VI-VI - THE RIGGING PLAN

This plan must provide all the elements making it possible to carry out the mast and rigging, standing and running, of the yacht.
For the masts, it must provide the characteristics of the minimum profile necessary: section, moments of inertia, all dimensions, nomenclature and sites of the accessories and equipment, positions, lengths and angles of the spreaders. In the same way for the booms.
In return, the manufacturer of the mast should provide the exact position of the fastening points of the rigging in order to allow the rigger to calculate exactly the length of his cables.
For standing rigging, one must indicate minimum strengths of the cables (or their diameter in a given grade), their type as well as the type of ends, turnbuckles, etc.
For running rigging, the diameters and specifications of the ropes must be provided but one generally leaves to the rigger the responsibility for calculation of the lengths. Which sometimes surprises!

VI-VI - 1. TRANSVERSE RIGGING

The first option to be defined in the drawing of the transverse rigging is the number of spreaders. Two preliminary decisions will determine this choice: on the one hand the relationship between the maximum spacing of the chainplates and the height of the mast, on the other hand the minimum angle of the shrouds.
The first will be dictated by the desire to return the jibs to the maximum to tighten the wind as much as possible. It is certain that this factor will be more important for a competition yacht than for a cruiser.
As departure bases one will be able to take a distance ‘e’ from the centreline equal to approximately 7 % of ‘I’ for the first and to 9 to 10 % for the second.
For the second decision, it will have to be acknowledged that, for equal transverse efforts, the angle being reduced, the load in the shrouds and compression in the mast will be high. A larger section and thus weight will result from this, as well as a greater difficulty of adjustment.
For a long time it was considered that an angle of 15° was a minimum below which it was not possible to go down without risk. Today, under the influence of the competition yachts produced which sail with increasingly small angles of incidence, one finds sometimes angles lower than 10°. In theory nothing would be opposed to it if everyone were conscious of the increase in loads that results from it, not only on the mast and the stays, but also on chainplates and the structure of the hull, transverse and longitudinal, with increasing height of the mast.
It can be wise to point out that, on the basis of an angle of 15°, the efforts will be increased approximately 25 % for 12°, 50 % for 10° and 90 % for 8°!
One should not forget either that, for the same lengthening of the stay, the angle is reduced; the displacement of the point of attachment is greater which involves in its turn a new reduction of the angle. The adjustment is thus more difficult and it would be logical, under these conditions, to increase the safety coefficients. This is also the reason for which, with rigs of this type, one often uses, for the Cap-shroud, rod of which the stretch is lower and more linear than the cable.
Personally I estimate that one should never go down below 14° for a cruising yacht* and 10° for a racing yacht taking part in races being able to profit from a closer jib.
The two preliminary choices being carried out, one will realize that the number of sets of spreaders is related to the ‘I/e’ ratio that will have to remain lower than the values below.

* Nevertheless a certain tolerance for the mast head cap-shroud for, these masts being practically never hammered, the top panel is less solicited than it could be, which corresponds to a higher safety factor.

	1 stage	2 stages	3 stages
Cruising	7,5	10	15
Race	10	13	20

The number of spreaders being defined, their position will determine the length of the mast panels. The position of the points of attachment should be such that the angles of the tangential to the distorted axis of the mast, be there any, so that it does not produce any imbalance between the panels and therefore an undesirable deformation of the mast. And of these points, particularly important is: the cap-shroud attachment at the head. It has in fact to be situated underneath attachment of the forestay in a manner to obtain a balance between the moments generated above by the Genoa and that moment below generated by the main sail. One sees there, the impossibility of a perfect solution since these two moments will vary according to the size of the jib and the reefing of the main sail. Precise calculations could be carried out only in a body completely hyper-static (mast and shrouds) and for all the possible cases. This problem cannot be determined elegantly by the elemental method.
The table below gives a first approximation of the bases that one can adopt for every panel from the bottom as a percentage of I for a mast stepped on the deck.

