooner sailor I know ever uses his gollywobbler, which is the whole *raison d'etre* for schooners. So why bother? Tradition, aesthetics...if that's your bag and you're willing to pay for it in boat speed, dollars, and difficulty in working your way off a lee shore, okay. But as a sensible rig on boats under 90 feet (27.7 m), it doesn't make any sense with today's technology.

Still, if you are attracted to the schooner rig for a new yacht, consider making both spars and sails the same size. This offers the advantage of moving mainsail to mizzen, and vice-versa should one sail be damaged. The larger foresail and forward triangle that come with this configuration will be faster than a traditional schooner rig. And you won't have such a huge mainsail to deal with.

For schooner aficionados everywhere, the sail they love the most is the gollywobbler (there are other names when the wind comes up, but these are not printable in a book designed for the general public!).

Gollywobblers have two halyards: one to the peak of the mainmast and a second to the peak of the foremast. These sheet through the end of the main boom and are extremely powerful on a broad reach. Getting one down in a breeze takes careful coordination on the halyards while running off and blanketing the sail in the lee of the main. (Port Townsend Sails photo)

Gaff Rigs

I have often thought about doing a modern gaff rig. These are, after all, potentially quite efficient if you can control the twist of the gaff to leeward and get your sails shaped properly.

Folks who sail with gaffs site a number of advantages. They have lots of sail area in a relatively efficient planform, and when the fisherman staysail is flying on top of the gaff, they can be extremely fast. The trade-off, as I see it, comes in handling the gaff. When hoisting the gaff, you must coordinate the peak and throat (the corners of the gaff).

My job as a 7-year-old was to call out the alignment to the men hoisting these on *Constellation*. That's three bodies handling one sail!

To be sure, the job on a smaller yacht can be done by one person, but it takes time. And dropping the sail involves controlling the swing of the gaff, which can be a real hassle off the wind and/or in a beam sea.

Still, set up with modern sailcloth, maybe carbon-fiber spars, and efficient winches, the performance of this rig might surprise many of those folks sold on the Bermudan sail concept!

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Two views of lovely gaff rigs (left). The schooner (immediate left) has very traditional proportions, right down to the four small jibs. The gaffs on the main and foresail are about the only way to get sail area into this short rig. In a breeze, especially when reaching, this boat rig will move right along. But I suspect in anything under 15 knots of breeze, she'll be pretty slow.

Contrast that to the gaff cutter (above, far left). Here we have a nice-looking main topped with a flat, efficient-looking fisherman staysail, together with staysail, yankee, and flying jib. That gaff-rigged main with the staysail on top is as efficient as anything you see on a racing boat, provided you can control the twist to leeward of the gaff.

This photo is taken at the perfect angle to look at twist. There's just a hint, and in a lot of cases with wind shear, you might want even more. I doubt there are many rigs that would push this hull any faster in these conditions. A single large jib would be faster, but not nearly so nice to look at. (Port Townsend Sails photo)

Blondie Hassler, one of the pioneers in singlehanded racing, loved the junk rig. The shot (above) of his boat leaving Capetown, South Africa, was taken after she was re-sparred — she had been rolled in a severe Southern Ocean gale.

The owner told us that his foresail had been damaged and that the smallest reef in the main was too large for the conditions, so he had been forced to lie ahull. He knew at the time this was a poor tactic, but felt he had no choice.

The three-masted rig (upper right) is often seen on larger junk-rig yachts. This is very traditional in the Asian context, and for a rig without winches offers versatility and ease of handling the smaller individual sails.

Middle and bottom right show an East/West combination — a jib-headed junk-rigged schooner. I suspect the jib helps to tack in light airs, and adds a nice leading edge flap to the overall rig. In light airs, it must help significantly with progress, especially on the wind and close reaching.

Junk Rigs

The junk rig has always intrigued me. The simplicity (not to mention low cost) of the unstayed spars and the apparent ease of handling, are cited as advantages. Tom Colvin has been an exponent of the junk for years. We have on several occasions met junk-rigged vessels cruising, and some have made amazing journeys in high latitudes. Of course, for at least a thousand years the Chinese have been using elliptical tip shapes that would look good on a modern America's Cup yacht.

The major drawback is light-air performance. It's difficult to get a good shape to the sail, and this is the most important aspect of light-air sailing.

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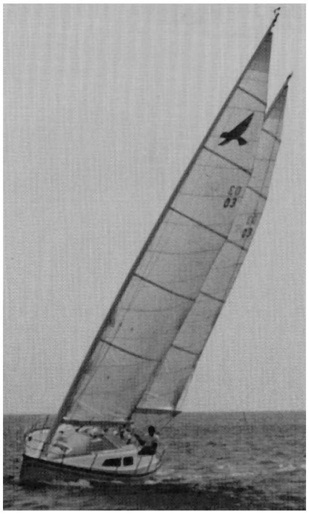
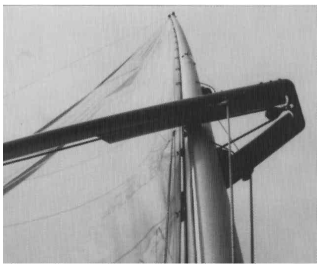
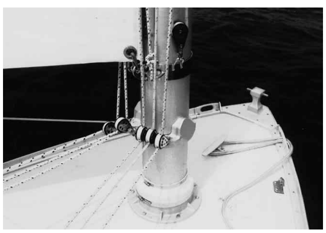


Above: Richard Black sailing his own Sparhawk design. The sails are set beautifully. As the breeze increases, the spars will begin to bend, flattening the sails.





Eric Sponberg sent us these photos of the Nonsuch 22 for which he designed the freestanding rig. The wishbone boom is particularly interesting. Because it is angled down, it serves as a vang as well as the boom, automatically controlling leech twist.

Modern Freestanding Rigs

Freestanding rigs have quite a bit to offer, picking up on the aerodynamic front where the Chinese left off a thousand years ago, and taking advantage of modern high-tech materials. They certainly offer more drive per square foot than a conventional rig, if the spar is faired into the sail. Another probable advantage is comparable or better reliability by reducing rigging components. They're certainly easier to sail than conventional rigs. And of course, they are much simpler, in that you get rid of a lot of rigging. But for offshore work you must have more flexibility than that offered by the basic sail inventory.

Richard Black, our computer guru, friend, and designer of freestanding cat ketches for many years, points out that all you have to do to get around my heavy-weather concerns is fit extra trysail tracks to each spar. You then end up with storm canvas ready to go on each. Pretty simple.

Richard also makes the point that there's lots of room for light-air sails in the form of giant mizzen staysails and/or mainmast spinnakers.

To get more input on these rigs, Richard suggested I call Eric Sponberg, a Newport, Rhode Island designer and engineer who has done the numbers on a bunch of freestanding spars.

The first thing I found out is that freestanding rigs, when built with carbon fiber (as most of them are), have a somewhat lighter weight and much lower center of gravity than an aluminum mast with all its wires and fittings. Less weight and lower CG means a stiffer and more efficient boat. Eric echoed Richard's comments that there have been few structural problems over the years, certainly no more than with stayed rigs.

These spars also can contribute to range of stability when capsized, since they're easily sealed or filled with foam, and all that flotation so far from the hull's center of buoyancy is like having extra tons of lead in the keel.

One of the keys to performance with a freestanding rig is matching mast bend to the boat's stability characteristics, then matching the sailshape to the spar. With the right combinations, mast bend will increase as sheet tension is applied, automatically flattening the sail. At a certain point when the boat starts to be overpowered, the tip of the mast bends off to leeward, allowing the leech to twist open, depowering the rig automatically. This is standard fare in most dinghy classes.

For a custom design, changing spar bend can involve a lot of work. Four or five recuts with the sailmaker would not be unusual. But with production builders there's the ability to experiment with prototypes until getting it right. When this is right, speed and comfort is the result in a breeze.

While I have not yet made any passages with this type of rig, I remain intrigued by the possibilities.

AeroRig

The AeroRig, developed in the U.K. by Carbospars, incorporates a number of intriguing ideas. The basic concept is to simplify sailing. The main and jib are sheeted to a long horizontal spar that rotates around the freestanding main mast. A single mainsheet controls this boom, adjusting both main and jib at the same time.

The jib is sheeted to a small athwartships track attached to the spar, and when beating it works like a normal self-tacking headsail.

One advantage of having jib and main forces coming onto the same spar is apparent when jibing.

As the main tries to swing across the boat, the forces are partially balanced by the jib, slowing down the travel of the boom to which they are both sheeted. This reduces those slamming loads you must deal with when a main is sheeted all by itself to the boom.

A second advantage comes in the relationship of jib to mainsail. Because the luff of the jib rotates to weather as the main is eased, the slot between the two sails remains constant. This means that when sailing free of the wind, the jib is in a wonderfully efficient position to influence flow over the leading edge of the mainsail. In effect, it acts like a Fowler flap on the leading edge of a jet.

The increase in lift coefficient, theoretically at least, could be on the order of 100 percent.

One of our Sundeer 56 owners, Mike Arthur, decided to give the AeroRig a try. While the aesthetics took a little getting used to, the rig apparently works quite well. We hoped to hold a sail-off between Mike and one of the conventionally sparred sisterships. However, this never happened.

Judging by the wind on the water and by the bow and stern waves, this AeroRig has the Sundeer 56 flying right along.

If the engineers get lucky, the tip of the mast will begin to deflect to leeward as the boat reaches its optimal heel angle, automatically freeing up the leech of the mainsail.

The AeroRig is being built in the U.S. by Forespar, under license from Carbospars. (Forespar photo)

Years ago, when I was fooling around with catamarans, we tried to come up with a leading edge flap and could never solve the engineering problems. Carbospars, together with carbon fiber, has done just that.

There are a couple of potential negatives. One is cost. Today, the cost of one of these rigs is several times that of a conventional rig. That will probably come down as more are built. However, in strictly financial terms, that extra money could be spent more efficiently if what you are looking for is performance. On the other hand, the theoretical ease-of-handling of this rig cannot be duplicated.

The other issue is sailing downwind in the trades in a rolling sea. Some users have reported a lot of crashing and banging downwind. There are probably ways to prevent the rig from doing this, but it is an issue that should be carefully evaluated.

SPAR ENGINEERING

Spar engineering is an interesting combination of numbers and (hopefully) real-world experience.

Because weight aloft is such a critical factor in comfort, performance, and range of stability, there is a continuous force pushing the sparmaking industry toward ever more efficient engineering solutions.

Most of this push comes from the racing set. While you never want to lose a rig in an important regatta, if you aren't dropping rigs now and then, you are making them too heavy.

The racing rig failures tell the engineers where the edges of the structural envelope are located.

A "gravity storm," as losing a rig is called in the business, is a good opportunity to find out what went wrong (not to mention a chance to sell a new rig).

Of course in a cruising context the issues are somewhat different.

While we certainly want performance and a good range of positive stability, we don't want to consider losing a rig. In addition, where racing rigs have to be carefully tuned and used with a degree of caution, and where an accidental jibe is expected to result in a dismasting, some abuse tolerance is necessary in a cruising context.

Still, unnecessary weight aloft in a cruising rig is a huge hindrance to performance. In severe weather, perhaps trying to beat off a leeshore, unnecessary weight and windage in the rig might make the difference between success and failure.

How do you know if the engineers are on the mark for your own needs? It's very difficult to tell. You also have to beware of the spar-extrusion inventory on hand. It may be that they'll try to sell you a section that isn't quite right, but has been sitting around for a while. The best approach is to work with a company you trust and to get several quotes comparing the various factors discussed in this section.

Before going on, let me tell you about an experience I had years ago with some of the engineers at Sparcraft. We were sitting in their offices in Southern California, looking at a huge computerized spread sheet with all sorts of data. It was a scientific-looking piece of work, something on which a programmer had spent many weeks. As we were looking at rigs for two large sisterships, and I wanted to get them as close to optimal as possible, I had the engineers walk me through the various factors in their spreadsheet, showing me how they were applied. What I was looking for was the logic of their engineering approach. When they had apparently finished, there was a pause. At the bottom left-hand corner of the spread sheet was a cell named "B-Factor" that had not been explained. This cell was a variable affecting the results of the entire spreadsheet. I pointed to the cell in question and asked what it was for and how it was used. The engineers exchanged uncomfortable glances. "Come on, guys," I said, "I'm not going to consider you for this order until you tell me what the 'B-Factor' is all about." After some hemming and hawing, the answer came back. "That's the *Bozo* factor."

Bozo?

After all of this scientific analysis, the guys in engineering would input a number that reflected their analysis of the *capabilities* of the crew. This could have as much as a 60-percent impact on overall design, if memory serves me correctly. Obviously, spar "engineering" is very much based on guesswork, experience, and an evaluation of what sort of crew-induced loads the rig will see (although today some spar builders are starting to use finite element analysis for rig design).

While the details of rig engineering are quite complex, the basic principles are not. What follows is a basic overview of the process engineers go through to determine the correct rig size.

Stability

The stability of the hull as it fights to keep the boat upright against the force of the wind is what puts most of the load on your rig. So rig loads are directly proportional to the stability of your boat. If stability goes up, say by increasing payload in the bilges, the rig loading goes up in proportion.

Generally, most spar engineers will take the stability of the boat at 1 degree of heel, then multiply this figure by the angle of heel at which they expect the boat to sail most of the time. If you have a righting moment at 1 degree of 2,000 foot pounds and you are assuming the maximum heel angle would be 30 degrees, the total load on the spar is assumed to be 60,000 foot pounds.

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With many cruising yachts, stability increases more or less in a linear fashion with heel angle. This being the case, the approach just outlined above works fine. But if you have a hull shape with high initial stability, and maybe water ballast, the stability at moderate angles of heel, say 18 degrees, will be much higher than what you find at 30 degrees. In this situation the rig engineering loads must be modified.

On most yachts stability continues to increase up to around 60 degrees of heel before it starts to taper off. If you suffer a wind-induced knockdown, your rig must cope with the higher stress levels coming from these greater heel angles.

In the olden days, before computers, everyone guessed at the stability curve of a given yacht after testing for initial low-angle stability. Today, however, most designers can develop a stability curve to use in conjunction with an inclining test to determine just what the loads on the rig will be. If your sparmaker does not already have this data, it is worth calling the builder or designer for the curve. If this fails, go to the U.S. Sailing Association for a performance package on a sister-ship, or contact Peter Schwenn at Velocity to develop this data from a set of your hull lines.

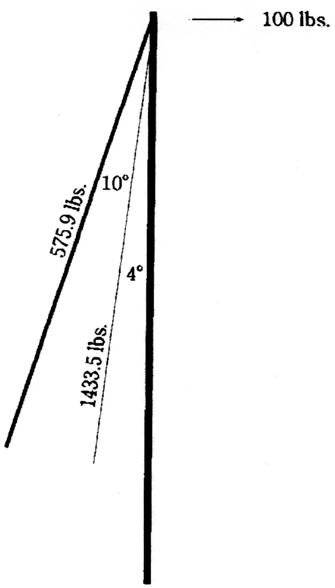
Factors of Safety

An initial *factor of safety* is placed on the righting moment at the maximum *normal* heel angle. This allows for an increase in load from heavy weather, and also accounts for the crew's abilities (or lack thereof!), as well as the desired longevity of the rig and rigging.

This factor of safety, multiplied by the real righting moment, creates a basic load that is used throughout the rest of the formulas. In many cases engineers will take the actual righting moment at 30 degrees, then multiply it by 1.5 or 2. This basic number is then used to determine the compression load on the mast and tension load on the rigging. In each of the subsequent steps, additional factors of safety are added on for each component so that you have factors of safety multiplied by factors of safety.

In real-world cruising you normally only sail at, say, 20 degrees. The righting moment at 20 degrees is much less than at 30. Thus, the normal factor of safety that your rig really has is usually more like 2-to-1.

It is important to keep an eye on the various factors of safety and how they relate to the way the boat is to be (or has been) used. You don't want to be too low or too high. Be realistic.



The heeling force on the mast is reacted by the sidestays. The load they see is a function of the angle. The wider the staying base (and therefore the wider the angle), the lower the shroud load. (Forespar drawing)

Shroud Angle and Beam

With a conventionally rigged mast, where side loads are taken by standing rigging, the tension on the shrouds is proportional to the cosine of the angle that the shroud makes with the mast.

As a result, the further out your chainplates are located, the lower the rigging loads. When the tension in the standing rigging goes down, the compression load on the mast is reduced. Both the rigging and the mast can be lowered in size, reducing weight and windage aloft. Having a wide staying base almost always pays dividend for cruising. The only negative comes with sheeting overlapping headsails when sailing hard on the wind. However, in a cruising context this is not such a critical issue.

Mast Compression Load

With the righting moment established and factors of safety allowed for, you now have a load that can be applied to the mast. Each shroud puts its load into the mast on a basis of the cosine of the angle it makes with the spar, so the more open the angle, the lower the loads, as we've seen. Spreader width affects this, so within certain limits (discussed later in more detail under spreaders), the wider the spreader, the better in terms of mast loading.

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INCLUDED ANGLE	MULTIPLE OF LOAD	INCLUDED ANGLE	MULTIPLE OF LOAD	INCLUDED ANGLE	MULTIPLE OF LOAD
1	57.299	12.25	4.713	22	2.67
1.5	38.201	12.5	4.62	22.25	2.641
2	28.654	12.75	4.531	22.5	2.613
2.5	22.925	13	4.445	22.75	2.586
3	19.107	13.25	4.363	23	2.559
3.5	16.38	13.5	4.284	23.25	2.533
4	14.335	13.75	4.207	23.5	2.508
4.25	13.494	14	4.134	23.75	2.483
4.5	12.745	14.25	4.063	24	2.459
4.75	12.076	14.5	3.994	24.25	2.435
5	11.474	14.75	3.928	24.5	2.411
5.25	10.929	15	3.864	24.75	2.389
5.5	10.433	15.25	3.802	25	2.366
5.75	9.981	15.5	3.742	25.25	2.344
6	9.567	15.75	3.684	25.5	2.323
6.25	9.186	16	3.628	25.75	2.302
6.5	8.834	16.25	3.574	26	2.281
6.75	8.508	16.5	3.521	26.25	2.261
7	8.206	16.75	3.47	26.5	2.241
7.25	7.924	17	3.42	26.75	2.222
7.5	7.661	17.25	3.372	27	2.203
7.75	7.416	17.5	3.326	27.25	2.184
8	7.185	17.75	3.28	27.5	2.166
8.25	6.969	18	3.236	27.75	2.148
8.5	6.766	18.25	3.193	28	2.13
8.75	6.574	18.5	3.152	28.25	2.113
9	6.392	18.75	3.111	28.5	2.096
9.25	6.221	19	3.072	28.75	2.079
9.5	6.059	19.25	3.033	29	2.063
9.75	5.905	19.5	2.996	29.25	2.047
10	5.759	19.75	2.959	29.5	2.031
10.25	5.62	20	2.924	29.75	2.015
10.5	5.487	20.25	2.889	30	2
10.75	5.361	20.5	2.855	30.25	1.985
11	5.241	20.75	2.823	30.5	1.97
11.25	5.126	21	2.79	30.75	1.956
11.5	5.016	21.25	2.759	31	1.942
11.75	4.911	21.5	2.729		
12	4.81	21.75	2.699		

Skip Chetelat at Forespar was kind enough to share this chart showing the relationship between shroud angle and load. You can see, for example, that between a tight shroud base with a 6-degree angle and one that is at the rail with a 10-degree angle there is a 66-percent difference in tension load on the wire and, therefore, compression load on the mast. (Six degrees has a load factor of 9.567, and 10 degrees has a load factor of 5.759). In the old days designers specified very tight shroud angles. However, it is now common to use 9 to 10 degrees as a minimum on many racing yachts, and even more on cruisers.

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Engineers add up the total load each wire puts onto the rig. This includes side shrouds, head and backstays, runners, and cutter stays. In addition, if they are doing things carefully, allowance will be made for halyard loads on each sail flying.

Finally, a figure is sometimes added for the amount of pre-tension in the rigging wire, which is present in addition to the actual sailing loads.

The sum total of these, factored by the cosines of their angles, adds up to the total compression load on the spar.

Ambient Loading

How a rig is used has a big impact on how it should be designed. For example, a racing yacht, sailed by an experienced and skilled crew, can be successful with a rig that has very low factors of safety. If someone makes a mistake, the rig comes down, but while it is up they are very fast. Besides, some folks get an adrenaline rush from sailing at the edge of the envelope.

A cruiser who spends his time on Long Island Sound or sailing between Southern California ports will be able to use a much lighter rig than someone who sails on San Francisco Bay, in New Zealand, or in the English Channel areas.

It's important to be realistic about how you plan to use your vessel when designing or evaluating the rig. And be sure this is clearly communicated to the folks with whom you are discussing your rig.

Cyclical Loading

Cyclical loading is the most difficult factor to analyze. As loads on your rig rise and fall, as the boat rolls back and forth, everything on the rig goes into varying degrees of tension and compression. Constant loads would be better for the rig in terms of longevity, but this is not the world we sail in. Throw in environmental issues like temperature range and salt-water corrosion, and you end up with a very difficult brew indeed — something that could be impossible to engineer on a numbers basis. All you can do is establish the type of sailing likely to be done, then understand that the higher the factors of safety, the longer a given structure will go before fatiguing.

What is important to recognize in all of this is that the lower the stress level at which a given item operates, the longer it will survive. This is more of an issue with tangs and standing rigging than with spars.

So, starting out with a very scientific numbers-oriented approach to spar design, we are reduced to a verbal description of how and where we will use our rig, hoping that the engineer listens and uses the correct factors of safety for what we need.

Obviously, real-world experience is a critical part of this entire equation!

Worst-Case Loads

With all of the basics now covered, the next step is to look at how the mast will be loaded in a variety of conditions, then choose the appropriate forces to use on the mast extrusion.

Take the cap shroud going to the masthead. Typically, the worst-case scenario for a cap shroud is a spinnaker knockdown. The load placed on the cap by a flogging chute trying to refill, then knocking you back down, are typically far higher than anything a jib would generate.

Intermediate stays are another example. With the full sails, the intermediate on a double-spreader rig carries only a fraction of what the cap and lower shrouds carry. But what happens when you reef the main and fly a storm staysail? The intermediate is now feeling almost as much load as the caps had felt, while beating with a full jib and main. So, on a cruising yacht the intermediate shrouds must be sized for reefed sailplan loads.

CHOOSING A MAST EXTRUSION

Armed with the total compression load on the mast, together with appropriate safety factors, we now get into the interesting part of the engineering — choosing an extrusion.

There are several factors to look at. One is the total compression load at the bottom of the spar and how much metal there is to absorb this load. If you know the load and know the properties of the metal with which you are working, it is quite easy to calculate the stress level at the bottom of the mast. This is usually expressed in terms of psi of stress on the aluminum extrusion.

The second issue is buckling. If you take a light wooden dowel and push down on the top, the middle bows in one direction or the other. The dowel is buckling under the compression load of

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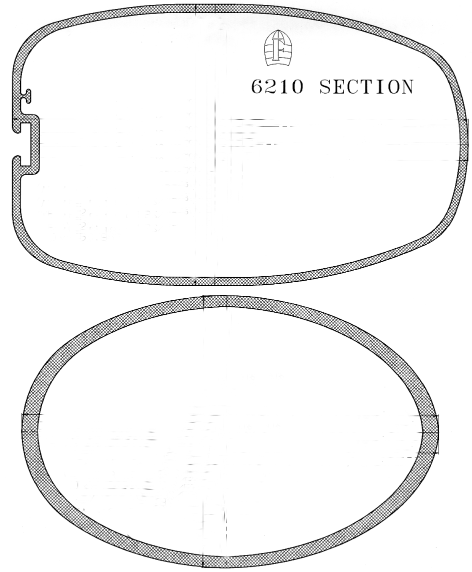

Here is a comparison of two different philosophies of spar design. Both mast extrusions have the same moments of inertia (stiffness). However, the Forespar 6210 section weighs 5.18 pounds/foot (7.63 kg/meter) while the smaller, thicker walled section weighs 6.734 pounds/foot (9.92 kg/meter. That's a difference of 30 percent.

The windage of the lighter section is a little higher and has less resistance to out-of-column deflection, but that huge difference in weight aloft is hard to overcome.

your hand. Continue to press, and at some point it will no longer be able to absorb the load. The dowel will break, generally in the middle, if the cross-section of the dowel is constant.

If you try the same thing again, with only half of the stick, you will find that you have to push much harder to get the deflection, and that the same amount of force originally used will yield only a fraction of the original deflection.

Unsupported Length

The key in this experiment, and in your rig, is the length between support points on the mast (the support points being where shrouds attach, deck, and keel). The column load on the spar is a function of the *square* of the distance between support points, so a small change can go a long way toward reducing the buckling load.

Look at the fore-and-aft support. If you have just a head and backstay the entire length of the mast, from the deck to the masthead is unsupported by any intermediate shrouds. On the other hand, look at the sides of the spar. Here you have a series of short panels between each spreader.

Obviously the load is much bigger in the fore-and-aft direction. That is why masts tend to be longer than they are wide. Of course this "aspect ratio" on the spar section also helps reduce wind resistance.

How Many Spreaders?

It is obvious that the more spreaders you have, the smaller the unsupported panels will be, and therefore the smaller the mast can be in a sideways dimension. Of course, you have the extra weight and windage of additional spreaders and rigging to consider, not to mention cost. Weighing the most efficient quantity of spreaders is something done with great care on racing boats.

Simplicity, ease of tuning, and cost are typically more important for cruising yachts than wringing the last ounce of weight and windage from the rig.

Runners/Cutter Stay?

You can break up the unsupported span in the fore-and-aft direction with running backstays and cutter stays. However, if you depend on your runner system for support and you make a mistake with those runners, down comes the spar.

While most of our rigs have runners and cutter stays for use with heavy-weather canvas, the rigs themselves are *not* runner-dependent. In other words, we typically ignore their presence in determining the extrusion fore-and-aft requirements.

Inertia

Once you finish deciding on spreader layout, and once you make up your mind about runner dependency, the next step is to calculate just how much stiffness the spar requires to resist the deflection that the compression loads are trying to inflict upon it. This is called "inertia," or stiffness.

Inertia is the result of the stiffness of the metal being used (called the modulus of elasticity), the thickness of the metal, and the distance separating the various bits of material.

For a given amount of material, inertia increases with the cube of the distance from the other sides of the shape. Therefore, as the spar cross-section gets bigger, stiffness quickly increases. A mast with a given weight per unit of length that is 6 inches (150 mm) wide will have 30 percent more stiffness than one that is only 1/2 inch (12.6 mm) thinner.

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If you think about the cascade of load on the mast, you will see that at the masthead the loads are lightest — the only tension loading the spar comes from halyard, head, back, and cap stays. As each shroud attaches coming down the mast, compression load keeps adding up until you reach the lower shrouds, which carry the sum of everything from there down.

Internal Stiffening

One strategy for dealing with a differing load pattern is to pick a basic extrusion that is strong enough for the upper panels, then stiffen it by bolting, riveting, welding or gluing additional material where needed. This shouldn't be excessively expensive.

Even better is to put the stiffening external to the extrusion. It is more efficient as it is further from the neutral axis of the spar and much easier to install.

Chemical Milling

Another approach, used on racing boats, is to start with a thick section, then chemically mill the aluminum to taper the thickness. You end up with thick spots where local loads occur, such as at tangs and spreader routes, and exactly the right amount of material for stiffness — an elegant but very costly process. This is less expensive in many cases, however, than internal stiffening.

Euiler Buckling

As you go through this process, it is possible to come up with an extrusion that has the correct inertia for the column compression loading, but with a very thin wall that that is subject to damage.

By looking at the Euiler buckling formula, it is possible to determine what the minimum wall thickness should be in any given situation. Typically, engineers stay well away from the Euiler minimums, as behavior of the extrusion when highly loaded relative to its Euiler capability is sometimes hard to predict. The edge of the cliff is not that distinct.

Extrusion Choice

Once you have established the shroud layout, and if you plan to use internal stiffening, then look at available extrusion choices. Rarely will you find one that is just right. One may be a hair too big, while another may be too small — although you can always beef it up with internal stiffening.

The relationship of fore-and-aft requirements to side-to-side needs will be critical. The taller your rig is, and the wider the side-shroud staying base, the more fore-and-aft stiffness will be required when compared to side-to-side stiffness.

This is where spreader choices ultimately are decided. A given section may have plenty of inertia fore-and-aft but could be shy side-to-side. In this case, reduce the side-to-side requirements by adding another set of spreaders and reducing the unsupported span.

Section Modulus

We need to discuss one more engineering concept before we can complete our choice of extrusions. Section modulus is a function of stiffness and how it is achieved. For example, it is possible to make extrusion light, yet stiff, by extruding the walls very thin but far apart. Remember that cube function! Alternately, you could have a thicker-walled shape, which weighs more and has its walls close together. Both shapes could have the same stiffness.

However, the thin-walled lightweight extrusion would have a lower section modulus than that of the heavier, smaller shape.

This becomes important when unexpected loads occur, such as rolling a spinnaker pole into the water or loosing a shroud. The higher modulus spar (the heavier, smaller section) has a higher ability to absorb load before becoming subject to local buckling (the Euiler formula discussed above). In short, it is more abuse-tolerant.

Final Decision

So how do you make the final choice? In most cases it is a series of what-if games, playing with different quantities of spreaders, rigging sizes, spar weights, and stiffening to come up with the best solution.

