RIGGING THE PETERSON CUTTER

By Jeff Stander
s/v *Beatrix*

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1 Introduction

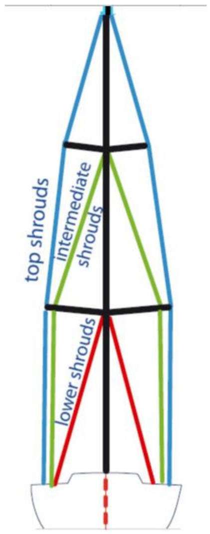
In 2012, when we re-rigged *Beatrix*, I wanted to "do it right" so I did a lot of research as well as hiring iconic master rigger Brion Toss to do an analysis. Dennis on Tango (KP44) also separately hired Brion Toss and sent me his comments which are included in this document (see appendices). I searched the Internet, read the relevant sections of Brion's "The Riggers Apprentice", and had a chance encounter in Port Macquarie, NSW (Australia) with Alan Blunt on *Cheyenne*, who was the original rigger for Jack Kelly Yachts.

Brion told me he thought the original rig on the KP44 was not well designed. Yet, many of the "original" rigs have sailed for decades without problems. Getting the rig right only becomes important when the current rig is too weak, or the weather too extreme, or you are a racer, or you just like doing things right. If you are re-rigging an original rig, this is the time to consider changing the design to one of the recommended rigs.

I have seen many different rig designs used on the Peterson Cutters. The worst ones are those with oversized wires. Brion has often stated that oversize wires can add to weight aloft and put extra stress on terminals, spreaders, mast, and chainplates. In Australia, some of the riggers will not downsize a rig without a sign-off from a naval architect. In my opinion, these guys are not riggers, but it might be worth the effort to get architectural approval to install a better rig when the opportunity presents itself.

2 Rig Design Elements

On our 2-spreader rigs, you find either *Continuous Rigging* or *Discontinuous Rigging*.



Continuous rigging

2.1 Continuous Rigging

Continuous Rigging allows all shrouds to pass over the spreader tips without termination.

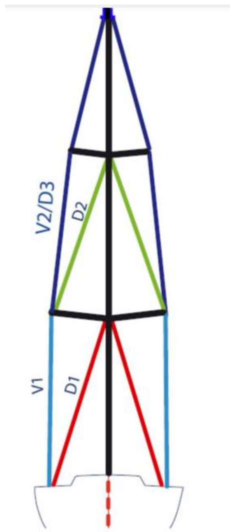
PROS:

- Ease of spreader design and installation,
- Straightforward tuning adjustment with all turnbuckles at deck level.
- Less expensive (thus favored by many builders of production boats)

CONS:

- Requires two chainplates or a link plate on a single chainplate
- Is harder to replace
- Has more weight and may be less stable (i.e. it has a rhomboidal component - although in a double-spreader rig this is less of a problem)
- Requires lower spreader tips that may exaggerate chafe and fatigue.

2.2 Discontinuous Rigging



Discontinuous rigging

Discontinuous Rigging is based on the principle of one stay in between each span, linked by tip cups or special link plates.

PROS:

- It is a stronger, better rig.
- Each span is fitted with the correct size wire to accept the loads, so the stays can be reduced in diameter progressively up the spar.
- The center of gravity is lowered, windage is less and often the total rig weight is lowered.
- Tuning, although done at deck and spreader levels, is easier due to the shorter span lengths, therefore less stretch in each stay. When tuning this style of rig I have found I never have to adjust the turnbuckles at the spreader level more than once (at installation), so the "convenience" factor of having all shrouds tuned at deck level is not a factor.

CONS:

- Rigging requires more terminals (therefore more expensive) and multiple sizes of wire
- V1 must bear load of both the D3 and V2/D3.
  - If the V1 is sized at 7/16" or 12mm this requires 3/4" pins on the V1 and larger turnbuckles for the V1.
  - Substituting 3/8" or 10mm Compact Strand (Dyform) for a larger diameter V1 helps to satisfy the extra V1 load requirements for the Discontinuous rig without requiring a larger diameter.
- If you use a Loos PT-3 tension gauge, it will not work on 7/16" wire and it is not calibrated for Compact Strand.
- The D2 wire has its tension tuned with a turnbuckle above the deck which makes initial tuning difficult.

