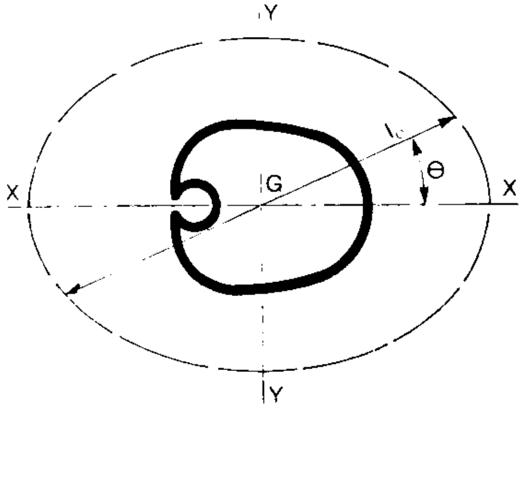
VI-IV - MATERIALS AND PROFILES OF MASTS

Today, almost all the masts are made of aluminium alloy with heat treatment, with alloys magnesium, silicon and manganese - A-SGM treated to T6. The differences of characteristics that one can note originate essentially from the silicon content and other ingredients and the process of heat treatment.
Nevertheless other materials were or will be used for the manufacture of masts: wood, steel, composite, etc.
The interest of a new material in compared to another is measured primarily by the ratio E_f/d^3* owing to the fact that the modulus of elasticity defines the critical load. But one must take account of the resistance in compression and of the ratio R_{ec}/d since the deflections depend on it and that the local stresses in a mast are always in compression - at least for a stayed mast.
* See section IV-II-2
It is interesting to recount then the values of the figure IV-XI:

	R_{ec}/d	E_f/d^3
Spruce	8,7	11742
Alloy A-SGM T6	10,74	356
Stainless Steel	3,4	37,5
UD R glass fibre with epoxy	33,3	734
UD HT carbon with epoxy	98,6	3844

One will note the excellent performance of spruce that, even with a wide safety factor to take account of the possible structure irregularities, comes practically equal to carbon fibre. The resistance in compression of this is often superfluous except for sections of large dimension and too thin a wall where the local buckling becomes the more critical factor. This will not be the case with a mast in spruce given the thickness of the walls.
It is necessary to take equal account, for masts in composite, of the fact that the fibre to the adhesive bond will not allow it to attain theoretical performances. To the other extremity one sees that the stainless steel, sometimes envisioned for the manufacture of masts, presents no interest.
For the moments of inertia of a mast being defined, there remains an infinity of possible dimensions according to the thickness that one gives to the wall. Nevertheless the section of the profile - therefore its weight - growing as the square of its dimensions while the inertia moments grow to the power four, the larger the exterior dimensions the more the thickness must be reduced to preserve the same section and the local buckling of the walls quickly becomes critical. For the same reason, a material with high resistance in compression allowing a reduction in the section of the profile will not be able, most of the time, to be used to the maximum of its possibilities.
In the Volume I studied the form of the aerodynamic sections. From the mechanical standpoint do not forget that the value of the moments of inertia according to different axes of the section follows an elliptic curve of which the axes have for length the longitudinal and transverse moments of inertia (fig. VI-27).

Fig. VI-27 Knowing the moments of inertia of a section, Ix and Iy, it is possible to know the moment of inertia I_θ for any inclined axis of the angle θ, it suffices for that to trace the ellipse having for axes the values Ix and Iy.



In addition the bending of the mast occurs in an intermediate direction - and variable in its height - between these two axes.
When one wishes to modify the bending characteristics of a mast by the addition of internal reinforcements, do not forget that their position will not be unspecified; one will favour the axis on which they will be located. And when one wants to stiffen the two directions simultaneously, rather than to place reinforcements on the two principal axes, one will locate them on the diagonal axes. Local internal reinforcements can be also planned for the fixing of the fasteners of stay.
In the drawing of the sections one will avoid flat parts whose local buckling strength would constitute a weak point. From this point of view an elliptic section represents the best compromise. For the same reason, on an open section (for the passage of a rope or a sail with roller) the internal wall will be always curved (fig. VI-28).

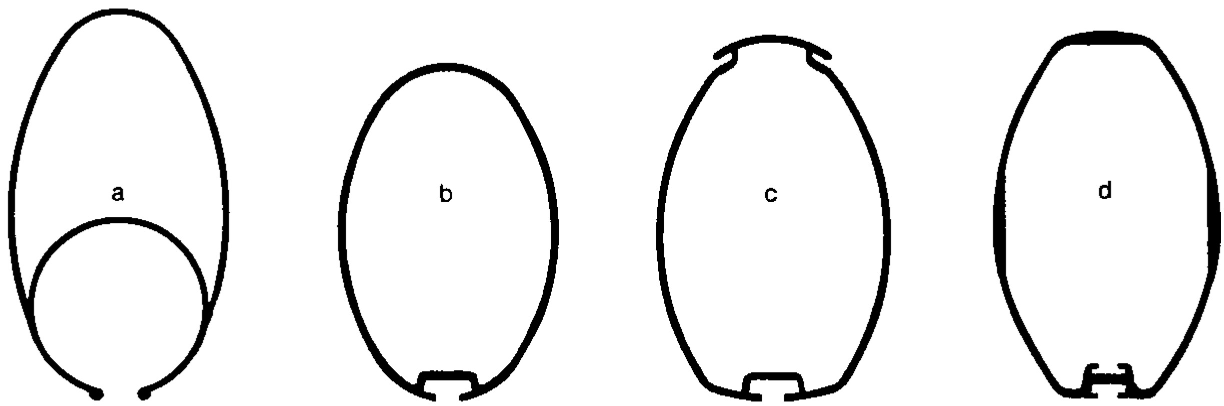


Fig. VI-28. Different examples of mast sections.
a - section Francespar for furling sails;
b - section Francespar classical elliptic;
c - section Z-Spar with rail of integrated pole track;
d - section Marechal to report high moments of inertia and reinforcement on the axes; the internal rail is destined to receive a plastic conduit for the electric cables.

