THE UNIVERSITY OF MICHIGAN

COLLEGE OF ENGINEERING

Department of Naval Architecture and Marine Engineering

Final Report

A STUDY OF THE FEASIBILITY OF PERMANENTLY HINGING AND OTHER MEANS FOR LOWERING THE MASTS OF SAILING YACHTS USING THE ATLANTIC INTRACOASTAL WATERWAY

R. B. Couch

R. A. Yagle

Harry Benford

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INTRODUCTION

Because of the controversy which has arisen over the possibility of a relaxation in the height requirements for bridges over the Atlantic Intracoastal Waterway, the Department of Naval Architecture and Marine Engineering of The University of Michigan was asked by the U. S. Army Corps of Engineers to study the feasibility of fitting hinged or telescoping masts to sailing yachts using the waterway. A short report of a preliminary study of this problem was submitted in June, 1958. (The reader is referred to the bibliography at the end of this report for a more complete reference.) Subsequently, the District Engineer, Corps of Engineers, Jacksonville, Florida, requested the University to investigate this matter further with particular emphasis on the costs which might be involved in the conversion of sailboat masts to hinged arrangements or in stepping and unstepping the masts to permit transit under low fixed bridges.

The question of vertical clearances under bridges crossing the waterway is of paramount interest to yachtsmen owning moderately large yachts, especially sailing craft, who might use the waterway for sheltered transit from north to south and return or to seek refuge from bad weather in the open sea. At present, the bridges are either of the bascule, swing, or lift type, and the minimum clearance, also conformed to by the power lines which cross the waterway, is 80 feet above mean high water. The high construction cost for each additional foot of clearance above some minimal value for the fixed type of bridges has necessitated giving consideration to a lesser clearance between perhaps 50 feet and the present 80 feet. As an appreciable number of tall-masted sailing yachts currently use the waterway, and presumably would wish to continue to do so even if the clearance were reduced, questions of some importance in this situation concern ways in which owners of such yachts can modify their boats to permit passage under new fixed bridges of lesser clearance, and what their expenditures will be.

This report describes the new study made by the authors. Since the previous report was not as complete as might have been wished by either the authors or the U. S. Army Corps of Engineers due to the shortage of time available for its preparation, the present report includes additional and more thorough discussion of the various phases of the subject with which it attempts to deal.

TYPES OF YACHTS AND WATERWAY USAGE

It is obviously impractical to include more than a cursory description of the types of yachts of interest in this study and of the practices and techniques pursued by those who design, build, and maintain them. Numerous books and such periodicals as Yachting, Rudder, and Motorboating are filled both with photographs and detailed plans of the boats and their rigging as well as with discussions of the relative merits of the various sail and rigging arrangements used on these craft. Thus it is assumed that the reader has some familiarity with yachts and yachting. The boats considered here are those whose mast heights above the waterline are 50 feet or greater. Figure 1 is a graph of the mast heights of a number of representative yachts against their overall lengths. It should be pointed out that most of the boats affected are relatively large, and their appointments are luxurious and a matter of pride to their designers and builders as well as to their owners. In the case of the racing yachts particularly, the care and the minute attention to detail devoted to selecting and maintaining even a fitting of minor importance is clearly evident to the casual observer. Yachts of this size are with but very few exceptions each of a distinct and unique design, and all embody the highest caliber of craftsmanship. The initial cost of these craft today varies between $1000 and $2000 per foot of length.

No attempt will be made to indicate just how many such yachts use the Atlantic Intracoastal Waterway or how often they may do so. It is pertinent, however, to discuss the conditions under which the waterway may be used since they have a direct bearing upon the suitability of one or another method of lowering the mast. These conditions are:

(1) Passing from a home mooring along the waterway to other bodies of water adjacent to it, to repair yards, or to sea, and return;
(2) Passing from northern cities through the length of the waterway to Florida and environs, and return;
(3) Entering the waterway from the sea to seek refuge from storms or to obtain repairs, supplies, etc., and return.