Beatrix originally came with Discontinuous Rigging, which is the preferred design. Continuous Rigging is only favored when less expense and ease of installation are important, as they are to a cost-saving boat-builder. Many of the Peterson Cutters have a Continuous Rig. If you are in the process of re-rigging from scratch, I would recommend shifting to the Discontinuous design.

2.3 Rigging Elements

The three transverse rig elements have designations like D1 or V2. These designators refer to the sections of the rig. Section 1 is from the deck to the lower spreader, section 2 is the span from the lower to the upper spreader, and 3 is the section from the upper spreader to the masthead. "D" or "V" refers to vertical or diagonal wire. Thus, D1 wires are the "lowers" running diagonally from the deck to under the lower spreader root. V1 refers to the vertical section of wire running from the deck to the outside of the lower spreader. V2/D3 is a single wire running from the outside of the lower spreader to the outside of the upper spreader and onto the masthead.

The Discontinuous Rig has seven different shrouds on the mast. Percentages are the percent of the shroud load that the wire carries (Toss, 1997). I find this a little confusing as it seems the percentages ought to add up to 100%. I suspect this is because some of the total load goes into the spreaders. These are Brion's numbers (except for V1, which is an estimate)

LOWERS (D1) - 25% apiece for doubles
INTERMEDIATES (D2) - 30%
V1 (50%) - **shares load for uppers and intermediates so should be stronger than D2 and V3/D2**
UPPERS (V3/D2) - 30%
JIBSTAY - 30%
BACKSTAY - 25%
FORESTAY (STAYSAIL) - 25%

The Continuous Rig would have the following six wires:

LOWERS (D1) - 25%
INTERMEDIATES (D2/V1) - 30%
TOP SHROUD (V3/D2/V1) - 30%
JIBSTAY - 30%
BACKSTAY - 25%
FORESTAY (STAYSAIL) - 25%

3 CONSULTING THE EXPERTS

I used Brion's book "The Riggers Apprentice" (Toss, 1997)[1] to help figure out the wire loads and sizing as well as direct recommendations from Brion and Alan Blunt.

3.1 Brion Toss

Brion has now rigged or provided consulting information on several Peterson Cutters so I wanted to use his analyses and information to develop a "standard" rig for our boats

I had a beer with Brion in 2012 when he gave an excellent presentation at the Australian Wooden Boat Festival in Hobart. He came to the Festival every two years. (Sadly, Brion died in 2020). He emphasized in his talk the downsides of using wire greater than necessary. '**Oversizing the wire can actually be dangerous,"** he said, "as it adds weight aloft and puts extra stress on toggles, terminals, spreaders, mast, and chainplates." It is also a LOT more expensive for larger-sized terminals. I see a lot of obviously over-rigged boats when walking the docks.

Brion's analysis supported my thinking that the "standard" rig on the Peterson Cutters was not well designed. I have often wondered if Doug Peterson designed the rig and (if he did) were his recommendations followed. Most of the USA KP44s were rigged in California. It never made sense to me that the V1 was sized the same as the V2 as it has to bear greater loads. Later I discovered that the original rig was different from what was on *Beatrix* (see below comments from Alan Blunt).

Brion's final recommendations are given in Section 4.2 on page 6. The short version is he recommends (for imperial wires) the following sizes:

- V1 Compact Strand 3/8"
- V2/D3 1x19 5/16"
- D1 1x19 5/16"
- D2 1x19 9/32".

3.2 Alan Blunt

In 2012, while anchored in Port Macquarie, NSW, I ran into a bloke named Alan Blunt, skipper of *Cheyenne*, out of Los Angeles. Alan is an Aussie, but for years owned Seatek Yachting Inc., a spar and rigging business in Wilmington, CA. He knew Jack Kelly and was friends with Doug Peterson. He was involved in the rigging of the first KP44s and has sailed many miles aboard one. So I rowed over to his boat with a bottle of Aussie Shiraz and asked some questions about my re-rigging quandary. He knew EXACTLY what I was talking about and confirmed and resolved a few key issues.