It is not always possible to obtain a mast in one length, generally for transportation reasons or of manufacture, but also because the manufacturers are limited by the length of the heat treatment ovens or of the anodising plant. In this case, the joint of the sections must carry out an important effect on the profile. It is necessary to look for the points where the bending moment is low and that correspond to the modulation points of the distorted mast. They are situated in the vicinity of the quarter of the panel above and below the spreaders. In any case it will not be necessary to place the joins too far from this as one too often sees.
The join will be effected by glue and fastened sleeve. The joint between the two extremities must be perfect, with no false support, in a manner to transmit uniformly the compression loads without introducing parasitic bending moments. In order not to create a too hard change, the internal sleeve, constituted of a rolled sheet of the same thickness as the wall, would be taper cut (fig. VI-29).

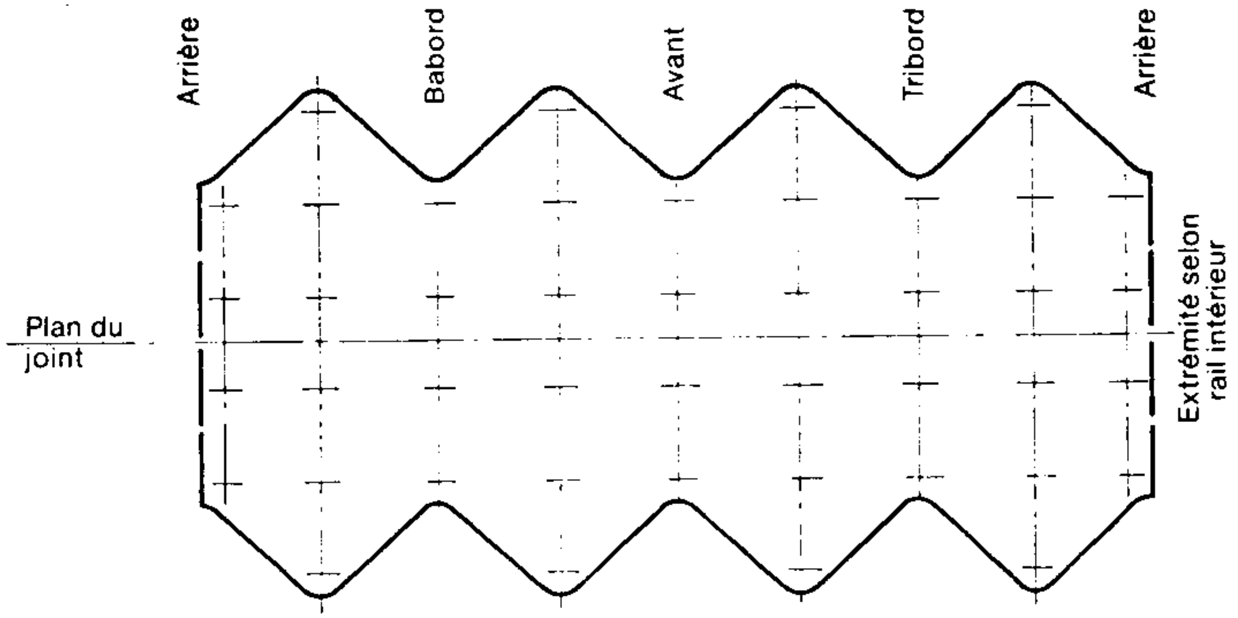


Fig. VI-29. Connection Collar for elements of mast. The height is equal at least to half of the interior perimeter of the mast; the "horns" are placed on the diagonal axes of the section; fixing is ensured by epoxy joining and Pop rivets counter-drilled with the mast. The joint, placed on the back face comes to butt against the luff rail; it is wise to bring back a guide out of U on the outside of this rail to avoid any risk of misalignment which would cause the blocking of the slides.

The alloy A-SGM having undergone a heat treatment, all operations of welding will reduce its mechanical characteristics. One will forbid oneself therefore all welding in a plane perpendicular to the axis of the mast, except of course, to the ends where only compression and shearing loads exist, for which the section is widely overabundant. In particular one will reject the spreader mountings fixed on a transverse plate and welded to the mast wall. The taper in the masthead necessitates a weld along the mast wall. This is admissible provided that the weld is carried out with the maximum of precautions to reduce the heat-affected width as much as possible.