The first of these seems the least important in this study. Yachts of the size in question require specialized maintenance and repair facilities no matter where their home moorings may be. It seems reasonable to presume that a fixed bridge restricting passage from the mooring to the repair yards or to sea would prompt the owners to change moorings. If the bridges were to become so numerous that the choice of mooring became very limited, it would, of course, become a much more serious problem. In any case, one factor in the discussion that follows must be the number of times a mast will have to be lowered in a given year.

The second of the above usages is the one of primary interest. There are many yachts which make such a passage every year, both northbound and southbound.

Others do so less often, but frequently enough to warrant their owners to be seriously concerned about the question of bridge clearances over the waterway. These yachts cannot, of course, sail down the waterway, and thus their masts and rigging need not be on board to make the passage. A number of yachts now using the waterway in this manner come from Great Lakes ports and have their masts unstepped to allow them to pass through the New York State Barge Canal with its very low bridges. The spars are normally carried stowed on the deck or on specially built portable frames above the deck. The advent of low fixed bridges along the waterway would require that the yachts coming from northern New England ports, those from Long Island Sound, etc., follow a similar practice or have means for lowering their masts temporarily to permit them to pass under each bridge. Once again, the number of bridges encountered would have an important bearing upon the method used to clear the bridges.

There are several factors which complicate the situation, however. Unstepping the mast before entering the waterway restricts the ability of those aboard to make use of the passage for working on their boats. It is now common for this period to be spent fixing or changing rigging, etc. Racing yachts require frequent adjustment of the rigging, and the time spent traversing the waterway is very often used to accomplish this. An unstepped mast precludes such activities and means that the cruising yacht cannot leave the waterway to sail out on a good day and that the racing yacht cannot enter the open sea to experiment with the latest innovation in her rigging. The yachts equipped with means to lower their masts temporarily could overcome these limitations but, unless the installation were expensive and complicated, would be delayed by each lowering operation. In all probability, a larger crew would also be needed, thus incurring additional cost to the owners who have hired crews take their yachts through the waterway without being on board themselves. These factors must therefore be given consideration in the following discussion.

The third usage listed above implies a limited number of occasions when the presence of fixed bridges along the waterway may impede these yachts from reaching safe mooring in case of a hurricane or accidental damage, for example, while at sea. These occasions are by no means limited to the pleasure craft discussed here, but it is likely that they occur more frequently for those who consider sailing an avocation. Even those yachts which customarily make their northbound or southbound passage outside the waterway do so with the comforting realization that the waterway is available in case of trouble. These owners would not, however, be inclined to install special equipment for lowering their masts if it appeared that they would be needed only a few times in the lifetime of the boats. This third type of usage need not be considered if the locations of fixed bridges over the waterway are so chosen that the inlets to harbors adjacent to the waterway are available to all yachts without the necessity of lowering their masts.

Figures 2 through 4 of this report are included to give the average reader some indication of the type of yacht being discussed and the extent and complexity of their rigging.

ATTITUDES OF INTERESTED PERSONS

As this is a feasibility study, it is desirable to take cognizance of factors other than costs and hardware design. The importance of the opinions and attitudes of owners as well as those of designers and boat yard operators concerning this problem should not be overlooked, even though it is not possible to measure this directly. Two aspects of these attitudes are of interest. These are the disinclination of yacht owners to alter their boats to provide a ready method for lowering the spars and the reluctance of designers and yard operators to evaluate realistically such alterations.

Most owners of large sailing yachts feel a keen sense of personal attachment to their boats. Their willingness to purchase such a craft initially at great expense or in many cases to have it custom-designed and built while they attentively follow each step, and then to provide the constant maintenance and upkeep such yachts require, attests to this. That they are normally reluctant to change the boat even slightly once it has proved to be a good sailer is not unexpected. This again is particularly true of the owners of racing yachts. The type of rigging such a yacht may have is probably what induced the owner to acquire it, and his familiarity with the rigging is in many respects the major factor in his skill as a racer. The authors have found, in talking with many owners, a great reluctance to give sincere consideration to having their rigging altered in any way which might affect the sailing efficiency of the boat. Whether or not a hinging arrangement in the spars of their own yachts could be shown to be as safe and trouble-free as having none does not seem to matter to them. Their answer to the obvious question of how else they would be able to traverse the waterway was usually a statement which in essence indicated that they would no longer use it. The prevalence of this attitude means that, as far as most yacht owners are concerned, any discussion of the merits of the several methods for lowering the mast of a yacht is somewhat irrelevant.