	1 spreader		2 spreaders			3 spreaders			
14°	52	48	40	35	25	28	29	25	18
10°	55	45	42	33	25	30	30	25	15

This allows for a progressive reduction of the length of the spreaders. For a mast stepped on the keel one will increase the percentage of the lowest panel by two points.
These heights are taken from the level of the chainplates. If the mast foot or the deck collar are located on the summit of a deck house, the height of this will be deducted from the lowest panel.
The distance between the forestay attachment and cap-shroud will be equal to about 6 S_f / $S_{g\text{-}v}$ one for thousand of the top panel.
In our example we had 6 x 42 / 20 ‰ of 415 cm length, becomes 5,2 cm rounded to 5 cm.
The progressive shortening of the spreaders is intended to facilitate the passage of the leach of the Genoa. One should not forget, however, that it leads to a reduction of the load on the lower shroud and consequently to an increase of the load on the cap-shroud and that these change very quickly.

For cruising yachts of which the foot of the jib does not descend to the deck one can gain by separating the lower shrouds more than the cap-shrouds, the crossroads corresponding to the height of the foot.

VI-VI - 2. LONGITUDINAL RIGGING

The angle of the forestay is situated generally in the vicinity of 20° with very rarely small variations seldom greater than ± 1°. This explains for two reasons, the first one aerodynamic for this angle corresponds to an axis of the appreciably vertical Genoa, the second mechanical for, as we saw, it can reduce by half - and even less with a 3/4 sail plan and a supple mast - in the top panel, between the halyard point of the Genoa and the attachments on the mast head. One will consider with great circumspection the sail plan or of rigging of which the angle of the forestay would be less than 18°.
The balance of the load of the forestay is taken up mostly by the backstay. The lengthening of the forestay under load that is applied being responsible for the importance of the direction that it takes under the load, it is essential to be able to recover this lengthening by a shortening of the backstay. It is therefore necessary, even on the cruising yachts, that this has access to a means of powerful and precise adjustment if one wants to preserve a good balance of the mast. If, on the racing yachts, one adopted almost everywhere the hydraulic actuating cylinder, on a cruising yacht all sorts of systems of hoists and of turnbuckles with wheel or crank are available.
One does not find a double backstay anymore today. This did nothing but to increase the weight and the windage. The one advantage could be to balance a little of the torsion provoked by the offset, on the before profile, of the forestay attachment. Again it was necessary for this, that it is the leeward backstay that is solicited. When, on a cruising yacht, one desires to release the rear deck of the presence of the backstay, one installs a bridle rather high to leave the passage of an adult. The tension system will be brought up on the bridle but, if it is not symmetrical, the backstay there will have to be secured by a cable pulley of the same strength or a bridle plate, in order not to provoke imbalance in the tension of the two sides of the bridle.
The behaviour of the middle of the mast is always a delicate problem; the only really effective means being furnished by one or two intermediate stays or a baby-stay balanced by a check stay and aft lower shrouds. But this provision has many disadvantages of a practical nature. The intermediate stays obstruct the passage of the sheets for tacking, the operation of the check stays is random with a reduced crew, they add more weight, windage and complexity in the upper rigging. As for the aft-shifted lower shrouds, they prevent the boom from properly swinging outboard for down wind sailing, which can be dangerous by causing involuntary gybing.
We will see that some vary the rigging plan according to the size of the yacht and the sail plan.

- Yachts of less than 7 m with 7/8 or ¾ rigging 7/8 or 3/4 (fig. VI-33)

Masthead rigging is practically unknown in this size of yacht. The rigging will consist therefore in a cap-shroud and a lower shroud, both aft swept, as well as the spreaders. The mast is held aft, then by the angle of the spreaders. This is assured only if the two cap-shrouds remain taught. In fact, if the leeward lower shroud relaxes, the resultant push of the spreaders quickly falls behind perpendicular to the load of the main sail and the mast is held more by the balance of the moments exerted by the main sail above and below the attachment of the forestay.
The lower shroud has a role essentially to limit the action of the push of the spreaders; they are therefore less loaded than the cap-shroud.
Attention should be paid, in this type of rig, to the position of the spinnaker halyard take-off. Too far above the attachment of the cap-shroud, can cause the mast to invert, its effect adding to the effect of the top of the main sail.
The tension of the forestay is balanced by the cap-shroud and also by the load of the main sail. In the larger yachts it can become necessary, especially on the 7/8 rig, to use a backstay. Too near, and it can help to bend the mast forwards, the surface of the main sail above the attachment being smaller. With the wind from behind it is essential to balance the load of the spinnaker. The angle of the transverse rigging towards the aft that, normally, at about thirty degrees can be reduced with use of a backstay.