These tapers are interesting not only from the viewpoint of the easing of the top end of the mast, but also to reduce the width presented to the wind and the harmful effects that result for the main sail. The cut will begin mid-way up the last panel for a masthead rig and the exterior dimensions will not be reduced by more than half. The bend of the reduction in dimensions will be parabolic. For a 7/8 rig, the cut will start mid-way up the last panel under the hound, but it is not possible to give a proportion and a reduction form of precise dimensions for they depend on the cut of the mainsail. This is the reason it is practically always necessary to foresee a jumper of which the angle of the struts should be adjustable to be able to absorb the bending of the mast in the two planes.

VI-V - ACCESSORIES AND EQUIPMENT

It is rare that one is brought to draw the various incidental mast fittings. The serious manufacturers propose a range that allows manufacturing almost for all the possible configurations of Rigging. It will be nevertheless important to study the equipment and to choose it according to a number of criteria.
It is not, of course, possible to review here all the proposed solutions and one will have to obtain the catalogues oneself.
Unfortunately these are mostly of a rarity, especially as for the description of the equipment. One is happy when one finds all the essential pieces of information to the choice of the profile: dimensions, thickness, surface of the section, moments of inertia and position of the centre of area.

VI-V - 1. Head of the Mast

One of the first qualities of a masthead must be the lightness since it is placed in a particularly unfavourable place not only for stability but especially for the cushioning of the rolling of the yacht. It will therefore be manufactured in welded alloy at the top of the mast.
The bracket on which the backstay is set up must present a sufficient rigidity vertically as well as transversely. The reach of the clevis pin must resist hammering. For that it is often necessary to double the thickness by a disc or a welded shape and, in the biggest sizes, a hollow pin of large diameter will allow associated lightness and large surface support. The same considerations apply to the fixing of the forestay but, for this it will be necessary to take account of variation of its initial angle that, as we saw, it can attain about ten degrees or less in the longitudinal direction and as much to each side. A double joint is therefore essential.
I could not impress too much on the importance of the diameter of the sheaves for the halyards. These are never rather large and practically all the premature rupture problems of halyards are due to too small a sheave. This was the case in particular of *Club Mediterranee**. All textile halyards, often used on the cruising yachts up to a dozen meters, suit themselves to smaller but wider sheaves. On the other hand, the halyards in Kevlar ask for sheaves at least as big as for steel wire. Such sheaves require, in order not to be too heavy, a carefully studied lightening. Transverse rigidity must be preserved so that they cannot foul themselves. The hub must be wider than the rim by some fraction of a millimetre so that it does not wear on the side of the housing, which would slow its rotation. The light alloy sheave will be provided with a bearing in poly-acetal, or equivalent material, preferably lubricated, with graphite or molybdenum. In the big dimensions, bearings with rollers or balls are necessary. In all the bores, the pin of the sheave must be able to be removed, without dismantling any other elements; the sheave of the jib halyard, for example, must be able be gotten out without being bothered by the forestay. The rollers or the balls of the bearings must be retained in cages. It should not be forgotten that these disassemblies will be often carried out with the mast in place.

The halyards must equally be able to be passed without removing the sheaves, this that implies a housing width at least equal to the diameter of the rope.
The rail or the boltrope throat of the main sail will always have to be provided with a headboard, even if the yacht is not destined for races. It is indeed always necessary to provide a minimum height between the axis of the sheave and the head of the sail so that it can easily orient itself without being prevented by too short a free length of the halyard.
This height must be of at least 6 times the [horizontal] distance between the back of the mast and the eye of the halyard point.

The lips of the sheave and housing of the jib halyard must allow an orientation around its static axis in a cone of 10° of half angle to the summit, with no fouling.

The halyards of the spinnaker must be able to orient themselves at least in a quarter of sphere unlimited by a perpendicular or horizontal plane to the mast and the transverse plane. The simplest solution consists in mounting a pulley to swivel on a fixed eye at the end of a small bracket. The eye will be inclined at 30° to the vertical and the bracket will be shifted to one side in a manner that the pulley does not come in conflict with the forestay (fig. VI-30).

When one desires internal halyards, this mounting is usable while allowing these to enter the mast by an exit hole at a certain distance under the head. The exit hole must be fitted with round edges on its perimeter or provided with a sheave to reduce the wear that one nevertheless cannot totally avoid. On the other hand the exit hole weakens the section of the mast in a particularly critical place.

If one is not limited by gauge problems one can use, for the spinnaker halyards, a sheave mounted in a cage pivoting around a vertical hollow hub in which passes the return of the halyard. This mounting is placed above the forestay allowing a lateral clearance of 180° with a single cage, but is a lot more limited with two cages. It is more inconvenient to lengthen the mast. It is the same with the use of spinnaker halyards exits consisting of vertical rollers. To tell the truth, still no one has found a satisfactory solution to this problem.