His recommendations are different from those of Brion Toss in that the uppers are 3/8" (although 5/16" appears to be an adequate strength). As nearly all the Petersons I have seen have 3/8" uppers, plus Alan's recommendation, I decided not to downsize the uppers to 5/16" as Brion recommended.

Here's what Alan told me:

1) The boat's original rig design was CONTINUOUS rigging (two wires to the deck). This was done to save money.
2) If the rigging is DISCONTINUOUS the V1 element (first vertical) should be 7/16" as it bears the load of the intermediates and uppers. [*As this requires larger chainplate holes, the use of Compact Strand will keep the size at 3/8" or 10mm while supplying the additional strength required (JS)*]
3) Otherwise, for CONTINUOUS rigging, the cap shroud, or upper, (V1+V2+D3) should be 3/8".
4) The intermediate wires, in either case, are 5/16".
5) The four lowers are 5/16".

[1] There is a 2016 Second Edition of Brion's book available.

4 RIG RECOMMENDATIONS

Considering what Alan and Brion have said, and weighing in practical matters (such as standard wire sizes and chainplates), I have two different recommended rigs for a KP44 (and presumably an F46). I also list the original rigs which should be upgraded as they are replaced. Both recommended rigs are of the Discontinuous type and use Compact Strand (Dyform or Powerflex) to increase the strength of the V1.

All rigs have the following fore-and-aft wires:

- 1x19 Forestay (staysail) 5/16” or 8mm
- 1x19 Jibstay 3/8” or 10mm
- 1x19 Backstay 3/8” or 10mm (or 11mm Dyneema Dux)

4.1 Standard Practical Rig (as used on *Beatrix*)

Based on Alan Blunt’s recommendations this rig retains the 3/8” (10mm) V2/D3 as opposed to the smaller wire that Brion Toss recommends. It is also more amenable to using standard metric wire sizes.

- Discontinuous Rig
- V1 Compact Strand 3/8" or 10mm
- V2/D3 1x19 10mm
- D1 1x19 5/16" or 8mm (double)
- D2 1x19 5/16" or 8mm

4.2 Brion Toss Optimum Rig

This has a slightly smaller D2 and V2/D3 and works best with the greater variety of imperial wire sizes:

- Discontinuous Rig
- V1 Compact Strand 3/8" or 10mm.
- V2/D3 1x19 5/16" or 8mm
- D1 1x19 5/16" or 8mm (double)
- D2 1x19 9/32" (or 7mm, which is not generally available)

4.3 Original Discontinuous Rig[2]

- V1 3/8" or 10mm (bears load of uppers and intermediates so this is too weak)
- V2/D3 1x19 3/8" or 10mm
- D1 1x19 5/16" or 8mm (double)
- D2 1x19 5/16" or 8mm

4.4 Original Continuous Rig[2]

- V1+V2+D3 1x19 3/8" or 10mm
- D1 1x19 5/16" or 8mm (double)
- D2 1x19 5/16" or 8mm

In conclusion, there are several factors to think about. The “optimum” rig is more expensive and more complex but has properly balanced pre-tension and loading which makes for a safer and stronger rig. Some of the other possibilities approach this but with fewer sizes of standard wire. Beatrix had the “Original Discontinuous Rig” but the “Standard Practical Rig” is a more practical solution while paying attention to optimum loading

[2] Likely not original on all vessels.

5 DIY Rigging on *Beatrix*

In 2012 we replaced all the rigging on *Beatrix* while the mast was in the boat. Shroud wires were removed from the mast and deck in opposite pairs. The upper shrouds were removed while using halyards and running backstays to stabilize the mast fore and aft. The mast is a bit "whippy" and you wouldn't want to be up there in a strong wind, but I had no problem being in a climbing rig at the masthead.

All the bronze turnbuckle barrels were dye-tested and none had any faults. At this time new roller furler foils were installed on the new jibstay.

All my terminations are Peterson (Hayn) Hi-Mod terminals. I cannot speak highly enough of these re-useable compression terminals. They are far superior to Sta-Lok and nobody uses Norseman anymore.