Assuming that you have covered yourself on the Euiler buckling issue, the final decision comes down to cost versus weight and center of gravity.

If cost is not an issue, always go for the lightest solution with the lowest vertical center of gravity to meet factors of safety.

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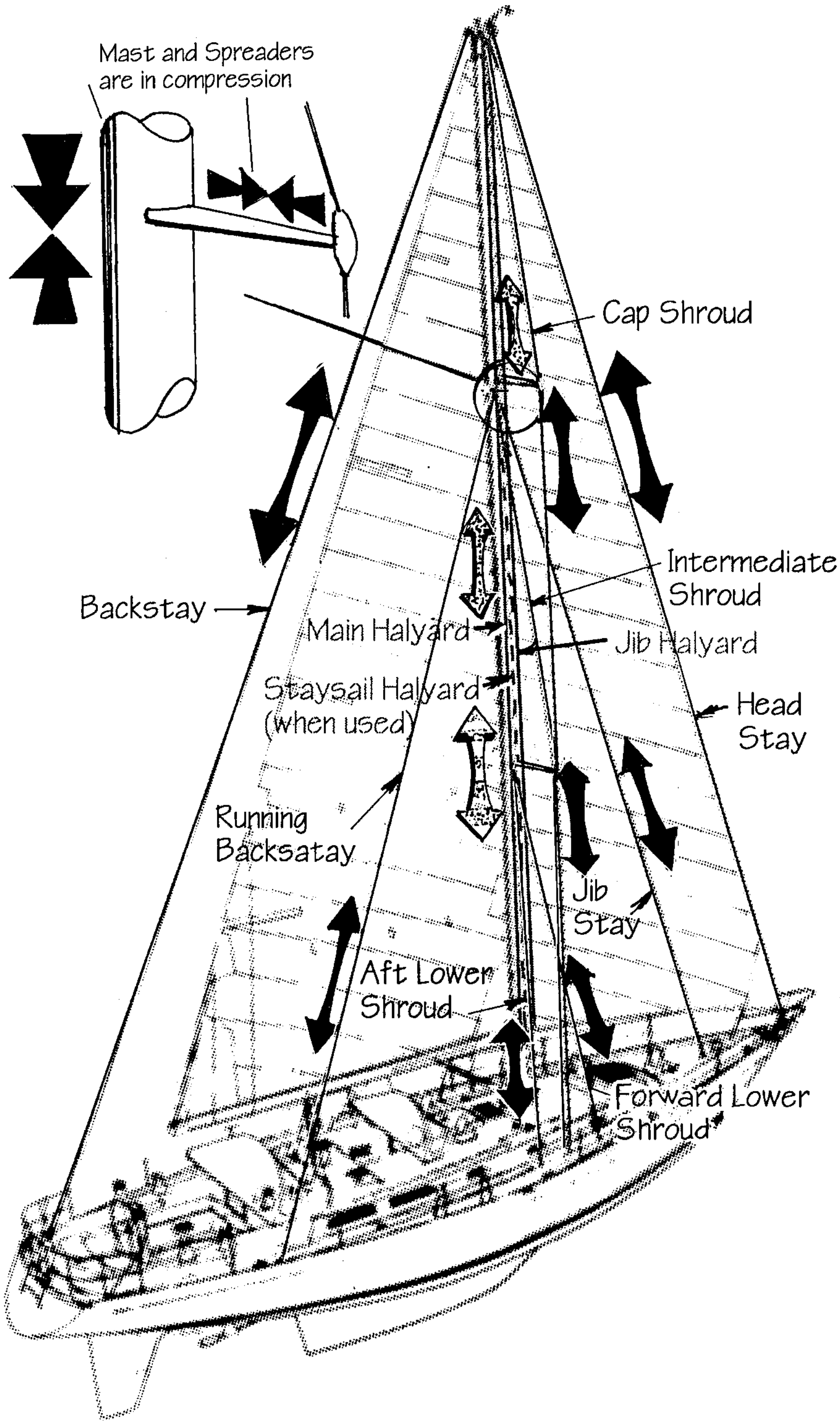

The loads that build up on a rig come from many sources, and are constantly varying as you move through the water and heel to variations in wind strength.

They start with the stability of the boat trying to resist the inclination of the sail plan to heel with wind pressure.

The restraining force is transmitted to the rig via the side shrouds. The headstay adds load if the jib is flying, and this is opposed by the backstay, so you have almost double headstay load acting at the masthead.

Then you have the halyard loads. These can add up to as much as 15 percent of the total compression, with modern sailcloth doing its job.

The spreaders are also working quite hard under compression as they "react": the load of the side shrouds. In addition, the spreaders also have to take the force of the mainsail pushing against their trailing edges when running downwind.

Many of these forces are difficult to predict without some serious instrumentation (which is beyond the means of just about any designer or builder, unless involved in a flat-out racing program). That is one of the reasons such high factors of safety are used with cruising boats — to allow for all of these "unknown" loads!

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SPAR CONSTRUCTION

The basic engineering we've been discussing is the foundation for your rig. In spite of the black art, or perhaps because of it, failures rarely occur in the extrusion. When a spar comes down, it is almost always precipitated by the failure of a small detail leading to a chain reaction.

Welding

Any time you weld a 6,000 series extrusion alloy, at least half of the strength is lost due to the heat generated by the welding process which removes the heat-treating of the extrusion.

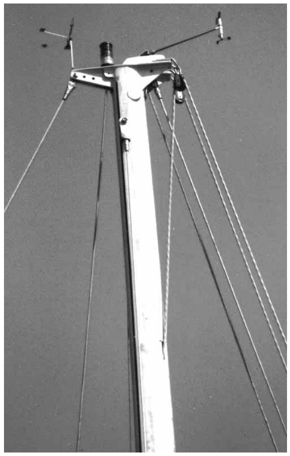
In many areas, such as masthead design, you allow for this and accept it. However, in other areas, where stresses are concentrated and difficult to deal with, such as in a gooseneck fitting or spreader base, the parts in question can be heat-treated after welding to bring them back to their original strength.

Masthead Design

We'll start off at the top of the spar, with masthead design, as this is the most complex part of most spars.

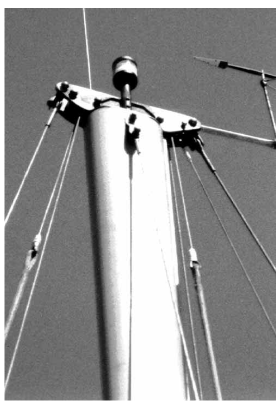
In a cruising context there are several key issues. The first is coming up with a backstay attachment that meets the needs of the owner. Structurally, the closer the backstay is attached to the extrusion, the less bending load there will be. This is good, as long as you never intend to use the backstay to bend the spar for mainsail control.

However, if you do want to bend the spar, unless you have a fractional rig with the headstay well down the mast, you will need a crane sticking out behind the mast so the backstay pressure can induce a bend into the spar (although a small amount of "pre bend" can be induced with static shroud loading and shoving the mast forward at the deck.

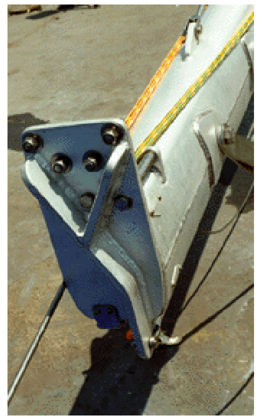


The masthead above has the backstay at the end of a long crane so that it can be used to pull some bend into the spar. There are a series of holes for the backstay so that the bend characteristics can be varied. Note the long crane to reduce chafe on spinnaker halyards

The masthead below has both headstay and backstay closely integrated into the spar. This reduces load, but also makes it impossible to use the backstay to induce mast bend for sail control.



A very elegant, lightweight masthead crane on a Whitbread Round-the-World Race boat.



The top of *Beowulf*'s masthead crane (above). Since there is no masthead backstay (except for runners) the crane is quite short at the aft end. The reinforcements you see here are in case we want to rig a permanent reacher headstay to the end of the crane on the front of the mast.

Another view (right) of the masthead on *Beowulf*. The runners can be seen attached to the sides of the mast just below the top of the mast. If they were attached to a crane, they would interfere with the headboard of the mainsail.

The cap shrouds are mounted a moderate distance below the top of the spar, reducing the internal clutter at the top and shortening the required wire length. This has the additional advantage of starting the compression load from the caps at a lower point on the spar.

To get away with this as far down the spar as on *Beowulf*, you need very wide stay angles.

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The stainless-steel chafe guard around this jib-halyard sheave (above) ensures that the halyard can never chafe against the edge of the sheave or a rough spot on the mast.

An interesting spinnaker-block detail on a fractional rig (above). The blocks are pinned to a universal joint that is attached to a heat-treated weldment. This is in turn bolted to the mast face rather than being welded. The use of bolts eliminates the possibilities of stress risers around the perimeter of the fitting that would occur with welding.

Skip Chetelat at Forespar talked me into using this vertical roller setup (right) on *Beowulf*'s masthead. In theory, it was lighter and would have less chafe. In case it didn't work, we put on a conventional crane for later attachment of blocks (and potential use with a reacher).

However, we found that it worked far better than any other system we've used. In 4,500 miles of sailing with spinnaker and reacher, we only had to shorten the halyard twice due to chafe. With a more conventional setup, it would have been more like every 500 miles at the most.

Masthead Sheaves

Masthead detailing is quite important to the loading on the spar and longevity of the halyards. Sheaves should run true on their axles. If they lay over to one side, there will be tremendous amounts of friction between the side of the sheave and the sheave box. Bronze oilite bearings on stainless axles are okay on boats up to about 50 feet (15.4 m). Above this, consider needle bearings or graphite-lined fiberglass. Both Harken and Lewmar make high-tech halyard sheaves with very low friction.

Sheave exits in the spar need to be carefully rounded to avoid chafe. Even better is a stainless chafe guard on the edges of the sheave box.

In case it's necessary to remove a sheave at sea, it's a good idea to have a small hole drilled opposite the axle-pin cover plate. A drift or small screwdriver can be hammered through this to push out a balky pin.

Another good idea is to tap a small hole right into the groove of the sheave. A threaded rod can then be screwed into the hole and used to hold onto the sheave after the pin is removed. This reduces the chances of dropping the sheave down the mast or overboard. Phil Garland, at Hall Rigging, points out that you can also tape a messenger line around the halyard sheave to keep it from dropping down the mast.

Spinnaker Halyards

The main issue with spinnaker halyards is chafe. There will be many situations in which the spinnaker is off to leeward, pulling at right angles to the boat. It needs a clean leadaway from the block, or it will quickly chafe on the side of the block. Before you know it, the chute will be in the water.

Be sure there are carefully executed chafe guards where the spinnaker halyard enters the mast. Any rough spots will quickly eat through a halyard under tension.

On Transpac Races some of the boats use a wire strap with a snapshackle permanently attached to the masthead to take the chute load. This eliminates chafe, but you do have to go aloft to attach or unattach the halyard (they do use tripping lines from the shackle to the deck, but they rarely work under load), so it may not be too practical for cruisers!

Spar Tapering

Tapering the masthead looks nice and saves some windage and a very small amount of weight. This used to be a costly option, but today most sparmakers can do it for just a few hundred dollars. It's worth the investment. Just be sure there's plenty of space left in the masthead to install halyard sheaves of the correct size.

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Mast Wiring

Nothing is more annoying than a loose wire slapping the inside of a mast extrusion when you're rolling downwind or bouncing a bit at anchor. To avoid this problem and to protect wiring from chafe, aluminum or PVC conduit should be run inside the spar into which the electrical cables are placed. Yes, this electrical conduit does add some weight, but if very thin-walled tube is used, its weight is an acceptable trade-off (Hall Spars has an interesting approach to this. They use a light weight Dacron sleeve which fits in a bolt rope. The bolt rope in turn fits into an extrusion inside the mast).

When spars are stepped on deck, getting the wiring below in a water tight fashion can be difficult.

This spar builder used pipes welded to flanges, which were in turn gasketed to spar and deck. A piece of clear hose clamped at the end made an excellent seal.

Attaching Hardware

Every time you cut a halyard slot or drill a hole to mount a winch or cleat, the spar is weakened slightly. A series of weak points concentrated in one area can lead to trouble. As a result, slots and holes should be staggered so that they occur over a large vertical area, rather than all at once.

Where the stress in the extrusion is high due to compression loading, it may be necessary to sleeve or reinforce around the stress risers and load concentrations caused by hardware attachment.

Electrolysis

To avoid cosmetic and structural problems with electrolysis, use rubber pads under all stainless or bronze hardware that touches the mast. In addition, put Never Seize or Duraloc compound on all fasteners.

Mast Doublers

There are significant loads in the bottom panel of the mast from the boom gooseneck, boom vang, and spinnaker pole. When the boom or spinnaker pole is rolled into the water with foreguys attached, stress rises dramatically. One way to deal with this is to add a doubler to the bottom panel of the mast. We frequently have these running from 3 feet (0.9 m) or so below the deck to above the highest point of the spinnaker pole.

In some cases it pays to take these doublers right to the heel of the mast. When this is done, the additional stiffening, held at the heel and the deck, significantly stiffens the rest of the spar in both directions. Since the weight is low, a doubler is a good way to beef up a spar and maintain center-of-gravity efficiency. Doublers are usually attached with epoxy and structural rivets.

A typical setup for a mainsail held onto the mast with a luff tape (left). This works much like a roller-furler. The sail is slipped into the feeder at the bottom, which aligns it for the slot above — not a good system for short-handed cruising, but very efficient in aerodynamic terms.

An old-fashioned external track (right). Note how closely the fasteners are spaced at the top of the trysail track. You will want the same type of spacing at each the location of the mainsail head for each reef.

Mainsail Track

Three basic types of mainsail track are in use today. Racing boats go with a boltrope slot, and this is certainly the most efficient. However, hoisting and/or reefing with a boltrope is a multi-person project, making slides a better bet.

With slides you can have a C-shaped track with a flat slide, which is most common on aluminum spars, or an external flat track with C-shaped slides, as is commonly used on wood spars. In either case, be sure at each reef point and at the head, that the track is attached extra strongly. If possible, my preference is to stitch-weld the track at reef points.

External Tracks for Full-Batten Sails

We've already discussed this under full-batten hardware. It's important to remember when considering this option that it is typically very heavy (although it does add some stiffness to the spar). Before paying the weight penalty and the significant costs associated with such a system, be sure that you really need it. We've done without for years on some very large yachts.

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Two very sophisticated approaches to headboard attachment. The system on the left incorporates a sheave for a 2-to-1 halyard. In both cases the headboard is pinned at the top and bottom of the carrier.

Headboard Connection

The headboard (at the top of the mainsail) is where all leech and luff loads are concentrated. If you think about how much force is on the sheet and on the tack adjustment, and then add some to this, you will get a feel for just how highly loaded this part of the sail is. So the headboard, and how the load gets into the rig, is an important issue to review.

When the mainsail is fully hoisted, there is very little load between the headboard and the mast; almost all is being taken directly by the halyard. But as you begin to reef, the leech load, trying to pull the headboard aft and away from the mast, must be totally resisted by the headboard connection to the mast. The more roach your sail has and/or the deeper the reef, the higher the loads. When the main is in a reefed condition, the halyard can react only to the luff tension on the sail.

If your headboard-to-mast connection fails while you are reefed, the head of the sail pulls back, placing a high stress on the first slide down the sail. This in turn will quickly fail, followed by the next slide. It's not unusual to end up with all the slides broken and the mainsail flying free at the head, held only by the tack and clew on the boom.

Obviously the connections between the headboard and sail track need to be robust! On most boats this takes the form of a metal slide, usually attached onto the sail with nylon webbing. Keep an eye on both the slide and the webbing, which will eventually fail from chafe. Note that sometimes the chafe is internal where you cannot see it.

As the mainsail loads become larger, you need to use a more sophisticated means of distributing the load.

Most of the recent sails made for our designs have used a heavy stainless D-ring at the head instead of a traditional aluminum triangular headboard. These rings are attached with Spectra webbing, which is extremely strong and chafe resistant. The rings are then attached to a metal slide or slides with stainless shackles.

Or, for an external track, there are several types of cars featuring roller bearings (like sheet-led cars) into which a special headboard is clamped or bolted.

Regardless of the system the load from the sail through the headboard must be evenly spread through the attachment mechanism and onto the track. If the load is uneven, there will be problems with the longevity of the hardware and with raising and/or lowering the sail. Uneven loads can cause the slides or cars to which the sail is attached to rack and bind as the sail is being hoisted or lowered.

Spreaders

Spreaders act to enhance the angle between the chainplates on the hull and where the shrouds attach on the mast. The longer the spreaders are (within reason), the lower the rigging loads and resulting spar compression will be.

On a cruising yacht, the spreaders should be as wide as practical. However, the widest spreader should not overhang the width of the boat, lest it be damaged while rafted or lying alongside a tall wharf. To avoid damage from wakes, it is always advisable to tie up and/or raft with spreaders and rigging out of line with pilings or other yacht's rigs. This lets you rock a few degrees back and forth without hitting the spreaders.

Spreaders are normally angled up slightly so that they almost bisect the angle between the vertical wire component and that which runs from spreader tip to the mast.

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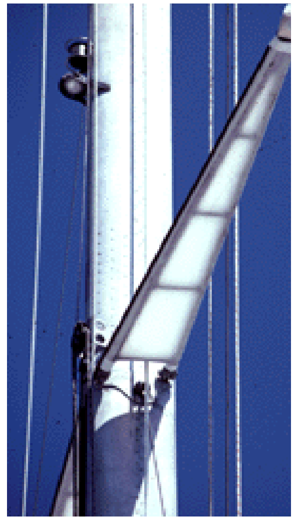

Okay, I admit it. I have a spreader fetish. I love elegant structure, and a well-detailed spreader is a thing of beauty, not to mention strong and light. Generally speaking, for really high mainsail running loads and lightweight construction, the best design uses leading and trailing edge tubes, joined by fore-and-aft webs of some form.

Of course, this shape adds windage, compared to a straight airfoil extrusion. If the tubes are optimized for the load, the forward tube, which sees most of the compression from the mainsail, will be somewhat larger than the aft tube. If you then add a light covering (like an airplane wing) between leading and trailing edges, the drag will be significantly reduced. And the spreaders will look really cool!

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Cruising spreaders take very high loads, especially when running (from mainsail pressure), so they need to be strongly made.

They also see high loading when you are in a severe knockdown and the rig is under water. I suspect (but don't know for sure) that many of the rig failures that occur during a severe knockdown are the result of spreaders collapsing from the dynamic water pressure.

Almost all spreaders are made from aluminum extrusions, usually in an airfoil shape, with most of the material distributed in a fore-and-aft direction to resist bending loads from the main. If you happen to have round spreaders, keep a very close eye on their bases.

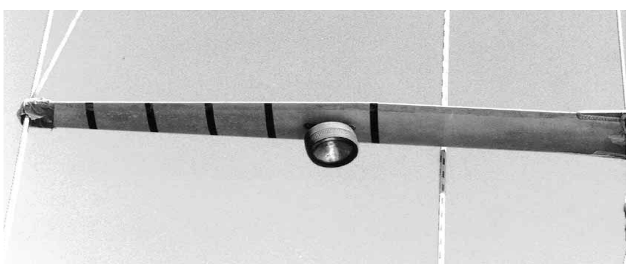
Wooden spreaders can be quite light and elegantly shaped. However, over time they tend to suffer at their bases and are frequently subject to dry rot.

Multiple Spreaders

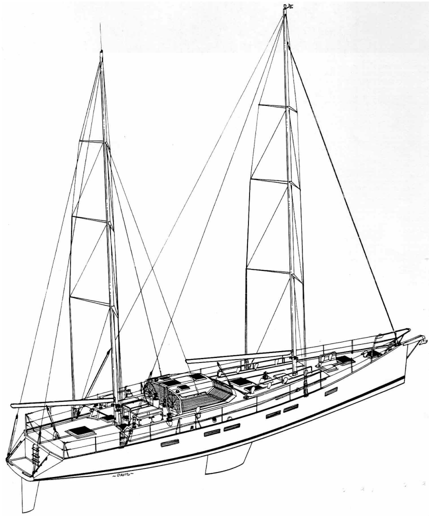
A series of factors influence how many spreaders is best. If you are looking at fault tolerance, the more spreaders you have, the better your chances of saving the rig should a side shroud let go. It also can help with the different load pattern caused by a deeply reefed mainsail and storm jib. On the other hand, having more spreaders means more complexity, as well as added wires and fittings and more things to go wrong.

Generally, the decision is made based on the lightest rig at a given level of safety, depending on the choices you have for mast extrusions. The narrower the width of an extrusion, the shorter must be the unsupported panels between spreaders. So, if you are trying to make a very long, narrow, low-windage section do the job, you may be forced to add spreaders to break up the panel length.

In a strictly cruising context, one of the issues to factor into the equation is replacement wire. Adding or subtracting spreaders may make it easier to have one or two sizes of wire as an at-sea replacement in an emergency.

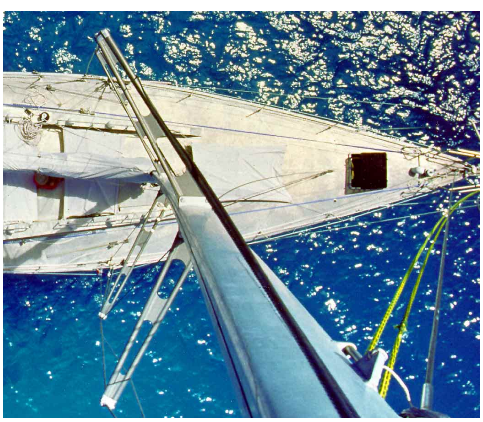


A simple tapered aluminum spreader with a wide base for spreading running loads. The black tape is for trimming the jib leech.



Both the Sundeer ketch rigs and the one on *Beowulf* depend on 25-degree swept spreaders to hold the mast up and the headstay tight. We have masthead running backstays, but these are primarily to adjust headstay tension for controlling the shape of the jib and to create a bit of mast bend for flattening the main and mizzen.

We do lose some angle on the boomed sails when running. However, the lost projected sail area, proportional to the cosine of the angle, is about 6 percent. When you compare this to the gains from the large main and mizzen roaches, you will find that we are way ahead.



Swept Spreaders

Sweeping the spreaders aft a few or more degrees has several beneficial effects. First, the spreaders generate a forward thrust component, equal to their compression load from the wire, which passes over the spreader tip, multiplied by the cosine of the angle between the spreader and a line perpendicular to the centerline of the boat. While this is typically a small force, it is enough to keep the mast from inverting (curving aft). This force that the spreader creates forward is reacted to by an opposite force pulling aft from the shroud attached to the tang below the spreader. The two opposing forces, one pushing forward and the other pulling aft, tend to lock the mast into place. The forward thrust is enough to prevent the mast from inverting in an afterward direction. Since spar inversion usually results in the mast coming down, this is an excellent feature.

Next, swept spreaders interfere less with the leech of inboard-sheeted headsails, adding valuable sail area to the staysail and blade jib.

The negative in all of this is that the swept spreaders interfere with how far you can ease the main boom when running. We think it is a penalty well worth paying and have been using swept spreaders on our boats for the last decade.

How many degrees of sweep? Most sparmakers feel about 8 to 12 degrees is about right. As you begin to increase the sweep angle, the windward shrouds pick up the headstay load from the backstay. At around 20 degrees of sweep, it is possible, with runners, to totally eliminate the standing backstay. However, when sailing free in a strong breeze, don't make any mistakes with the runners! Come back another notch to 25 degrees, and the side shrouds will carry the headstay load without help from runners — although you may want runners for mast-bend control (this increased angle results in very high cap shroud loads, so your engineering has to be spot on).

This is the approach we've adopted on our ketch rigs, when we want big roaches on our main and mizzen and a free space in which to fly the mizzen headsails.

Because the aft sweep stabilizes the spar in a fore-and-aft direction, the required moments (stiffness) can be reduced and still have the same factors of safety. On racing boats this reduction in weight and windage is commonly taken. However, we have always left our fore-and-aft moments the same, preferring to take this bonus as an extra factor of safety.

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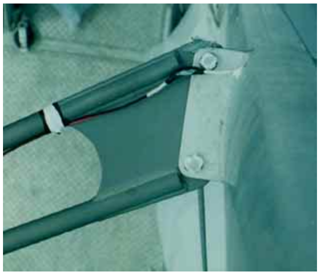
Spreader Bases

Spreader bases are more prone to failure than just about any other part of the rig. This is due to high loads from the mainsail pushing while broad-reaching or running. Keeping the main well vanged will mitigate this slightly, but in the end you need a strong spreader for long passages.

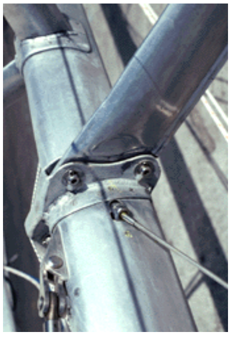
There are lots of ways to accomplish this, as shown on this page and the next one. The main thing is to be sure the base is strong, with the load well distributed over a wide area into the spar. The spreader should be built so that no stress risers are near the base.

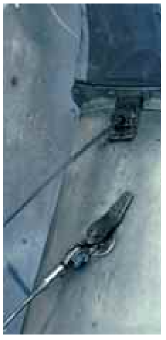
We almost always specify that welded spreaders be heat-treated to bring the aluminum back to pre-welded structural properties.



A series of different approaches to the spreader base problem (above and below). All have one thing in common — the widest possible base to react to mainsail pressure when broad-reaching or running, and to spread the load into a wide area of the mast.

The closer to the mast corner you come with the attachment point of the base, the less internal reinforcing between the sides of the mast extrusion will be required.





What not to do (right). A narrow timber spreader (far right), with a few bolts to hold it in place against the pressure of the mainsail. This will work for coastal sailing, but the spreader will quickly fail offshore.

The detail on the adjacent right has a casting that accepts the spreader, intermediate stay, and cutter stay. The casting has been welded all around the perimeter. This is another "cut here" detail, and in the event of a rigging failure will precipitate immediate problems.

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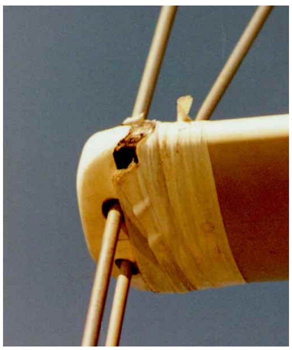
Spreader Tips

With 1x19 wire rigging, the main issue regarding spreader tips is to be sure the wire remains in place when slack and heeled to leeward. Otherwise, the shroud or shrouds can come loose. If you tack or jibe, causing whatever is loose to become the windward side, down comes the rig.

The solutions are not complex. Usually, careful seizing with multi-strand seizing wire does the job.

With rod rigging the issues are more complex. Very careful attention needs to be paid to how the rod bends as it passes over the tip, or stress risers will eventually lead to failure.

This unusual spreader tip was fabricated for us by Forespar, and is welded to the tubular spreaders they supplied for *Beowulf*. The cap shroud is held in place by an undersized piece of seizing wire, which was later changed to a piece of 3/32-inch (2.5mm) stranded wire.



It's important to be very careful with how rod rigging is treated. The norm used to be what you see here (immediate right) — a careful bend over the end of the spreader. After numerous failures, a stem-ball system (three lower photos) was developed. If you have continuous rod to the deck, be sure to check it periodically where it runs over the spreader ends.

When you have discontinuous rigging, with the intermediate and cap tying together at a lower spreader, some form of integrated tang arrangement is required (left). This is usually done in stainless steel and fits over the end of the spreader.

Three different ways to approach discontinuous rod rigging. All employ an articulating joint, so no bending stress can occur in the rod itself. If you are thinking about rod, this is the only way to handle this detail for cruising.

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Keel-Stepped Spars

When the mast is held firmly with wedges on top of the keel and at the deck, a structural *couple*, called a bond beam, is formed. This structure is made rigid by the fact that the two ends are securely held.

The part of the bond beam projecting upward from the deck is also stiffened by this couple. The result is that the bottom section of the mast from the deck up toward the first spreader is much stiffer than if a pin connection were made, with the bottom of the mast held only at one point as in a deck-stepped spar.

A keel-stepped spar can get by with moments of inertia that are from 20 to 25 percent lower than on a deck stepped spar. As a result, the keel-stepped spar will be around 10 percent lighter with a lower vertical center of gravity.

In addition, if dismasted through the loss of a backstay or lowers, you'll normally be left with a stump perhaps a third of the distance to the lower spreaders, to which you can attach a jury spar.

Deck-Stepped Spars

A deck-stepped spar has no additional stiffening from the keel and deck, so the spar needs to be heavier and stiffer to take the same load for which the keel-stepped spar is designed. The partial exception to this is when you have a very strong tabernacle into which the mast is placed. This tabernacle can bond the bottom of the mast, but it is not nearly as effective as a true keel-to-deck couple. Deck-stepped spars are typically used when a mast often needs to be unstepped — i.e., if low bridge divides your dock from the ocean.

With no spar penetration of the deck, there is no mast boot to leak. On the other hand, a rigging failure from which you could recover with a keel-stepped spar will lead to an immediate dismasting with a deck-stepped system.

Some deck-step aficionados point to the fact that you are likely to suffer less damage when a deck-stepped spars goes over the side. True, this is easier to clean up after, but in an oceangoing context it's a small compensation for very real negatives.

