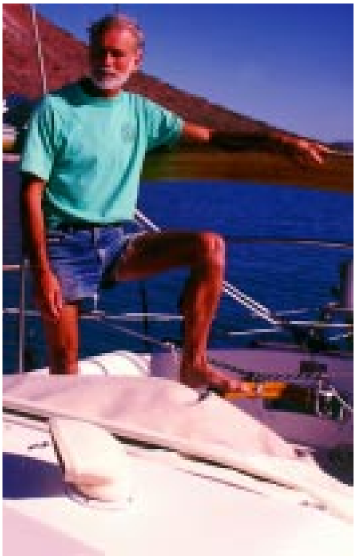
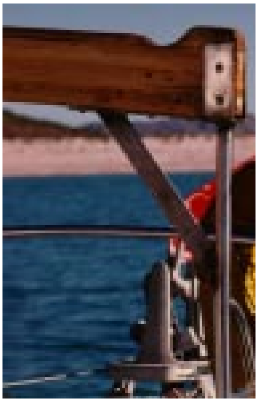




Tim Traill demonstrates how his boom gallows provide security and support for the helmsman. They are relatively easy to execute — just be sure you have a sturdy diagonal brace (right) to keep the structure from sagging side to side.

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.

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 65 percent. For a double-spreader rig the caps get 30 percent, intermediates 30 percent, and lowers 55 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, 0.55 x 22,125-12,168 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 the spreaders make.

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 onboard, 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 gunnel 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.

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 non-corrosive 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.

		CONVENTIONAL 316 1x 19				**DYFORM 316 1 x 19**				**CONVENTIONAL 302 1 x 19**		**CONVENTIONAL 316 7 x 19**			
NOMINAL DIAMETER		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 manufacturer's 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.

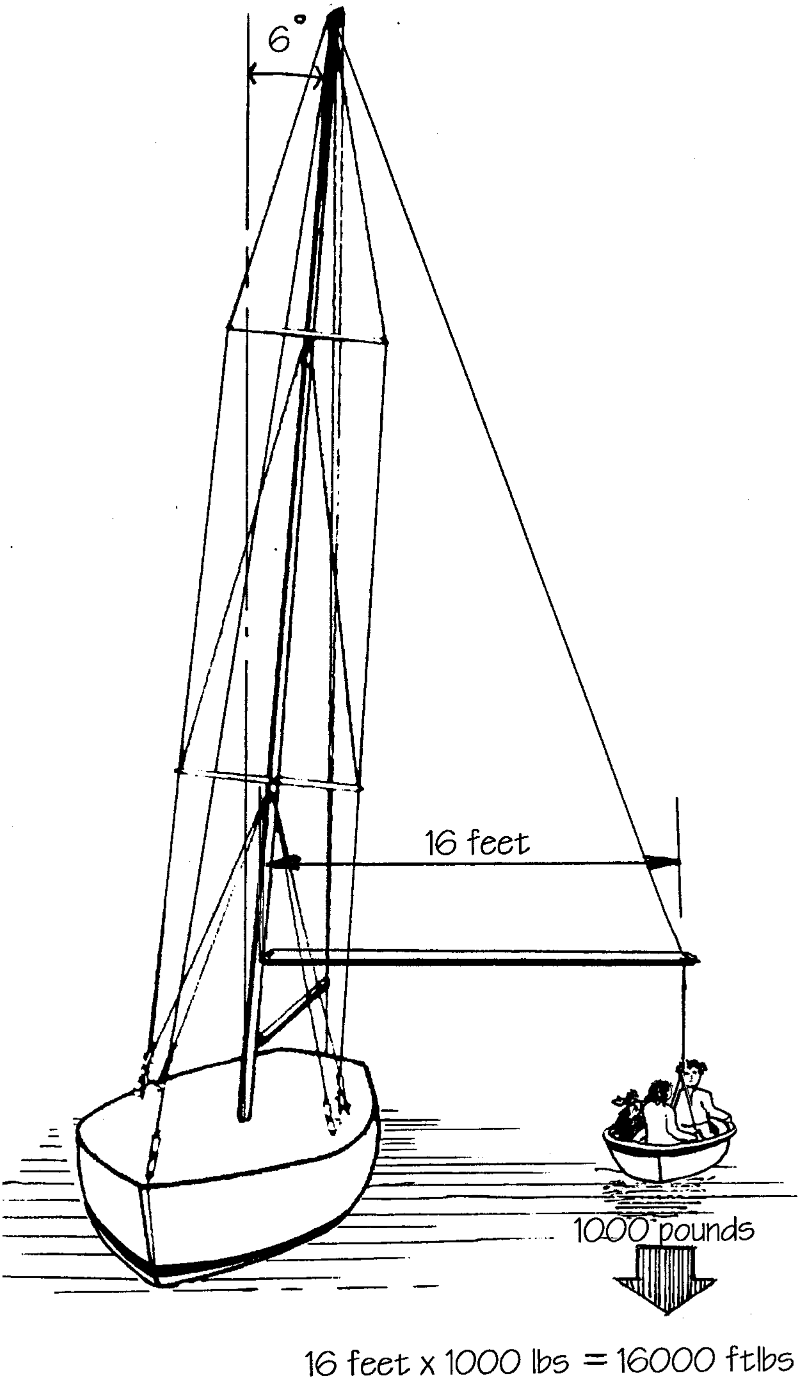
		CONVENTIONAL 1 x 19 316 GRADE				DYFORM 1 x 19 316 GRADE			
SIZE		NOMINAL BREAKING STRENGTH		NOMINAL YIELD STRENGTH		NOMINAL BREAKING STRENGTH		NOMINAL YIELD STRENGTH	
INS	MM	LB	KG	LB	KG	LB	KG	LB	KG
3 / 16	4.76	4,062	1,846	2,640	1,200	5,054	2,297	4,043	1,838
	5.00	4,513	2,051	2,933	1,333	5,506	2,503	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.



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.