Yacht designers and boat yard operators, whose opinions and assistance were also secured as part of this study, were almost unanimous in their requests that they not be quoted and their names not be mentioned in this report. Through word-of-mouth communication and the great number of articles and editorials in the periodicals devoted to yachting, all these people, including those not in areas affected, are very much aware that the possibility of reducing the clearance now maintained for the waterway is being considered by the Corps of Engineers. Whatever the cogency of their reasoning may be, their attitude affects this question.

UNSTEPPING MASTS

The most direct means for lowering the mast of any sailing yacht is to unstep it. Figure 5 indicates how the spar is normally supported by a step in the keel structure and extends up through the deck. Unstepping a mast therefore means lifting it bodily from this position by means of a hoist or a crane. This is not an uncommon practice for yachts which are hauled out for the winter, no matter what their sizes.

For the yachts whose usage of the waterway is limited to infrequent passages along its entire length southbound or northbound, unstepping seems to be the most desirable means for lowering the mast. The fact that many do so now establishes that the required facilities are available and that the restrictions entailed can be endured. These restrictions, some of which have been previously discussed, include the inability to work on the boats' rigging while in passage and those which result from having a stowed spar projecting well over both the bow and the stern. Figure 5 indicates the arrangement referred to in the last item. Most sailing yacht proportions are such that this cannot be avoided. The difficulty of navigating the waterway with such an unwieldy overhang is obvious, and the possibility of damaging the spar cannot be discounted. The added expense of the unstepping and stepping operations is another factor involved.

The following table gives a concept of the cost of this item, but requires some clarification. Only the three areas are included, although figures obtained

TABLE I

COST OF UNSTEPPING AND RESTEPPING AN 80-FOOT SPAR

Area	Unstepping		Restepping	
	Normal No. of Man Hours	Price	Normal No. of Man Hours	Price
Miami	18-20	$100-$150	15-18	$80-$100
Detroit	6-8	$65-$100	8-10	$75-$125
New York	10-12	$100-$120	12-15	$120-$150

from California, other Great Lakes ports, and other areas along the Atlantic coast indicated that these are typical. In regard to the Atlantic Intracoastal Waterway, only the New York and Miami figures are pertinent, but the Detroit figures are included for contrast. The lower costs in Detroit seem to be due to the frequency and speed with which this operation is done. There are a number of facilities and skilled workmen ready on very short notice to do the job.

Also, it appears to be very common in the Detroit area for the owner or a member of his crew to do much of the preparation required prior to the actual lifting, such as marking turnbuckle settings, tagging each stay and shroud, insuring that threaded fittings are free to turn, removing the boot, etc. It can readily be seen that this list is quite lengthy by even a casual inspection of any large sailing yacht or by an inspection of Figs. 2 through 4. This practice does not seem to be followed in the Miami area, however, partially accounting for the higher costs despite a lower cost per man hour. In the New York area, some persons reported that this practice was followed almost exclusively while others had never found it to be so. It was also apparent that the Miami area does not have as many facilities capable of unstepping a tall mast as might have been expected from the large number of yachts of this size that frequent the area. In several cases, truck-mounted cranes were rented by boat yards when an unstepping operation was contemplated. The contrast between this and the Great Lakes area where even some relatively small yacht clubs have facilities for handling long spars is noteworthy. It is probably justified to presume that there would be some reduction of the cost figures in the Miami area if the advent of lower fixed bridges across the waterway caused an increase in the number of unstepping operations. The above figures do not vary appreciably with length of the spar within the range of interest.