Deck Wedges

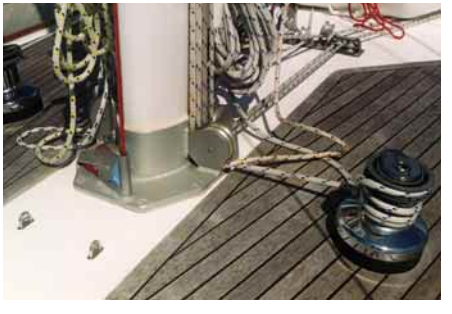
In order to gain the most benefit from a keel-stepped spar, the mast must be carefully wedged at the deck. On modern yachts with aluminum spars, wedges can be made from hardwood or from a very hard rubber. The spar is first centered from port to starboard, then positioned fore-and-aft. Next, wedges are driven in until the mast is held securely in the deck opening.

With some spars it's a good idea to have a little "pre-bend," perhaps an inch or two. This will be partly accomplished by some "kick" at the deck with the wedges.

Spartite

One of the problems with mast wedges is getting a good fit. At sea, with the boat jumping around, the wedges tend to work, often cracking and working their way out at the most inconvenient times.

The movement allowed by many wedge systems is not only bad structurally, but it makes it much more difficult to keep a mast boot watertight.



The traditional mast collar (left) required a series of wooden or hard rubber (typically 40-Shore hardness or above) wedges. The wedges need to fit securely between mast and collar and be evenly spaced on all four sides. The corners are not as important. Wedges should have a notch at the top to prevent them from dropping down below.

An alternate approach (right) is to have a tight-fitting deck collar, then use a hard-rubber grommet of constant dimension between deck collar and spar. This approach typically leaves 1/2 inch (12.6 mm) or so of space. The top can then be caulked and, if you are lucky, may remain water tight. However, it's best to have an external boot as well.

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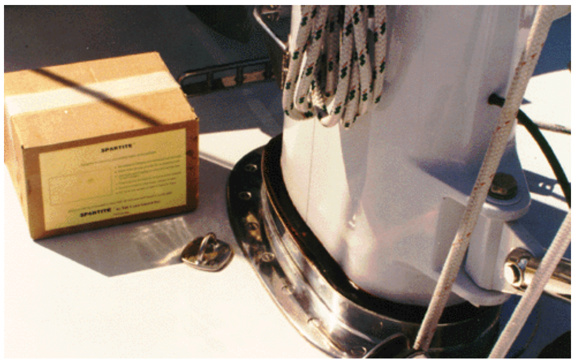
The Spartite system is quite easy to use. When I re-did *Beowulf*'s main and mizzen mast I was able to make both sets of wedges in a little more than an hour.

Start off by taping the mast, then putting Vaseline as a mold release on the spar and deck collar. Foam rubber is then pressed down to the bottom of the cavity formed between the mast and collar. To seal the foam, Spartite supplies some modeling clay. Work this down on top of the foam, and seal it to the mast and deck collar.

Run a band of tape around the perimeter of the mast collar. This will form a dam which allows the Spartight to run over the upper edge of the collar.

The two components are then mixed together, allowed to stand for a few minutes, and poured into the space between the mast and collar. It sets quite quickly, and you can begin to clean up. After a few days of curing, you are ready to go sailing.

Spartite says it is possible to use their molded wedge as a water seal. However, we sealed the edges with SikaFlex, then put a conventional boot over the mast collar.

This is where the Spartite system comes into play. This is a two-component synthetic resin with a modest amount of flexibility. It is cast as a solid plastic insert between the mast and the deck collar. This forms a perfect wedge all of the way around the mast, provides an excellent wedging action, and minimizes mast movement.

We tried the system on *Beowulf*'s main and mizzen, and I really like it. The kits are complete, come with easy-to-understand instructions, and in less than an hour you can have yourself one very tight-fitting cast mast wedge.

The Mast Boot

One of the most difficult — perhaps I should say nearly impossible — things to execute properly is the deck-to-mast boot, which prevents seawater and rain from leaking below.

I have *never* seen any form of mast boot that did not eventually leak!

There are several problems. First of all is the difficult physical transition from a large opening in the deck to a smaller mast. Then sun and pollution eventually take their toll. Add in some degree of mast movement at the deck (which you hope to eliminate but won't entirely), and the result is a series of problems calling for ingenuity.

The first ingredient in a successful scheme is the mast collar. Ideally, this provides an upstand of 2, but preferably 3 or more inches (50 to 75 mm) onto which the boot is attached. Next is the primary boot. This can be made of wetsuit material, PVC, neoprene-coated cloth, or a section from the inner tube of a truck tire.

It's best to slip a pre-made boot over the mast before it's stepped. This way you can be sure that the circular boot is well glued and sealed.

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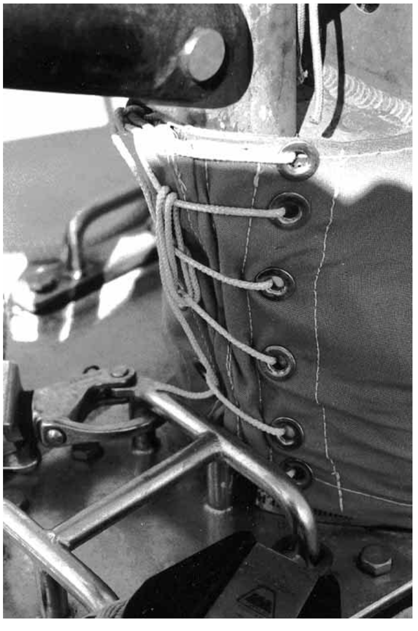
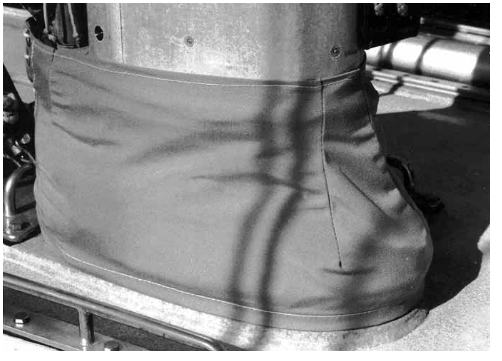
Three variations (above) on the same theme. From left: A Forespar molded boot matches the mast section and adjacent deck collar. Next, a neoprene-rubber boot has been stretched around the mast and deck collar for a tight fit, then "welded" together. Finally we show a traditional duct-tape boot, one of the best forms of waterproofing known to man.





A mast boot will last much longer if shielded from the sun (above and left).

If the mast collar has a flange at the bottom, or if your deck is exposed on the underside, you can take a mast ring (right), fit a soft rubber gasket to it, and use it to seal off any leaks that may get into your boot. Then drill a hole on each side of the mast, about 1/4 inch (6 mm) in diameter, letting the accumulated water drain through the mast into the bilge.

This boot must then be fastened to the deck collar and the spar. Long stainless hose clamps are best. In order to ensure a good seal, we use a layer of 1-inch-wide-by-1/4-inch-thick (25mm x 6mm) neoprene tape between boot, spar, and upstand.

If you're paranoid about the mast leaking—as I am—a second boot can be added over the first.

Finally, some form of a decent-looking sun cover has to be made, usually from an awning or cover material.

What about eventual leaks? Silicone may help. A roll of duct tape never hurts. Or, you can take the finishing ring belowdecks and make it into a seal. Suppose you have a tight-fitting teak ring around the mast fastened to the headliner or deck head. If this ring is routed on its top and edge where it interfaces with the headliner and mast, a soft neoprene gasket (such as is used with deck hatches) glued in will seal the mast leaks. Drill a small hole right at the top of the gasket on each side of the mast, and any accumulated leakage will drain down into the mast.

THE BOOM

The boom on an offshore cruising boat will ideally be one or two sizes heavier than one used for inshore work. This beefing up permits accidental jibes, as well as the occasional roll into the sea when power reaching. With little difference in cost, the weight increase is typically less than 10 percent for an increase in stiffness of 50 percent.

Goosenecks

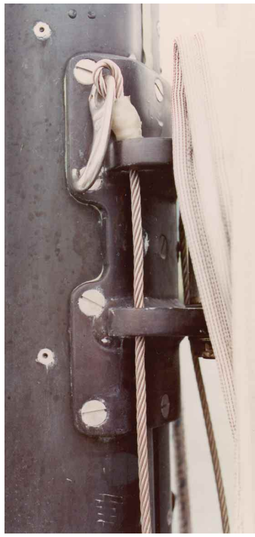
There are probably more problems with the gooseneck on offshore yachts than any other piece of rigging. It has to take tremendous compression loads at all sorts of uncomfortable and structurally inefficient angles. Then the load on it reverses each time the boat rolls.

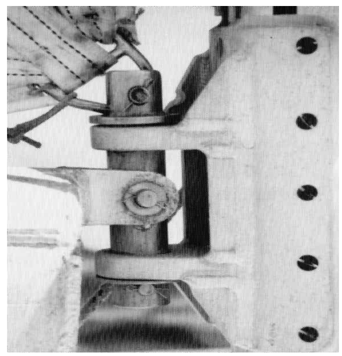
As the fittings wear with age, they jump around more and more in a seaway, leading to more wear. So the gooseneck needs to be sturdily made. Also, be careful with how it's attached to the mast. Aluminum lugs welded to the mast are not as satisfactory as a separate aluminum fitting bolted and epoxied into place. Welding directly onto the mast extrusion can cause critical weakening.

Because of the reverse cycle loading on the gooseneck (and vang attachment), the bolts tend to come loose. If a couple work loose, the load shifts to the tight bolts. Pretty soon one or two of them crack, leaving the remaining bolt or two to take the whole load. During the next squall —which will of course occur during the middle of the night — the remaining fasteners will fail and the boom will be adrift.

The epoxy bond between the gooseneck fitting and mast helps to prevent movement. As long as it is intact, the fasteners should stay tight. Eventually the epoxy bond will fail.

Test your gooseneck and vang fasteners periodically to be sure they are tight.



These four gooseneck fittings (above) share a common theme — all are heat-treated aluminum weldments bolted and epoxied to the mast. The two on the right are from 67-foot and 56-foot (20.6m and 17.5m) Sundeers. They are way oversized, larger than a maxi yacht would use. The lugs and pins are huge. Yes, they are heavy — probably an extra couple of pounds (1 kg) — not much for all the added security.

The lugs on the front of the boom also have to be sufficiently strong. The ideal situation is to weld the lugs through slots in the boom extrusion. If this is not possible, then they should be welded on both sides to a heavy end cap. Be sure both sides are fully welded. If there is room for a gusset on the outside to resist bending, that is even better.

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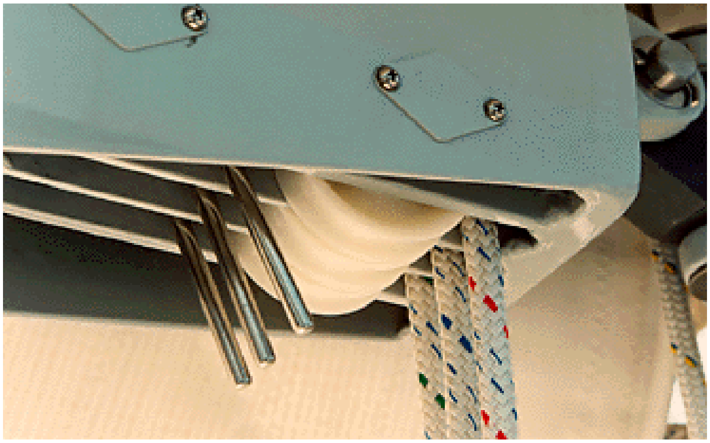

Compare the jammers' handles on these two booms. The handles to the left are long and beefy enough to enable the crew to release the jammers under load. The boom above will require a winch to relieve the jammers when loads are high.

Boom rails (right and below) are convenient handholds when working to leeward. They also provide a good place to hang gaskets and halyards.

Internal Jammers

It has been common practice now for a number of years to build a series if internal jammers into the front end of the boom. These typically handle the clew reefs, the outhaul, and perhaps a topping lift.

In order for these to work properly, the jammers need to be of good size with reasonably sharp teeth. Generally, they only work with high loads while transferring from one winch to another.

However when they do hold, they can be very difficult to unjam. This requires a long handle to generate some leverage.

Alternatively, you have to take up the load on a nearby winch, then release the jammer and hold it open while the line in question is eased.

The jammer will take some maintenance from time to time, so it should be easily disassembled. The problem usually comes in withdrawing the shaft onto which they fit. It is not unusual to have it frozen to the aluminum in the boom. Using a liberal dose of Never Seize or Lanocote will ensure that it comes apart when necessary.

Boom Rails

Boom rails can be very handy when working on deck, especially if you have to work to leeward of the boom. They also make a good tie-down point for sail gaskets, covers, and loose lines.

We've seen them on a number of Whitbread boats and have recently started to fit them to some of our own designs.

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Boomvang

Boomvangs are an absolute necessity for controlling sailshape downwind. The vang must be powerful enough to keep twist out of the leech and the main off the lee rigging. It should be weaker, however, than the boom to which it is attached. If you end up rolling the boom under a wavetop when reaching in strong breezes, something may give —it's best if it's the vang.

Rail Vangs

We have found that by taking the vang to the lee rail instead of the mast base when running or broad-reaching, it does double-duty as a preventer. This has been tested several times, when we have jibed unintentionally in heavy going. However, for this to work you need a heavily built boom. Otherwise, the preventer should be led to the end of the boom where the risk to the boom structure is less during a jibe.

When vanged to the rail there should be about a 45-degree angle leading out so the attachment point on the boom is well outboard. This reduces bending loads on the boom.

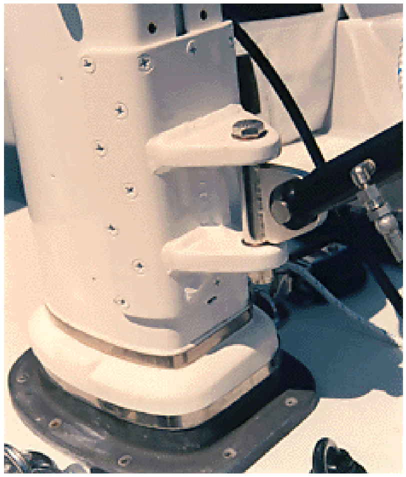
The control end of the vang should always lead to the cockpit where it's easy to adjust (without going forward and getting wet!) and ready to cut or throw off in an emergency.

The loads at the deck end will be enormous, so be sure that whatever the vang is attached to is extremely stout and through-bolted with heavy backing plates. Don't use a stanchion base!

Hydraulic or Mechanical Vangs?

Mechanical vangs are available for yachts up into the 60-foot (18.5m) range. Where they can be used, they have several advantages over a hydraulic unit. First, they are easy to install, since they do not require

We developed this early version of a mechanical vang for *Intermezzo II* in the late 1970s. It was a pipe within a pipe, so that it limited how far the boom could drop. We then had an external tackle for controlling tension. It worked well for reaching as well as for jibing back and forth in close quarters. However, when offshore and broad-reaching or running, we also used a vang to the rail.



The attachment of the vang at the mast base is almost as highly loaded as the gooseneck fitting. This one was built for one of our Sundeer 64s. Yes, it is very oversized, but you won't see it failing.

The vang attachment should be as low on the mast as possible to improve the vang-to-boom angle. However, leave room for the mast boot.

A number of companies now make mechanical vangs. For offshore work it is best to buy one a size or two larger than what the books claim you need. You can limit the restraining force by using control lines with a bit of stretch.

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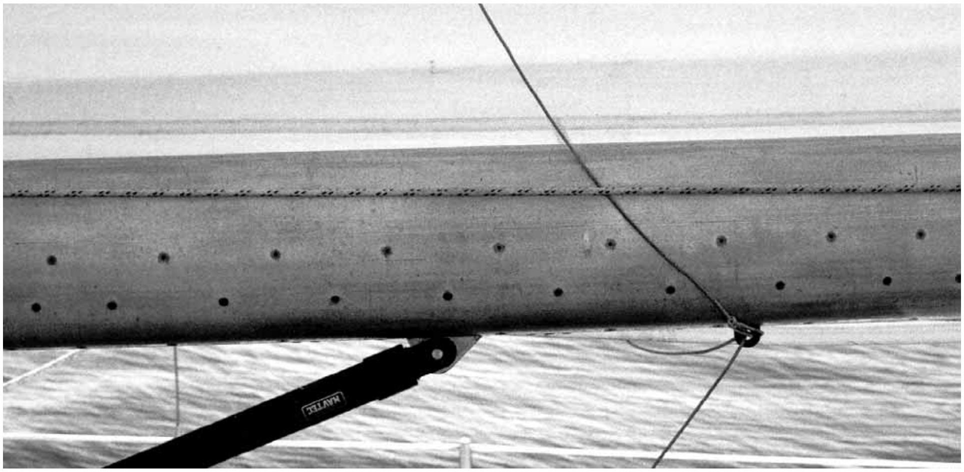
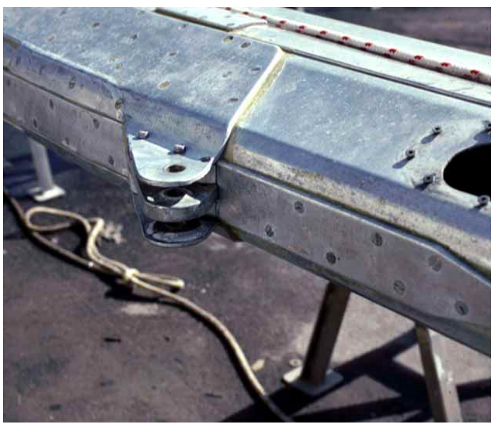
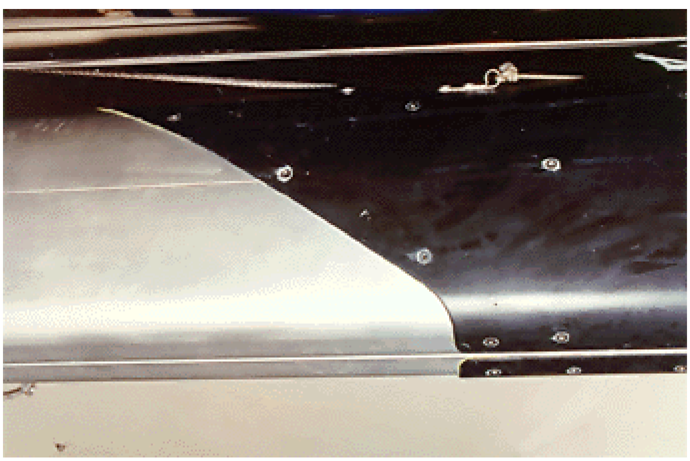
plumbing. Next, if moderate-stretch control lines are used, they will give a bit under shock load, helping to reduce the impact on the boom and hardware. Finally, it is typically easier to dump a mechanical vang in a hurry should the need arise — in a broach, for example.

Hydraulic vangs make sense on larger yachts, especially if a hydraulic system is already in place for the backstay and cutter stay. They allow you to develop high forces over a period of time.

Hydraulic system are always fitted with pressure-relief valves on the back side of the pump panel. Make sure your relief valve is set to pop before the vang can damage the boom when the boom is being dragged through the water in heavy-reaching conditions.







Four examples of vang doublers. In all cases the reinforcements extend well forward and aft of the vang attachment point.

Note the external attachment hardware (right). This is the ideal attachment solution, as a stress riser isn't created by a slot in the bottom of the boom.

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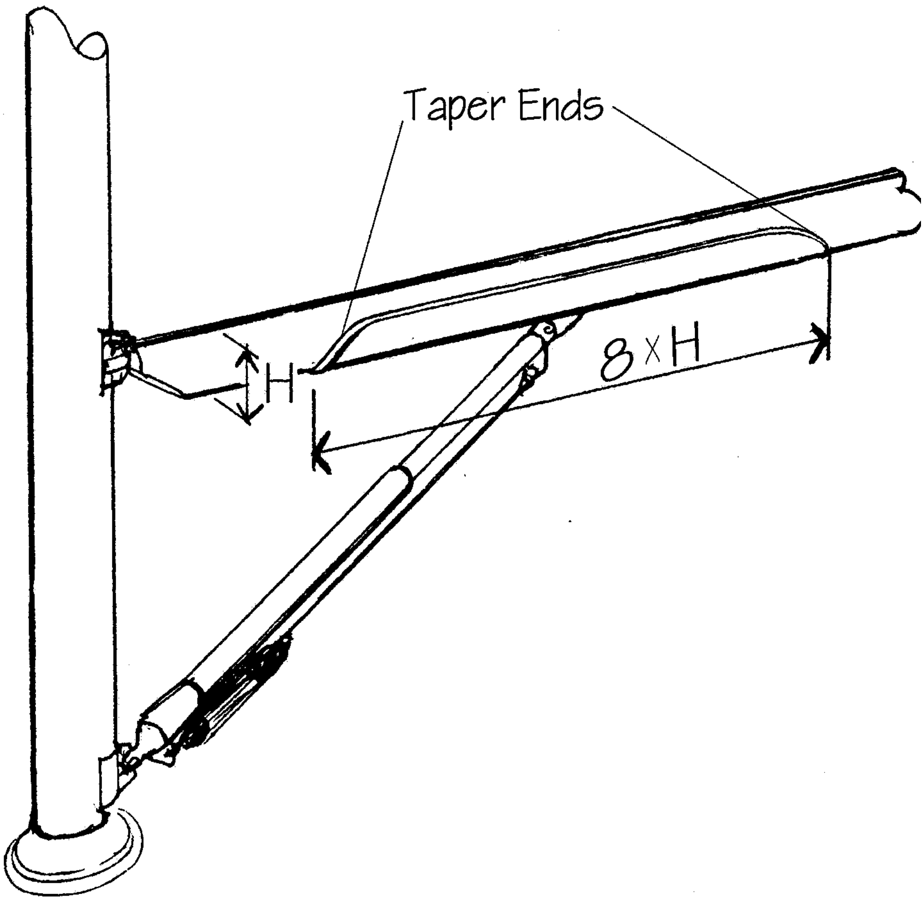

We always specify a vang doubler for our booms, adding some needed "beef" where the boom encounters the highest stress. Over the years, we've found that a ratio of eight times boom height works well for length. Be sure to taper the ends of the doubler, so as not to cause a stress concentration at the end.

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Vang Doublers

I like to use a boom doubler for the vang attachment on the boom. We typically make these about eight times the boom height in length (i.e., for a 8-inch/200mm deep boom, the doubler would be about 64 inches/1.6 m long). This not only reinforces an area of high stress from the vang loads, but it helps to replace the strength lost when a vang attachment slot is cut into the bottom of the boom.

Topping Lifts

The topping lift is the most cantankerous piece of running rigging aboard. They love to wrap themselves around backstay insulators and chafe on the leech of the mainsail. The only solution is to use a long, heavy piece of shockcord to keep them tight when the boom lifts. They should be heavy 7x19 stainless-steel wire, plastic-covered to minimize chafe, with a rope tail. A high tech alternate is Spectra or Vectran rope. It is lighter, and does not chafe the mainsail leech as does wire.

The only advantage of a topping lift is that if rigged properly, it can be used as a spare main halyard.

Using a compression strut like on *Intermezzo II*, a new "Quik Vang," or a hydraulic kicker will eliminate the need for a topping lift, since these all support the boom.

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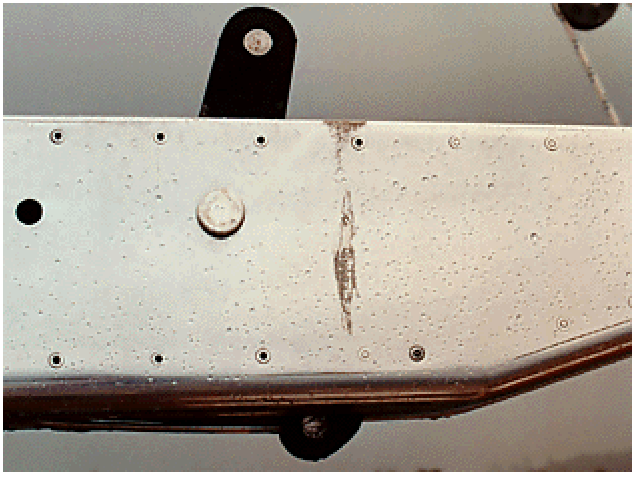
Clew-to-Boom Connection

The connection of the mainsail to the boom receives one of the highest concentrations of working loads on the rig. On a long-term cruising yacht, thousands of sailing miles will probably put a great deal of wear and tear on this gear. In addition, you must be able to adjust the outhaul tension to ease draft into or take draft out of the mainsail. There are all sorts of ways to achieve this. The traditional system is to use a stainless or bronze car attached to a track that is bolted to the boom. The connection to the sail needs at least 20 degrees of movement on each side of the boom to allow for a fair lead when the outhaul is eased. Otherwise, hard spots will develop in the sail around the clew hardware, which can eventually lead to failure.

Today it is common to use high-tech ball-bearing or slide-rod lubricated cars to make the adjustment process easier. Another approach we've used with surprising success is to do away with the car and track and use a Spectra webbing strap wrapped around the boom and through the sail instead — usually two or three wraps do the trick. The strap has Velcro sewn to one side. The Velcro actually carries the load, but we stitch the end closed before we head offshore just in case. When you want to adjust the outhaul, the strap slides along the boom. This works so well that it will be standard on all of our future designs



We've seen a number of Walder Boom Brakes (above) on cruising yachts. By adjusting the tension on control lines, these devices limit the speed at which a boom can swing across the deck during a jibe.

A traditional outhaul car, welded from stainless steel, with a built-in outhaul system (upper left). If you use this sort of car, be sure that the clew ring can swing easily from side to side to align itself with the sail.

An interesting approach (lower left) on a large yacht. The black lever is connected to the clew with a shackle. It rides on a pivot point inside the boom. A hydraulic cylinder is attached to the bottom of the lever. As the lever arm is adjusted forward or aft, the clew of the mainsail is eased or tightened.

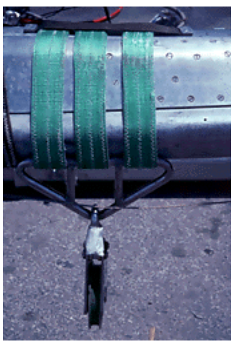
Mainsheet Attachment

You would think that something as innocuous as a mainsheet attachment would be pretty simple to get right. Yet we have had more trouble with this detail than just about anything else in our own rigs. First, the mainsheet bails are highly loaded. If they happen to be inboard from the boom end, the mainsail increases the load with a long lever arm. The load is always changing direction. When beating, it is more or less in line, heading straight down. But when broad-reaching, it pulls from the side. The angle fore-and-aft also changes. Over the years this flexing back and forth tends to fatigue the fittings. The bails themselves and the boom to which they are attached often have a localized failure as a result.

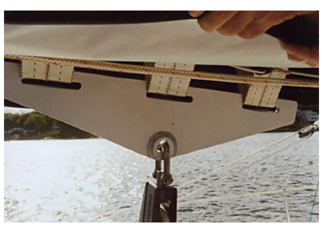
On a number of occasions, sparmakers have told me that our requests for heavier mainsheet bails were way out of line with what they normally supplied. Eventually we would find that even our heavier requirements were not enough.

What can you do? Keep a close eye on fittings, watching for telltale stress cracks. If the blocks can articulate easily, and if the load has a flexible alignment path so the bail has minimal bending, you have a better chance of a long life. Also, keep a piece of line handy to lash the sheet to the boom. Or better yet, keep a safety line through the shackle on the sheet block and around the boom.

These three main sheet attachment details have similar positive characteristics. (left and above) The mainsheet block can easily move about in both directions. Also, the boom bails never see a bending load as the boom is eased, because the shackles attaching the blocks can slide along the bail, keeping itself in alignment with the load path.



Mid-boom sheeting on pilot-house yachts (above) often finds a conflict between the companionway hatch and the mainsheet. With a hatch garage in the way, it is difficult to transfer the load of the sheet efficiently into the house structure. We've used the approach in this photo on several large motorsailers. The mainsheet has two attachments points, one on each side of the hatch garage, with the sheet coming back to the winch mounted on the aft end of the house.



This is a more efficient structural connection (above and two right photos), especially for mid-boom set-ups. Using a strap allows the sheet to always pull in a fair direction to the boom, without creating any bending load on fixed bails. With a fixed bail, a bending load most often results in failure. In addition, there are no holes around which stress concentrations (and eventually cracks) can form.

On our own boats we've simplified this by substituting a piece of line wrapped several times around the boom and through the mainsheet block.

With strap or line you need some method of keeping the attachment system from sliding forward when the boom is eased. This can take the form of a metal strap fastened to the top of the boom, or a line pulling aft along the boom to keep things from sliding forward.

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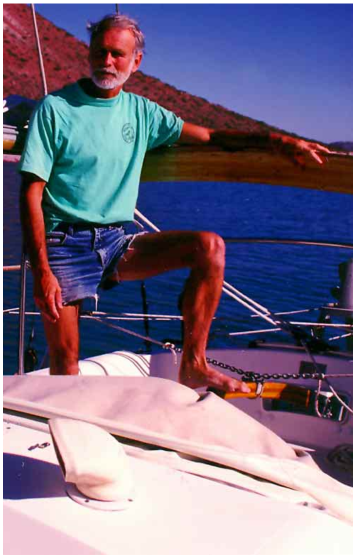

Tim Traill demonstrates how his boom gallows provide security and support for the helmsman. They are relatively easy to execute — just be sure you have a sturdy diagonal brace (right) to keep the structure from sagging side to side.