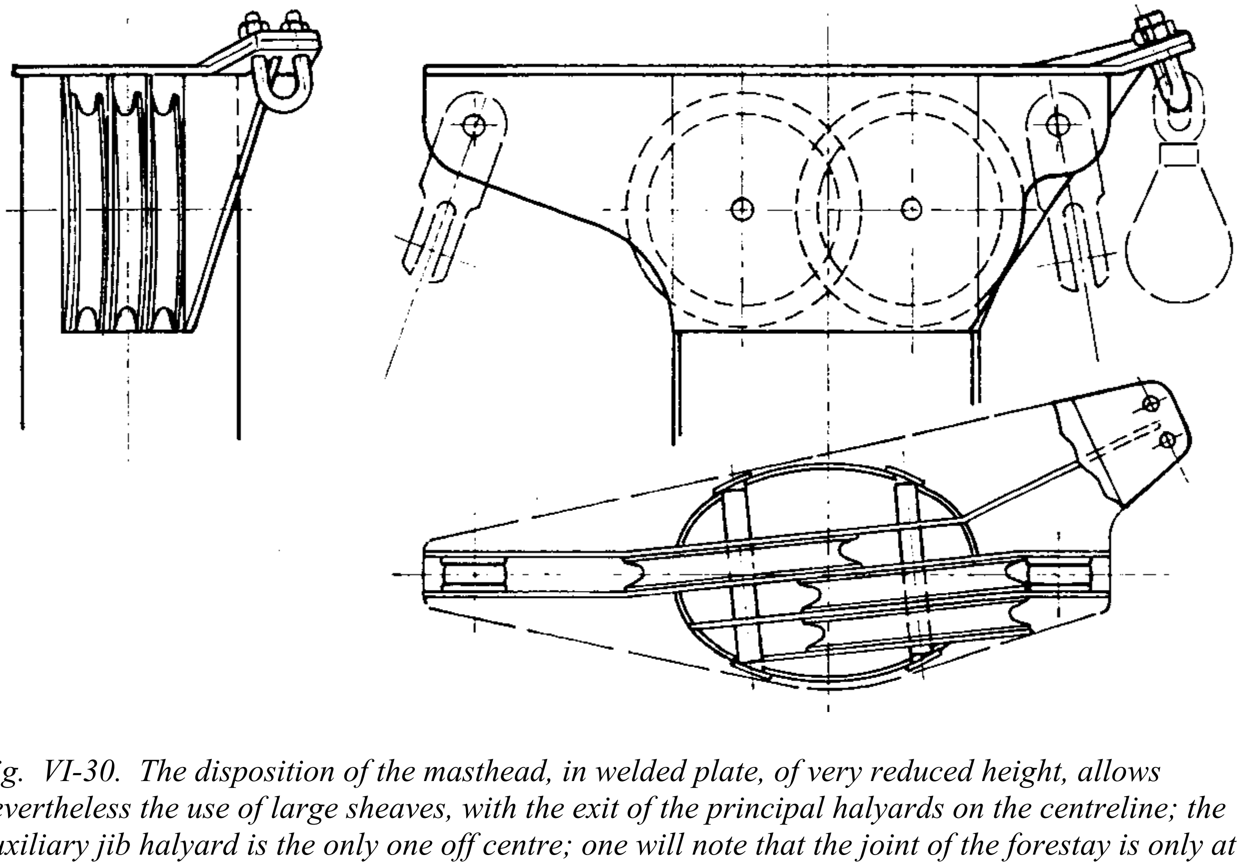


Fig. VI-30. The disposition of the masthead, in welded plate, of very reduced height, allows nevertheless the use of large sheaves, with the exit of the principal halyards on the centreline; the auxiliary jib halyard is the only one off centre; one will note that the joint of the forestay is only at an angle of 10°. The only inconvenience lies in the fact that the sheaves can only be dismantled by the removal through the opposite side to the halyard exit; the pins are kept by screwed on small plates. The thickness of the plate is doubled, in way of the forestay and backstay pins, by internal welded discs; as against double veneers welded equally to the extremity of the bracket.

VI-V - 2. FIXING OF THE SHROUDS

The classical system of chainplates fixed on the gunnels is an inheritance from the wooden masts. This remains perfectly valid so long as one does not seek optimal aerodynamic qualities. It must however respond to a number of stresses.

The free part of the chainplates must be long enough to leave space at the end of the axis for the assembly of its pin. Its play with the lug must allow a reduction of the initial angle of at least 2°, when the mast is curved. The chainplate can be single when the shroud is provided with a toggle, or double in the case of an eye, the most frequent solution.

In both cases one must check the bearing load and it will be often necessary to double the thickness by a disc or a welded plates. When the chainplate is two plates, the spanning of the two plates must be symmetrical in order not to create a false loading. The tang is generally taken on a bolt through the mast. It is essential that this bolt is provided with a spacer to join the two walls, thus reducing the secondary stresses (fig. VI-3 1). Here again it is necessary to verify the bearing load, not only between the tang and the bolt but especially between the bolt and the wall of the mast.

A hollow tube or a socket of big diameter generally allows the resolving of this problem at the level of the tang but a doubling in stainless steel must be fastened on the wall to distribute the load and to support the bulk of the bearing load. In any case the pieces do not bear on a threaded part of the pin and the nuts must be provided with a lock system.

To diminish the aerodynamic turbulences on the mast, but often also by preoccupation with a reduction of the cost price, the manufacturers adopted clash of systems of fixing the stay to the mast wall. These systems do not have anything basically bad with the proviso of respecting a number of rules.