Restepping the mast is often a more complicated operation than unstepping it. Proper marking of the fittings, etc., when unstepping means that confusion can be avoided when rerigging the mast, but it is very seldom that the task has been completed until after the yacht has been sailed. This permits tuning and adjusting shrouds and stays which may be too taut or too slack, wrapping fittings, properly locating and securing anti-chafing gear, etc. The figures in Table I again reflect the proportion of this sort of work done by the owners themselves in different areas. In any event, the owner would much prefer not to have to carry out the whole procedure any more often than absolutely necessary. Those who sail at both the northern and southern ends of the waterway, thus traversing its length twice a year, would be faced each year with unstepping their masts twice and restepping them twice. Racing yacht owners would probably balk at this since their trimming is so much more critical a factor than it might be for those owning cruising yachts.

Another factor with reference to unstepping masts is that the mast and rigging may be damaged during the operation. The masts themselves are normally tapered and hollow, built up of four pieces of spruce or from aluminum extrusions. They are as light in weight as possible for the sometimes tremendous loads to which they are subjected. Figure 6 shows two typical mast sections. Spars are relatively expensive and somewhat delicate items, and the possibility of their striking the yacht deck or the dock or some other solid structure during the stepping or restepping operation must be carefully avoided. The rigging normally lifted with them can mean a total weight for large sailing yachts of a ton or more, even though the mast itself may be only half of this. Spreaders, sail track, sheaves, masthead lights, and other items attached to the mast can be easily damaged if extreme care is not used. Replacing a mast may mean an expense of several thousand dollars even if most of the fittings can be salvaged.

Some thought has been given to the possibility of unstepping only the upper portion of a mast. At first glance, this idea seems reasonable since the shrouds and stays keep a mast in compression and a relatively light and inexpensive socket-type fitting could be used to fit the upper portion to the lower mast. Upon arriving at a bridge with less clearance than the mast height, it would be possible for members of the crew to go ashore and perhaps from the bridge itself lift out by hand the upper portion. This assumes that its length is 10 feet or less and that its weight is in the order of 100 pounds. However, certain stays and shrouds would have to be free and their weight added to the top mast weight. Additional standing rigging supporting the lower portion independently would be needed with such an arrangement. A break in the sail track is inherent in this scheme, and thus the socket-type mast fitting must be keyed such that accurate alignment of the two sections of sail track is assured. This means that it must be relatively heavy and carefully machined, and that it could become quite expensive. These and many other objections, including the opinions of the yacht owners that it would be unsafe and impractical, seem sufficient cause to reject the scheme. At least several yachts having such an arrangement would have to be operated successfully before this scheme could be really evaluated. The use of such an arrangement for antennae or other light items attached at the masthead should not be overlooked, however. The complete cost of the installation of a socket fitting in the upper part of a typical 80-foot spruce spar is estimated by the authors to be $1250. This includes the changes required in the standing rigging as well as fabricating and attaching the fitting itself. The cost for a hollow metal spar could be somewhat less depending upon how extensive the standing rigging alterations might have to be.

PERMANENTLY HINGING MASTS

In discussing the feasibility of fitting a large sailing yacht with a hinged mast, a distinction must be made between building such an arrangement into a new yacht and modifying an existing one. The former would be the most straightforward as many of the problems associated with a hinged mast can be anticipated and the whole design oriented toward eliminating them. It follows that altering an existing yacht might prove to be a rather complex procedure as elements of the structure and the rigging would also have to be changed, and the effect of these changes may in turn affect other items.

These statements are admittedly very general and cannot be made more positive because, to the authors' knowledge, there have been but two sailing yachts of the size in question designed and built with hinged masts in the United States in recent years. One of these, a motor sailer designed by Sparkman and Stephens, Inc., and named Versatile, is in all respects an appropriate vessel for inclusion in this study. The other, an off-shore cruiser designed by Philip L. Rhodes and named The Seafarer, is primarily a motor cruiser and has relatively short spars. It thus falls outside the class of sailing yachts with

which this study is concerned. Some other large American-owned yachts do have hinged masts, but these were built in Europe and in at least several instances these features have never been used by their present owners. One such craft of rather large size with two heavy masts was inspected by the authors. Indications were that the hinges had not been used for years, if ever. A more substantial number of smaller yachts with hinged masts of heights less than 50 feet have been designed and built in the United States. But again, they are not of particular interest in this discussion. Many European sailing yachts and working "barges" as well have hinged masts, and the Thames and the waterways of the Netherlands, for example, are traversed continually by vessels of this type. But here also the mast heights and the rigging are somewhat less in size and complexity than those being dealt with in this report. Thus there is not much in the way of experience upon which to base very conclusive statements concerning the feasibility of hinging the masts of large sailing yachts.