Boom Gallows

Boom gallows can serve a number of functions. First, they provide a secure resting place for the boom, relieving the topping lift and keeping it from swinging back and forth when you are working on it (or at anchor in a rolly anchorage). Should the topping lift fail or release suddenly, the gallows will prevent the boom from dropping below a certain point, protecting those in its shadow.

They can provide an excellent spot for the person steering to hang onto and/or brace himself. Finally, they provide an excellent aft support for a cockpit awning.

On the other hand, they tend to clutter the cockpit, make it difficult to get to the stern, and add weight and windage.

If you have a mechanical or hydraulic vang that supports the main boom, gallows probably don't make sense. But if a topping lift provides sole support for the boom, they may be a good addition.

STANDING RIGGING

Now let's look at some of the details in rigging. The first thing to do is to establish a basis for the size of the various elements in the rigging system. To do this you have to look at working, ultimate, and cyclical loads. Like so many things in sailing, the hard engineering is based on experience rather than on pure numbers. Miles at sea, reverse-cycle loadings, temperature, and even variations in water salinity play a part in determining these figures.

Basic Rig Engineering

Having the correct size of standing rigging is critical for the long-term safety of your spars. Because so many engineering factors go into projecting these requirements before a boat is launched, it's not unusual for designers and builders to be somewhat off the mark. However, there is a simple means by which you can check the rig loads and establish the factors of safety working for you.

Righting-Moment Tests

The primary information needed to calculate the proper size of the rig and its elements is the actual righting moment (RM) of your vessel in its normal cruising trim. I like to do our RM tests at full load, since we usually seem to cruise loaded to the gills with gear, much of which is stowed low in the boat, where it contributes to stability.

It's really very simple to do an RM or inclining test. Start on a windless day. It must be absolutely calm, with no surge or chop. The boat should hang free from the dock, and docklines should be slacked off.

Rig the spinnaker pole, and square it up perpendicular to the centerline so it's extended as far over the side as possible. If you don't have a spinnaker pole, use the main boom. Next, add weight to the end of the pole to heel the boat. Measure the heel angle, and calculate the weight on the end of the pole.

We usually use the dinghy, loaded with spare anchors, outboard, gas cans, and a body or two. Each item is weighed. To measure the angle we take a plumb bob on a light line and suspend it from the overhead inside the boat.

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If you have the height of the string attached to the plumb bob and the distance offset from center, it's easy to derive the angle with a calculator. Say the height is 6 feet and the offset of the plumb bob is 10 inches, or 0.83 feet. Divide the base by the height or 0.83/6 = 0.138. Then use shift (or inverse) tangent (Tan) on the calculator, which will give you the angle, in this case 7.9 degrees.

Let's say the total of weight on the end of the pole is 1,000 pounds and the distance from the end of the pole to the mast is 16 feet. Multiplying distance by weight gives you moments, so 16 x 1,000 = 16,000 foot pounds. The pole also has to be added in. If it weighs 40 pounds, this is multiplied by half its length, or 40 x 8 = 320 foot pounds. The total moments then are 16,000 + 320 = 16,320 foot pounds. Divide this by the measured angle to find righting moment at 1 degree: 16,320 / 7.9 = a righting moment of 2,106 foot pounds.

Rigging Loads

Armed with the righting moment at 1 degree, we're now ready to calculate the actual loads on the standing rigging. There are many sophisticated ways of doing this, as well as some simple approaches to get a ballpark figure. What follows is the approach used on a majority of yachts rigged before the middle of the last decade.

We start with the righting moment at 1 degree of heel; multiply by 29.5 (to get the RM at 30 degrees); then multiply again by 1.5 for a margin of safety. Take this total and divide it by the distance from the center of the mast to the center of the chainplates at the deck (in one direction only). This provides PT — the total load on the chainplate if all the side shrouds came to a single point. This load is then divided according to your rig into a variety of wires.

There are lots of different thoughts on how the loads are actually spread. One approach used for years by many designers estimates for a single-spreader sloop or cutter, the cap shrouds (to masthead) carry 45 percent, while the lowers (divided by 2 if they are fore-and-aft) get 55 percent. For a double-spreader rig the caps get 30 percent, intermediates 30 percent, and lowers 40 percent.

Let's try an example. Assume an RM of 2,500 foot pounds at 1 degree, with a chainplate width of 5 feet, on a double-spreader sloop. For example, 2,500 x 29.5 x 1.5 = 110,625 / 5 = PT of 22,125. So, for the cap we get 0.3 x 22,125, or 6,637 pounds; for the intermediate the same thing; and for the lowers, 0.40 x 22,125 = 8,850 pounds for single lowers, or half this if there are fore-and-aft lowers. These are (theoretically) the actual loads on the wire. Later on, we'll add in factors of safety.

If you have a rig with aft-swept spreaders, increase the rigging loads by the cosines of the angles of the spreaders.

Ketch Allowances

Calculations for a ketch rig involve some additional logic. The mainmast is always assumed to carry full load, in case the mizzen is furled. The mizzen, on the other hand, is assumed to carry somewhat less. That 1.5 factor in the formula is usually dropped to 0.5, effectively reducing the load by two-thirds. But what if you have a really large mizzen, and you start reefing the main first? In this case the loads will be higher. How you treat your mizzen calculations depends on its proportions and how you intend to use it.

With our very large mizzens we tend to shoot for a spar and staying system that will carry 100 percent of the righting moment without a factor of safety. This means that normally with a jib or staysail set, there will be a normal factor of safety. However, if the boat were caught by a sudden gust with only the mizzen set, with everything tuned correctly, the mizzen would stand.

Factors of Safety

If we went sailing with rigging sized as above, only allowing for stability-induced loads, everything would work fine until the first wave hit the bow — at which time the shock loading could send the rig tumbling over the side. Therefore, we add in a safety factor.

How safety factors are determined can vary tremendously. As a general rule, most naval architects develop safety criteria for a boat's spars at a stability figure based on the vessel carrying half her intended payload. Yet many cruising boats carry full-designed payload and then some. The result is a reduced factor of safety. However, if you know your own boat's loaded stability, you can calculate more precisely.

There are a number of reasons for a healthy safety factor, all related to real-world experience. As we've already briefly discussed, the first is the fatigue that comes from extended usage and the corrosive atmosphere in which most of us sail.The next thing is reverse-cycle loading. This is caused by the rigging loading up and then easing off as a boat heels when sailing upwind or rolls downwind. This is potentially much more fatiguing to the rigging elements than the basic sailing loads.

Another damaging factor is sloppy rigging. This is particularly relevant to lower shrouds, which are usually left looser than the caps or intermediates, and which end up slatting back and forth. All that slop works the wire terminals, prematurely fatiguing them. (One way to mitigate this problem is to use well-lubricated double-action toggles on your turnbuckles. Another is to use shock-cord restrainers on the lee-side rigging.)

Shock loading is another consideration. The stiffer the hull structure and the heavier the spars, the more shock load from wave impact will be transmitted to the rigging. A decade or two ago, this wasn't the significant factor it can be today, because today's hulls are stiffer and the rigging has less stretch.

Shock loading is a two-way street. Stronger, less stretchy wire also transmits shock to the chainplates, spars, and hull. On older yachts with timber construction, it's necessary to consider this factor when re-rigging. "Traditional" rigging was very stretchy and helped dissipate loads before they damaged the hull.

All of these additional loads are covered by the factor of safety.

Normal practice among naval architects is to use a factor of safety between 2.25- and 2.75-to-1 on standing rigging. For offshore work, my preference is to stay at the higher end of this range.

The next step in our procedure is to multiply the load in the wire by the appropriate factor of safety for your intended cruising — say 2.75, the example we've been using. For the cap shroud, 2.75 x 6,637 gives us a wire with a required breaking strength of 18,251 pounds.

Choosing Wire Size

Then you see what wire strengths and sizes are available. In our example we could use 3/8-inch 1x19 stainless wire with a breaking strength of 17,500 pounds, a little under our needs, or jump to 7/16-inch at 22,500 pounds, quite a bit on the high side.

If the boat were heavily loaded when we did the inclining test, I think I'd stay with the 3/8-inch wire. Excessive weight aloft quickly robs us of stability and comfort when sailing upwind. But if I expected a lot more gear on board, I'd be tempted to go with the heavier wire.

Tang Factors

In order to be sure the entire system is working together, the turnbuckles, toggles, hull tangs, and mast tangs must all be sized to carry the full strength of the wire, plus an additional factor of safety. One thing to examine carefully is the bearing and shear on mast chainplates. If you see a gigantic chainplate at the gunwale and a featherweight on the mast, you know that something is out of balance. It's the norm for tangs to be designed to carry at least 50 percent higher loads than the rigging wire and fittings.

Another danger to watch out for is stress risers. Any sharp edge, corner, or change in direction structurally is a potential stress riser. If located where load can occur, this will usually concentrate and increase local stress as much as 300 to 500 percent. An example of this could be a chainplate bent at an angle, with a hole right through the bend. The stress around the edges of that hole will be five times what the rest of the chainplate is taking. If it's going to break, guess where the failure will occur?

Always make sure the lead from the chainplate through the turnbuckle and up the wire is fair — no kinks, bends, or hard spots. If there are fore-and-aft lowers hanging on a common tang on the mast, be sure that the pins rotate freely so that when the mast moves its load from the forward to the aft lower, the pins can rotate and the swages aren't bent back and forth.

VCG and Displacement

If you now measure the freeboard at the bow, stern, and several intermediate points, you can call the designer to give him the freeboard data together with your RM calculations. He can then very simply develop your vertical center of gravity, total displacement, and range of stability.

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Wire Materials

Virtually every vessel we've seen cruising uses stainless-steel wire for standing rigging. Some "stainless" steels are not quite stainless. Type 316 is by far the best, but some wire and swage fittings are made of type 302. This is more subject to staining and stress corrosion than type 316, but it is also about 15 percent stronger.

Another approach is to use Nitronic 50. This hybrid material is noncorrosive and somewhat stronger than normal stainless, although it costs about 50 percent more.

Brion Toss, a professional rigger (and marvelous writer) pointed out to me that galvanized wire offers several advantages for standing rigging. For one, it's about a third the cost of stainless, and for size or weight is a little stronger. That can add up to a pile of savings when rigging a spar. To get around the maintenance issue, Brion suggests either painting or a periodic wipe-down with a mixture of anhydrous lanolin and mineral oil. The same end terminals can be used, too.

Wire Construction

There are a variety of wire constructions. Most popular is 1x19, which has 19 strands wrapped around a single core, with relatively low stretch characteristics. On some boats 7x19 (with a core of 7 strands), is also used for such rigging as runners. It's more flexible but also stretchier than 1x19. Halyards are often made up of 7x19 wire, which has smaller multiple strands and is very flexible but is too stretchy for any standing-rigging requirements.

There's a relatively new wire out called Dyform, made by British Ropes. Dyform, which is made from type 316 stainless, is somewhat stronger for its diameter and/or weight than conventional wires and has substantially less stretch. It looks like it could be the material of the future.

Yield Strengths

One thing to bear in mind when selecting materials and sizes for rigging is the yield point of what you are using. You will always want a rig to operate below the yield point under its highest loads. Exceeding the yield point will result in a permanent stretch factor in the rigging and loss of strength.

With 1x19 wire, the yield point is typically reached at 50 percent of the ultimate listed strength. With rod, it's usually around 80 percent of ultimate.

NOMINAL DIAMETER		CONVENTIONAL 316 1x 19				DYFORM 316 1 x 19				CONVENTIONAL 302 1 x 19		CONVENTIONAL 316 7 x 19			
		APPROX. WEIGHT		MINIMUM BREAKING LOAD		APPROX. WEIGHT		MINIMUM BREAKING LOAD		BREAKING STRENGTH		APPROX. WEIGHT		MINIMUM BREAKING LOAD	
INS	MM	LB / 100 FT	KG / 100 M	LB	KG	LB / 100 FT	KG / 100 M	LB	KG	LB	KG	LB / 100 FT	KG / 100 M	LB	KG
3 / 16	4.76	7.12	10.6	3,960	1,800	8.5	12.7	4,928	2,240	4,700	2,131	5.65	8.41	2,827	1,285
	5.00	8.20	12.2	4,400	2,000	9.1	13.5	5,368	2,440			6.24	9.29	3,124	1,420
7 / 32	5.56	10.1	15.1	5,295	2,470					6,300	2,857	7.73	11.5	3,857	1,753
	6.00	11.8	13.4	6,336	2,880	13.0	19.4	7,810	3,550			9.00	13.4	4,488	2,040
1 / 4	6.35	13.0	15.0	7,084	3,220	14.8	22.0	8,844	4,020	8,200	3,719	10.1	15.0	5,031	2,287
9 / 32	7.00	16.1	18.2	7,810	3,550	17.4	26.0	10,802	4,910	10,300	4,671	12.2	18.2	6,116	2,780
5 / 16	8.00	20.9	23.8	10,208	4,640	23.2	34.5	13,530	6,150	12,500	5,669	16.0	23.8	7,986	3,630
	9.00	26.5	39.5	12,914	5,870										
3 / 8	9.53	29.0	43.2	14,476	6,580	32.7	48.7	19,272	8,760	17,500	7,936	22.6	33.7	11,330	5,150
	10.00	32.8	48.8	15,950	7,250	36.3	54.0	21,494	9,770			25.0	37.2	12,474	5,670
7 / 16	11.00	39.7	59.1	19,294	8,770	45.7	68.0	26,620	12,100	23,400	10,612				
	12.00	47.2	70.3	22,880	10,400	54.2	80.7	31,746	14,400			35.9	53.5	17,952	8,160
1 / 2	12.70	53.3	79.3	25,630	11,650	59.5	88.6	34,833	15,800	29,700	13,469	40.2	59.9	20,123	9,147
9 / 16	14.00	64.3	95.7	31,196	14,180	77.3	115	42,460	19,300	36,500	16,553	48.9	72.8	24,420	11,100
5 / 8	16.00	84.0	125	40,832	18,560	98.8	147	56,320	25,600	44,000	19,954	66.53	99	29,988	13,600
3 / 4	19.00	118	176	47,564	21,620	138	206.6	70,400	32,000						

Here are manufacturers' values for various types of rigging materials. This data typically includes a built-in "fudge" factor. Notice the difference between 302 and 316. The 302 is quite a bit stronger although more prone to rusting. The 7x19 is used for halyards.

SIZE		CONVENTIONAL 1 x 19 316 GRADE NOMINAL BREAKING STRENGTH		CONVENTIONAL 1 x 19 316 GRADE NOMINAL YIELD STRENGTH		DYFORM 1 x 19 316 GRADE NOMINAL BREAKING STRENGTH		DYFORM 1 x 19 316 GRADE NOMINAL YIELD STRENGTH	
INS	MM	LB	KG	LB	KG	LB	KG	LB	KG
3 / 16	4.76	4,062	1,846	2,640	1,200	5,054	2,297	4,043	1,838
	5.00	4,513	2,051	2,933	1,333	5,506	2,503	4,405	2,002
	6.00	6,498	2,954	4,224	1,920	8,010	3,641	6,408	2,913
1 / 4	6.35	7,266	3,303	4,723	2,147	9,070	4,123	7,256	3,298
9 / 32	7.00	8,010	3,641	5,207	2,367	11,079	5,036	8,863	4,029
5 / 16	8.00	10,472	4,759	6,807	3,093	13,877	6,308	11,102	5,046
3 / 8	9.50	14,847	6,749	9,651	4,387	19,766	8,985	15,813	7,188
	10.00	16,359	7,436	10,633	4,833	22,045	10,021	17,636	8,017
7 / 16	11.00	19,789	8,995	12,863	5,847	27,302	12,410	21,842	9,928
	12.00	23,466	10,666	15,253	6,933	32,560	14,769	26,048	11,815

The data in this table is based on actual breaking strengths, as opposed to the previous table that includes a fudge factor. The yield strength is also included here. You should always be below yield when you reach your point of highest load (before factors of safety are applied).

NAVTEC NITRONIC 50 ROD PROPERTIES

ROD	DIAMETER		MININIMUM BREAKING STRENGTH		WEIGHT		PIN DIAMETER		CHAINPLATE THICKNESS 316 STAINLESS STEEL		CHAINPLATE THICKNESS 6061-T6 ALUMINUM	
SIZE	IN	CM	LBS	KGS	LBS/FT	KG/M	IN	MM	IN	MM	IN	MM
-4	0.17	4.4	4,900	2,227	0.08	0.12	0.31	7.95	0.17	4.42	0.28	7.10
-6	0.19	5.0	6,600	3,000	0.11	0.16	0.38	9.53	0.20	4.97	0.31	7.98
-8	0.23	5.7	8,500	3,864	0.14	0.20	0.44	11.13	0.22	5.48	0.35	8.80
-10	0.25	6.4	10,700	4,864	0.17	0.25	0.44	11.13	0.27	6.89	0.44	11.08
-12	0.28	7.1	13,000	5,909	0.21	0.32	0.50	12.70	0.29	7.34	0.46	11.79
-17	0.33	8.4	18,100	8,227	0.29	0.44	0.63	15.88	0.32	8.17	0.52	13.14
-22	0.38	9.5	23,300	10,591	0.38	0.56	0.63	15.88	0.41	10.52	0.67	16.91
-30	0.44	11.1	31,000	14,091	0.51	0.76	0.75	19.05	0.46	11.67	0.74	18.75
-40	0.50	12.7	37,300	16,955	0.67	1.00	0.88	22.23	0.47	12.03	0.76	19.34
-48	0.56	14.3	47,600	21,636	0.85	1.28	1.00	25.40	0.53	13.43	0.85	21.59
-60	0.66	16.8	60,900	27,682	1.17	1.74	1.13	28.58	0.60	15.28	0.97	24.55
-76	0.71	17.9	76,000	34,545	1.34	1.99	1.25	31.75	0.68	17.16	1.09	27.58
-91	0.77	19.5	90,000	40,909	1.58	2.36	1.38	34.93	0.73	18.47	1.17	29.69
-115	0.88	22.2	117,000	53,182	2.06	3.06	1.56	39.70	0.83	21.13	1.34	33.95
-150	1.00	25.4	150,000	68,182	2.69	4.00	1.75	44.45	0.95	24.19	1.53	38.88
-170	1.07	27.1	170,000	77,273	3.05	3.54	1.88	47.63	1.01	25.59	1.62	41.12
-195	1.13	28.6	190,000	86,364	3.40	5.06	2.13	53.98	0.99	25.23	1.60	40.56
-220	1.19	30.3	217,000	98,836	3.81	5.67	2.25	57.15	1.07	27.22	1.72	43.74
-260	1.31	33.4	260,000	118,182	4.63	6.89	2.44	61.93	1.19	30.10	1.90	48.37
-320	1.50	38.1	340,000	154,545	6.04	9.00	2.50	63.50	1.51	38.38	2.43	61.69
-400	1.75	44.5	470,000	213,636	8.23	12.25	2.50	63.50	2.09	53.06	3.36	85.27
-760	0.71	17.9	76,000	34,545	1.34	1.99	1.25	31.75	0.68	17.16	1.09	27.58

Skip Chetelat at Forespar uses this table for calculating chainplates. Navtec rod sizes and properties are given on the left. He then solves for chainplate thickness. To arrive at the width of the chainplate for aluminum, a good rule is to multiple the pin size by 3. If you had a 1/2-inch (12.6mm) pin, the chainplate would be 1 1/2 inches (38 mm). To get the distance from the pin center to the top of the chainplate, multiply the pin diameter by 2. For stainless-steel chainplates, use the same approach for chainplate width. However, for height above the center of the hole, this can be reduced to 1.75 times the pin diameter.

These are general guidelines. If you are installing new chainplates or building new, your situation should be checked by a qualified engineer.

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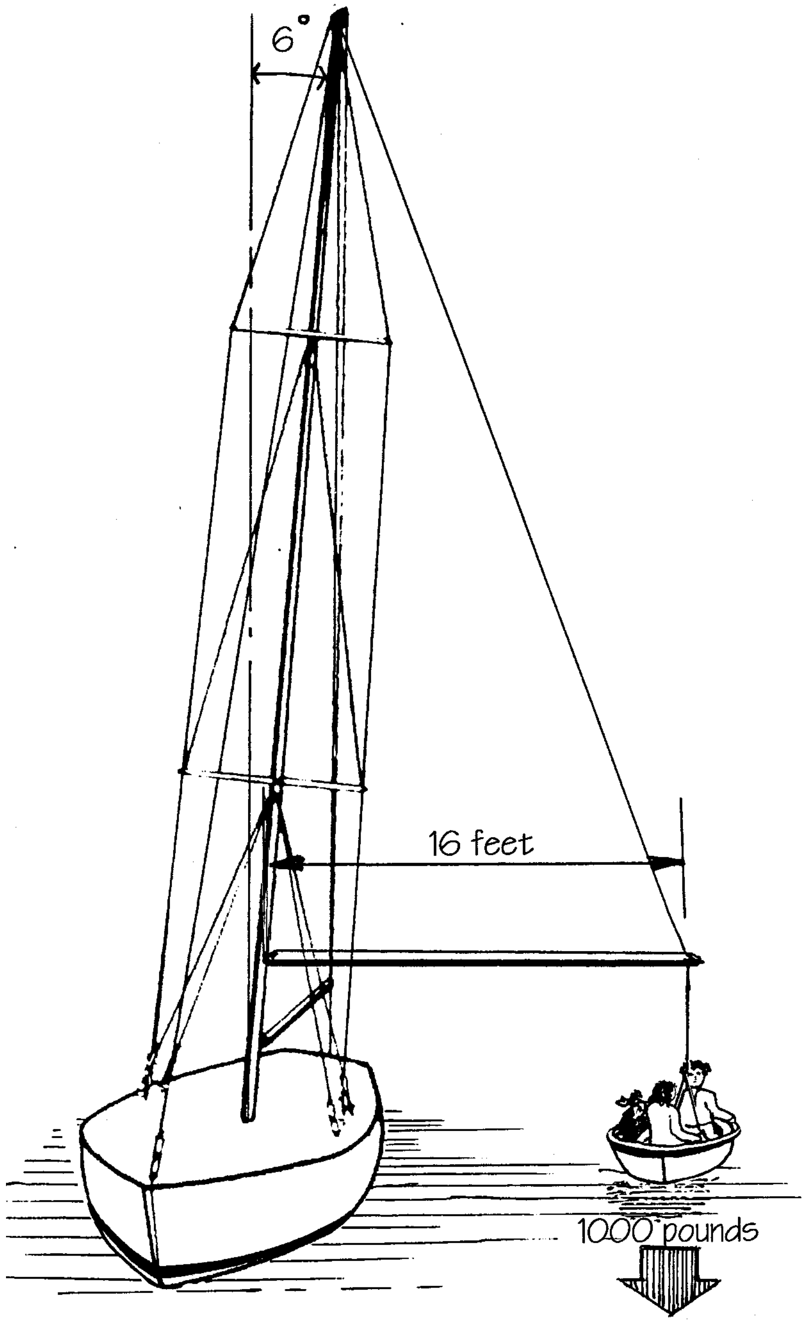

16 feet x 1000 lbs = 16000 ftlbs

Doing an inclining test to find out your righting moments is surprisingly simple. Once you have the data, all you need is a calaculator with basic trig functions.

As righting moment is the key to all structural decisions on your rig, this data will enable you to judge for yourself how conservative (or skinny) your factors of safety actually are, and what, if anything, needs to be done for the future.

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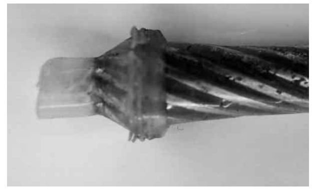
Terminals

End fittings are very controversial. Swages, if properly done, are excellent and give reasonable service. But as with anything in the primary structure chain, you must keep an eye on them. Rarely will they fail without ample warning. We met only one boat on our circumnavigation that ever had a complete failure underway with a swage fitting. On the negative side, some people feel that in the tropics they deteriorate rapidly due to salt-water corrosion. *Intermezzo*'s rigging, for the most part, was eight years old when we left, and had seen quite a few miles. With the exception of one lower shroud that started to strand, we never had a problem in the additional 30,000 miles we put on it.

The other approach is the StaLok/Norseman type of terminal. These work well and have the added advantage of being reusable if you carry spare cones. A good compromise is to use swages

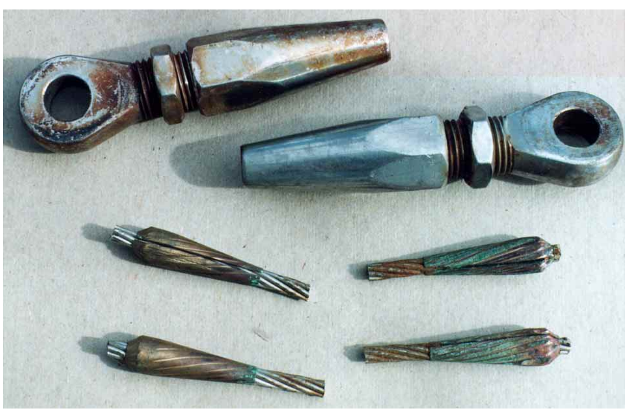


The StaLok terminal (far left) is a little easier to install than the Norseman (middle two photos). But in either case, you can deal with them on your own, as long as you pay attention to the instructions. It's a good idea to do the first couple of fittings with the help of an experienced rigger, just to be sure you get it right.

Both of these systems work on a similar principle. The central core of the wire goes through a hole in the center of a cone (above right). The outer strands of the wire then go over the outside of the cone and bend over the angled head. The clamping pressure applied by the outer housing, as it is tightened on its threads, keeps the wires from slipping.

There is a debate about whether or not to seal these fittings. The norm is to put a dollop of sealant in before final assembly so that it squeezes out the ends and through the wire. In theory, this keeps out salt water and other contaminants. On the other hand, stainless needs oxygen to maintain its anticorrosive properties. If salt gets to it and no air is present, corrosion will start. If you do use a sealant, use a gray silicone made for metal. Bathroom sealants have a mildew retardent which will attack the metal.

I don't know the answer to this argument. However, we've always sealed our fittings and so far have not had a problem.



How well does the Norseman type of terminal stand up over time? Al Liggett sent us the photo to the left of a cap-and-lower-shroud terminal from *Sunflower*. These terminals are 20-year-old Taiwanese copies of the real thing, and have significantly more than a circumnavigation's worth of miles on them. It would be pretty hard to improve on this performance!

on the mast-end of stays and the StaLok fittings on deck, where they're subject to more corrosion. We've used this approach when we've been able to have properly made rolled swages on the top. However, as wire size increases, it becomes more difficult to have swages properly rolled, especially outside of the U.S.

Typically, 3/8-inch (9.6mm) is the most riggers go with their roll-swaging equipment. Beyond this point, it is better to use the Norseman-type of fitting on both ends.

One thing to check carefully with any swage is that it comes out of the dies nice and straight. If it doesn't, the wire should be discarded and a new swage affixed. Do not let a rigger straighten a bent swage with a hammer or vice. This creates stress risers and will eventually end in a failure.

Don't discard the concept of splicing wire for terminals. Properly done, a splice, even in 1x19 will be as strong as the wire. Note — the emphasis here is on who does the splice. Tests from around the country show a variety of breaking strengths with wire splices. They can be as low as 65 percent, or right up to the wire limit.

Traditional rigging is pretty much a lost art. When you find someone who knows how to do the job right — like Brion Toss in Port Townsend, Washington — seeing the work in progress is like watching a maestro conduct an orchestra.

7x19 wire is relatively easy to splice. I even used to know how to do it myself. But 1x19 is a real bear.

A key factor for long life is the proper type of thimble. If loads are high, use a solid or braced thimble A plain thimble is liable to compress with age, and the load will eventually force the wires into a tighter radius than they can tolerate.

In the olden days, the precursor to the StaLok/Norseman fittings used hot lead (which melts at a relatively low temperature) to hold wire ends in place. Today we use a catalyzed epoxy.

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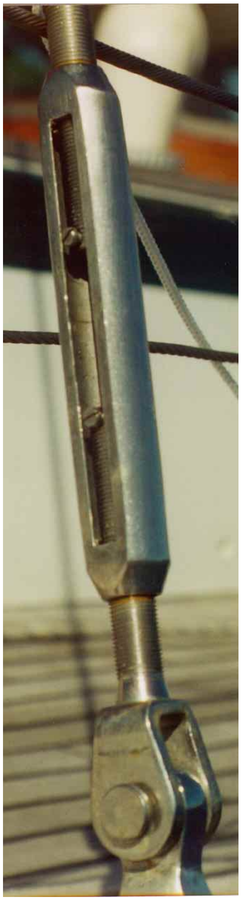
Turnbuckles

Many kinds of turnbuckles are on the market today. Those with a double-acting toggle are best. Only open-body turnbuckles should be used on an offshore boat. The closed-body turnbuckles don't allow you to see what's going on inside, and are subject to various corrosion problems. If there's a choice of bronze or stainless, bronze is better — it's less subject to fatigue failure than stainless. Never use stainless bodies with stainless screws, because they'll eventually gall and seize.

