The Shock of the Old

Part 7: Loading Up The Mast

Moray MacPhail continues his series on refining traditional rigs for today's sailors

Last time, I began the process of working out the mast loads starting with an estimate of the righting moment and using rig parameters as follows:

- **Mb** – the ratio of the mast height to the half beam. I have taken mast height as the distance between the point at which the cap shrouds are attached and the deck.
- **Hm** – the height of the hounds – where the spreaders and lower shrouds are attached – as a proportion of the mast height from the deck.
- **Sb** – the length of each spreader as a proportion of the half beam.

We saw how the rig height affected the lower mast load and though it was not dramatic, we saw why you can't just add more height to a rig and hope to go faster. In addition, an early casualty was the rule of thumb that the mast load should be about equal to the displacement; a factor of 1.5 would seem to be a safer assumption if you want to use just the one number.

Above: Hounds and spreaders are low and lower on these bermudan rigged yachts in Bayona but much higher on the lone gaffer – see page 50.

Lower Mast Design Loads

But moving on, Figure 1 looks at the effects of changing the height of the hounds (Hm). An upper limit is probably 80-90%, otherwise the base of the lowers is too narrow and/or they are taking too much load. Or cap shrouds become redundant. It depends how you want to view it; spreaders are meant to reduce the rigging loads after all.

The lower limit occurs either when the spreaders don't deflect the caps any more, at which point they become useless or when the cap angle is 9˚. In practice 50% of the mast height is a normal lower limit for the position of the hounds and is reasonably common on bermudan rigs with a single set of

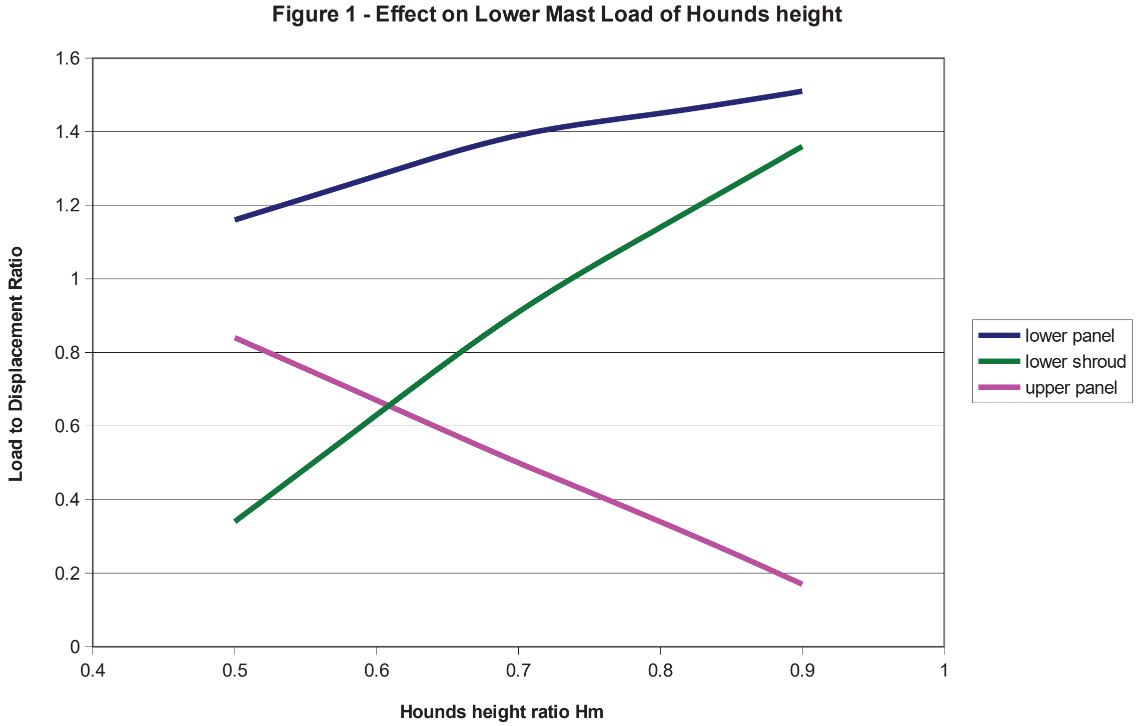
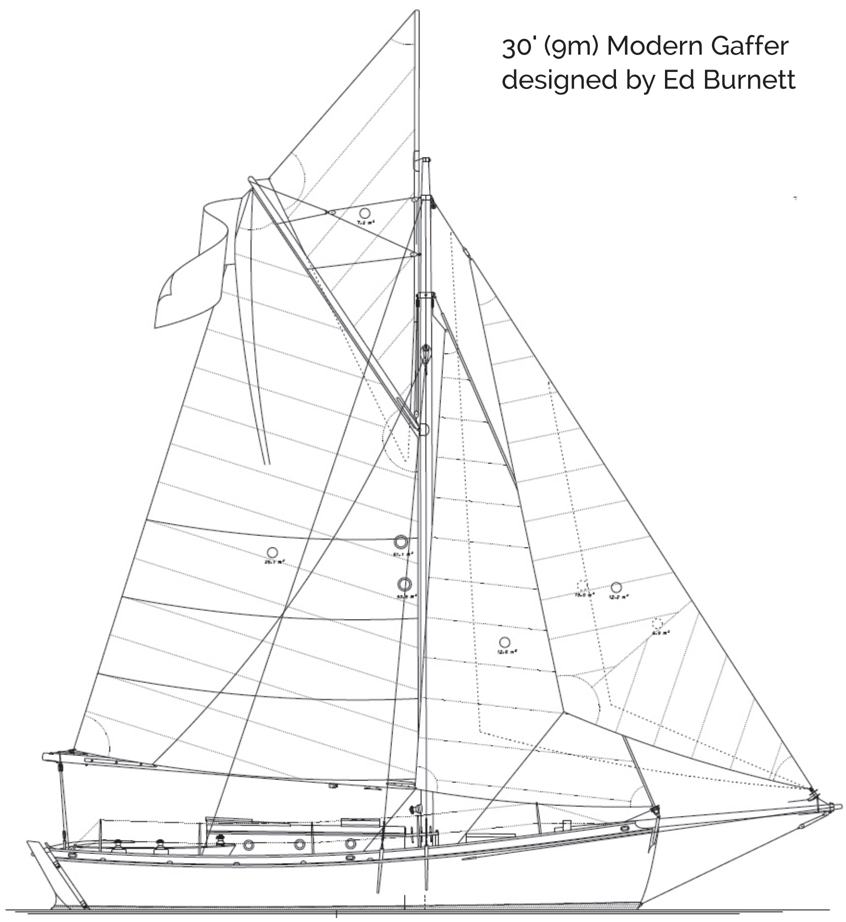