The majority of installations of hinged masts make use of a tabernacle. Figure 7 shows how one arrangement of this device supports the base of the spar while allowing it to pivot about an axis somewhat higher. If this axis is below the location where the boom is attached, there is no break required in the sail track. The spar itself, at least from this point on, can be similar to the spars of yachts having no tabernacle in that it can be hollow spruce or aluminum or whatever the designer may choose. In many respects, this mounting is actually like the standard stepped mast, but with the pivot support corresponding to the deck and the base support replacing the step in the keel. For the same mast height above the waterline, a somewhat shorter spar is obtained.

There are, however, two complications which are readily apparent. The first of these is that the tabernacle and associated structure must be substantial enough to support the mast as well as the usual keel step and deck structure do. This is not an unreasonable requirement and merely means that the tabernacle design must be carefully considered and that the deck beams and their supports must be stronger than usual. A fairly large number of modern large sailing yachts now have their masts stepped on deck for other reasons, so problems arising from the latter requirement have already been solved. The most obvious arrangement is also indicated in Fig. 7, in which the tabernacle is stepped on the keel. The tabernacle could be fabricated of metal as a low position means that its weight is not so critical.

It is the second complication, however, that causes most yachtsmen to look unfavorably on this scheme for lowering masts. The actual lowering operation, assuming it is done by the crew on board while the yacht is in the waterway, is a bigger job than they choose to undertake without outside help. Their reluctance seems reasonable when one considers that perhaps 2000 pounds of spar and attached rigging is involved. Hinged masts of this type are generally much heavier than others to minimize the number of supporting stays. Special winches, fittings, and cables would be required, along with extra bracing and framing, if the operation were to be made quite safe. Perhaps the forestay(s) could be used to restrain the spar by bending on to it another length of cable and lead-

ing this through a snatch block shackled to a fitting at the bow and thence to a winch. The backstay, or running backstays, could be handled by the crew to pull the mast back. The shrouds would all be disconnected. The spar could thus be lowered until it was resting on the deck or a special fitting on the deckhouse. The proportions of most yachts, however, are such that the lead of the restraining line from the bow to either the masthead or the peak of the foretriangle would be such as to make the tension in this line and the shear in the pin at the tabernacle, as well as the loads on the spar, increase tremendously as the spar gets farther from its normal upright position. This is indicated in Fig. 8. At any intermediate position in the operation, the stability of the configuration is very tenuous unless the tabernacle-to-mast hinge is very substantial and well-made. These factors indicate that the installation is not as simple as might be presumed at first glance, and that while ingenuity and good design may cut both expense and bulkiness, they can do so only to some relatively slight degree.

It is possible that the mast need not be lowered completely, but only tilted until the overall height above the waterline is sufficiently reduced. This is the authors' understanding of the procedure on the Versatile, mentioned earlier, which has a tabernacle-like arrangement. In this instance the hinge is essentially two 1-inch steel plates with lugs 2 inches in diameter, with the hinge pin being 1-1/8 inches in diameter. The upper plate is attached to the mast by a 2-foot-high 3/16-inch steel collar. The two flanges on the plate are bolted together when the mast is upright by sixteen 3/4-inch bolts. These dimensions are given to indicate the size of the hinge fittings rather than to present details of a particular design. Each installation would require a special design suited to the other features of the yacht. But if the mast is not to be lowered completely, it certainly should not be left lowered part way for very long unless additional lines are used to secure it well.