Turnbuckles should be carefully greased with anhydrous lanolin or a dry form of molybdenum disulfide before rigging. This makes them easier to turn when you tune and retune the rig. If for some reason you do not have double-acting toggles on both ends of the turnbuckle, you can achieve the desired effect by adding one or two toggles at the ends of the clevises.

Be sure that the clevis pins between shroud and turnbuckle and between turnbuckle and deck tang are lubed and turn freely. If they bind at all, they may be difficult to remove in an emergency and may restrict toggling action.

Note: When you periodically inspect your turnbuckles, be sure to check the threads carefully — they can cause stress risers. If a failure, occurs it is typically at a thread.



Four different turnbuckle configurations. Going from left to right, the first photo shows an open-barreled turnbuckle with a Norseman fitting integrated into the top screw. This system eliminates one set of connection elements, but does not provide toggle action at the top. You will want to be sure that the leeward rigging does not go slack, flogging the wire back and forth.

The turnbuckles with the black toggles were made for us by Navtec (the toggles have been powder-coated with Sermatech ceramic coating to resist corrosion with the aluminum tangs). The toggles are two sizes larger than normal, so that the oversized pins have enough bearing surface in the aluminum chainplates.

Next is a Norseman turnbuckle. These units are handsome and sturdily made, but do not have toggles — hence the external toggle, part of which you can see at the bottom of the photo. Note the small bolts used in lieu of split pins to keep the body from unwinding. A much cleaner and sail-friendly approach than split pins.

The last (right) photo is a Graham Screw from New Zealand. This clever design is quite lightweight and does not require a split pin for security. It uses a small set screw.

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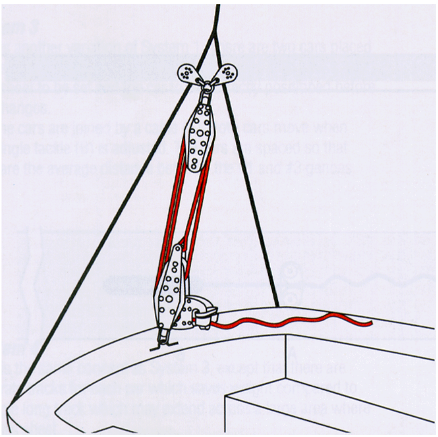
Backstay Adjustment

The backstay keeps the headstay tight. As you increase tension it pulls the masthead aft, tensioning the headstay. Sailing upwind on a reach or in windy weather, a tight headstay minimizes sag and in turn helps to keep the jib flat. Off the wind and in light airs you want just the opposite — an eased backstay, soft headstay with sag, and more shape in the jib. There are all sorts of adjustment systems, from sophisticated hydraulics to simple wire bridles with a block and tackle between two legs.

In port, on most boats, you will want to ease off on the backstay to reduce rig and hull loading.



There are many ways to tension the backstay, depending on the loads involved and how fast you need to do the job. The simplest, if loads are light enough, is shown in the left-hand illustration (courtesy of Harken). With a wire bridle at the bottom of the backstay forming a ramp, you can generate substantial force by pulling down on the two blocks riding on the bridle. The system is failsafe in that if the adjuster ever fails, bridles are still intact.

The rest of the photos show mechanical adjusters and one self-contained hydraulic unit. Variations on each of these themes are available from your local rigger. When space allows, I prefer the unit with the large-diameter handle, since it is always ready to use. However, you need enough space between it and the pushpit to be able to swing the wheel.

Self-contained hydraulic units make sense once the rigging loads require 3/8-inch (9.6mm) wire sizes and above. While slower acting, they offer a far higher mechanical advantage than is available with geared units.

When looking at a hydraulic backstay adjuster, be sure there is enough turnbuckle adjustment between wire and cylinder so that in the event of a total hydraulic failure, the backstay can be tightened the correct amount with the turnbuckle.

When we built *Intermezzo II*, we installed twin side-by-side headstays (left), set 1 foot (0.3 m) apart at the deck. They were opposed by twin backstays at the masthead, so that the off-center load of the headstay into the masthead would not cause a twisting action.

We spent a good chunk of our first long trade-wind passage with a light jib to weather on a pole and a balloon jib sheeted through the end of the main boom to leeward. We eventually found that carrying the main paid dividends and gave us a sail behind which we could blanket the headsails when dropping them during squalls. By heading up a few degrees on course we were able to keep the leeward sail filled.

However, you do not need twin headstays to fly twin jibs downwind. A light headsail can be flown with its luff free, like a triangular spinnaker. If you add a roller-furling drum to the system, you have most of the advantages of twin headstays without the extra weight and windage aloft that comes with twin stays.

Our first *Intermezzo* came to us with a single headstay. In New Zealand we added a second stay, with its tack 3 feet (0.9 m) aft of the headstay and down 6.5 feet (2 m) from the masthead. Our #3 jib fit nicely on this stay.

TWIN HEADSTAYS

Twin side-by-side headstays offer some advantages, along with a host of problems. They allow you to set twin jibs downhill and — of more significance to me — offer two different-sized headsails hanked on and ready to go when reaching or beating. To be successful they must be on a structurally stiff boat with fore-and-aft stays set up very tight. Otherwise, the weather stay, if it's working, will sag onto the leeward stay and the jib hanks will foul each other. Naturally, it will happen to a hank halfway up the stay, which will then jam on the way down. Another problem often arises when you're sailing free with the headsail hanked on the weather stay — the luff of the sail rubs against the leeward wire, causing serious chafe. Chafe between roller-furled headstays can also cause problems.

The other approach is to use two headstays, one abaft the other (as on *Intermezzo*), with the outer stay carrying the light headsail. This necessitates rolling up the outer sail for tacking or jibing, but that isn't too big a price to pay. The distance apart can vary from 1 foot (0.3 m) to several, depending on rig and sail size. The more space, the easier the tacking or jibing of the outer headsail.

Be careful with the relative tension of the two fore-and-aft stays. The aft stay, which carries the heavier jib, must be the tighter of the two.

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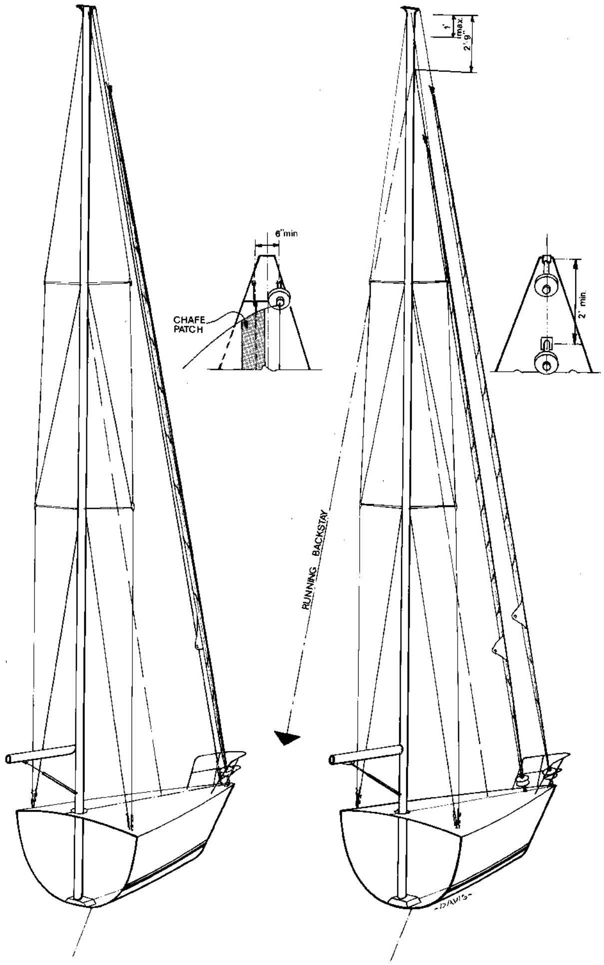
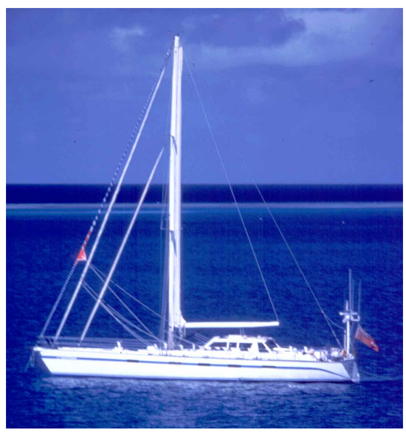
There are two approaches to twin headstays (right) — side-by-side and fore-and-aft. Of the two, the fore-and-aft configuration is easier to work with at sea. If you have side-by-side headstays, make sure you have the maximum possible separation between them at both the masthead and the deck.





Three views (above and right) of the original triple headstay on one of our 74-foot (22.8m) motorsailers.The middle of the three headstays was considered the structural headstay and was quite heavy (5/8 inch/16 mm).This carried the working jibs.The outer stay was designed for light-air sails and for running and was only 3/8 inch (9.6 mm). Because it was so much lighter than the structural headstay, it would stretch a bit as the backstay was used to tension the heavy headstay for upwind work.Thus we didn't have the typical problem of having to split the backstay load between two equal headstays (with the result of excessive sag in both).

The inner shroud is for staysails and storm jibs.

We eventually removed the outer headstay and set this light-reaching jib as a free-flier, on the same roller-furling unit that had been used before.This reduced windage and weight aloft when the sail was put away and allowed us to use a much lighter sail without sun cover,which set much better off the wind in light airs.

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TWIN BACKSTAYS

Twin backstays, one to each quarter, are frequently seen on cruising boats. With twin side-by-side headstays, twin backstays are necessary to help counteract any eccentric load that may be put into the masthead crane by the off-center headstays. With a single headstay, twin backstays make little sense structurally. If you want a higher factor of safety, take a small percentage of the weight of the second backstay and add it to the first.

When a centerline backstay interferes with headroom at the helm, it may be desirable to have twin backstays or a split backstay to generate headroom for the helm area.

RUNNING BACKSTAYS

If sailing a cutter or a double-headed rig of any sort, you'll need running backstays to offset the pull forward of the cutter stay. They're a nuisance, but rigging them properly can make life easier. To begin with, rope tails directly from the 1x19 backstay wire to a winch in the cockpit area are the easiest way to control them. Usually a 2- or 3-to-1 tackle is used. Remember that the blocks and their attachment points must have a breaking strength equal to or greater than the 1x19 wire. For pulling and holding the unused backstay forward, I use a piece of 1/4-inch (6mm) braid run through a block positioned on deck so the retrieving line will hold the wire just clear of the aft side of the lower spreader. The line is led aft to a jam or camcleat in a convenient spot.

Aside from supporting the mast, running backstays have several other advantages. If you're running free and have to turn the boat quickly with a jibe, the main boom will fetch up on the set runner and drive the boat quickly into the wind, stopping way almost instantaneously.

Runners are also great as a midpoint attachment for deck awnings, especially if you have a single-sticker. And, of course, they make a nice handhold.

STANDING INTERMEDIATE BACKSTAYS

One way to get around runners is to use a permanent intermediate backstay. In this system, a chainplate is placed a little way aft of the after lower shroud, which carries the cutter-stay load. It requires a much heavier wire and adds considerably to compression load on the spar, since the staying angle is so tight compared to what you normally find with a runner.

When the time comes to run downwind, there's another drawback. There will be considerably more chafe on the mainsail from this wire, and the boom angle will be somewhat limited. Still, in some cases these make sense, especially for onshore work where a lot of tacking is done and runners are a bother. Offshore there isn't much sailhandling to be done anyway, and there's plenty of time to deal with regular runners.

With a new design, remember that runners can be done away with if a bit of spreader sweep angle is incorporated into the rig. The forward thrust of the swept spreaders opposed by the diagonal shrouds just below the spreaders tends to lock the stays in position.

LOWER SHROUDS

It used to be common for all cruising boats to have fore-and-aft lower shrouds. These provide side support, more or less split between the two wires, as well as a fore-and-aft lock on the mast due to the angle between the two wires. Additionally, the two shrouds, in conjunction with the cap shroud, provide a nice base for a series of steps up to the leeward spreader.

But there are some negatives, mainly regarding sail interference. Any sail that sheets inboard of the shrouds will have its leech interfered with by the forward lower. And the main boom will come to rest against the aft lower. Additionally, because these stays pretty well lock the mast in place in a fore-and-aft direction, it is difficult to get any spar bend below the middle of the mast.

On older yachts, on which spars are engineered to depend on fore-and-aft lowers, they are better left in place. My feeling is that for new rigs, a single lower is far better on sail trim. It is better to pay a slight weight penalty in the mast than to have inefficient sails.

CUTTER STAY

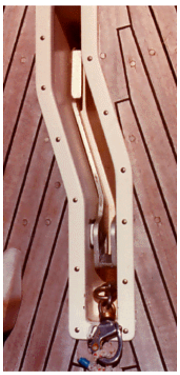
The cutter, or intermediate, forestay adds a potent weapon to the offshore arsenal. It provides a means of bending-on storm canvas that does not need the crew going all the way to the bow. By bringing the center of effort aft, it works better in extreme conditions, especially when flying a deeply reefed mainsail or trysail.

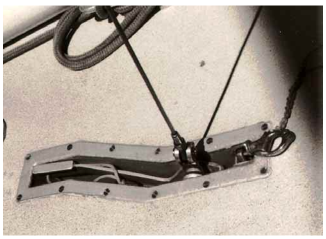
No vessel should head offshore without a cutter stay unless it is a fractionally rigged sloop with small headsails to begin with.

The problem with cutter stays is that they are in the way of the big jib when the time comes to tack. Not only does this significantly slow the tacking process, but every time the jib has to bend its way around the cutter stay, the life is shortened. This is bad enough with Dacron sailcloth, but if you happen to have laminated sailcloth, the effect is even worse.

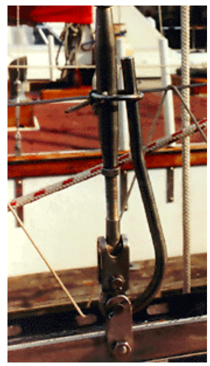
The answer lies in some form of quick-release mechanism, several of which are shown nearby. The alternative is to use a fast pin at the top of the turnbuckle, then unwind the turnbuckle when you are close to land and likely to be short tacking. Or, you can roll up the outer jib before you tack. This is the approach many of the BOC boats take.

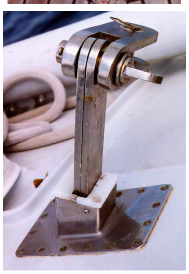
A word of caution. Although it is not a good idea for cruising, some rigs depend on their cutter stays for intermediate fore-and-aft support of the spar. If you have a cutter stay and it is not fitted with quick-release gear, you may want to check with your local spar maker or rigger about the conditions in which the stay can be safely removed.

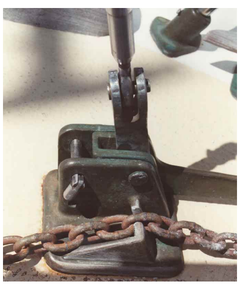




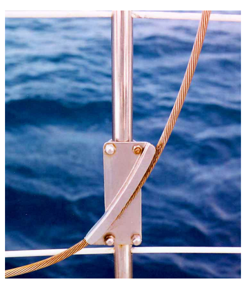
Over-center Highfield-type levers are neatest if they are let into the deck. This allows you to have the tack of the staysail or jib right down at deck level. Allow for the troughs to drain overboard. They can also be mounted above deck. This is a much simpler installation. The only negative is the fact that a hanked-on headsail will now be stowed several feet (0.6m) above the deck. This may cause a visibility problem from the cockpit and should be checked when you are sitting under the dodger.







Some form of "fast pin" (left) will help in removing and replacing the cutter stay. These are available in most marine stores in a variety of sizes.



When the cutter stay is removed, it needs to be stored so that it doesn't bang the mast. A gently radiused stainless guide can be used to transition the stay to where it is facing horizontally. A small tackle is then attached to the end of the stay and is snugged down tight. This change of direction will need to be far enough forward of the mast, so that in a chop the cutter stay cannot hit the mast when it starts to whip.

When we have hydraulics aboard our designs, we fit a hydraulically tensioned cutter stay. The stay or tang (left) runs through the deck and is attached to a hydraulic cylinder mounted on the centerline of the forepeak.

By slacking off the hydraulics, the stay is easily removed. With this system it is important to have the relationship between the cylinder and the pennant such that when the cylinder is fully retracted, the end fitting on the pennant cannot bear against (and possibly collapse) the deck. Sometimes it is necessary to put a stop of sorts on the cylinder piston to limit its ability to retract.

Another approach that is deck-mounted but still has a low profile for stowing a hanked-on headsail is shown here. The handle is forward and down when the stay is in position and tensioned. Make provisions to keep the jibsheets from catching on it.

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MAKING THE PIECES FIT

Any time you assemble a rig with components from a variety of sources, odds are some piece will not fit correctly. Pin sizes might be too small or too large, or some of the pre-swaged wire will be too short.

Take every precaution in specifying pin sizes. Most turnbuckle and end-fitting suppliers offer a variety of pin sizes for their products, so specify pins that will work between elements. However, there is almost inevitably a screw-up. This occurs even when a single rigger has the job of supplying everything. Allow a couple of extra days for a bit of machine work making new or turning down oversized pins when the rig first goes into the boat.

Mistakes happen. These link plates (left) are on my dad's boat. Note the difference between the upper and lower clevis pins. We were supplied with the wrong size Norseman fittings and could not get correct-size ends for three weeks. Needless to say, we all wanted to go sailing, so these link plates were created in order to bridge the pin diameter difference. Had we used the smaller pin of the Norseman in the turnbuckle toggle, the pin would have been working at close to its yield point — not a healthy situation for long-term rig security.

In an emergency you can substitute a bolt for a clevis pin (center), but never allow the threaded portion of the bolt to carry load. The threads create stress risers and reduce the working diameter of the bolt.

Sometimes the problem is in the width of one of the jaws (right) through which a clevis pin must pass. There should be very little free space on the pin. Otherwise, it will eventually bend, increasing stress on the pin and making if difficult, if not impossible, to remove.

If there is an unavoidable gap, fill it with washers, as shown here, to reduce the tendency to bend. However, there will still be some tendency to force out the jaw of the toggle. In this case the split pin becomes loaded in shear. If you take this approach, use a stainless split pin as large as possible. And make sure the jaw of the toggle is not being bent out of shape. You can also sometimes force the toggle closed with a vice grip, vice, or a hydraulic press if there is one in the neighborhood.

ROD RIGGING

Not many years ago a conservative cruiser wouldn't consider rod rigging for serious offshore voyaging. Sure, Whitbread, BOC, and lots of inshore racers used it, but these were win-at-all-cost sailors. From a cruising perspective, we're concerned with longevity, repairs in foreign waters, budget, and the ability to jury-rig in case something happens offshore. Of course, performance is a factor to cruisers, too. If rod rigging can compete with conventional wire cost and reliability, while reducing windage or weight aloft, then it ought to be considered.

With these factors in mind I've been watching the development of rod rigging as it applies to cruisers for the past two decades. I've talked with riggers and sparmakers in various parts of the world, cruisers who've used it, and the folks at Navtec who pioneered rod rigging. Here's what I've learned.

Rod has three factors to commend it. First, the typical everyday rod is made of Nitronic 50, a special steel alloy that is highly resistant to salt-water corrosion. Since the best conventional 1x19 rigging wire is only available in type 316 stainless steel, score one for rod. More on this later.

Second, rod typically stretches 30 to 35 percent less than 1x19 wire under load. This means that initial rig tension needn't be as high with rod as with 1x19 (creating less static load on the hull — especially important with wood boats). Stretch can also affect the size of rigging required.

Finally, the terminations or end fittings on rod are more efficient at transmitting load and avoiding stress from bending than with swages or the Norseman/StaLok fittings used with 1x19 wire.

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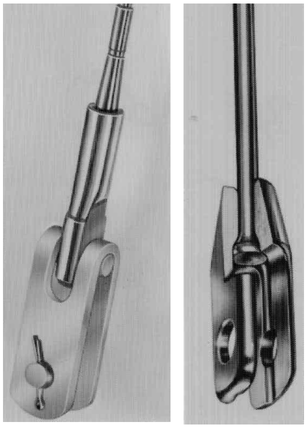

Two typical cruising-style upper terminations from Navtec. Both depend on a cold-formed head.The rod is placed in a powerful hydraulic press into specially shaped dies, then the metal is drawn into the button shape that holds it in place in the end fitting.

These are three pretty powerful advantages. However, rod also has some drawbacks. It's difficult to stow spare sections of rigging. Rod should be stored in a coil 200 times its thickness — a 3/8-inch diameter rod would take a 6-foot coil. The proper connection of tangs and spreaders is critical. And there's no prior warning if rod is going to fail. With 1x19 you might detect a swage crack or broken strand in time to make a change.

On balance it appears as if the rod-rigging system has matured enough to warrant consideration from the serious offshore-cruising community.

Of course, if rod is out of the ballpark price-wise, we can forget the rest of the story. To get a handle on comparative pricing I called Frank Colaneri, chief engineer and owner of Bay Sailing. Frank deals with many kinds of rigging materials — conventional 1x19, Dyform wire, and rod. He told me that when you get to 1/2-inch wire or -30 rod (the equivalent size,) the costs are about the same. You hit this point at 45 to 50 feet of boat length. Above this size, rod offers a savings. Below it, there's a premium.

For a Bristol 41 he's about to re-rig, the price for rod rigging, including new turnbuckles, comes to $3,500. Using 1x19 with swaged terminals, this would run $3,200. Any performance or longevity benefit makes the cost differential (50 percent on a 30-footer) become insignificant.

Let's examine some of the issues further.

Corrosion

One heavily pitched aspect of rod is the fact that it's made of Nitronic 50, an unusually strong and corrosion-resistant material. This means you can pretty much dismiss corrosion as a long-term concern. Of course the importance of corrosion resistance varies with your cruising plans. In higher-latitude sailing it doesn't seem to be an issue. For long-term cruising in the tropics there have been occasional problems with 3/16 stainless-steel wire and swaged end fittings. However, using Norseman/StaLok type fittings at the bottom (you can use regular swages at the top) seems to pretty much take care of this issue. We've yet to have a serious corrosion problem with 1x19 used this way, despite plenty of tropical cruising. Still, the thought of a noncorrosive Nitronic 50 rigging system is comforting.

Stretch

Two types of stretch occur in rigging under load. The first is the inherent elasticity of the material. In this case, rod and 1x19 come out about the same. Because of the construction of 1x19 wire — a series of wires wrapped around a core — the wrap tries to tighten when the wire is loaded. There will be some give, of course, leading to additional stretch. If you took a 100-foot piece of 5/16-inch 1x19 and -12 rod, and tensioned each to 25 percent of breaking strength (about 4,000 pounds), the wire would stretch 3 inches while the rod would stretch 2.11 inches. If your longest side shroud (the cap) is 50 feet long, the difference would be just under 1/2 inch. Is this important? That depends on your type of rig and its structural requirements. Steve Loutrel, chief engineer at Navtec, explains it this way: "If you have a short to moderately tall rig, the odds are the rod or wire sizes will be determined based on strength requirements. A narrow shroud base and/or narrow spreader widths also tend to orient the need toward strength." In this case, stretch isn't as much of a factor.

On the other hand, Steve points out that "taller rigs and those with wider chainplate locations or wider spreaders can typically have lower loads. Smaller diameter rigging can be used *if the stretch of the rigging material is not a factor*."

This is where rod really comes into its own. The lower stretch characteristics mean a lighter-weight rod can be used than would be the case with wire. That means less weight aloft and lower windage as the rod is inherently smaller in diameter than 1x19. However, you do have to be careful with fatigue if the rod is going to be used at a very high percentage of its breaking strenght during much of its life. In a cruising context this means *not* reducing rod size as would normally be allowed by the stretch characteristics

Even where stretch isn't critical to keeping the rig in tune, it does play a part in loading your hull. Wire must be set up tighter initially to preload it (to get rid of the initial stretch). This preload factor adds to the strain on the hull at rest and to the total compression loads on the mast when sailing. Rod is set up more loosely.

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Attachments

What has made rod rigging a commercially viable and seagoing material is the cold-heading process, an efficient means of terminating the ends of each piece of rod. It works like this: The end fitting is slipped over the rod. The rod is then put into a hydraulic press which *cold-forms* a mushroom shape on the end of the rod to keep the fitting from slipping off. This mushroom shape transmits the tension in the rod to the attachment fitting, which in turn connects to the chainplate. The process takes less than two minutes. Compare this to the time it takes to put on a Norseman or Stalok fitting! In the process of cold-forming, the end of the rod is work-hardened, dramatically increasing its strength.

There are lots of different attachment systems for the ends of the rod. Race boats use a special tang assembly in conjunction with a fatigue indicator. According to Steve Loutrel, flexing is what weakens the rod, and that is what these fatigue indicators show. After half the life of the rod is used, the indicator breaks off and falls down. When you see this, you know it's time to make some rigging changes.

Frank Colaneri, however, feels that it is better to use a marine eye fitting at the end of the rod. This way, conventional tangs, turnbuckles, and spreader attachments can be used. The advantage of this system is that it is user-serviceable. If you have a problem at sea or in a faraway port, you can remove the offending section without disassembling the rig. This approach is heavier and adds some windage, but he feels it makes the most sense for cruising.

Spreader Connections

If you're interested in using rod rigging, the most important question is how to handle the rod-to-spreader intersections. There are two ways to go. The first is to use a single, continuous section of rod from the tang on the mast to the turnbuckle at the deck. With a two-spreader rig, both your cap and intermediate shrouds would end up at deck level. With both turnbuckles on deck, the rig is somewhat easier to tune.

If this approach is taken, make the bend in the rod precise, usually plus or minus 1 degree. A reinforcing tube is placed over the rod where it meets the spreader. This bend is the weak link in the rod system. In the early years of rod, many failures were due to improperly angled spreader bends.

Discontinuous rigging is the second method. In this case there is one heavy leg from deck to the tip of the lower spreader. The intermediate then goes from the mast at the upper spreader to the lower spreader tip, where it is joined by the cap shroud, which goes to the masthead. With this system, the large angle over the spreader end is made with stainless toggle plates or a special ball fitting so the rod doesn't have to make the bend. This is the more reliable of the two approaches.

Repairs While Cruising

What happens if you need to replace a section of rod at sea or in a distant port? The best approach is to carry a section of 1x19 wire, made with a swage fitting on one end, then use a Norseman/StaLok terminal to get the length right for whatever needs replacement. With marine eyes on your rod there's no mating problem. However, if you've chosen to go with specialized end fittings, you'll need a short piece of rod with a jaw on the loose end to make the transition from rod to wire.

What happens if you accidently bend a piece of rigging against a dock? It appears that rod can be bent back into shape more easily and with less fatigue than 1x19 wire. Of course, at some point the bend becomes severe enough with either material that the section of rigging must be replaced.

Does rod make sense for your cruising plans? From a cost standpoint, the noncorrosive properties of rod mean you'll get more service life than you might with 3/16-inch wire, especially in the tropics. And that extra life will more than offset any initial higher costs. There's a definite advantage in reduced windage and a potential reduction in weight aloft if your current wire size is stretch-limited. The smooth, round shape also reduces chafe on your sails.

And reliability? It appears that if you apply conservative cruising factors of safety when sizing the rod, if you make sure the cold heads are properly done, and if you take care with how the rod interfaces with the spreader tips, you'll end up with a good cruising rig.

While we've looked at rod many times for our designs, we've used it on only one of our rigs, the 72-foot (22.2m) ketch-rigged *Locura*. She had quite a tall rig, and the owner really wanted rod. After the first owner put on quite a few thousand miles, he sold her to a couple who did a westward circumnavigation. As far as I know, she has had no major problems with her rig.

In most cases, however, our rigs are quite short and not stretch-limited in terms of rigging. So there's no real structural advantage to the rod.

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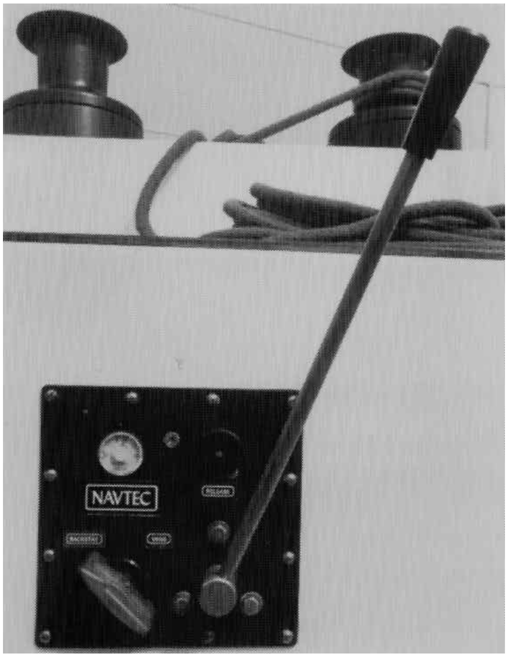
HYDRAULIC RIG CONTROLS

Hydraulic rig controls used to be equated with high-tech racing boats. Cost and lack of reliability kept them far from the cruising fleet. But with costs dropping and reliability increasing, they're beginning to find their way on board serious cruising yachts. Since the latter half of the 1980s, we've been using them with a very small incidence of problems.

Why hydraulics at all? Because hydraulic rig controls offer an effective means of controlling backstay tension and boomvang, and help perform a number of other chores aboard that would be difficult or impossible with any other approach.