In no case should the fixing be carried out directly on the light alloy wall but on a part of reinforcement, generally in stainless steel, able to support the stresses of the bearing load. This part must relate to the thickness of the wall of the mast to transmit the compressive forces, fastening rivets or screws alone not being able to provide this function. Nevertheless the opening in the partition must be as small as possible because it is always located at the level of a large bending moment. Especially, the system of fixing of swaging on the cable and its tang must allow a clearance under tension of several degrees in all directions. This condemns the ends in T of which the bar is only a simple cylinder. The reach always must be spherical. In order to align the cable with its range, the end is sometimes bent, it will be necessary to watch that the play between the wall and the heel is sufficient that in any case it does not come to rest on it, otherwise one can be assured to provoke a rupture of the cable at the entry into the end, that is to say latter to height of the heel. Moreover, the section on the bent part must be such that it cannot distort under the load. Without any doubt it is the combination of these two defects that caused the failure of the trimaran of Kersauzon, Jacques Ribourel. Lastly, is it necessary to specify it? A security system must prevent the end from escaping its housing.

The attached shroud being located, usually, in proximity of the root of the spreader, ensuring the liaison between the walls. If it is not , a tie must link the two opposed parts.

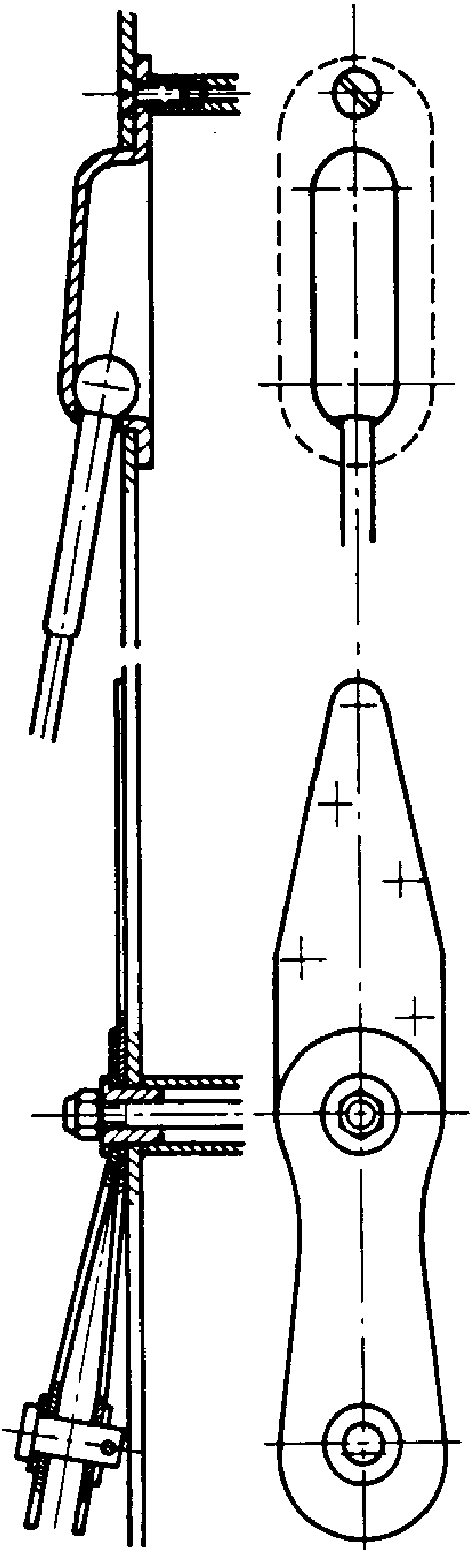


Fig. VI-31. Two systems of shroud attachment.
Top: a spherical end is retained by a pressed stainless steel cup. The articulation is excellent; as well the range on the mast. The retaining screw is screwed in the spacer transferring the lateral load to the two walls. When two shrouds attach themselves to the same place it will be necessary to shift the attachment in height of a distance equal to at least three times the length of the opening.

Below: classical tang in the shape of blanket. One will note the socket increasing the diameter of the wall in the mast and on which comes to be centred on the spacer, and the gap of the fixing holes of the distribution plate.