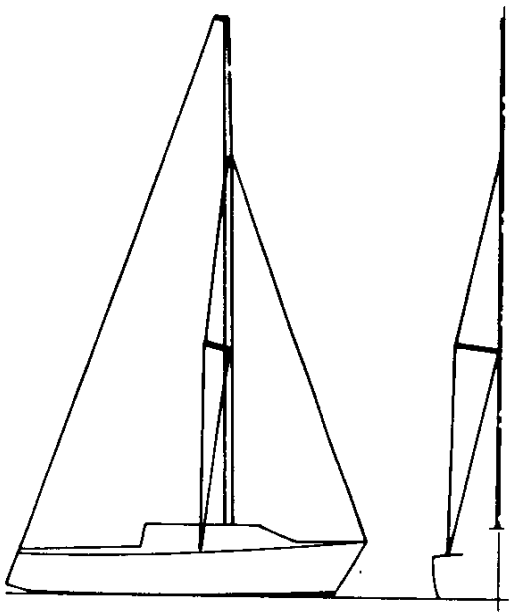

Fig. VI-33. Gréement 3/4 d'un voilier de moins de 7 m.

- Cruising Yachts with masthead rigging and one set of spreaders (fig. VI-34)
It is undoubtedly the simplest case. The longitudinal behaviour of the middle of the mast is set either by a pair of fore and aft lower shrouds, or by a baby-stay and aft lower shrouds.
The angle of the lower shrouds will be approximately 6° on both sides of the vertical, and that of the baby stay at least 10°. Attention, the jolts to the baby stay can be very strong and its chainplate will have to be connected to a solid structure on the hull.
On yachts that are not intended for the deep-sea cruising, the lower shroud can be in the same plane as the cap-shroud, and the baby stay, which remains essential, can be releasable under quiet sea conditions.

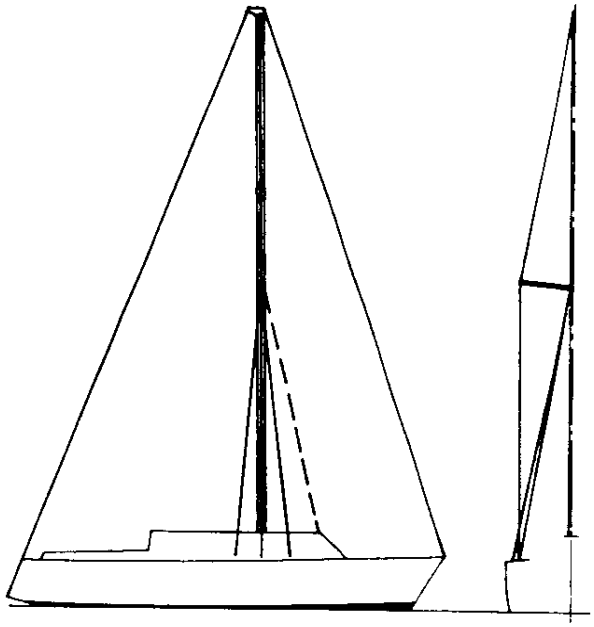

Fig. VI-34. Rigging at the head of a yacht of 8,50 m with one set of spreaders; the pair of front lower shrouds can be replaced by a baby stay.

- Cruising Yachts with masthead rigging with two or more sets of spreaders (fig. VI-35)

It is with these rigs with several panels that the longitudinal behaviour presents the most difficulties. If the sail is that of a cutter, an inner forestay is taken to the higher spreaders. This can be sufficient to prevent mast inversion, but it needs to be balanced by a running backstay.

If the boat length exceeds ten meters, one will be able to place a pair of fore and aft lowers or a baby stay and an aft lower shroud. But today rigging of a cutter is often mixed, i.e., with moderate wind; one rigs only a genoa of a sloop. The inner forestay and the runners can then be released if the state of the sea allows it, but the behaviour at the level of the first spreader must be preserved.

When the sail plan is a sloop, one will use an inner forestay coming to hold the mast between the two spreaders. The forward behaviour is normally secured by the mainsail but one will be able to supplement it by a check stay when the conditions of the sea require a firmer hold.