A Note on Hi-Mod Terminals
Before our current rig was replaced; I examined the 3/8" Hi-Mod compression terminal on the 3/8" wire backstay. This was installed maybe a decade earlier when I bought the Harken backstay adjuster.[3] Although it was difficult to remove (it had not been opened in maybe 10 years) the wire was undamaged and not corroded. This has convinced me that the uncompromising fail-safe design and ability to easily remove and replace the termination make Hi-Mods the best terminals to use. I never need to worry about a swage failure with Hi-Mods, so we proceeded with the all Hi-Mod option, top and bottom, although it is seriously more expensive than swaging. Yes, swaging can be perfectly fine, especially if you carefully pick your rigger, but it can and does fail. Hi-Mods just won't fail –they don't have that "hard edge" or encapsulated non-aerated wire to worry about. The wires are not bent and sealant is explicitly not recommended for these fittings. Installation of a fitting takes less than two minutes. I also never had to take my wires to a rigger with a swaging machine, so I could do the job myself, wire-by-wire, and save money and KNOW that the job was done well. The Hi-Mod terminals are distributed in the USA by Hayn Marine and are manufactured in the UK by Peterson.

I had a problem with the 10mm Compact Strand wire because, as it turns out, the KOS (Korean) wire is made slightly oversize. This is the reason some wire seems "stronger" than others; it is actually bigger, e.g. 10mm might actually be 10.5mm. Peterson UK (who makes Hi-Mods) manufactured (at no cost to me) some special "crown" pieces for my Compact Strand terminals to accommodate the oversize wire.

In practical terms, wire sizes like 9/32" are not very common in Australia, which is now mostly metric, so I was restricted to using 8mm and 10mm wire available in 1x19 and Compact Strand. Therefore, *Beatrix* was re-rigged with transverse shrouds as follows:

- V1 — 10mm Compact Strand
- V2/D3 — 10mm 1x19
- D1 and D2 — 8mm 1x19.

According to Brion and my calculations, I could have used a smaller 8mm 1x19 V2/D3 wire, but I chose to follow Alan Blunt's advice and used a 10mm 1x19 "upper"; I still have a better load distribution than before by using the stronger Compact Strand on the V1. Any wire size over 10mm (or 3/8") immediately incurs a tripling of costs for terminals, turnbuckles, re-sizing chainplate holes, etc., which is why sizes like 1x19 7/16 (11 mm -- not available in Australia) or greater are not practical. 1x19 9/32" (7mm) is also not always available (certainly not in Australia).

[3] This was a Harken B500 backstay adjuster operated with a winch handle. Sadly it is no longer manufactured.

Beatrix's backstay is Colligo Dyneema Dux with an embedded SSB antenna wire. No isolation terminals were required. The Harken Backstay Adjuster made tensioning the backstay easy. The backstay was ordered directly from Colligo and cost about US$610 including brackets. The entire rigging project cost about US$3,400. If all the wires had been swaged the cost would have been about $1000 less. Much of the cost is in the Hi-Mod terminals which are completely re-useable. The next re-rig will be relatively inexpensive. If you plan to keep your boat long enough to replace rigging more than once it is cost-effective (as well as stronger, safer, and personally satisfying because you can DIY) to opt for Hi-Mod terminals.

The rigging analysis is interesting and also more indeterminate than I had hoped for. Here is what I have found out:

1) Oversizing the wire can actually be dangerous as it adds weight aloft and puts extra stress on toggles, terminals, spreaders, mast, and chainplates. It is also a LOT more expensive for larger-sized terminals.
2) The V1 wire in a discontinuous rig bears the load of both D2 (intermediate) and V2/D3 (upper).
3) The loads are apportioned at 25% for each for double lowers (D1), 30% for intermediates (D2), and 30% for the cap shroud (V2/D3). This means that V1 theoretically bears around 50% of the load in a discontinuous rig. Some of the loading on the D2 does go into the spreader.
4) Static tuning guidelines are always given as % of Breaking Load, yet it seems to me that absolute loads are more significant. If I use 10mm wire where 8mm might do, then I would want a lower % of BL on the larger wire to get the same pre-tension load as the 8mm. Another reason to not over-size the wire.
5) A LOOS gauge can help with static tuning.
   a) Measurements
      i) Backstay (3/8") tensioned to 15% of breaking load for local (Puget Sound) sailing. Offshore cruising requires 10 – 20%.
      ii) Aft and forward lowers should be tensioned to 10 – 12 %.
      iii) V1 should be tensioned 15-20%.
   b) The LOOS gauge has its percentage measurements calculated against 304 wires, not 316. Tension, of course, is the same for equal size wires, no matter what alloy it is made of.
   c) LOOS gauges can go bad. Mine had a stretched spring which read OK for smaller wires and exaggerated the loading for larger wires. (I compared it to a friend's gauge). Old LOOS gauges can be sent to the factory for a new spring and calibration.
6) Transverse loads (Shroud Load) is calculated as RM_{30} * 1.5 / (Beam / 2). For the KP44, the righting moment at 30 degrees is estimated at 72,000 lbs. The shroud load calculates out at 19300 lbs. The recommended safety factor is 2.5. There seems to be some confusion in the numbers as Selden's RM_{30} calculator produces what I think is the "design load" which is the same value as I get from the analysis using Brion's table after applying the 2.5 safety facture. This works out to be approximately 48000 pounds. Since this also agrees with wire recommendations from both Alan Blunt and Brion Toss. I will therefore stick with 72,000 pounds of RM_{30} as the approximate measurement until someone actually and accurately measures it.

I have created a spreadsheet to handle all this calculating: see (Rig Design and Tuning.xlsx and Rig Design and Tuning.pdf). There are far more complex naval architecture programs on the web which are not useful for our purposes.

All the research on the Net and much study have led me to believe that, except for high-end yacht racing, rig design is mostly based on experience and rules-of-thumb handed down from designer to designer and rigger to rigger. Basing a rig on the vessel's 30-degree righting moment (RM_{30}) seems fairly standard, but where did that number come from? Someone supposes that RM_{30} represents the maximum loading a vessel will experience under full sail in a fresh wind. But what about dynamic and shock loading? These issues appear to be handled with a safety factor of 2.5 to 3.0 which implies some pretty big assumptions.

However, as stated above, too big a rig is dangerous too – it can break the boat! Too weak a rig can break the mast. Most boats don't get into a situation where they are stressed beyond their safety factors, but it can happen.

The odd thing is that Brion Toss specified a rig (as part of a paid consultation) that has a smaller wire than his calculations show. Because of the 20% increased breaking strength over “standard” 1x19 316 wire strengths the size Brion specified would work. What I have learned is that the V1 definitely MUST be larger than the wires above it (in the Discontinuous Rig) as it has to handle loads from both intermediates and uppers.

APPENDIX 1. The Drama of Rigging

Rigging is a “dark art” based largely on the empirical experience of riggers and nautical designers, and only partially on scientific knowledge. Whereas I am certain that very serious computer software is applied to the hull strength and rig design of America’s Cup and ocean racers, I have found very little useful information on Plain Old Cruising Boats. I turned up a few dissertations on the subject. The only useful and applicable formulas come from Brion Toss’s book *The Rigger’s Apprentice* (Toss, 1997) and are based on the 30º righting moment. This is supposedly 72,000 lbs. for our boat according to the table on page 136 of TRA. This gives you the ability to calculate a theoretical transverse rig load which is apportioned among the various rigging wires depending on the rig type (discontinuous vs. continuous). I have incorporated this into an Excel worksheet. These are static calculations and dynamic loads can often be greater, which is why a reasonable safety margin is built into any design.

Based on my talks with KP44 rigger Alan Blunt I think the current discontinuous rigging, while more expensive, is the best solution for wire rigging. The big factor is deciding to upsize the V1 wires to accommodate the combined loads of the uppers and intermediates. NONE of the existing KP44s that I have seen do this – they mostly have 3/8” wire on the V1, and V2/D3, with 5/16” wire on the D2 and D3. Nevertheless, the experience of other skippers on different boats, the rigging analysis, and common sense all say that a 7/16” V1 would be the correct wire to use. However, other factors argue against upsizing the V1 diameter. These include increased expense for terminals and wire and having to modify the chainplates to accept a larger clevis pin.