VI-V - 3. SPREADERS

Today spreaders are mostly manufactured in profiled tubes. It is unfortunate that the manufacturers do not profit from it to wedge them to a negative angle of incidence of about ten degrees, which would reduce their windage a lot. All the big classical architects knew that.
In the vertical direction, the spreader must be fixed according to the bisection of the angle of the shroud to its passage at its end in order to avoid all parasitic loads. Its fixing nevertheless must possess a certain flexibility to take account of the small errors that can introduce themselves to the mounting of the shrouds, due to variations to their lengthening when the mast works and bends.
In the longitudinal direction, the loads on the fixing can be very high when the mast is curved forwards. It is therefore good that this fixing is secured in two points as distant as possible, forward and behind the spreader bar, rather than to the centre, to reduce the stresses on the band fastened on the mast, a certain flexibility is nevertheless favourable. This band will be developed enough to divide up the compression load over a large area and, if need, the two opposite fittings will be connected up by a tie-bar with spacer. A good system consists in articulating the fixing on a horizontal axis of which the bearings are combined with the band while the spreader's plate is done with interposition of a sheet of neoprene (fig. VI-32 a). Nevertheless, for the yachts up to about eight meters, a fixing on a bolt through the mast is admissible, provided that this applies the same criteria as that for the fixing pin of the tangs (to brace and distribute the load). Besides, they are able to be confused.
The spreader working in buckling can be reduced in section from the centre towards the extremity. Nevertheless the manufacturers sometimes use longer sections than necessary to have a big fixing width on the mast, in this case the taper is done on the whole length of the spreader.
The extremity comprises of an end in which movement of the cable is locked. In any case it must not concern the extremity of the tube and, rather than a locking by an exterior screw, it is preferable that the screw be interior to the end and bears on a shoe receiving the cable and making it possible to round off with sufficient angle (fig. VI-32 b).
This assembly is imperative for the stays leaving the spreader. The shoe will have sufficient play to let the stay orient itself and the end of the thumbscrew will be spherical.
One will avoid of course any system containing parts welded to the mast, in particular those using a broad horizontal flat part crossing the mast and onto the ends of which the spreader section is fixed; with such a system the side resistance of the mast is often reduced by more than 30 % by the reduction in the characteristics of metal.
With rigging on several sets of spreaders, does one have to take all the upper shrouds to the deck or not? Without any doubt - yes.
One gains there initially in facility of adjustment, it is never very easy to go aloft to adjust a turnbuckle at the end of a spreader. One also gains there on wind resistance because two smaller cables in tandem will have less wind resistance than a larger cable *. It will simply have to be taken care that they are placed one behind the other.
This implies that all the shrouds pass by the ends of spreaders although only the upper shroud correspondingly will be locked. It is the only disadvantage of the system when the mast curves but then the spreader is subjected to longitudinal loading whose effect on its fixing can be very high. Still this is a disadvantage only from this point of view because, for the behaviour of the mast, that is very favourable since the points of support thus made up in the longitudinal plane make it possible to reduce the moment of inertia of the mast in this direction.
One does not lose in weight since the single cable should have a section equal to the sum of both others and one will not have the weight of the articulated fitting at the end of the spreader; as for the turnbuckle its weight will be placed better at the deck.
If nevertheless, for various reasons, one preferred the solution of the single cap-shroud, the articulations at the end of the spreaders should allow a certain freedom of the cables not only on the transverse level but also in the longitudinal direction.

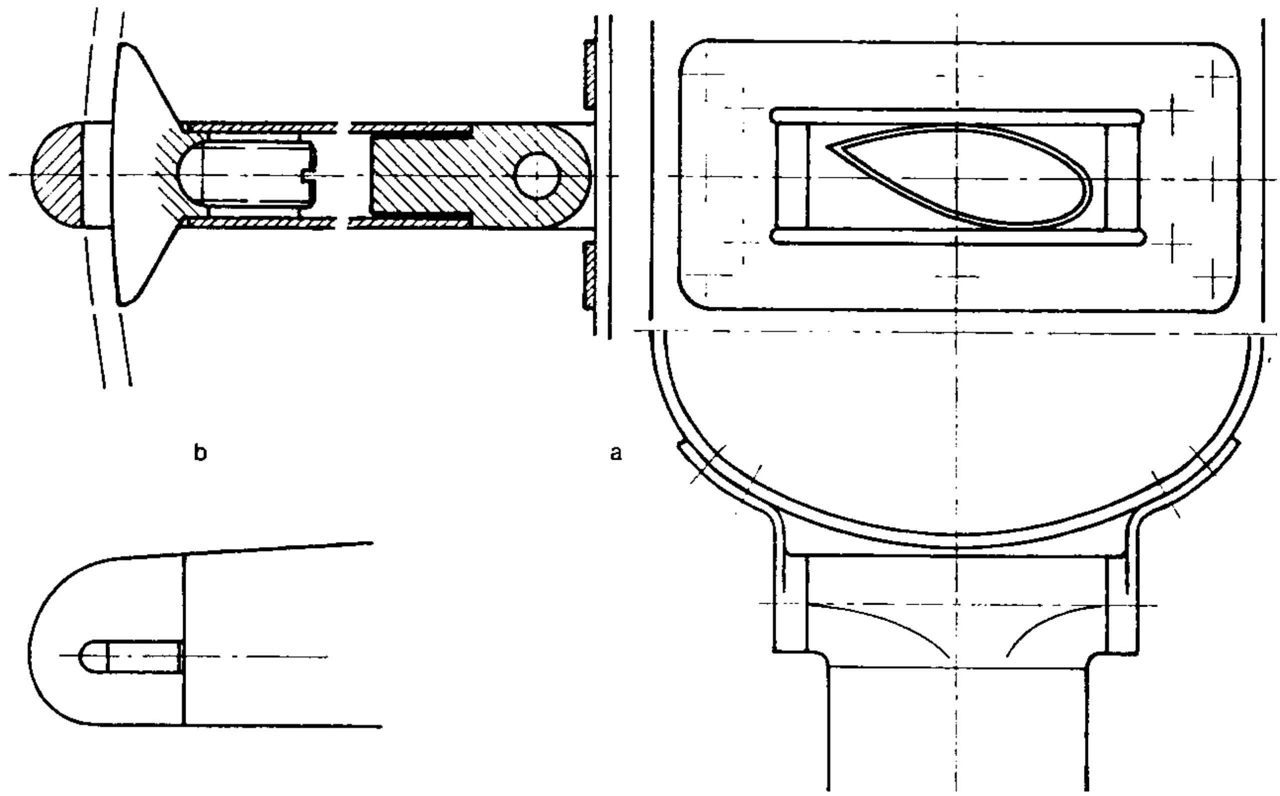


Fig. VI-32 Details of assembly of spreaders. On the left, end with tightening of the cable by an interior clamp. For the cables up to 6 mm one can also use a clamp or a hook with the wire passing by outside, provided that the range of the cable in the end is with the suitable radius, taking into account the angle of the stay and the width of the end. On the right, fixing articulated on the mast; the hinge fitting consists of a plate of steel cut out and reinforced with the ranges of the axis; taking into account the important envelopment of the section of the mast, a spacer is not necessary. One also can, on the largest profiles, use bearings screwed spacers crossing the axes. Note the negative incidence of the shaped bar.