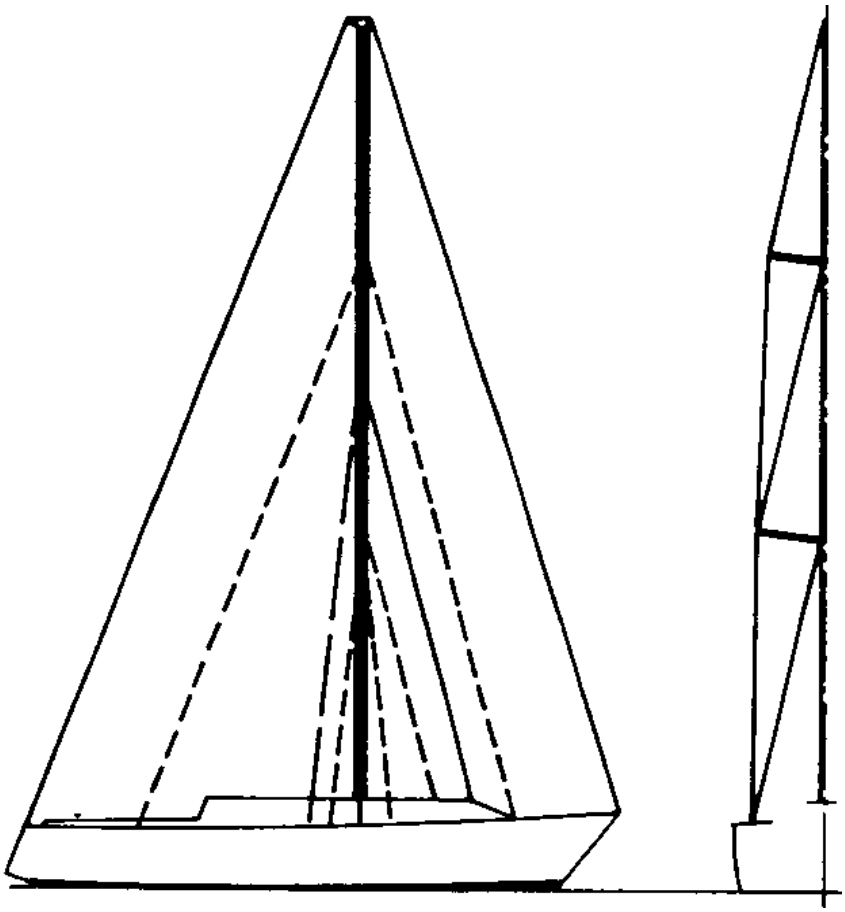

Fig. VI-35. Rigging at the head of a yacht of 10,50 m with two set of spreaders. For a larger yacht or a cutter, the baby stay will be replaced by an inner forestay (which can be releasable), balanced by the runners, and two fore and aft lowers, or aft swept lowers and a baby stay.

- Split Rigging (fig. VI-36)

Two requirements of balance are essential in this type of rigging: that of the load of the forestay and that of the bending of the mast. That the transverse rigging comprises of one or two set of spreaders, there will always be a runner at the height of the forestay and possibly a second at middle height of the fore-triangle. Except on the larger yachts, where the behaviour backwards will have to be resisted by at least a releasable inner forestay, the whole of the transverse rigging is placed in the plane of the mast in order to allow its bending.

The balancing of this bending is controlled by three elements, the backstay, the check stay and possibly a jumper. The reciprocal action of the sail and the mast can thus be regulated at will. The jumper is a rhombus laid out between the head of the mast and the top panel and whose struts are swept forwards so that it acts on the higher panel of the mast in the two directions longitudinal and transverse.

To be able to correctly distribute the action between these two directions it is necessary that the angle of the struts is adjustable. But the presence of the jumper obstructs the passage of the leach of the genoa.

When, as in the preceding case, no former staying is envisaged, it is necessary to pay great attention to the behaviour of the lower panel of the mast when one is with loose under spinnaker. At this time indeed, the push exerted by the boom becomes very high, and that while at the same time there is no more bending of the mast. On units of certain importance it becomes necessary to envisage a releasable baby stay.