It is questionable how often an owner would like to go through the procedure of lowering a mast either part way or completely in any one day or even in one week. Those yachts with large professional crews may not have this problem to the same degree, but the owner who mans his boat with a few friends and himself could not be expected to be enthusiastic at the prospect of having to lower the mast even once. A set of worm gears, the rack attached to the spar and the pinion to the tabernacle or deck, could conceivably be arranged to allow lowering with little effort on the part of the crew. Alternate arrangements also occurred to the authors, and undoubtedly to others, but only cursory investigation was needed to prove that any proposed device would be bulky and unsightly. It is perhaps more a matter of aesthetics than engineering, but there seems to be some limit to the alteration of a graceful sailing yacht prior to its taking on the appearance of a work boat. This is certainly borne out by the comments the authors heard from yachtsmen in the course of conducting this study.

Thus far little attention has been given to the expense of the tabernacle type of mast-hinging arrangement. For a new sailing yacht of the size and type in question, designed for and built with a tabernacle and hinge, the added cost

over and above that of a yacht of the same design but without the mast-lowering features could amount to $4000. This includes the extra design time required as well as the cost of the tabernacle and hinge and heavier adjacent structure, a larger than usual winch, and special heavier fittings where appropriate. The figure could probably be nearly $1000 less if many yachts having hinged masts were designed and built using the same arrangement and thus some of the same design special fittings and rigging. The figure could well be $1000 more if special gearing or other devices were incorporated in the design. If an existing yacht were modified by installation of a tabernacle and hinge arrangement, using the same spar cut off, the cost could approach $6000. These figures do not vary appreciably whether the spar is spruce or aluminum and depend only to a small degree upon whether the height is the 80 feet assumed or 10 feet more or less. These estimates are the authors' with some substantiation by others. They are rounded off because they are meant to be typical and because certain installations may include items of the order of less than $100 not included in others.

Some thought was given by the authors to a hinge located higher up the mast. The weight of the portion to be lowered would then be reduced to some more reasonable value, and the forestay and the backstay could be used to accomplish the operation with a winch of a size normally on board. The resulting break in the sail track could prove troublesome in time, although a keying scheme could overcome that difficulty. The hinge would have to be well made, and, since the mast is kept in compression by the standing rigging, a locking pin or bolted flanges would be needed to provide the continuity the spar must have to withstand bending stresses. Just how the spreaders and jumpers might be fitted would depend on the strength of the spar. In any case, some ingenuity and sound engineering applied to the problem could result in a safe workable design. The cost is estimated to be approximately the same as that of the socket arrangement mentioned above for a new boat of the same size, and not much greater for the alteration of an existing one if the same spar could be cut at the chosen location. This scheme would hardly mar the appearance of the yacht except for the additional standing rigging which would probably be needed. Despite these advantages, it is just as unlikely that very many yacht owners would use this arrangement any more readily than they would the tabernacle and hinge. Such a scheme would have to be proved safe and easily managed by several actual installations before any of the yachtsmen or naval architects contacted would give it serious consideration.

The rigging of a modern sailing yacht in particular represents the culmination of years of experience and experimentation. It cannot be denied that any mast-lowering device would of necessity hinder the achievement of optimum performance. Therefore racing yachtsmen can almost categorically be eliminated as potential users of permanent mast-lowering devices. The owners of cruising yachts are, however, more suitable prospects for accepting mast hinges as integral parts of their boats. Should they be willing to meet the expense involved and not object too strenuously to the changes required in the rigging and some elements of the deck or deckhouse structure, there still remains the inconvenience of actually carrying out the mast-lowering procedure. The shrouds and

stays must all be disconnected, for example, and then connected and readjusted after the mast is raised again. Unless bulky and expensive apparatus is used the number of crew aboard probably should be greater than is normal, and even then some danger to both the mast and rigging and the crew is inherent in the operation. It is the authors' opinion that these owners would choose to unstep their masts rather than fit hinging equipment if they wished to traverse the length of the waterway. It has previously been stated that owners whose home moorings were so located as to require lowering their masts to gain access to the open sea or yard facilities would, in our opinion, elect a new home mooring free of such complications. Thus it appears that the third use of the waterway, as a haven in case of accident or storm while at sea, is the only strong reason which might cause owners to accept a permanent arrangement for lowering their masts. Proper location of low-clearance bridges could alleviate these worries.