VI-V - 4 FOOT OF MAST, EXITS OF ROPES AND OTHERS

One often pays little attention to the foot of mast, however this has at least two important functions, its behaviour in the horizontal plane and the definition of the point of support compared to the centre of area of the section. This last point calls for some explanations. If the foot of mast and its baseplate are flat, there is little chance but that they are parallel, the least difference in angle, and the foot will bear to fore or the aft, introducing a bending moment and thus a bending into the lower part of the mast. For a mast on the deck, if the support is on the fore this moment can balance that of the boom, it is thus not unfavourable. It will not be the same if the support is to the aft, which unfortunately is the most frequent case; it is the reverse for a mast on the keel. Under the baseplate, a clamp should then be placed compensating for the variations in the angle.

One also can, as on the 12 m J.I to interpose between the two parts a very hard rubber plate distributing the pressure. But best is still to give to the foot of mast a round form with a centre of curve placed forwards of the centre of the section profile (or to the back for a keel stepped mast), one will thus obtain a shift according to the rake which will be more progressive.

It is essential that the mast is fixed in, or on, a base-plates of a sufficient height to avoid any risk of exhaust as we saw that that had probably arrived at the time of the first dismasting of PEN Duick VI. However, if the mast is stepped on the deck one should not ensure this connection by an axis crossing the two parts because, in the event of dismasting, the wrenching of the base-plate could cause a water way. This plate must be bolted, through the deck, to the plate of the pillar and not simply "fixed" by four drive screws as it is too often seen.
The openings in masts provided for the passage of various items are as many entries offered to the rain, it is thus essential that a drainage hole be envisaged at the base.
If the mast is stepped on the deck the hole will be bored in the foot. If it is stepped on the keel another hole will be bored above the deck collar, on the front face, and a polystyrene foam stopper will be inserted below.
The sealing of the deck collar of a keel stepped mast is ensured by a mast boot, rubberised cloth held on the mast and on a pad on the deck collar by metal clamps. One should not forget, of course, to seal the throats and rails.

Two other harmful effects of the light alloy masts affect comfort: noise of the ropes and electric cables to the interior and heat exchange. This last disadvantage can be tiny by coating the part of the mast located under the deck with an insulating coating as one uses some for piping. Stuck inside a fabric sleeve closed by a zipper, it will be easily removable for the dismasting.

The noise of the halyards is much more difficult to eliminate. One can however use the following method. One cuts out rigid foam plates to the interior profile of the section, which one bores to thread them and stick them on rigid PVC tubes as light as possible. The whole being then slipped inside the mast before the installation of the fittings. One can be satisfied with two conduits only if they are large enough to pass several ropes. Their ends will be largely widened and their position will be calculated to be in line with the passage of the halyards. The electric cables will be simply wedged in notches spared on the circumference of the holds. The spacing of those will be 1,50 to 2 m and the exits of cables will be provided with a grommet.
The mast must be blocked in the deck collar by hard rubber chocks placed in front of and behind and whose covered sector will be for each one, equal approximately to the quarter of the circumference of the profile.
The exits of ropes can be located either in the foot of mast, or with height. This solution is however very dangerous because the mast is weakened at a particularly vulnerable place.
At a certain time much of masts of Arpeggio perished by strong wind for this reason. If this solution nevertheless is adopted, the passage through the wall will be reinforced and the halyard protected from chafing by round lips or a cage with two sheaves in tandem.
The openings in the mast will end in round-offs and they will be shifted in height of at least three times their length, in order to not ever have two openings in the same plane. Alignment with the winches is always difficult to ensure correctly. Plates on which they are fixed should not be parallel with the mast but be directed so that the axis of the winch forms an angle of approximately 100° with the halyard turned on the basis of headstock. In the same way, a wedge must never be placed on the axis of pull of the rope that comes to moor but form there with it an angle of 15° with 20° in its plane.
Bases of winches must be firmly fixed, if possible with a row of rivets in the axis, and more on the edges of the support. The nuts of the attaching bolts of the winches must nevertheless remain accessible to a spanner.
The rollers, little used nowadays, must be placed sufficiently far from the exit sheave of the halyard so that the its angle does not vary by more than 3° between the two ends of the drum.

VI-V - 5 ARTICULATION OF THE BOOM

The majority of the articulations of the boom are assembled on a carriage in order to allow a taught sail by a hoist of tack. These carriages slide, generally rather badly, in the throat or the rail used for the boltrope, or in a brought back rail. To improve the slip it would be necessary that these carriages are provided with trimmings out of charged Teflon or poly-acetate, but the throats and the female rails, of too small section, do not allow it. That becomes however possible when the rail is used only as guidance and that the carriage runs, on both sides, directly on the mast. This solution is besides by far the best to balance the important overhang of thorough of the boom to the bearing paces.

The two axes, vertical and transverse, must be as close as possible one to the other and the back face of the mast so that the position of the boom has the minimum of influence on the tension of the ropes. Nevertheless, the clearance of the boom must be able to reach 90° each way, 20° to 30° upwards and downwards.