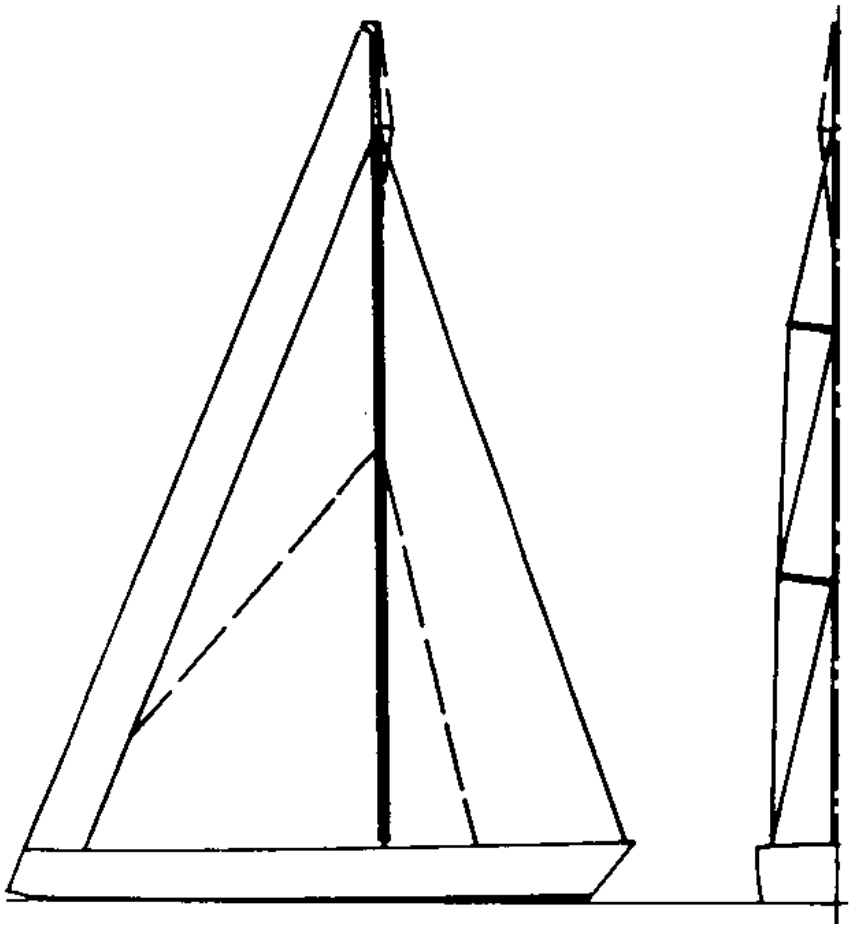

Fig. VI-36. For a 10-15 m yacht with a 7/8 rig, the runners are essential; the longitudinal behaviour is controlled by a baby stay and the check stay.

VI-VI - 3. THE MIZZENS (fig. VI-37)

Except to the bearing paces where they can support a staysail, these masts are subjected only to lateral and fore-aft forces.

Their lateral behaviour is thus ensured by traditional rigging with cap-shrouds, one or two sets of spreaders, and a lower shroud. The transverse rigging can be shifted backwards to compensate for the bending of the mast.

The longitudinal behaviour is ensured, in general, by an intermediate stay at two-thirds height of the sail and having a forward angle of ten degrees. It should be taken care that this does not obstruct the clearance of the boom of the mainsail.
The halyard of the staysail is provided with a thrust to the head of the mast and returns, as far as possible, to be useful as a running backstay.