So an increase from 3/8” to 7/16” for the V1 wire is quite an expensive jump because of the HUGE price increase of the Hi-Mod terminals, over $800. When trying to tune the rig not too long before the re-rig job, I was up the mast while my mate Niall was on deck and I was trying to get a balance of tension between the uppers and intermediates and I did not quite get it right – the intermediate was tensioned to 12% while the upper was tensioned to 8% (this is 1210 lbs. on the D2 and 1100 lbs. on the V3/D2). More tension needs to be moved to the V3/D2 and probably more tension overall. However, this would require around 2300 lbs. on the V1 (which is now reading 1400 lbs. (18-20%) on the Loos PT-3 tension gauge.[4]

With this setup, I could see the top of the mast tipping leeward under stress (which is not necessarily a problem). The big issue is that the leeward rig should not go slack from lack of pre-tension until it is time to reef.[5] It is clear that static measurements are only a start to proper rig tuning and adjustments under sail must be made.

Unless I want to tension a 3/8” (or 10mm) wire past 20% of breaking load or have a lower pre-tension in the uppers and intermediates, I would have to upsize to the 7/16” wire (11mm not available). On the other hand, the empirical evidence is that these Petersons have been sailing for over 30 years without an obvious problem using 3/8” V1 wire (unless you count stories about slack leeward wires due to lack of pre-tension and my difficulty getting the tensions balanced and high enough in the uppers and intermediates). I would like to poll the Peterson Group on this subject.

PROS of a larger diameter (stronger) V1: properly balanced pre-tension and loading which makes for a safer and stronger rig.

CONS: three wire sizes instead of two, about $850 more expense, the requirement to enlarge pin hole in chainplate to ¾”, and a negligible amount of additional weight (5 lb.).

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[4] I have learned that the Loos tends to over-estimate the upper range of tension as it ages and the spring stretches

[5] A good description of pre-tension (and many other things) is found in Ivar Dedekam’s book Sail and Rig Tuning

At this point, Chris Kennedy of Fisheries Supply suggested using 10mm Compact Strand (Dyform or Powerflex) which is 16% stronger than the 10mm 1x19 wire as compared to the 7/16" wire which is 27% stronger than 10mm 1x19.

Since the 10mm Compact Strand has not crossed the magical "big boat" threshold this saves over $800 in rigging expenses while gaining about 60% of the up-sizing advantage of the 7/16" 1x19.

In other words, it is a good compromise between the empirical solution (stick with 3/8"/10mm) and the theoretical/recommended solution (upsize to 7/16").

So, that's what I have done.

One other option is to replace each pair of lower spreader tip link plates with a solid stainless link plate ($32 for materials) and use forks instead of eyes. One of Brion Toss's riggers recommended this to Terry Hudkin. I like the idea, but I kept the original setup. It is less elegant but I could not see where the single plate was more functional.

Notes on chainplates.

If you still have original chainplates YOU NEED TO REPLACE THEM. Stainless chainplates corrode out of sight and I guarantee any 40-year-old chainplates will have crevice corrosion; some of it serious.

I have come to believe that stainless steel is NOT a good choice for chainplates (see this article by Brion Toss). A superior alternative would be titanium, aluminum bronze, or silicon bronze. The bronze is easily workable, strong, and does not corrode in seawater (or tarnish, in the case of aluminum bronze). The titanium is also strong and non-corrodible, but not so easy to work. The price of titanium chainplates has dropped to where they are close to 316SS and there are several manufacturers on the Internet that advertise custom fabrication. I also believe doubler plates (thick washers welded or brazed to the chainplate) are important to reduce point loading on the clevis pins; note that some rig failures have been attributed to crevice corrosion from badly welded doubler plates. The use of titanium or bronze chainplates makes corrosion a null concern. **Any doublers should be brazed (if Bronze) or welded (if SS) before the final drill-out of the chainplate.** This ensures absolute alignment of the holes in all plates.

Using heavier gauge material also reduces point loading on the pins. For the same reason, all chainplates must have a fair lead with their shroud. I have seen external chainplates on the lower shrouds in which the rigger did not bend them to make a fair lead. Improper articulation (too few toggles) and poor leads will lead to rig failure.

APPENDIX 2. Brion Toss's KP44 Rigging Analysis

Master Rigger Brion Toss wrote this letter to the skipper of KP44 Tango, Dennis Todd, who kindly shared the report with me.