The tack shackle fixing and the hooks of the reef points will be up on the vertical axis and articulated in the vertical plane.

VI-V - 6 - EQUIPMENT OF THE BOOM

Those are summarized primarily with the attachments at the clew and of vang and with the reefing device.

The first must be sufficiently resistant not to become deformed while leaving with the pulley which is fixed there a liberal side clearance at the bearing paces. It is preferable that the clamp is articulated on a transverse axis. Their fixing must be as distributed as possible, in particular for the vang.

Additional anchoring points must be planned for the reserves used with the back wind.

The vang can consist of a jack, hydraulic or mechanical, which makes it possible to remove the balance or, more generally, of a hoist.

Its point of fixing will be always on the mast or its baseplate. If it is fixed on the deck, which is often the case for a deck stepped mast, it is imperative that an interior tie connects the deck to the baseplate. This is valid for all the keel stepped mast yachts that do not have a bulkhead in the immediate vicinity.

A tackle of the vang will be always as short as possible. A pendant in sheathed cable will connect it to the boom. It will be always preferable to reduce the number of purchases of the tackle for the benefit of a winch. The speed of manoeuvre will be perhaps a little less but the output higher.

The lower fastening point of the vang must have all the freedom of orientation necessary. One too often sees shackles or pulleys to relate to an incorrect fitting at the foot of mast. In the case of a rigid vang in particular, the lower point of fastening must be an articulation similar to that of the boom, their vertical axes being aligned.

The same considerations on the length and the number of purchases are valid for the hoist of the main sheet.

The reef lines like that of the clew tension, are almost always returned, via sheaves placed in the end of the boom and by the interior of this one, towards jammer cams placed below the in-board end. It will have to be checked that the provision of the exit sheaves does not cause a relaxation of the line when one manoeuvres the locking cams, which unfortunately is often the case. From a surface of mainsail of a score of square meters one uses a winch placed under the boom or on the back of the mast for easier hoisting. In the second case the winch base must be held off the mast to leave the passage for the tack line.

The lazy end of the reef lines can be fixed on an eye placed on the side of the boom. If this eye is assembled on an adjustable slide in a rail it is still better because its position is critical for the adjustment of the sail. But if the boltrope is equipped with slides, it will be enough to tie the lazy end around the boom, which eliminates the always-dangerous protuberances.

For the clew tension, which requires precision and force, the first reduction could be obtained while passing the line in a pulley with swivel attached on the sail, the lazy end coming to fix itself on the end of the boom. With mainsails of more than 40 m^2, the pulley will be assembled on a ball or roller carriage on which the clew will be shackled. Not to forget that the end of the boom must be equipped with a point of fixing for the mainsheet.

VI-V - 7 SPINNAKER POLES

The first thing to be defined will be the process of gybing which will determine the type of ends of the pole and the fixing to the mast *.
For the small yachts one generally uses the method of the reversible boom. The two ends are identical and there is a point of fastening on the mast, either one or more bales fixed, shifted in height, or an eye or a fork articulated on a carriage. It will have to be checked that clearance is possible in all the portion of sphere delimited by the deck and the shrouds, without the end being able to be wedged causing its inevitable failure. Because of the reversibility, the topping lift and downhaul must be attached to the middle of the pole, but it is only on the very small yachts (with the spinnaker less than approximately 30 m^2) where the bales can be fitted directly to the mast. Beyond the bending stresses to the loose end, when the pole comes to touch the fore stay, would be too high and manoeuvres will come to stick on goose legs in cable fixed on the ends in order to make the pole work only in compression. Their angle at the ends must be at least 15° and one will use a sheathed cable to avoid it being caught the hair.
From 80 m^2 it is not possible any more to plan to take down the pole from the mast by wind or sea efforts. The reversibility of the boom can nevertheless preserve an interest for the facility of manoeuvre when one pole is used. In this case the ends have a conical external form allowing their fitment in a bell fixed on a carriage with balls, rollers or slides ensuring a sliding motion without effort when it is in service. One should not forget that the push of the pole, very high, almost always occurs with an important offset. The design of the carriage and the rail, and its fixing, must take account of it.
The height adjustment of the carriage must be ensured by a means having an effective blocking [tackle].
The topping lift and downhaul are fixed on the end of the boom, the downhaul, in general, passing through a pulley fixed on the deck, behind the forestay. The effectiveness is thus greater at the loose end , where the load is highest.
For the spinnakers of large surface area or when rigging does not allow gybes with only one pole (fixed baby-stay, cutter...), two poles are used. Their symmetry is not any more of interest. One then uses sometimes, on the carriage, a gooseneck engaging in the end of the pole where it is retained by a bolt. This system is simple, light, offers less protuberance on the mast than the bell but it can be extremely dangerous for the hand of the crewmember that must direct it to engage it.

The choice of the ends and the system of locking of the brace is more within the competence of the user than of the architect. Nevertheless this one will have to take care of its solidity (in particular its fixing on the pole) and of its maintainability (disassembling). The order will place by the interior of the pole and will arise, is in the middle if the boom is symmetrical, that is to say towards the mast. With spinnakers exceeding 50 m^2, the jockey-pole being used to hold out the clew sheet becomes essential. Its fixing on the mast must be provided for.