Hydraulic Theory

The systems work in a relatively simple manner. A hydraulic pump — either in the cockpit area or mounted directly on the cylinder — sends hydraulic fluid, under pressure, to the cylinder in question. With a very high degree of mechanical leverage at the pump, enormous forces can be built up and transmitted efficiently to the hydraulic cylinders via high-pressure hoses.



There are two major concerns when installing a hydraulic system. The first is the ergonomics of the pump handle. Ideally, you will be able to get your chest into the pumping action. However, since the height of the panel is usually limited by cockpit height, the ideal location is rarely achieved.

The second issue is access to the plumbing behind these panels — one connection for each cylinder, plus the hydraulic-fluid expansion tank. (The expansion tank must be the highest element in the system, and you'll need access to the top for checking fluid levels and re-filling).

You will want the system installed so that you can reach it easily and keep an eye out for leaks.

Sometimes the expansion tank is impossible to mount so that the top is easily accessible from inside. In this case it may be possible to have a small plug on deck and fill from above. The small panel (left) has a single pressure gauge and selector valve to allocate pressure to any of four functions.

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Scott Trask, a design engineer with Navtec Hydraulics, explains, “The fact that the system is being used just for force transmission, as opposed to transmitting power, means friction losses are almost negligible — typically 5 to 7 percent.”

Sizing Hardware

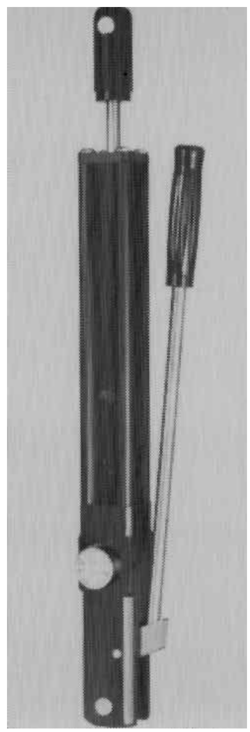
The first factor is how big a cylinder to use. Step one is to make sure the cylinder and its hardware are at least equal to the breaking load of the wire to which they are attached. The next consideration is mechanical advantage between the pumper (you or your crew) and the load on the wire. Leverage is a function of pump-handle length, the pump design itself, and the cross-sectional area of the hydraulic cylinder. Engineers state this as a formula — handle force equals mechanical advantage of the pump, multiplied by the force in the wire, divided by the cross-sectional area of the cylinder, minus the piston cross-section.

Since the piston area of the hydraulic cylinder naturally gets larger as rig loads increase (because of the higher breaking loads required), your mechanical advantage increases to keep pace. It takes more strokes on the handle to get the same amount of length adjustment from the cylinder. For example, if you have a 7/16-inch (22mm) backstay wire, with a breaking strength of 22,000 pounds (9,977 kg), the normal Navtec 22-cylinder size would offer a mechanical advantage of 230-to-1. At 230-to-1, if you put 25 pounds (11 kg) of force into the handle, you would be able to tension the backstay to a force of over 5,000 pounds (2,267 kg) after making some allowance for friction.

A single independently mounted pump can be used to control backstay, cutter stay, boomvang, and other functions such as outhaul or flattening reef, if its pressure to the individual cylinders is controlled by a series of valves. Since the main control panel is a major investment and cylinders are pretty inexpensive, once you have decided to go with a basic system, it makes economic sense to investigate all the options.

Many larger yachts go with two-speed pumps, the gears on which are changed by twisting the handle.

Having an individual pressure gauge for each cylinder makes it easier to keep an eye on the various loads in the rig.



A self-contained backstay cylinder by Navtec.

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Backstays

Let's consider a typical installation on a backstay. This is an ideal application because you need a very large amount of force to tighten the backstay and flatten the headsail when sailing to windward. Off the wind, being able to ease the headstay means more luff sag and more draft in the jib. At anchor, easing the backstay all the way off reduces rigging load on the hull.

One option is to go with a self-contained unit, in which the pump is mounted right on the cylinder. This makes installation a snap. However, you cannot drive any additional functions from this pump. If you have a mechanical vang and some other means of adjusting your cutter stay, this may make sense.

With twin backstays or a bridle, two cylinders will be used with a T between them to equalize pressure.

Below 7/16-inch (11mm) wire, we prefer to stay with mechanical adjusters. From this size up, we go with hydraulics, due to the loads.

Vangs

On a typical cruising boat, after the backstay system, the boomvang is the next candidate for hydraulics. Aside from doing an efficient job at controlling boom lift, a hydraulic vang will also hold the boom up in light airs to reduce leech tension, or when the sail is dropped — thereby eliminating the need for a topping lift. Nitrogen gas is used to force the cylinder out, supporting the boom when the hydraulic pressure is eased. Typically the nitrogen is charged at between 500 and 900 pounds per square inch. Even better is the practice of choosing the hydraulic vang length so that when it's all the way compressed, it holds up the boom mechanically. This way if you have a hydraulic failure, or if nitrogen gas escapes, you still have a built-in topping lift. If you can't get the vang length just right for this, have a piece of plastic machined to clamp around the piston. This prevents the vang from dropping too far.

One of the things to watch with a hydraulic vang is the load on the boom gooseneck and vang attachment point. The forces can be enormous, typically several times higher than you will see with a stretchy rope vang, which tends to relieve itself under shock load. Connections to your spars (goosenecks fittings and vang bales) that work well with rope may be somewhat undersized for a hydraulic vang.

Cutter Stay

As we've already mentioned, the next spot to look at using a cylinder is on your cutter or staysail stay. Being able to adjust the tension here means a nice straight luff for the staysail under load, and an easy time removing the cutter stay for short tacking. But you do have to be careful not to stress the spar by over tightening the stay. A wooden or plastic block on the hydraulic cylinder can be used to limit travel, eliminating this risk.

Operating Pressures

One of the reliability concerns in any hydraulic system revolves around operating pressures. While hydraulic systems become more efficient as pressure increases, they are also more prone to trouble. Higher pressures put more load on pump and cylinder seals and work hoses harder. So keeping pressures low makes sense on a cruising yacht. Backstay pressures should be in the range of 1,000 to 2,000 pounds per square inch, while vangs can be somewhat higher — although on race boats, pressures as high as 4,000 psi are often experienced. Since pressure is a function of the load and cylinder cross-section, it follows that the larger the cylinder used for a given load, the lower the working pressure. Going up a size, especially on the boomvang, doesn't cost very much extra and yields benefits in maintenance

Plumbing

Next you have to look at plumbing the installation itself. The plumbing of a modern system is simpler than you might suppose, with only one hose to each different cylinder.

Two basic plumbing materials are in use — stainless-steel pipe and Kevlar-reinforced hose. Of the two, Kevlar hose is by far the easier to work with. End fittings are swaged onto the hose with a portable tool. With a moderate degree of care, they will last indefinitely. Any fittings that are exposed should be stainless steel. Cadmium-plated fittings can be used if protected from salt water. Most fittings are simple high-pressure flare-style equipment, available from industrial supply and/or hydraulics houses worldwide.

Watch out for hose chafe. The hose moves slightly as pressure changes, and over time this can cause problems wherever the hose touches something hard. Bulkheads are particularly troublesome in this regard. Be sure that chafe grommets are used at each tie-down point and through each bulkhead.

Another reliability concern is cleanliness. A small particle of dirt lodged in a check valve will render the system inoperable. Taking care to keep hose ends covered during installation will eliminate this source of trouble.

Backup

If you're heading offshore with hydraulics, it's prudent to look at various forms of failure, how they'll affect your ability to manage your yacht, and what must be done to cope with the problem.

On deck I always assume that the worst is about to happen — in this case total hydraulic failure. As a backup we use extra-long (Fail-safe) turnbuckles between cylinder and rigging wire. Thus if a failure occurs we can tighten the turnbuckle by hand to regain rig tension.

You can also purchase mechanical locks that prevent the cylinder from easing past a certain point. In fact, if you run the lock down and then ease off the cylinder against the lock, you will eliminate the hydraulic load on that cylinder. This is a technique frequently used aboard long-distance ocean racers.

Of course, you'll want to carry spare hydraulic fluid. Hydraulic oils are color-coded to indicate additives. Matching the right oil to the chemical makeup of your seals is important to the seals' longevity. Most marine systems use No. 10 yellow non-detergent oil. In a pinch, almost anything can be used for a short period — even automatic transmission fluid. However, number ten motor oil is a better bet for a temporary substitute.

When you start up the system, it's necessary to bleed excess air from the lines. This is accomplished by cracking the plumbing connection fittings at each cylinder and the pump, and by pumping up a bit of pressure to let the air bleed through. Even if this is done for you at installation time, you should still know how to bleed the system in case of an air leak later on.

The last area of concern is with the seals between the cylinders and pistons. The key here is to keep the piston rods clean and scratch-free. If they're smooth and shiny, nothing will affect the seals. But a nick or scratch can cause the seal to wear and begin to leak. Changing seals requires special tools. If headed offshore, it's wise to carry the tools required — and be sure to have spare seals for each size piston.

Pressure-Relief Valves

Most hydraulic systems incorporate a pressure-relief valve in the control panel that you can adjust. These are typically set at 3,500 psi at the factory. If loads in the system exceed this level, the hydraulic pressure automatically bleeds off the pressure. Pressures on a cruising yacht are usually 2,000 psi or less. In this case, you may want to adjust the pressure-relief valve to reflect this value.

Do You Really Need Hydraulics?

Now we get to the critical question — how essential are hydraulics? If you want to be able to adjust headstay tension, and thereby the shape of the headsails and mainsail, and if the backstay wire is above 3/8 of an inch (9.6 mm) in diameter, odds are you need hydraulics at this position.

For the vang there are many other options, ranging from the integral mechanical vangs like those sold by Forespar and Hall, to good old-fashioned rope vangs between boom and mast and boom and side rails.

As boats get larger, hydraulics become the norm. However, we designed *Beowulf*'s rig in such a way that we wouldn't need hydraulics. Mast bend and headstay sag is controlled with secondary winches in the cockpit, and vang loads are taken by the large travelers and tackles between boom and toerail.

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BENDING THE CRUISING RIG

Of all the concepts to make their way from the racing fleet to dyed-in-the-wool cruisers, none has the potential to increase performance and comfort as much as using mast bend to control mainsail shape.

"A bendy rig on a cruising boat?" you ask. Sure, and a conservative one at that.

First, the basic advantages. Bending the center of your mast forward in a smooth curve pulls sailcloth from the middle of the sail, making the sail flatter and moving the point of maximum draft forward where you want it as the wind picks up. Both of these factors reduce your boat's heel, makes the boat faster, and keep the crew a lot more comfortable.

Before you run for your hard hat and start worrying about falling spars (what sparmakers refer to as a "gravity storm") rest assured that, properly engineered and tuned, a spar design which allows for a modest amount of mast bend can be as safe as a rigid mast system.

The key structural issues are simple. First, most spars can tolerate a modest amount of forward mast bend without difficulty. The reverse, as we discuss in the chapter on spar engineering, is not the case. Second, it's possible to set up spar bend controls so that the risk of damaging the rig through operator error is reduced to an absolute minimum.

Conservative Bending

The conservative approach to mast bend useful in a shorthanded cruising context varies considerably from that found on fully crewed racing yachts. Let's talk about the amount of spar bend first. By "cruising mast bend" we mean deflecting the mast only about one spar diameter forward. Thus, if your mast measures nine inches fore and aft, you would bend it, at the maximum, that same nine inches (a racing yacht might bend the same spar three times this amount). When the mast is at its most relaxed position you might have a nice full mainsail with a camber ratio of perhaps 14 percent. The camber or draft ratio is the depth of the sail divided by the horizontal or luff-to-leech dimension. Crank up to maximum bend and that sail goes to six percent. Thus you have a powerful sail off the wind or in light airs and a flat efficient shape when the wind picks up and for use to windward.

Creating The Bend

The key to this concept is how you achieve the mast bend. On a racing yacht, bend is forced into the spar by using eccentric loading on the masthead crane. The headstay terminates at the front of the masthead (or lower on a fractional-rig spar) while the backstay attaches to the aft end of a cantilevered horizontal crane. Because the backstay has a long lever arm it tends to force the mast below the top to bow forward when the backstay is tensioned. Running backstays or checkstays are then used to keep the mast from bending too much. A little bit of eccentricity in the masthead crane is a good thing because it always keeps the mast bowed slightly forward, but a system which has so much eccentricity that checkstays are required to prevent too much bend means that if a mistake is made with the checkstays the mast may crumble. And that's a concept which leaves a lot to be desired on a cruising boat!

Ideally, on a cruising boat the masthead crane should force about 75 percent of the desired bend into the spar at maximum backstay tension. The final bend is then pulled in with a cutter stay.

The means of adjustment of the cutter stay and permanent backstay will vary with the size of your yacht. On smaller yachts, splitting the backstay eight or nine feet off the deck and putting a bridle between halves with a modest block and tackle can exert enormous force — quickly, simply, and inexpensively to tighten the permanent backstay and induce that initial bend. If the bottom of the cutter stay is attached to a car on a centerline track, a tackle can be used to pull it forward. This will in turn, pull in your mast bend. Larger yachts will probably opt for hydraulic cylinders to do the work.

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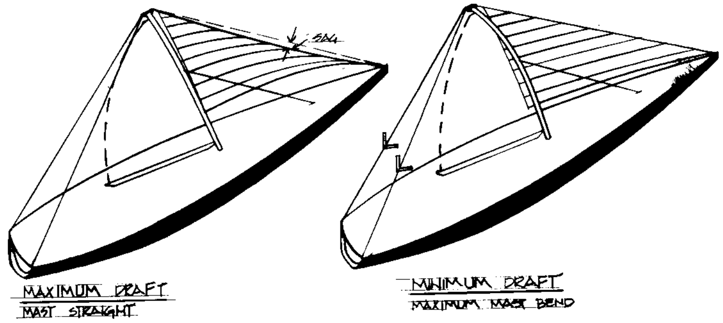
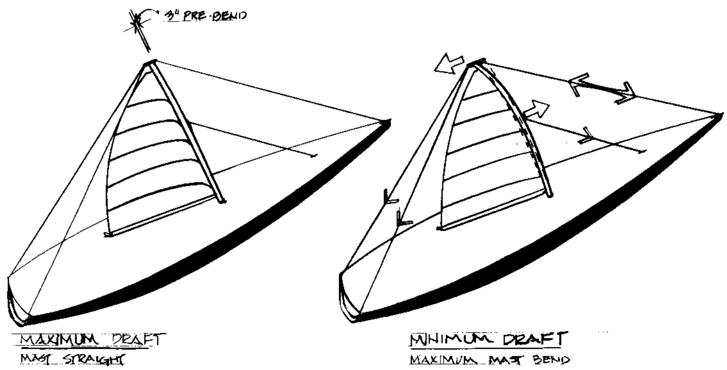


When the headstay sags off to leeward the sail cloth in that sagged area ends up as draft in the body of the jib (top drawing). If you can control headstay sag with rig tension, a flat jib can be shaped; while in lighter airs, the headstay can be eased off putting draft back. Otherwise, you have to guess at sailing conditions with your sailmaker and hope you aren't too far off with your sail shape most of the time.

The same thing happens with mast bend, but in reverse. Backstay tension, used to keep the headstay tight, bends the mainmast center forward because of the eccentric loading of the masthead crane (this is also helped by cutter stay tension). The forward bend pulls cloth out of the mainsail, flattening it in the process.



Safety Limits

By properly setting maximum and minimum limits on these stays you can substantially improve the safety of the system. The backstay should be adjusted so that when it's fully released you still have the minimum desired amount of prebend in the spar. (Most sparmakers suggest that one or two inches of initial forward bend be left in the rig when the backstay is eased.) If the masthead crane eccentricity is correct (and this is usually adjustable by moving the backstay forward or aft along the crane) overloading mast bend with too much backstay tension will not be a problem.

When you tune up the cutter stay it should be adjusted so that at maximum release, the spar still has its minimum prebend. At the other end, you have a stop for maximum tension (or forward travel if on a track) so you can't pull the spar too far forward.

If you're using hydraulics for spar control, by adjusting the turnbuckle on the backstay you can induce initial minimum bend while a safety lock to limit maximum travel will keep the cutter stay in position. With the system set up correctly, even a total hydraulic failure will not affect the safety of the spar system.

Lower Shroud Factors

Many modern yachts are equipped with single lower shrouds. Rigged in this manner your spar will bend from the deck to the masthead in a continuous fair curve. If you have fore-and-aft lower shrouds, and many cruising yachts do, almost all of the bend will take place above the intersection point of the fore and aft lowers. You can accentuate the bend slightly by carrying the after lower somewhat more loosely than the forward one. Spars with double spreaders will benefit from this approach. But if you have just a single set of spreaders, with fore-and-aft lower shrouds, bending your mast is not feasible. You can apply some backstay tension to flatten your main a bit while sailing upwind in moderate to heavy air, but these systems are essentially meant to stay in column.

Reefing

One area where bend control can improve safety is when you are deeply reefed. As long as the head of the mainsail is above the staysail stay the mast will naturally tend to have forward bend as leech tension pulls the mainsail headboard aft. But when the head drops below the staysail stay it is trying to pull the lower panels of the mast aft. If the mast inverts as a result, certain disaster will quickly follow. If weather conditions dictate a deep reef, by keeping backstay tension high you can ensure that the mast bend stays forward even with the mainsail headboard pulling aft.

Using Spar Bend

The control of mainsail shape offered by the bendable spar opens up a whole series of possibilities for helping boat speed and sailing comfort while reducing weather helm. Let's see how these controls work offshore.

Starting from the dock or anchor, the backstay and cutter stay will be relaxed; no use in keeping unnecessary tension on the rig or hull when you're not sailing. Not sure of what breeze the day holds in store for us, we keep the backstay eased as the mainsail is hoisted and sheeted home. In light airs the sail has a nice full shape with the pocket about mid-way aft. As the jib is set and cranked in, the boat starts to accelerate and heel. With the backstay eased there is a considerable amount of sag in the headstay. Since we're reaching in light airs the fullness of the jib helps keep the boat moving, and the helm feels good with just touch of pull on the rudder.

Outside the entrance to the bay we head up hard on the wind. The jib is now too full and the main is being backwinded as the jib is sheeted in hard. We tighten the backstay, taking sag out of the headstay. This flattens the jib. The mast bends slightly from the backstay tension, taking some of the pocket out of the mainsail. Pressure on the helm is eased and some of the mainsail luffing is reduced. With 14 knots apparent wind the five inches of mast bend looks just right. We sail along for an hour or so and the afternoon wind starts to build. It's now blowing a steady 17 knots apparent with gusts to 20. We're barely able to cope with the gusts as the boat heels over and weather helm really asserts itself. Without a bendy rig, now would be the point at which we would have to reef the mainsail.

Instead, the backstay is cranked up to its maximum and we start to tighten the cutter stay. The cutter stay efficiently pulls the mast forward. The mainsail is now almost board flat. The point of maximum draft has moved forward and weather helm goes back to a tolerable level. Heel angle is reduced substantially. The speedometer climbs perhaps half a knot, too.

We power along for another hour and the headland is rounded. Now it's a broad reach to the next anchorage. With sheets eased and the boat moving nicely off the wind, we decide the main can use more camber (curvature). We ease off the cutter stay. The mast unbends itself back to its initial position and the mainsail changes to a good off-the-wind shape.

Going Bendy

What's your next step if you want to try out a bendable cruising rig? First, see your local rigger or sparmaker for his recommendations. Many older spars are so conservatively engineered that they will adapt nicely. The next step is your sailmaker. You'll want him to look at your ideas and get a feel for how much mast bend he would like to see for your existing or new sail. After this, be sure your spar is correctly tuned and that the backstay and cutter stay positions, when they are fully extended, are such that the mast still has its minimum required fore-and-aft bend towards the bow.

If a new spar is in the cards, things get a lot easier. You will want a good-sized masthead crane with a variety of attachment points for the backstay. Next, consider using a large reinforcement or doubler from belowdecks to the lower spreaders. This will allow you to switch from double lower shrouds to single lowers, as it will stiffen the bottom section and keep it from pumping. Using a good-sized spinnaker-pole track from deck to lower spreaders also helps mast strength and allows you to stow the spinnaker pole vertically when required.

Remind the sparmaker that this is a conservative bendy rig, and you want it set up so that regardless of what mistakes the crew makes it will stay in the boat. It can be done.

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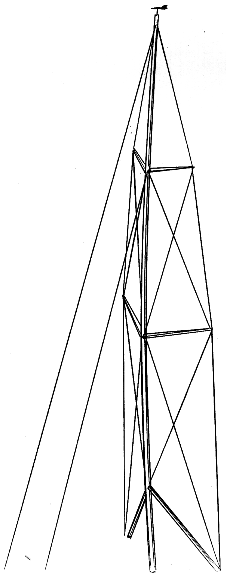
B&R RIGS



A schematic of the B&R rig (above) as it is set up on *Route 66*. (B&R illustration)

Lars Bergstrom and his long-time partner Sven Ridder developed their B&R rig in the 1960s. It is an elegant solution to the problem of panel stiffness, mast cross-section, and reliability.

Basically, they added a series of reverse diagonal stays to a conventional rig. Instead of having just one diagonal from the spreader tip up, they added a second from the tip down.

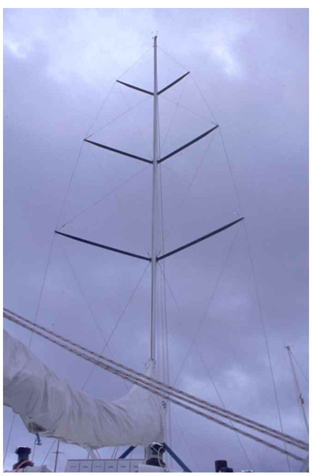
This allows rigging on both sides of the spar to be set up as a truss, with the pull of each wire opposing its opposite member. The lee side rigging stays taught, and because the mast is held more tightly, the cross-section of the mast can be smaller. A smaller mast cross-section means less windage and flow disturbance over the front of the sail.

When they started to work with BOC boats, they added some wrinkles. To begin with, spreaders were swept aft at 30 degrees. When you take two 30-degree aft-swept spreaders and oppose them with a headstay, no backstay at all is required.

The next step was to incorporate a tripod at the mast base, above the deck, to take the compression load of the rig and efficiently distribute it into a wide area of hull — as opposed to a very concentrated load with a conventional mast step on the keel or hull bottom.

When they worked up the rig for *Route 66* they added a final neat idea — a boom that was fixed in its horizontal plane so that no sheet vertical loads were taken on the sheet, and the vang was a permanent structure.

Thursday's Child (right), one of the first BOC boats to use the B&R rig. Elimination of the backstay not only unloads the hull, but also makes it possible to use a high-roach mainsail that is far more efficient than a triangular-shaped sail.



Route 66 from the stern (above).

The B&R tripod (above) spreads the mast load into the hull and reduces the required length of the mast. (Lars Bergstrom photos)

One interesting feature of the combination of swept spreaders and reverse diagonals is that the mast can be pretuned with a certain amount of mast bend, the amount of bend being adjusted by the reverse-diagonal stay tension. Once tuned, the shape is locked in by the opposing forces of reverse and normal diagonals. No intermediate stays are needed to hold the mast forward.

If you want to adjust headstay tension with the B&R rig, rather than employ a backstay, you adjust the headstay tension (typically with a hydraulic cylinder). The headstay pulls against the two sets of aft-swept shrouds.

The stiffness or inertia required in a B&R rig is anywhere to one-half to one-quarter that of a conventionally-stayed rig, according to Bergstrom.

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This makes for a huge difference in weight and windage aloft, even taking into account the extra tangs and reverse diagonals.

One of the advantages of this type of rig is the greater degree of redundancy than other rigging plans. You are not as much at the mercy of every piece of rigging on the boat.

In the last BOC race, Steve Pettingill was driving *Hunter's Child* hard on a spinnaker reach when one of his shrouds terminals failed. He was able to drop the chute and rig a temporary repair than enabled him to finish the leg and the race, ending up second overall for the best American finish ever. With a conventional rig, losing a weather shroud would have meant the end of the rig and the race.

The trade-off in this rig is the increased complexity, and the restricted sail angle when running before the wind.

CARBON-FIBER SPARS

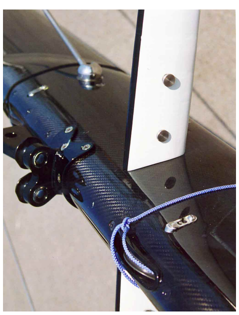
For the past decade we have watched the development of carbon-fiber spars with a great deal of interest. After all, who wouldn't want to reduce weight aloft?

Consider the advantages of a major reduction in weight: Vertical center of gravity drops, range of stability improves, sail-carrying ability gets better, less motion, and less pump in a seaway.

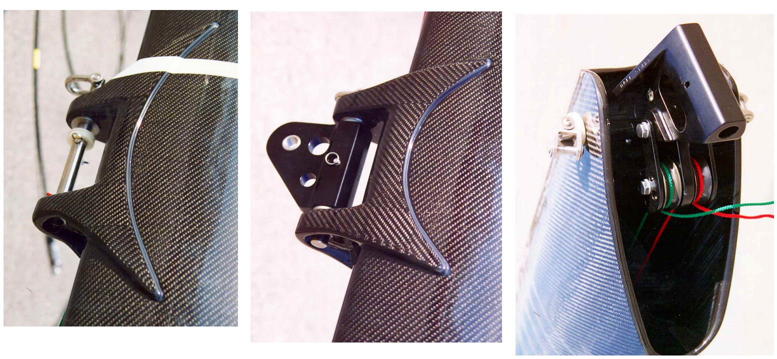
So far, so good. When carbon fiber was first being used for spars, the cost premium ran three to five times that of a quality aluminum stick. Today, the premium is down to about 30 to 50 percent more than a custom spar and shows signs of dropping even further.

Adding this much to the cost of your spar may not be a big overall increase in the total cost of a boat. Will the benefits be worth the cost? Or is there a better way to spend the money to obtain boat speed?

Although carbon-fiber spars are typically painted so you cannot tell them from their aluminum cousins, these black spars and their integrated fittings (above) look like works of art.



A typical spreader bar detail (above). An aluminum compression plate runs through the spar, over which sits the spreader.



Goosenecks (above) are detailed in a manner similar to what you would find on an aluminum race boat rig — gracefully tapered reinforcements with the actual connecting (or wear) surfaces built up in aluminum. Clevis pins are stainless steel. (All photos this page courtesy of Hall Spars)

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An interesting mainsheet detail. This is a Vectran strop for attaching the mainsheet block. It is used instead of a shackle to eliminate the metal to metal wear of a shackle and boom bale. Many BOC boats are using this approach as well. It also makes sense for cruising.. (Hall Spars photo)

Vang attachment to the boom is done with an internal aluminum or stainless weldment, fastened in place with a series of stainless bolts.

The laminate in this area will be built up to take the concentration of stress from the vang loads and the stress riser created by the slot in the boom. (Hall Spars photos)

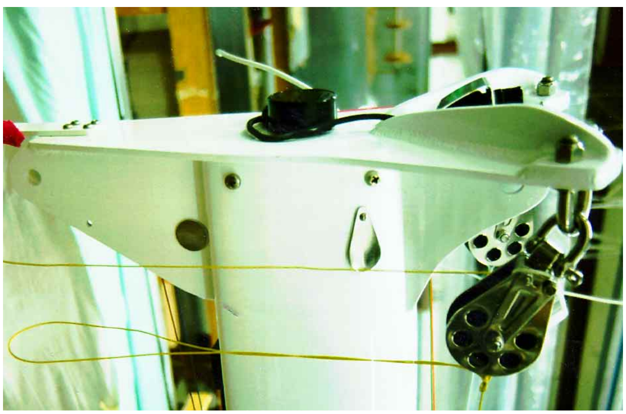
Much depends on hull design and rig height. Older designs with long overhangs and very tall rigs will benefit more than a short-overhang yacht that pitches less going upwind. A short-rigged vessel will benefit less than a boat with an extremely tall rig.

If you are shy on light-air performance and want to increase rig height, but have a VCG problem or are limited by range of stability, the only option may be to put a taller carbon rig in the boat. Or, if draft is a major issue, an efficient way of reducing keel depth is to reduce rig weight.

Weight Savings

If you plan to spend a ton of money on a fancy lightweight rig, be sure of exactly what the weight savings will add up to. As with anything to do with rigs, reality can vary from theory.

If you break your spar package into its various weight components, you end up with the following: Mast tube, hard spots (winch bases, mast head, halyards, spreader bases), spreaders, boom,



Using aluminum or stainless hard spots on a carbon-fiber spar is less costly and only slightly heavier. However, the metal must be isolated from the mast laminate — especially with aluminum. These details show one of our older designs, a Deerfoot 2-62. The owner was looking for more performance from reduced weight aloft and a taller rig. GMT, the sparbuilder, isolated the various materials with fiberglass laminate. (GMT photos)

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attached hardware (winches, cleats, sail track, spinnaker track), standing rigging, and running rigging. Of the total rig weight, for the average aluminum rig, the tube itself weighs typically between 40 and 45 percent of the total.

The most cost-efficient way to build a carbon-fiber rig is to use aluminum spreaders and an aluminum boom. If hard spots on the spar are made of stainless and aluminum, this leaves only the carbon-fiber tube to you save on weight.

Tube weight savings range from 30 to 50 percent — depending on whom you talk with, the production process used, and the type of carbon fiber.