Dennis,

Rig sizes should of course not be arbitrary; they should reflect the loads that are imposed on each piece. In the case of this vessel, there was an apparent anomaly, in that the 3/8" V1s which extend from the chainplates to the lower spreaders, were quite a bit weaker than the combined strengths of the 3/8" V2s, which go to the masthead, and the 5/16" D2's, which go from the lower spreader to just under the upper spreader. If the upper two wires were the right size, then the V1s were too small, and vice versa. It was also possible that ALL of them were the wrong size, having no relationship to the vessel's righting moment. So it was clear that we had to start by determining the loads that the vessel put onto those wires before we chose new wires for a re-rig.

There are several ways to do this. The simplest one is to consult "Skene's Elements of Yacht Design" for a chart showing typical loads for a vessel of a given waterline. This is a remarkably reliable chart, in my experience. For a KP44, with a waterline of 38'8", we can derive a load on the shrouds in the neighborhood of 33,750lbs, once we have taken the vessel beam and safety factor into account. About 60% of this load can be expected to land on the V1s, which means about 20,000lbs, and this translates either to 7/16" 1x19 or 3/8" Compact Strand. For more on this process, see my book, "The Rigger's Apprentice."

To double-check the accuracy of those chart-derived figures, the owners arranged for a direct incline test. Because righting moment increases in approximately a straight line through at least 30 degrees of heel for monohulls, even a small amount of heel, from a small load, can be extrapolated for loads at large angles of heel. My favorite method for such a test is to have as many people as will fit lined up along the rail of the boat. Their weight, times their distance from the centerline, gives the foot-pounds of force heeling the boat. The resulting angle of heel can be measured old-school, using a pendulum and square, or new-school, using an inclinometer on a smartphone.

In the event, a sufficiently large group of friends wasn't available, so the owners placed a weight at the end of the boom, swung the boom out to the side, measured the heel, and repeated the exercise on the other side. The results were consistent side-to-side, and the extrapolation showed righting moment fairly close to that derived from the chart, just a bit higher, but resulting in the same wire sizes.

Based on these results, we installed 3/8" Compact Strand V1s, 5/16" 1x19 V2s, and 9/32" D2s. These sizes reflect the typical distribution of load, and the V1s are no longer overwhelmed by the upper two wires.

Note that this wasn't the only KP44 with anomalous wire sizes. Also, note that the rigs aren't collapsing all over the place. But the dimensional changes on this boat accomplished two important things:

First, we achieved a consistent, desirable factor of safety for all components. Previously the V1s were weak relative to the combined strengths of the wires they supported, meaning they were more likely to fail. That hazard was now gone.

Second, we were able to reduce weight aloft, so that the boat will sail better, have less weather helm, need reefing less often, etc.

--Brion Toss

APPENDIX 3. *Tango*'s RM_{30} Test Results

Here's how we did the incline (righting moment) test that Brion asked for.

We filled several dry bags with water, tied them to the end of the boom, and swung the boom out as far as it would go on both sides. We measured the amount of heel using a smartphone and used a tape measure to get the distance from the centerline to the boom end on both sides. We weighed each of the water-filled dry bags and the boom end with a spring scale.

Here are the results of the incline test.

The weight at the end of the boom totaled 211 pounds. The weight of the boom (measured with a spring scale at the aft end) was 60 lb.

With the boom and personnel centered, the boat heeled 01.3 degrees, starboard high.

With the boom out to starboard, personnel centered, the heel was 01.3 degrees, port high (02.6 degrees total heel). The estimated distance from the centerline to the boom end was 189 inches.

With the boom out to port, personnel centered, the heel was 03.8 degrees, starboard high (02.5 degrees total heel). The estimated distance from the centerline was 192 inches (both centerline and tape end were estimated).

Despite the relatively small weight and angle of heel, it was enough to give him the information he needed.

Unfortunately, I don't know the exact tonnage of Tango. I assume that it is close to 30,000 pounds.

Dennis
s/v *Tango*

Toss, B. (1997). *The Complete Rigger's Apprentice: Tools and Techniques for Modern and Traditional Rigging.*