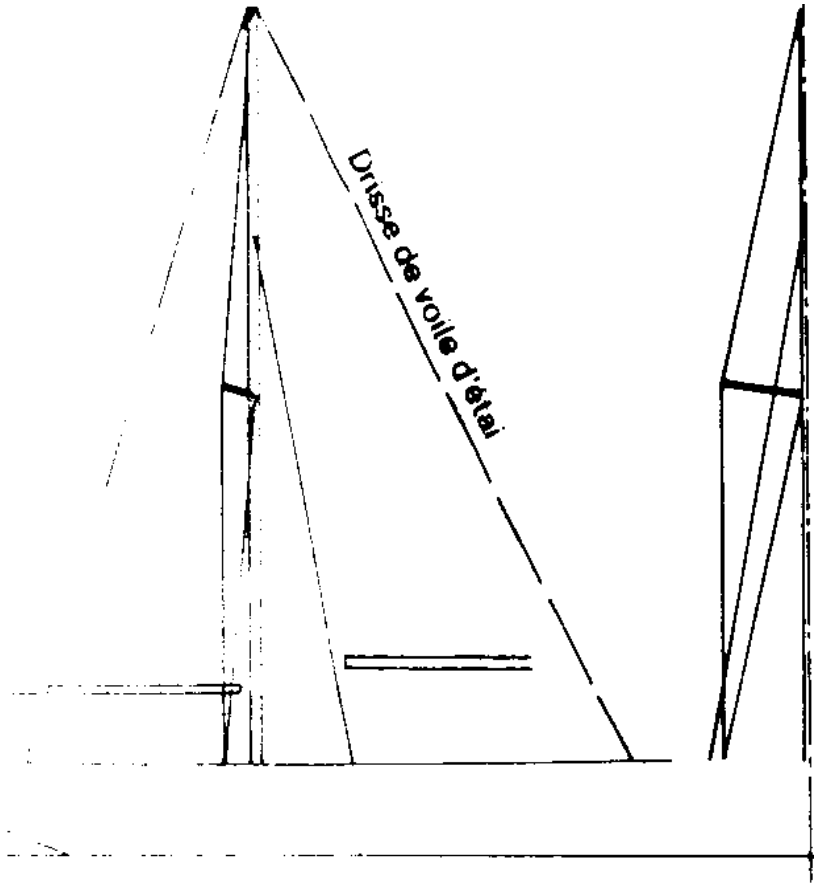

Fig. VI-37. Gréement d'artimon.

VI-VII - THE SAIL PLAN

I will not extend here on the choice from the type of rigging which is treated in the first volume and sails and rigging. It however remains to see some practical problems of adaptation or interference with the hull and rigging.
The surface area of the sails having been determined according to displacement and of the program of the yacht, the distribution between the fore triangle and the mainsail will determine the position of the mast. And it is there that the first difficulty emerges. That the mast is deck stepped and supported by a pillar or that it goes down on the keel, its site and the associated structure must be integrated in the movements without harming itself.
It will often be necessary to move one or the other to lead to an acceptable compromise, which is far from always being easy.
One will then carry out the first control of the relative position of the centres of sails and hull, given according to the methods shown in chapter III. It then remains to measure the horizontal distance between the centres of sails and hull and to check if this variation corresponds to the values given in the volume I (Ch VIII-B-1-c).

It will probably be necessary to carry out an installation of the plan of the hull without harming the distribution of the weight.
The architect will thus be brought successively to make a circular step reviewing: the sail plan - position of the mast – movements - variation of the centres of sails and hull - plan of the hull - ballast – sail plan, etc., as many times as it will be necessary to arrive at a satisfactory result.

Some points remain to be checked. For example, it is always preferable that the end of the boom cannot be caught in the backstay at the time of an unforeseen gybe. That for an arc of circle having for its centre the gooseneck and for radius the overall length of the boom should not cut the backstay.
When sailing down wind, that the higher batten will not comes in conflict with the cap-shroud.
The sail plan will have to include all the necessary indications to the yacht and the particular specifications such as reef points, slides of mast and boom, jib hanks.
It will have to be specified, if dimensions correspond to the sail slackened or normally hoisted, which is generally the case, in particular for the yachts measured for racing. For lack of this precision one is likely to lead to a too large sail that one cannot hoist normally and a boom that hangs lamentably. All measurements of gauge concerning the sails and the mast must be given.
When the jib halyard is metal, its hoisted position must be constant which that is the length of the jib luff in place. It is thus necessary to provide each sail with a halyard pennant, and possibly tack, in order to keep a constant overall length.

The architect should also determine the fabric weights of the various sails. Unfortunately it often rests for that on the yacht. It is certain that this one is perfectly able to define it but at the time of consultations near several yachts it is essential to provide them common data if it is wanted that the proposals are comparable.
Certain foreign architects, like the office of Sparkman & Stephens provide to their customers a diagram of reduction of sail according to the real wind.

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