As more real-world cruising experience is gained with these rigs, I would expect to see even better savings. The conservative rigs today probably have an extra fudge margin since the material is so new and the industry lacks a substantial historical database.

Fault Tolerance

When a mast tube fails — almost always in buckling, due to the failure of a piece of rigging allowing the spar to get out of column — the failure mode is usually localized buckling of the tube wall. The structural properties of carbon fiber are such that you can bend it much further out of column without localized buckling than would be possible with an aluminum mast of similar stiffness. This makes the rig more fault-tolerant. There are several amazing stories of rigs that have stood up under load while being jury-rigged after a piece of rigging wire or an end fitting failed.

Material Types

The structural capability — primarily the compressive strength and stiffness (modulus of elasticity) — of carbon fiber comes in various grades. At the low end of the scale, values are typically 80 percent of the very best stuff. Price, however, goes up geometrically, with the best grades of carbon fiber costing two to four times as much as the more mundane grades.

Manufacturing Processes

Here is where the debate really heats up, literally and figuratively. The structural efficiency of a laminated spar is a function of the carbon fiber's inherent strength, the orientation of those fibers, the strength of the resin bonding everything together, and the amount of voids (or air) in the resin. Resin acts as a glue and is much weaker than carbon, so that any resin over the minimum required to bond the fibers together is wasted weight. Both the strength of the resin and the resin-to-carbon ratios are directly related to the temperature and pressure under which the laminate is cured. Theoretically, the higher the heat and pressure, the better physical properties you can achieve. Almost all carbon-spar builders use pre-impregnated carbon fibers with a resin system that does not start to cure until it reaches a significantly elevated temperature. The use of pre-pregs (pre-impregnated reinforcements) allows the entire laminate to be put into or onto the mold at once, then vacuum-bagged together. The part is then placed in an oven and cured.

Hall Spars uses an aerospace-style autoclave for the curing process. This autoclave can reach extremely high pressures and temperatures, and they claim significant advantages for its application. Not surprisingly, spar builders that do not use an autoclave say there is not a great difference between the autoclave and spars laminated under a vacuum bag at elevated temperatures. There are a number of major design firms which now require the use of an autoclave for carbon spars on their designs.

Fiber Orientation

For pure compressive loads, a straight up-and-down mast orientation would be most efficient. However, once a bit of bend gets into the equation, the fibers on the inside of the bend — those that are in compression — try to pop out through the surface. If this happens, a total compressive failure results. So, off-axis fibers are placed into the spar laminate.These also help to control twist or torsion in the section. Some of these run at right angles, and some on the diagonal. The actual mix varies with engineering philosophy and spar design requirements. Off-axis fibers generally represent between 20 and 35 percent of the total.

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Hardware Attachment

Hardware attachment has been a problem for many spar builders. With aluminum bases or mastheads, you have to worry about corrosion between the aluminum and the carbon fiber. Because aluminum is less noble, it corrodes. Where aluminum is used, it must be isolated totally from the carbon. Some builders use a fiberglass laminate between the two surfaces while hard-anodizing the aluminum base.

Many builders today are doing away with metal parts almost entirely, switching to carbon fiber for winch bases, halyard leads, and mast heads.

Where bearing is required, as with sheave axles, a stainless sleeve may be inserted into the carbon-fiber laminate.

Sail tracks are most often attached by drilling and tapping a metal track affixed on the inside of the spar.

Lightning

Lightning is tough to handle even with a good conductor to discharge the static electricity before a hit occurs, or to conduct it to ground (the sea) after it hits the mast. An aluminum spar provides a good conductor, but what about carbon fiber? The carbon itself works pretty well. However, a resin matrix creates internal resistance, so the transmission of the energy imparted by a lightning strike is inefficient.

With resistance comes heat, and with heat comes potential failure in local areas — often difficult or impossible to detect.

I asked three spar manufacturers about the lightning issue and did not get a satisfactory answer. Everyone agrees you need to provide an efficient ground path. Some recommend running a #4 AWG cable from masthead to ground plate. Others talk about bonding in a special metal mesh on the aft surface of the spar to conduct electricity down the *outside* of the mast (this way if there is a heat problem it is outside the laminate—leaving the internal, structural laminate undamaged).

I don't know the correct answer. I only know that the issue troubles me. It would take some careful analysis of the data before I could accept any of the suggested approaches.

One way to get a feel for how strongly the spar makers feel about their solutions is to see if they will guarantee your spar in the event of a lightning strike.

The last of the Deerfoots was fitted with a carbon-fiber spar from Eric Goetz's company. They have a traditional lightning rod at the top, with #4 wire running down the inside of the mast tube and then to a keel bolt. This vessel has been hit twice by lightning. One of the hits was strong enough to knock out all electronics, including unattached handheld gear. Visual inspection yielded no signs of internal structural damage in the laminate.

Longevity

Let's take a look at the other problem — longevity. We know anecdotally, on a short-term basis, that carbon does work. It has a good track record in BOC around-the-world races, and it has become the material of choice for mega-yachts in the last few years. Companies like Carbo Spars in the U.K. and GMT and Hall Spars in the U.S. have been building carbon-fiber spars since the late 1980s. Failures have been rare. But how well it does over decades of use is open for debate. Only time will tell.

Decision Time

Does carbon fiber make sense for you? Forgetting budget for a moment, if your boat has a tall rig and a problem with pitching or rolling, you can reduce total weight aloft by 8 to 20 percent, with a huge impact on comfort and performance.

What about for long-term cruising? Here I get a little less comfortable. Certain spar makers have a large database from which to engineer, and by now they ought to know what it takes. Still, we are only at the beginning of the learning curve with this wonderful material.

As costs come down, and as the experience base for owners and builders to draw upon grows, I suspect we'll be seeing more and more carbon-fiber spars in the out-of-the-way cruising areas.

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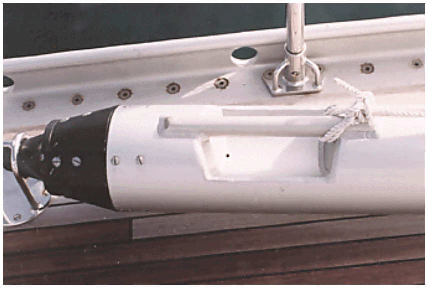
SPINNAKER POLES

Spinnaker-pole size should be conservative. We've seen small-diameter poles often sold as whisker poles for jibs. They work fine in bay waters, but offshore, running before a good-size sea or carrying a jib at close apparent-wind angles, their failure rate can be high. Even if you don't intend to carry a spinnaker, the pole should still be sized for these loads. It should be at least as long as the base of your foretriangle.

The pole should be as light as possible. A large-diameter pole with thin walls will be stronger than a skinnier, thicker-walled pole of the same weight. *Intermezzo*'s spinnaker poles were 6 inches (150 mm) in diameter. Sitting on deck they looked like they weighed a ton, but in reality they were thin-wall tubes that had been chemically milled even thinner. Substantial diameter made them extremely strong but light. I could pick up their 25 pounds (11.3 kg) with ease and maneuver them singlehanded in a seaway.



The biggest issue with any spinnaker pole is handling it. Having something built in that you can get your hand around is a great help. Here are two approaches. The welded-in handle is a nice detail and not too costly to execute. The inboard end, however, will need to be carefully detailed so as not to lose too much metal where compression is at its highest.

My favorite approach is sewn webbing — light, easy to execute, with no impact in the pole strength.

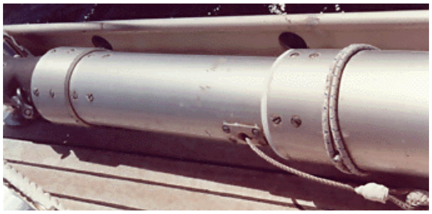
Carbon Fiber

Another approach for larger poles is carbon fiber. Pole weight can be cut 30 to 50 percent using this material. It used to be that carbon-fiber poles cost two or three times more than an aluminum pole. But the day is drawing near where the costs will be almost the same.

The drawback is with impact. Carbon fiber doesn't like to bang into the headstay — a normal occurrence when sailing shorthanded. To mitigate this problem, the end of the pole is wrapped in protective foam padding with a leather cover. Specifying an outer wrap Kevlar in the impact areas will also add to longevity.

End Fittings

A wide variety of end fittings are available today. Simple piston ends and mast cars with rings are the least expensive and work well, up through 35- to 40-foot (10.7m to 12.3m) boats. For larger boats, it's wise to investigate the articulated cup, male and female inboard end arrangements.



Telescoping poles are usually more trouble than they are worth. If you are headed offshore you want a pole with plenty of beef. It is hard to detail a telescoping pole to be as strong as one made from a single piece of pipe.

When reaching with the spinnaker, the mast gear on the end of the pole is in straight compression, but when running with either chute or jib, you have to contend with the compression load as well as a bending moment. To carry this, the mast fitting and track have to be stoutly made and strongly attached. The track should be tapped and bolted if possible. Avoid rivets unless they're structural, and even then use them as a last resort. If the spinnaker car–track loads were in plain shear or sideways load, rivets would be fine. But there's the possibility of a combination of shear and a lifting type of load, as the car tries to rotate the track off the mast.

On the outboard end of the pole, a fitting with gently rounded shoulders is critical. Otherwise, chafe on the afterguy is a major problem. You'll want to be able to trip the outboard end fittings from the mast as well as from the outboard end of the pole.

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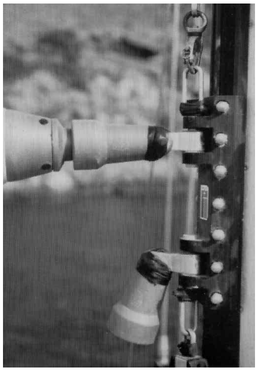
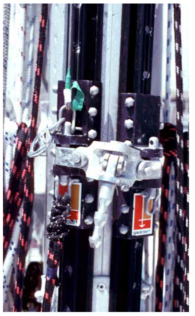
One Pole or Two?

If you are set up correctly, with a long-enough mast track and removable cutter stay, single-pole jibes are very quick and easy to accomplish when carrying a chute in light airs. However, as the breeze starts to build, some sea begins to roll under the boat, and boat size increases, twin-pole jibing begins to look quite attractive.

By rigging the spinnaker with two sets of sheets and guys, the leeward pole can be connected to chute and guyed down before you jibe. There is no time pressure and the spinnaker is always under total control. In fact, in sloppy running conditions, it helps to fix the chute between two poles. This is such an effective means of limiting the risk of twists and reducing oscillations that using two poles at once is banned in racing.

Of course, the second pole takes space on deck and costs money. *Intermezzo* came to us with two and we sold one after the first year of cruising. However, we generally specify two poles on our larger yachts, so that they are available in case sea and wind conditions dictate their use.



On smaller yachts, a simple plunger-type inboard end fitting and ring car will do the job nicely. Keep the track well-lubricated and free of burrs, so the car can move easily (left).

We prefer to use clunky-looking bell-style inboard ends (middle photos). These have a higher factor of safety than the piston-style fittings. When there is any misalignment between pole and mast car, they help to reduce bending-load failures.

The length of the toggle between receptacle and car should be as short as possible. The shorter this toggle is made, the fewer problems you will have keeping the attached hardware in alignment. The various pinholes need to be carefully drilled and kept to tight tolerances, so that slop is at a minimum.

If you stow your pole vertically, the toggle must be long enough to allow the receptacle to align itself with the pole in the vertical position.

Twin spinnaker tracks (above) add reinforcement to the front of the mast, but also force you to use twin poles when jibing, since you cannot square back a pole connected to the leeward track.

Note the piston-style connecting pin. These are of such small diameter that they have a pretty high failure rate with time and must be watched carefully.

Generally speaking, the easiest way to control the height of the spinnaker pole butt (mast end) is with a continuous tackle. However, several different forms of line drivers are available around the world.

If you go for one of these systems, make sure the locking mechanism is secure, easy to operate, and not subject to accidental dislodging. A spinnaker pole dropping on your head from some distance aloft will have a deleterious affect on your health.

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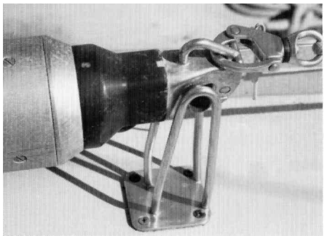

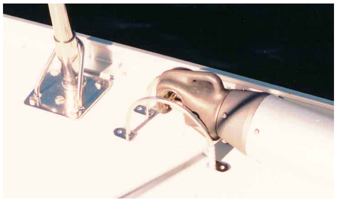

Spinnaker-pole hardware should be robust for offshore work (above and left). A wave sweeping across the deck will exert huge amounts of force on the pole. Mounting hardware should be through-bolted, preferably with backing plates.

A vertically stored pole (above right) with a nicely faired bottom bale welded to the spar.

Two approaches to capturing the pole on the pulpit (left and right). This will make handling the pole in a rolling sea much easier.

Spinnaker Pole Storage On Deck

The best place to store spinnaker poles is on deck. Here they are relatively low in terms of center of gravity, and windage is not a factor. In terms of handling, properly set-up poles on deck are almost as easy to handle as those mounted on the mast.

The key is to mount the poles fairly far aft. This way, when you attach the topping lift and push to pole forward, the forward end automatically lifts up. You can fiddle with positioning of the pole to find an ideal location, so that when the pole is ready to connect to the mast, the forward end rests on the pulpit.

Mast Storage

There are several ways to store poles on the mast. With a single pole, use an extended centerline track long enough to take the full length of the pole. Twin poles require two separate tracks placed on the corners of the mast. The mast hardware should be heavily made, as there can be tremendous bending loads when walking the poles forward to get them into sailing position.

The cheapest approach is to use a fixed pivot point on the mast at the upper end of the pole. The lower outer end is then hoisted up to sail clew height by the pole topping lift. The disadvantages here are that the pole cannot be brought down to deck for storage, and that the clew of the headsail to which the pole is attached must be very high, since the pole's inner end can't be adjusted down.

The next scheme is to pivot the bottom end of the pole at about shoulder or working height on the mast. When stored, the outboard end of the pole is propped up into a chock aloft. The problem here comes in properly securing the pole when it's aloft. If you're pounding into a head sea or rolling around in light airs, it's virtually impossible to stop the rattling of the poles completely. And you can't adjust the inner end of the pole to keep it horizontal when in use.

Chicken Stays

The chicken stay is a temporary support for the mast, used to offset some of the load of the spinnaker pole. Usually a short wire with a turnbuckle at the end is attached to the mast about 6 or 8 feet (1.84 to 2.2m) off the deck. The bottom end of this runs at a 45-degree angle from the centerline to the cap rail. In heavy going, it will add substantially to safety factors, especially if the pole is rolled into the water. Of course if your cruising rig requires chicken stays it is probably a bit on the light side for carrying a chute in any sort of a breeze.

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Now here's a bowsprit! This is my dad's first sailboat, a friendship sloop, on which I was conceived (or so the legend goes). The bowsprit on *Duchess* was almost one-third of the boat's length, right in line with today's sport boats. Except this probiscus does not retract.

TRADITIONAL BOWSPRITS

Having grown up with bowsprits I can tell you that nothing is quite as adrenaline-rushing as being stuffed through the face of a sea while standing on wobbly bowsprit netting and trying to hand an outer jib.

Today most folks use roller furlers for their bowsprit-led headsails, so unless something goes wrong, there's little fear of getting wet.

If you are considering one of these devices, look hard at the connections on the bow stay and side stays. The lead of your anchors to the water, around the bobstay is always a problem. For tide against wind, and/or situations in which the boat is oscillating on the hook, a good idea is an attachment point for the anchor rode below the bobstay at the waterline. This lets the boat swing without fouling the rode.

If designing a boat with a bowsprit, examine the cost issues carefully. Bowsprits are expensive to execute. In almost all cases you could have a longer hull for the same or less investment, with additional waterline and a more stable platform from which to work on the headsails.

MODERN BOWSPRITS

It must have been about a decade ago when I first saw the Ultimate 30 with its huge bowsprit. I looked at this device — at least half as long as the boat hull — and thought to myself, now there's an idea for cruising!

At the time, since *Sundeer* was new, I thought long and hard about adding a sprit. In the end, we had so many other new things to learn that I didn't pursue it — although we added one for her next owner.

The potential advantages for beam- and broad-reaching are substantial. First, the asymmetrical spinnaker shape flown from the bowsprit is much more efficient than a symmetrical chute for tight apparent-wind angles. With the tack of the sail so far forward, the clew can be quite high, giving a nice lead for close- and broad-reaching. With less mast overlap and a forward luff, there is less (or no) tendency for the boat to round up in puffs. And since jibing is of course similar to working with a large, light jib, sail handling is much easier.

When the time came to build the Sundeer production series, I sat down with the TPI engineers to develop a retractable-bowsprit design that would work for daysailing and offshore.

They had a pretty good database, having built a whole bunch of retractable carbon bowsprits for the J-Boats. In theory, scaling up in size to the larger Sundeer 64 should have been easy.

The first day we sailed with the bowsprit, we were flying a moderately-sized spinnaker John Conser had made for us. The air was light, and the sail and bowsprit combination worked wonderfully. We noticed a bit of flexing in some powerboat chop, and when we came in I asked the TPI engineers about the flexing. "No problem," was the reply.

The next time we sailed the boat with a bunch of folks from a magazine. After messing around with working canvas, we set the chute in 14 knots of true wind and took off like a shot. As we headed out toward the sound, a series of seas swept in towards us. The bow blasted through with only slight deceleration. That very light shock loading, however, was enough to do in our undersized bowsprit.

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Back to the drawing board. Several weeks and a great deal of weight later we had a design that, after further modifications, has worked without difficulty since.

The point I want to make is that sprits that work for sport boats will not necessarily stand the gaff offshore, with the boat blasting through big seas and occasionally stuffing the bow.

Bowsprit Loading

Theoretically, bowsprit loading can be calculated by looking at the sail area carried in the spinnaker and the amount of wind in which the chute can be carried, then adding a factor of safety.

Most loading is in line with the direction of the luff, pretty much vertical, with a small percentage of load trying to bend the sprit to leeward.

There also needs to be a healthy dose of real-world experience.

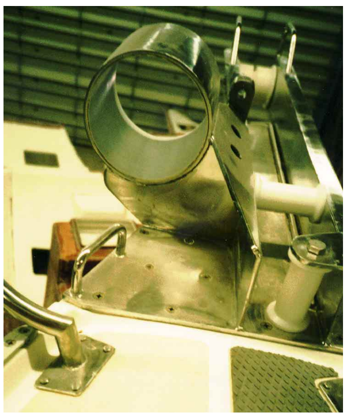
Cantilevered

Most modern sprits are cantilevered, meaning they are supported at the bow, and aft some distance on the deck, but the portion that protrudes forward is not supported.

In this configuration the loads are primarily bending in nature, much like a spade rudder. The bow fitting has the highest concentration of the bending load. The buried (inboard) portion of the sprit counters the bending load.

The longer the inboard portion is, the lower the loads on the two connection points.

An interesting comparison of the same spinnaker being flown with and without the bowsprit (above and left). Notice how much flatter and more open the leech is when the chute pulls the tack forward than when it is aft at the stemhead fitting. (Billy Black photos)



We incorporated the forward bearing for the sprit into the bow weldment, which included the bow-roller assembly for the 176-pound (80kg) Bruce anchor. The inside of the stainless pipe was lined with teflon to ease the passage of the sprit on its way in and out (above).

One of the sprits stowed (left). The forward end is held in the stainless carrier, while the aft end fits into a socket on the deck. You can see the butt-end carrier just forward of the hatch (and aft of the cutter stay). This is about four times the strength of what we started out with.

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Three different views of Sundeer 64 bowsprits.The projection forward was just 8 feet (2.4 m) — not particularly aggressive. However, the sprit ended up weighing almost 120 pounds (54.4 kg), so anything longer than that would have been difficult to handle due to increased weight. Note the inboard end fitting (lower photo).This turned out to be too light and was replaced with something a lot stronger.

Stiffness comes from the diameter and modulus of the material, so a cantilevered sprit is an ideal situation for a large-diameter carbon-fiber laminate.

One way to substantially reduce the bending loads is to introduce a fixed bobstay, limiting the amount the pole can bend upwards.

Retractable Hardware

Hardware obviously needs to be robust. There is no problem getting the load out in the bow area, since plenty of structure is concentrated in this area. However, the inboard end of the pole, back some distance, will fall in the middle of a large deck area. Unless this sits on a bulkhead, some form of internal stiffening will probably be required to take the compression load on the deck.

Negatives

There are several negatives with retractable sprits. The first is cost. Second, they require a fair amount of deck space for storage. Finally, for daysailing you can put up with the fact that you cannot run with a centerline-tacked spinnaker, but broad reaching and running when cruising will call for a pole — although you could tack the chute to the bowsprit and sheet the clew to weather through a pole.

Many sport boats and all J-Boats retract their bowsprits into the interior. This is clean-looking and does away with exterior storage issues. However, they are difficult to keep watertight and in heavy down- or upwind conditions, significant amounts of water can find its way into the hull. We do not feel this is a good concept for cruising. If you plan to have a retractable sprit, it should be deck-mounted so that water leakage is not an issue.

Another approach is to have a sealed housing tube, with bowsprit extender lines led forward and over the bow. Pitching the tube slightly down at the bow ensures it will self-drain.

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PIVOTING BOWSPRITS

The geometry of the pivoting bowsprit is the key to a system operating within moderate, predictable loads.

A removable preventer wire keeps the sprit from going past centerline, while the lazy guy (leeward side) makes it impossible for the sprit to pivot too far aft to weather.

When the pole is close to the centerline the bowsprit spreaders act like a jockey pole with a conventional spinnaker pole, keeping the guy angle from getting too tight.

When the pole is angled aft, the guy has a nice, wide, low-load angle with which it can control the sprit.

When we designed *Beowulf* we thought we would use conventional spinnaker poles with asymmetrical chutes. In an offshore context, this would afford the best of both worlds. But when we began to consider the required pole size, we realized we would be forced to go with carbon fiber, and that two poles would be required. *Beowulf* is a hair big for two people to dip-pole jibe the spinnaker! As you can imagine, the cost — not to mention the space taken by two 8-inch (200mm) spinnaker poles — was substantial. So we decided to take another look at the bowsprit, this time in an articulated form so we could rotate it and bring the luff around to windward. We mocked up the concept, and it looked feasible. The engineering was simplified by the fact that we'd have a bobstay and two side stays, with rigging much like a mast. The bobstay took the upward forces, while the side stays retracted the force, pulling the pole to leeward.

A number of BOC boats have tried this approach — the result being broken hardware. Investigating their problems, it seemed to us that mistakes with the after guys were the main culprit. If the guy is eased too far, so that the pole goes past center, the loads build geometrically.

Construction Details

Rather than go exotic, we constructed the bowsprit from welded aluminum. For the 8-foot (2.4m) sprit we used a 4-inch (100mm) schedule-40 pipe. We used 2-inch (50mm) pipes for spreaders and constructed a heavy weldment just forward of the headstay to take the compression load. For the bobstay we had a bit of a conundrum. It had to be able to support the sprit and my weight when no sail was lifting the end. This meant the bobstay would have to take some compression load.

We looked at using a -30 piece of rod rigging. Not only was this expensive, but it looked marginal for holding up my weight, especially if the boat were to hit a wave, inducing any G loads. We ended up using a chunk of solid 1 1/4-inch (32mm) aluminum rod. This was twice the diameter of the stainless rod, but would support my weight at one-quarter the cost.

For minimum loads the bobstay should come as low on the bow as possible. However, when the pole is angled aft, the lower the bobstay is at the bottom, the more drag it would have. In the end we compromised, bringing the base of the bobstay up one-third of the way from the waterline. This was enough to keep it out of the water in light airs when the drag would be most critical.

The total weight of the bobstay, bowsprit, and control lines was about the same as two carbon-fiber spinnaker poles.

Rigging

To control the angle of the sprit, we used guy wires attached to the end of the sprit and coming back to chainplates on the rail, abeam of the mainmast for best angle when running.

When the pole was on the centerline, these guys would fit over the end of fixed spreaders. These spreaders serve the same function as a reaching strut and keep the angle between the hull and end

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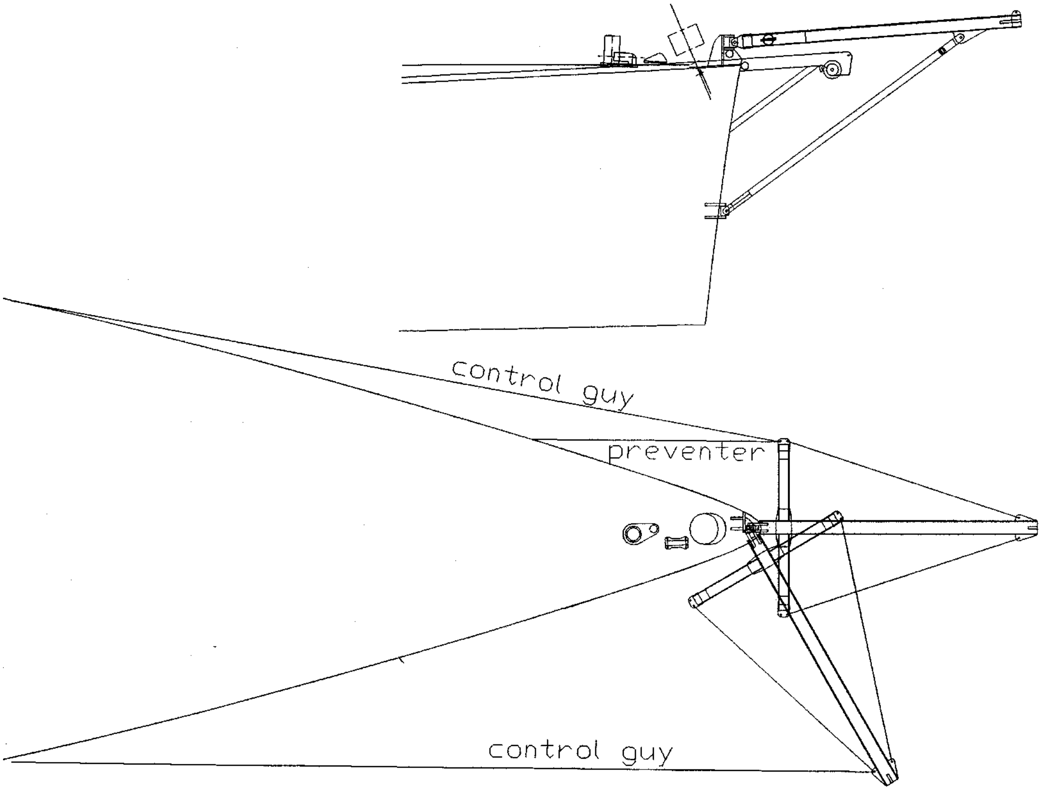

Here are two illustrations of *Beowulf's* bowsprit. At top you can see a side view of the sprit, the dolphin striker (or bobstay) which prevents the bowsprit from lifting, and how this interacts with the anchoring gear — a tricky proposition. The anchor sprit is lower than the bowsprit. The top of the 176-pound (80kg) Bruce anchor is below the bottom of the bowsprit. When the bowsprit is rotated over the anchor (to starboard) there is ample clearance.

The plan view (looking down) shows the bowsprit in the centered position, and when canted at maximum angle (to starboard). Note the preventer line that makes it impossible for the bowsprit to move past center by accident — a leading cause of premature death among these moveable appendages. When the bowsprit is square back in broad-reaching position, the guy has a very nice angle with which to work, reducing loads. We used 5-to-1 tackles led to #40 winches in the cockpit to control angle. Even at the limit in wind strength for our main spinnaker, this after guy-controlled bowsprit angles without a great deal of effort on the winch handle.

of the sprit from getting too tight. The guys were made from 3/8-inch (9.6mm) galvanized 7x19 wire. We attached 5-to-1 tackles to the end of the guys, leading back to the cockpit area, where they ran through a Lewmar rope clutch to a #44 winch. To control the tack, a 4-to-1 tackle was led from the end of the sprit back through a jammer to a winch at the mast.

Wary of the accidents that had befallen the BOC boats with pivoting sprits, we added preventer guys to the system. These were short lengths of wire with a heavy snapshackle on the end, attaching to a chainplate about 6 feet (1.8 m) from the bow. The weather guy is always attached as soon as we have the pole in position after a jibe.

If someone were to ease the control line too far, or if it were to break, the preventer would make it impossible for the sprit to go past center.

After 8,000 miles of passaging with the system, we have made two changes. First, the 4-to-1 tackle at the tack has been changed to fiddle blocks, because the side-by-side sheave blocks tended to twist under certain conditions.

Second, we added a retrieval line to the top of the tack-block stem, led through a block back a bit from the stem, which goes to a mast winch. This allows us to pull the luff of the sail aft before dropping it in strong winds (closer to the mainsail, where it is more efficiently blanketed).

In Use

We used the sprit with both an asymmetrical chute and a large reaching jib. The chute was jibed just like a jib. The only trick to the maneuver is to be sure the sail is well-eased before heading dead downwind, so that the clew is even with the headstay and ready to be pulled through. We never had a problem with a wrap, and although we carried a spinnaker net aboard, we never used it on the headstay.