Figure 1: Effect on Lower Mast Load of Hounds Height

spreaders. For gaff rigged boats, the spreaders have to be above the saddle or jaws sliding up the mast and therefore will have relatively high hounds, typically 70% of the mast height. You can see that as hounds go higher, so the loads in the lower panel increase. This has a compound effect, in that the load on the lower mast panel is increasing at the same time as the unsupported length is growing. That longer panel may therefore require a heavier mast section than for an equivalent bermudan rig of the same sail area on the same boat. If you convert from bermudan to gaff, you will need to bear this in mind.

Changes in the spreader length have virtually no effect on the lower mast load, so we can ignore that for now. Combining the figure in W147, where the mast height varied and Figure 1, where the hounds height varies, creates Figure 2 which shows how the lower mast load varies with both these factors.

For a given righting moment on a given hull, the main influence on the lower mast load is the hounds height (Hm), with the mast height (Mb)



30' (9m) Modern Gaffer designed by Ed Burnett

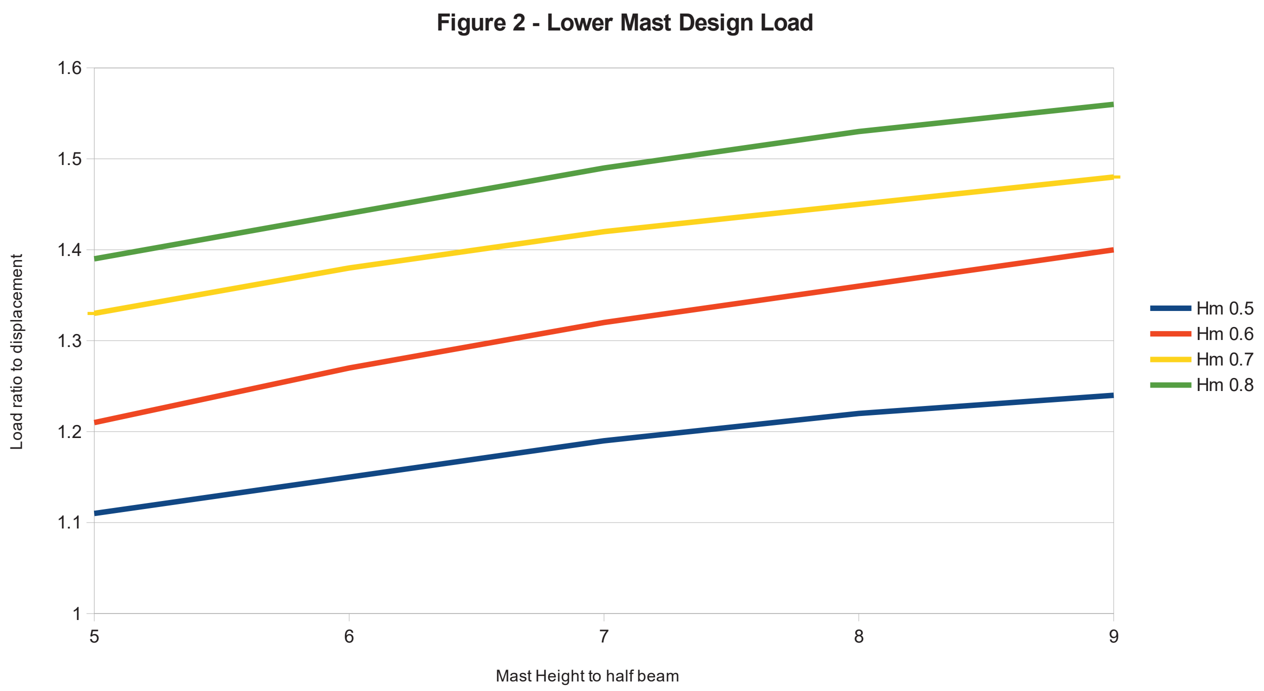


Figure 2: Lower Mast Design Load

secondary but significant. Usefully this diagram can be reduced – within a few percent– to a simple equation:

Lower mast design load = ((0.94 * Hm)+ (0.04 * Mb) + 0.456) * displacement

Since Hm and Mb are just numbers, the mast design load will be in the same units we used when measuring the displacement: kg, tons, tonnes or Newtons.

This is also a good time to remind ourselves that the displacement is the weight of the boat as picked up by a crane, not the Thames or rated tonnage.

And that is it: plug in three numbers and you get a lower mast design load. It is unlikely to be perfect but it is almost certainly better than guesswork. In the case of our 30' (9m) modern gaffer, the hounds height (Hm) is 0.75, and the mast to half beam (Mb) is 6.93 giving a lower mast load of 1.44 times the displacement. I have found the method gives good answers for a range of 'normal' boats from 23' to 66' (7-20m) and 1.5 to 30 tons/tonnes displacement.

Shroud & Upper Mast Panel Loads

Though the spreader length had almost no effect on the lower mast design load, as it increases – if all else stays the same – then the loads on the cap shrouds reduce because of their greater angles and loads on the lowers rise because they are taking more load from the caps.

Which makes sense and tallies with Figure 1 where increasing the hounds height for a given spreader length has the same effect. In practice, spreaders are unlikely to be more than 90% of the beam to avoid fouling headsails and hitting other boats if alongside and every one is rolling about.

Figure 3 comes from combining the results from hounds height variation and spreader length variation. It shows the proportion of the mast design load taken by the lower shrouds for a range of hounds heights and spreader widths. Unlike the mast load figure, it does not reduce to an easy equation, so I'll have to leave it graphically presented, and you can put your own numbers in.

The lower boundary is represented by spreaders which don't reach the cap shrouds, the left-hand boundary set at a hounds height of 40% and some of the data in the upper right corner represent impractical arrangements because the lower shroud angles are too small. We can see how significant a change to spreader length can be for the loadings in the shrouds.

I have put in lines indicating where lowers are taking the same load as the caps – and thus could be made from the same wire – and also where lowers are taking twice the load. In that case you would have two lower shrouds of the same size and type of material as the single cap shroud. The lowers are almost always more highly loaded than the caps, particularly for gaffers and luggers where the hounds are necessarily high up the mast. For those rigs, we are likely to need a pair of lowers, or lowers made from a heavier diameter wire.

So we have the lower mast design load and the proportion of it which the lower shrouds take. Again using the figures from our example here – Hm of 0.75, Sb of 0.5 – we get 0.72 times the mast load in the lowers.

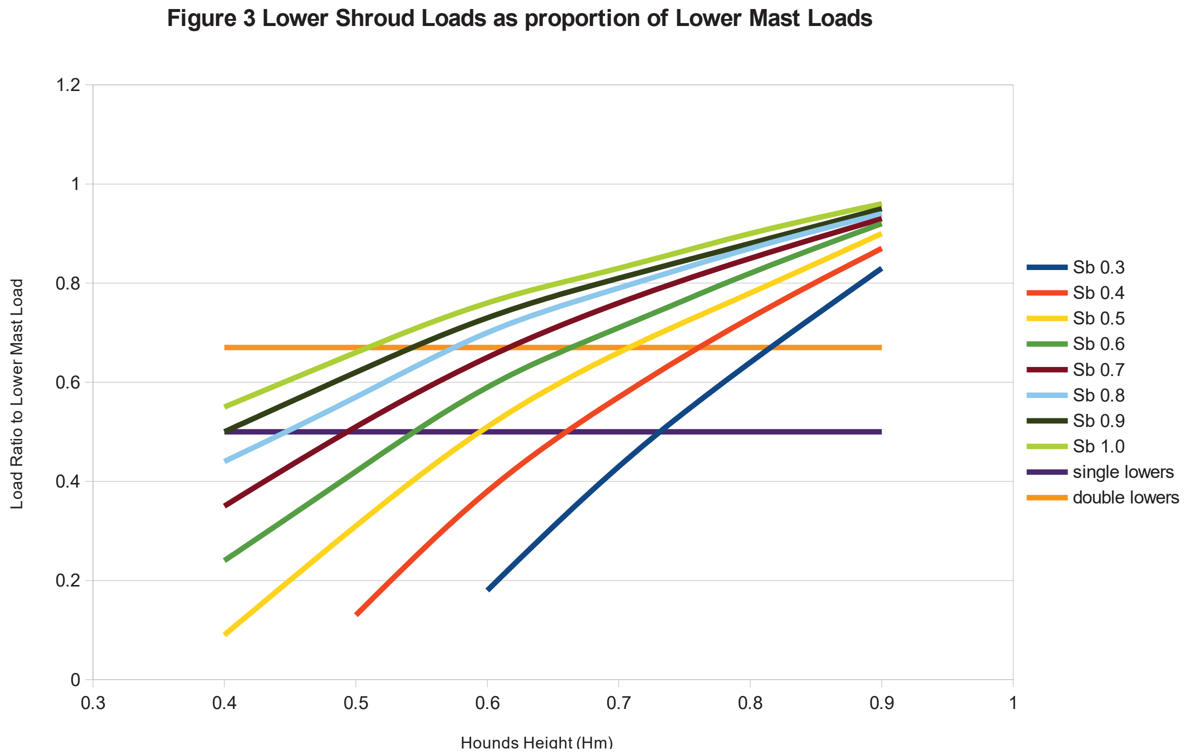


Figure 3: Lower Shroud Loads as proportion of Lower Mast Loads

Moving to the caps and the design load on the upper mast section, I am going to make the heroic assumption – probably OK given the factors of 2.5 to 3 incorporated in the method – that they are both equal to the total load less the amount which the lowers are taking, so in our case it's 0.28 times the mast load.

So summing up for our example boat, using the ratios of mast/beam of 6.93, hounds/mast height of 0.75 and spreader/beam of 0.5, we can get a good estimate of:

- Lower mast design load, 113680 N (=1.44 x displacement in N)
- Shroud design loads for the lowers, 0.72*113680 = 81850 N
- Shroud design loads for the caps 0.28*113680 = 31830 N
- Upper mast design loads, also 31830 N

Next time, we will see what is needed in practical terms to resist those loads and work out the sizes for stays and other components. In the meantime, I hope I've explained why the masts and stays for traditional rigs need to be different to those for bermudan rigs.

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Below: *High hounds on a 28' (8.5m) cruising gaffer based on a Falmouth Working Boat; see 'Gaff Rig for Cruising' in W113. Photos: the Holmans.*