With the reacher, which has its own roller-furling drum, we found that when the sail was unrolled, the furler tended to rotate the tack blocks, wrapping the control line around the tackle in the process. There are several approaches to this. One is to add a control stick (in effect a long piece of pipe) to the roller-furler assembly, and bring the control line through a block on the end of this stick. This makes it impossible for the whole unit to spin.

The second is to fix a piece of track to the top of the bowsprit, to which the roller furler is attached, then control the in-and-out position of the furler the same way you would a mainsheet traveler, with control lines to the traveler car. We found the control stick, although a bit cumbersome, worked fine.

Does This System Make Sense for You?

We love sailing with our pivoting bowsprit. It is truly easy to use, and very fast. The ability to get the luff of the chute or jib that small distance to windward allows us to carry these sails as deep as 155 degrees apparent (more if we put a reef in the main to allow air flow over the top of the forward sail).

For a boat like *Beowulf* with the ability to pull its apparent wind forward, it is the ideal system. However, if you cannot accelerate rapidly off the wind, odds are you will be better off with a conventional pole for running.

If you want to look at a system for your own boat, there are a couple of critical issues. The first is the geometry of upper and lower pivot points. They must be in line for the tip of the bowsprit to scribe a constant arc. By in line I mean over each other. If you have minimal overhang, as we do, this is easily accomplished by bringing the pivot point on deck aft a bit. When you do this, the bowsprit will swing through the area normally dominated by the anchor storage system and the pulpit.

In our case, starting from scratch, we were able to integrate the anchor roller into the entire weldment, carrying the anchor just below the sprit so the sprit rotates over the anchor when the anchor is stored. Also watch interference between the head of the anchor and the bobstay. When at anchor, we angle the bowsprit to port. This moves the sprit and bobstay out of the way of the rode and the shank of the anchor when it is pivoting back aboard.

Finally, the front of the pulpit needs to be open in front, with no vertical support until aft of the furthermost pivot point of the sprit.

While the loads of such a system are high, they are similar to those of a reaching chute. Any good spar engineer should be able to develop the numbers and bits for you.

There are two negatives in this system. First, I don't like the looks of the bowsprit and related hardware sitting on the end of the boat. Some would say it enhances our short ends, but to me it is plain ugly. The second problem is when you are docked or maneuvering in tight spots. Of course, by pivoting the sprit away from the closest obstruction, you can significantly reduce the length forward — but it takes us over an hour to remove the sprit. In reality, unless we have to fit in an especially tight spot, this just isn't going to happen.

Does this system make sense for you? If you are building new, I heartily recommend it, especially if you have a quick boat that can pull the apparent wind forward when sailing off the wind in light to medium air. Retrofitting to a boat with a short overhang forward might make sense. But if you have more than 1 or 2 feet (0.3 to 0.6 m) of overhang, it will be very difficult to get the geometry right.

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HEADSAIL ROLLER FURLING

Roller furling has become so pervasive in the last decade that everyone seems to accept it as the norm. That it offers benefits for daysailing is undeniable, but when you head offshore there are some issues which need to be carefully looked at.

Vertical Center of Gravity

To begin with, almost all roller-furling systems add significantly to weight aloft, especially if sails are furled in a hoisted position.

That weight aloft raises VCG, increases windage, reduces range of positive stability in a knockdown, and causes the boat to pitch more when beating.

Of course, you could drop and stow roller-furled sails at the onset of a blow, but few cruisers do that.

Sail Shape

A roller-furled sail has a higher clew than you might otherwise use. Off the wind this is fine, even an advantage, but upwind it is a big negative.

Because you cannot have battens in the leech, the leech must be hollow. For overlapping headsails this is the norm. But a modern mainsail-driven rig with non-overlapping jib will have significant loss in area and efficiency with a hollow leech and narrow head angle (compared to a full-length upper batten).

Because of the roller-furling drum at the bottom and the swivel at the top, you will lose close to 3 feet (0.9m) of luff length with most systems — a huge hit in sail area.

Reliability

If you are dependent on the roller-furler system, what happens if — or maybe we should say when — it fails? A control line chafes through or wraps around the bottom of the drum, or maybe the sail splits leech to luff in a partially rolled condition and cannot be unfurled to be lowered or rolled up.

Bearings fail, halyard swivels break, extrusions come apart. It's essential to have an answer for everything that can (and will) happen.

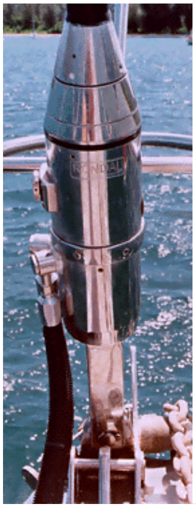
Changing Down

As the breeze starts to build, you want a smaller headsail in the forward triangle. If you try to reef your jib, several things happen. First, the sail is subject to loads in an area that is not engineered to take them. Even if the sail has reinforcement patches at specified reef points, it will be harder on the fabric than a sail designed for heavier wind loads.

A working sail heavy enough for strong winds will be too heavy for light and medium airs.

And in spite of all claims to the contrary, there is no such thing as a roller-reefed sail that looks as good as a fully deployed sail. As you reef, the sail gets fuller — exactly what you do not want. (For the third time writing a book in 15 years, we asked sailmakers for photos of roller-furled headsails beating in a breeze. Not a single sailmaker responded with a photo. That has to say something!)

There are several ways to go with the roller-furling gear. Simple manual controls work best. However, on large yachts the trend is to use hydraulic furlers. When loads get this high, I prefer an electric winch for furling. This reduces cost and weight compared to adding a hydraulic system.



The best thing to do when the breeze comes up is to change down to a sail designed for the wind range in which you are sailing. This means flatter cut, heavier cloth, and smaller size as wind increases.

Problems occur if this change takes place on a bouncy foredeck in a building breeze. Even with two people to handle the sail, one with halyard in one hand and the other working at the headstay, it will be a real chore to get the sail down and secured without losing it overboard. It's even more difficult to feed in the new sail without it jamming in the feeder or going overboard.

Jib hanks make the job easier to perform. The key is to change before necessary and/or use a working headsail that is conservative in size and weight — but this is, of course, too small and heavy for light airs. Another approach is to have a good-sized staysail and change down to it early, leaving you with the weight and windage of the roller-furled sail aloft. But none of these is as efficient as a properly-sized sail.

When Roller Reefing Works

Most modern roller-furling systems can be used for reefing when sailing off the wind. Yes, the sail will be fuller, but downwind this is not an issue.

Now that I've made the case for jib hanks, let's take a look at some of the details of roller furling.

Hardware

To begin with, be sure to choose the best gear available with a reputation for reliability. There are several hardware issues to address. One is bearings. How big are they, how easily serviced, and how often do they need changing? Next is the connection of the sections of extrusion that fit over the headstay. The method of attachment is the key to a long, trouble-free life. More problems occur because of set screws coming undone than just about anything else. Drum design and how the lines feeds on or off is another issue. I want to be able to see what is happening with that line.

Mast Issues

The lead between jib halyard and the roller-furler swivel mechanism is critical when the sail is fully hoisted. Unless there is an anti-wrap device, such as the one used by Profurl, the halyard needs to make a 15-degree angle to the headstay, or the jib halyard will wrap around the swivel and foil when you try to roll the sail. This means that the halyard sheave must be down the mast farther from the headstay tang than would otherwise be the case.

If you have small jibs that are short on the hoist, use a luff tape extension to get the halyard high enough for the required angle.

Control Line

The line or wire controlling the roller-furler drum should be as large as you can use and still get the desired amount on the drum. This is easier on your hands and tends to feed on the drum better with less chance of overrides. The larger the diameter of the wrap around the drum, the better will be your leverage when rolling up the sail.

The lead to the drum must be perpendicular to the headstay.

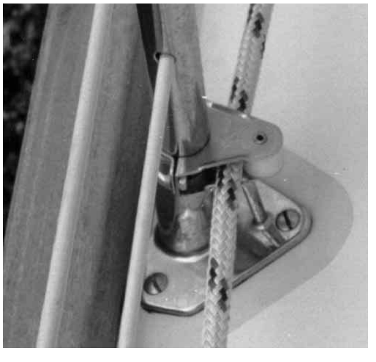
There are several ways to bring the line aft. We tend to go the simple route and bring it outside the stanchions, accepting the friction of the smooth stainless stanchions as the line bends around. At the aft end where the line comes across the deck to the cockpit, we have a turning block that leads to a winch, with a rope clutch to take the load once you are finished with the winch.

Cutter Stay

Every now and then we see a boat with a roller-furling cutter stay as well as headstay. We feel this is a mistake, as it makes it difficult, if not impossible, to change the size of heavy-weather headsails — in addition to adding another big chunk of weight aloft.

Whose Gear?

Now we get to the tough question. Because I have very little direct experience, I hesitate to recommend one company over another. However, in the last 15 years we've used two companies on our clients boats with good success. One is the Reck-



Two approaches to leading the furler control aft. We've always simply run it outside the stanchions, trusting that the smooth stainless surface will offer minimal friction.

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man Company from Germany, and the other is Profurl from France. Profurl is quite a bit less expensive and lighter and has been the choice for all our production boats. When the new owners of *Sundeer* decided to go for a furling system, we fitted Profurl and they were very happy with it. As much as I hate to admit it, we've now added a Profurl unit to the headstay of *Beowulf*.

Mariner System

Years ago — it must be close to 30 years now — Tracy Holmes developed one of the first production roller furlers. His system used a drum at the bottom and a hexagonal shaped tube at the top, affixed to the headstay with set screws and epoxy. The jib was hanked on in conventional fashion and hoisted until the head swivel was over the hex tube. When you rolled the bottom drum, it forced the tack around, while the top of the sail followed a turn or so later. While you could not reef with this system, for furling it worked great. We used one during our circumnavigation.

The gear is no longer made, but if you see some in a used marine store, grab it. It offers the best compromise, since it is lightweight and makes it easy to change sails that are still hanked on. Hank chafe inside the rolled sail does not seem to be a problem.

Free-Flying Headsails

We've already talked briefly about free-flying headsails on roller furlers. The technique has been around for at least 50 years. We used it on catamarans in the 1960s. Basically, you take the lower drum unit from a roller furler, and add a halyard swivel at the top. The headsail then has a plastic-coated wire sewn into the luff, seized at close intervals. When the drum at the bottom starts to turn, it forces the sail to roll up around itself. For downwind sails, this works quite well.

Recently, sailmakers have been using low-stretch lines like Vectran, Technora, or Spectra with some success. *Beowulf* has Vectran luff ropes on the reacher and mizzen jibs. These sails can be rolled up in 20 knots plus of apparent wind. When you drop the sail and are ready to stow, it will flake or coil into a very tight space. For lightweight upwind and moderate-weight reaching sails, the system works well.

Sundeer's working jib stored on the headstay, in a self-draining well on the foredeck. To make this work, the headstay at the deck level was about 3 feet (0.9 m) aft of the bow tip.

The jib was easy to hoist and to put away and had the advantage of being attached with hanks. However, it was not as simple to use as roller furling. The subsequent owners changed to a Profurl headstay-furling system.

Horizontal Roller Furling

When we designed *Sundeer* we did not want to use roller furling. Yet we wanted a system that would enable us to easily stow the jib. We ended up with a self-draining well on the foredeck, into which the headstay ran. The jib would be flaked on deck, then rolled horizontally into the well, after which the doors would be closed.

If we wanted to change down in size, the smaller, heavier jib would be hanked onto the headstay on top of the stowed working jib — a very easy-to-use system.

This is not the sort of thing that retrofits easily. It is better to plan for it from the beginning. The headstay will be set back from the stem a bit as it has to intersect with the headstay tang at the bottom of the storage well.

MAINSAIL FURLING SYSTEMS

There are several things that need to be considered when thinking about a mainsail roller-furling system. On the most basic level is the type of sailing you do. The higher the latitude and the further offshore, the more reliable the reefing system should be. Then there is sail shape itself. All mainsail-reefing systems except old-fashioned slab reefing have restrictions on sail shape. Windage and center of gravity are other factors. Some systems increase windage and have so much weight aloft that sailing stability and range of stability in a knockdown are compromised. Cost is certainly an issue as well.

What drives people to roller reefing for mainsails is a desire to better control sail size, to get under way more easily, or to quickly put the boat to bed after a sail.

With a slab-reefing system, the sail has to be uncovered, then raised and lowered, furled, and finally covered. I suspect it is the covering operation at the beginning and end of the day that takes the most time.

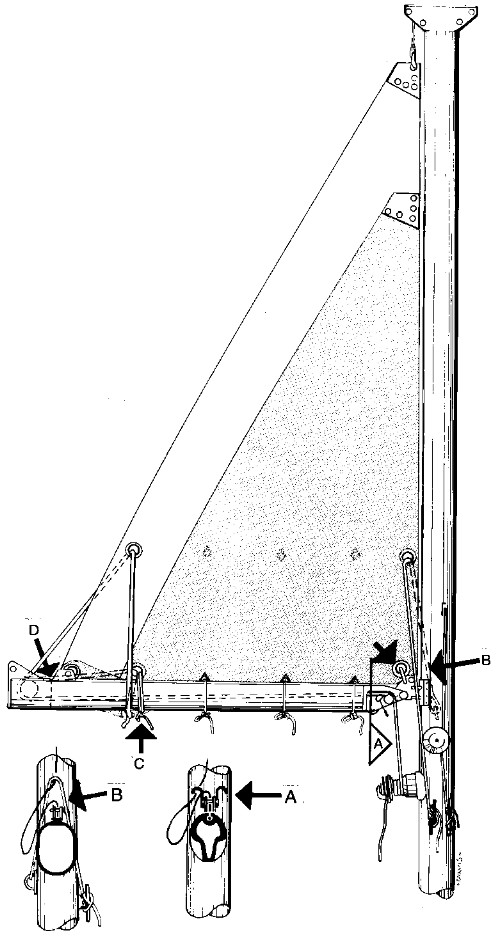
Many sailors with thousands of miles of experience will swear that their approach is the only way to go. However, what is right for you depends on how much performance you are willing to give up, where you sail, and how much budget can to devote to mainsail handling.

Slab Reefing

Slab reefing is the simplest of all the reefing systems we've seen. It can be used without feathering the boat into the wind, in virtually all conditions, and allows as many battens and as aggressive a roach on the mainsail as you desire. When combined with lazyjacks, furling is straightforward.

The key issue that affects sailhandling — and this includes covering and uncovering — is access to the boom. If a boom is so high that you need a stepladder to work with it, then covering the sail will be a real pain. On the other hand, if the boom is low, covering it and attaching the halyard will be simpler.

In the days before mechanical and hydraulic vangs, it was common to have the gooseneck fitting attached to a heavy vertical track on the back of the mast. When the sail was lowered, the main boom would drop down on the track so that it was easier to work on. With rigid vangs, this is no longer used. On our own designs, we try to keep booms from crossing cockpit areas, then keep them very



Slab reefing is the simplest, most reliable, and fastest of all reefing systems. "A" and "B" above represent two approaches to tack control. "A" is the traditional hook onto which a ring is dropped. "B" is our preference, a continuous line that can be used to winch down the luff when broad reaching.

A new boom will usually have built-in sheaves at the end for the reefs, as in "D." However, there will be one vertical leg, as in "C." The only critical element is to get the lead on the clew aligned correctly. The average of the angle between the two legs of the reef pennant should bisect the luff from the clew.

You can add turning blocks on the outside of an existing boom running the clew reef lines outside.

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low. This not only makes them easier to work on, it also keeps the center of effort in the rig and vertical center of gravity low.

Where the boom does cross a cockpit area, we keep the gooseneck (forward end) as low as vang geometry allows, and then cut the mainsail so that the clew is raised above head clearance in the cockpit area.

How Many Reefs?

With slab reefing it's important to decide in advance how many reefs are needed in the main. We typically fit one good-sized bite for the first reef, a second really deep reef, and sometimes a third reef that is sized more like a healthy trysail than a main.

The only negative with excessive reefs is that each one is a hard spot on the sail, adds bulk when furling, and tends to make the sail set poorly in lighter airs. Having more reefs than you are likely to use can be counterproductive.

Reefing Lines

The first big question with reef lines is whether to use a single line control, with both clew and tack pulled down and led by a single line. This can work quite well on smaller yachts with moderate loads.

The major problem to deal with is the load on the tack fitting. Because you have a single line system, the load from the clew runs through the tack. This tends to distort the tack.

If you do not intend to use a single line system, then you need to decide how the reef tack (luff) is to be handled. There are two approaches. One is to put "horns" on the front end of the boom, to hold the tack of the mainsail in place. The other, which we prefer, is to have a long line rigged from one side of the mast, through the reef-tack position, and back down to the other side of the mast. What you have, in effect, is a long cunningham adjustment. In moderate air-reefing situations, you simply pull this line to tension the luff of the sail by hand. After the clew is set, tighten the halyard.

However, when you are sailing off the wind and/or in strong winds, where the main may not come down on its own, you can winch the luff down with this over-length cunningham. The attachment points for this line, on both sides of the mast, should be forward and down relative to the final location of the reefed tack. Down helps oppose the halyard tension, and forward opposes the load on the foot. A 45-degree angle usually works well.

We locate a set of heavy padeyes on each side of the mast, with cunningham lines tied to one side and led through the other. The lines then go through a rope clutch so that they can be led to a mast winch if required.

Internal or External

At the back end of the boom, you have to decide how to rig the clew reef lines. The most common way with new spars is to build blocks in to the aft end of the boom and then lead the lines down the inside of the boom, past a built-in jammer, and over another sheave. Here the lines exit in a downward direction, going to a reefing winch. This is a clean system but does not show chafe. It must be done with care so the lines cannot chafe once inside the boom.

Or you can mount cheek blocks externally, lead them forward through a rope clutch, then have a padeye to which you mount a snatch block (or another cheek block) to divert the reef line to a winch.

In either case, for offshore work the reefing pennants should be heavy, typically two sizes larger than the mainsheet. This allows for the inevitable chafe on the clew ring. Or, using a Spectra or Vectran line can reduce the need for such a heavy reef pennant.

The positioning of the aft dead end of the clew reef line and the cheek block need to be done so there is an aft as well as vertical pull. Usually an angle of about 60 to 70 degrees works well. Remember that this changes with each reef, with attachment points moving forward on the boom with each successive reef.

Behind-the-Mast Roller Furling

Starting in the early 1960s, headstay roller furlers were moved behind the mast and used to roller furl mainsails.

These systems were set on offset weldments that put the sail 6 inches (150 mm) or so behind the mast section. This offset at the head and bottom of the spar tended to induce eccentric loading, so the mast sections had to be made heavier than normal to compensate.

These systems worked just like a roller-furled jib, with all the attendant disadvantages. The big-

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gest problem was in sail-shape control. As the breeze increased, the mainsail stay (or extrusion) would sag to leeward, adding draft to the sail. To compensate, the main was cut with a hollow luff, just like a jib. In light airs, the combination of the hollow luff and straight (unsagged) luff wire created a board-flat sail — just the opposite of what was wanted. Between lack of shape control, hollow leach, and weight aloft, I would guess that these systems at best generate 70 percent of the power of a conventional main.

Both *Wakaroa* and my dad's *Deerfoot* were originally fitted with these behind-the-mast systems — against my vehement protests. After a couple of years both systems were changed.

If you are thinking about using such a system, be sure to have a track fitted for a trysail or larger Swedish mainsail, in case the roller furler fails.

In-Mast Roller Furling

The next step was in-mast roller furling. This worked like behind-the-mast systems, only the rotating extrusion to which the main was attached was in a pocket built into the aft end of the spar. This did away with the sag problem, since the aft edge of the extrusion would keep the sail from sagging aft.

Over the years these systems have been made more reliable. However, they have to be used carefully to avoid jamming the sail, and when sailing free in heavy airs you have to head into the wind to feather the rig before freeing or furling. As with the behind-the-mast system, there are no battens. This in turn forces you to use a hollow-leech sail that is not only smaller than normal but that has higher induced drag due to an effective loss of aspect ratio with the narrow, pointed head shape. The masts themselves are quite a bit heavier, with rig weight typically going up by as much as 30 percent compared to a conventional spar. Windage increases as well with larger spar dimensions.

If you are retrofitting such a system, check your range of positive stability. This drops significantly with the increased weight aloft.

Roller-Furling Booms

Roller-furling booms have been making a comeback of late. Many of the new mega-yachts sport them, and a number of sparmakers are pushing the concept. The basic idea has been around for most of this century. I grew up on CCA racers, all with roller-furling booms. As you reefed, the boom was rotated with some form of geared mechanism. The halyard was carefully eased, and someone pulled on the aft end of the sail to try to keep the shape fair. It was a three-person job and took some time. The logic behind it was that you could evenly distribute load along the foot of the sail, and it was faster than carefully tying in a series of reef cringles. Once Dacron came on the scene, with its strength, slab reefing became the system of choice.

The new systems use the same principle, except the roller furling takes place inside the boom. There's a rotating shaft, around which the sail is rolled. You can use full-length battens as long as they are not too thick and are correctly angled. There is a critical relationship between halyard tension, boom rolling or unrolling speed, and boom angle. We've talked to two experienced owners who have the new in-boom furlers. Both had previously sailed yachts with in-mast furling systems and went to the boom approach because of better sail shape, lower center of gravity, and less windage. Both say that the boom systems require a higher level of skill to operate than the in-mast systems. Nevertheless, they prefer the sailing performance of the new systems and would not change back.

The Race

On our last cruise to Fiji aboard *Beowulf* we spent time cruising in the Yasawa Islands, along with Mayer and Kathryn Page on their 60-foot (18.5m) *Lady Kathryn*.

As we both preferred sailing to powering, we liked to race at the beginning and end of each short passage. The contest (unofficial, of course) was who could get underway more quickly and who could get their sails stowed and be reading a good book sooner. Keep in mind that we were operating under a slight handicap. *Beowulf*, being a ketch, had two complete rigs to uncover, hoist, put away, and recover at the end of the day. Mayer and Kathryn had only one rig to deal with and were using a fully automatic, hydraulically powered roller-furling boom.

Starting at the same time, we found that we could get our mainsail uncovered, hoisted, and trimmed in slightly less time than the opposition. It's true that we had to work a little harder, since

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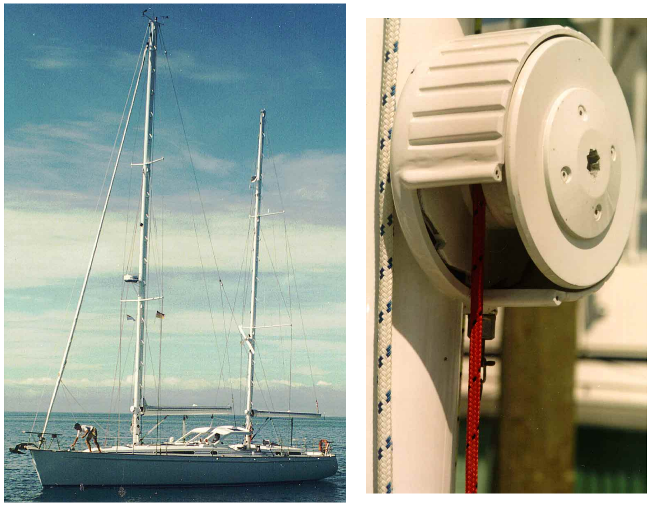
A Laurie Davidson Kiwi-built ketch we saw in Fiji with roller-furling booms on both main and mizzen (right). This boat used the Leisure Furl system. The Leisure Furl features a universal joint between the boom and a rotating mechanism mounted on the forward side of the mast.



The Southern Spars system is a step up in sophistication, complexity, and cost. It drives the boom with a hydraulic motor mounted in the forward end of the boom. Note how the mainsail track projects aft of the spar at the bottom. The track is curved to keep the sail from bunching at the front end of the boom. One of the negatives with this system is wear and tear on the mainsail luff.

we had to leave the cockpit to take off the sailcover while they just sat in the cockpit and pushed buttons. Of course, the mizzen was a dead loss, but then we sailed so much faster that it was a reasonable handicap.

We'd typically arrive at the next anchorage close together, albeit with *Beowulf* in front. We would have our main dropped and gasketed in the same time as their mainsail. But we still had a five-minute job (for one person) of covering the sail.

So the time issue came down to this: Is the cost and complexity of in-boom furling worth the five minutes of effort covering a sail?

To be fair, let's look at this in the context of layout. *Beowulf*'s boom was just 3 feet (0.9 m) off the deck, very easy to work on. The boom on *Lady Kathryn* was at least twice this high and would have been more difficult to work with.

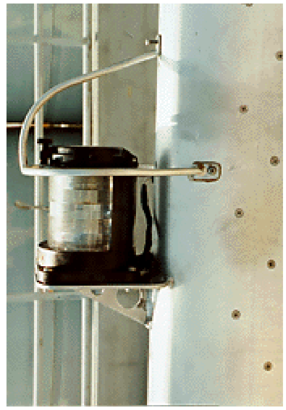
When we did the design work for a sistership to *Beowulf* for some clients who had sailed one of our earlier vessels (with slab reefing), we went through this exercise again. The owners had looked at the in-boom systems. and they came to the same conclusion — that for the effort of covering the sails, it was not worth the cost and complexity of in-boom systems, not to mention the difficult reefing when sailing free in heavy-going.

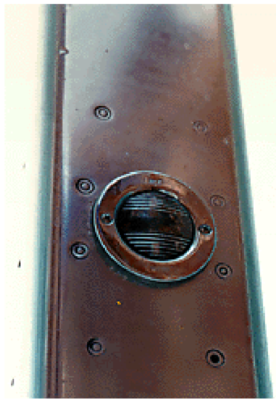
We are now working on a more easily deployed sail cover.

LIGHTING

There are a series of issues with lighting the deck for working and the sails for trimming. On one hand, you need enough light to accomplish the task. (The better you know the boat, the less light it will take.) On the other hand, the higher the light intensity, the longer it will take to regain night vision. Often a small amount of light will get the job done, but certain occasions require significant amounts of light.

Protect steaming lights (right) from headsail chafe. Mount them just above the cutter stay to minimize reflected light.





If your boom happens to overhang the cockpit, having a light built into the bottom of the boom is a clean way to light the cockpit at anchor (left).

Deck Lighting

Lights mounted on the lower spreaders are typically used for deck lighting. These are available in conventional floodlight form and in halogen bulbs. We prefer floodlights, as they have a lower intensity and the bulb filaments seem to last longer. The lights are mounted on the lower spreaders, usually in the middle. We like to aim one side well forward, toward the middle of the foredeck. The opposite side is usually aimed straight down. It is important to try to aim it so the helmsman is not directly blinded by the edge of the glare. Most deck lights are 50 watts. Two deck lights of this strength are good for substantial lighting.

Frequently only a small amount of light is required. There are several ways to accomplish this. One is to mount a much smaller light on the leading edge of the mast. The other is to drop the voltage to the spreader lights, either through an electronic dimmer or by feeding the lights a reduced voltage with a tap on the batteries. The dimmer is easier to wire.

Sail Lighting

Often illuminating the luff of the headsail at night is necessary for trimming. Of course, you could walk forward with a flashlight. But then you would have to come back to ease or trim the sheet, and then check again. Besides, you might get wet leaving the cockpit — we are cruising, after all.

Our answer is to use the steaming light on the front of the mast that is required by international regulations. This 120-point white light has plenty of power, even on small yachts, to light up the headsails.

For this to be easy to use, the switch for the steaming light should be handy to the cockpit. This way you can flick it on for a few seconds, then turn it off easily.

Cockpit Lights

Lighting the cockpit involves different issues. Here we are primarily concerned with nighttime ambience, as well as the ability to see food and drinks, and the faces of our companions. Spreader lights, even with a mizzen mast handy, are too harsh and far away. The simplest approach is a kerosene lantern — but then you must carry kerosene aboard. Another approach is a small light fixture on a long lead, temporarily attached to the boom or underside of the awning. If the boom overhangs the cockpit, a low-intensity sealed light built into the boom may be the solution.

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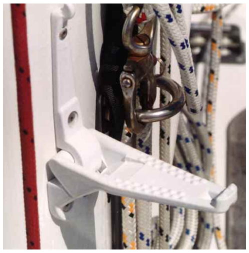
GOING ALOFT

Whether you need elevation to see underwater obstructions, or are a bit short to get the main halyard attached, every yacht requires a means of getting a short distance aloft. For working on the cover or halyard, strategically placed winches, jammers, and mast bars will do the trick. Other times, it is easier to add some retractable steps. Regardless of the system chosen, you need to be able to use it with at least one hand free to do some work.

When the time comes to gain a bit more altitude for keeping watch, the issues change substantially. Security and comfort over a period of time become most important. It's easy to spend an hour or more on your perch while navigating through coral. In this case, a comfortable base for your feet is important, along with a secure method of holding position while the boat moves.

Most cruisers work out a way to get to the lower spreaders, then sit or stand on the spreaders to keep watch. The tricky part is transitioning from the steps to the spreader.



There are lots of ways to get aloft. From a security standpoint I prefer to have ratlines between the aft lower shrouds and cap shrouds. This offers plenty of hand-holds.

However, without fore-and-aft lowers, mast steps become more viable. For traveling a short distance up the mast to attach the main halyard or to put on the sail cover, folding steps work well. To get to the spreaders or higher, a closed step will be required (middle left).

Once aloft, if you are watching for coral, it may be some time before you can return to the deck. A comfortable perch makes this job much easier. It can be as sophisticated as an enclosed basket (middle left) or simply a platform added to the top of the lower spreaders (lower right).

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