OTHER MEANS FOR LOWERING MASTS

Other methods for lowering the masts of large sailing yachts have been suggested from time to time. An example of these is some means for telescoping an upper portion of the mast into the more permanently fixed, hollow lower portion. Here again, some ingenuity applied to the problem could result in a workable design. But the lower portion of the mast, and preferably the upper one also, would have to be of metal. They would have to be much stronger, and consequently heavier, than normal because spreaders and jumper stays could not be used on the upper portion. The sail track alignment details would be complicated, although recessing the track into the mast would produce a fewer number of problems than if it were of the usual external type. The bolts or pins for securing the upper portion to the lower portion when the mast is in its usual extended position would have to be removed by a crew member working part way up the mast each time the mast was to be lowered. And upon raising the mast again, these fastenings would have to be replaced. Over and above all these advantages are those which result from the fact that such an arrangement would be more expensive than any other so far discussed and from the general attitudes of owners toward anything smacking of gadgetry.

Another example of a somewhat less likely means of lowering masts is what might be called a split mast. This involves fabricating a mast from perhaps eight extruded metal sections which are bolted or otherwise fastened together along their lengths much as a built-up hollow spruce mast is made up of several pieces glued together. If enough sections were used, each could be light enough to be handled relatively easily. The time and effort involved in removing the innumerable fasteners and the excessive flexibility seem sufficient reasons to preclude such an arrangement from serious consideration except in some very limited and special situations.

CONCLUSIONS

There are probably other means for lowering masts than those mentioned in the report. And there is, of course, an infinite variety of modifications which could be made to any of the schemes discussed. In certain cases, some arrangement may very well be to an owner's liking even though it has many disadvantages. By the same token, owners may reject a scheme which can be shown by logic and sound engineering to be entirely suitable to their particular needs. It is difficult to generalize when the opinions of individuals are an important parameter in a given situation. This, then, is justification for the major conclusion by the authors in the study. The primary factor in considering the feasibility of incorporating any permanent arrangement for lowering the masts as a feature of large sailing yachts has to do with the owner himself. While some owners may be, and several already have been, willing to install such means, it is the opinion of the authors that the great majority will not. This is based on conversations with many of them both in areas adjacent to the Atlantic Intracoastal Waterway and elsewhere in the United States.

Of the various permanent means for lowering masts which have been considered, the tabernacle with the hinge just above the deck or deckhouse is, in the opinion of the authors, the least objectionable. But there can be little doubt that most owners will prefer to have their masts rigged as at present and will have them unstepped each time it becomes absolutely necessary that they be lowered. Implicit in this statement is the opinion that owners will use those portions of the waterway obstructed by low bridges only under the most extreme circumstances. Those who have done so before, however, will continue to traverse the length of the waterway with their unstepped spars secured on deck, and others may follow such a practice for the first time.

A general summary of the cost figures mentioned in the report is given in Table II. The reader is reminded that many of the values are estimates by the authors, but are based for the most part on relevant information secured from yard operators and practicing naval architects.

TABLE II

SUMMARY OF COSTS

UNSTEPPING AN 80-FOOT MAST . . . . . $ 100

RESTEPPING AN 80-FOOT MAST . . . . . $ 115
(Figures vary with geographical location, complexity of rigging, and amount of preparation, and finishing up undertaken by owner, but not appreciably with height within range of interest.)

INSTALLING A SOCKET-TYPE FITTING AS MEANS FOR UNSTEPPING UPPER PORTION OF SPRUCE MAST $1300
(Figure would be less for new yacht or for metal spar; would depend upon changes required in standing rigging; would not vary appreciably with mast height.)

INSTALLING TABERNACLE AND HINGE IN NEW YACHT $4000
(Figure would be slightly less with metal hull; varies only slightly with mast height.)

INSTALLING TABERNACLE AND HINGE IN EXISTING YACHT $6000
(Figure would depend upon whether existing spar could be cut off and re-used; slightly less for metal hull; varies only slightly with mast height.)

INSTALLING HINGE IN UPPER PORTION OF MAST $1300
(Figure would be less for new yacht or metal spar; varies only slightly with mast height in conjunction with standing rigging changes required.)

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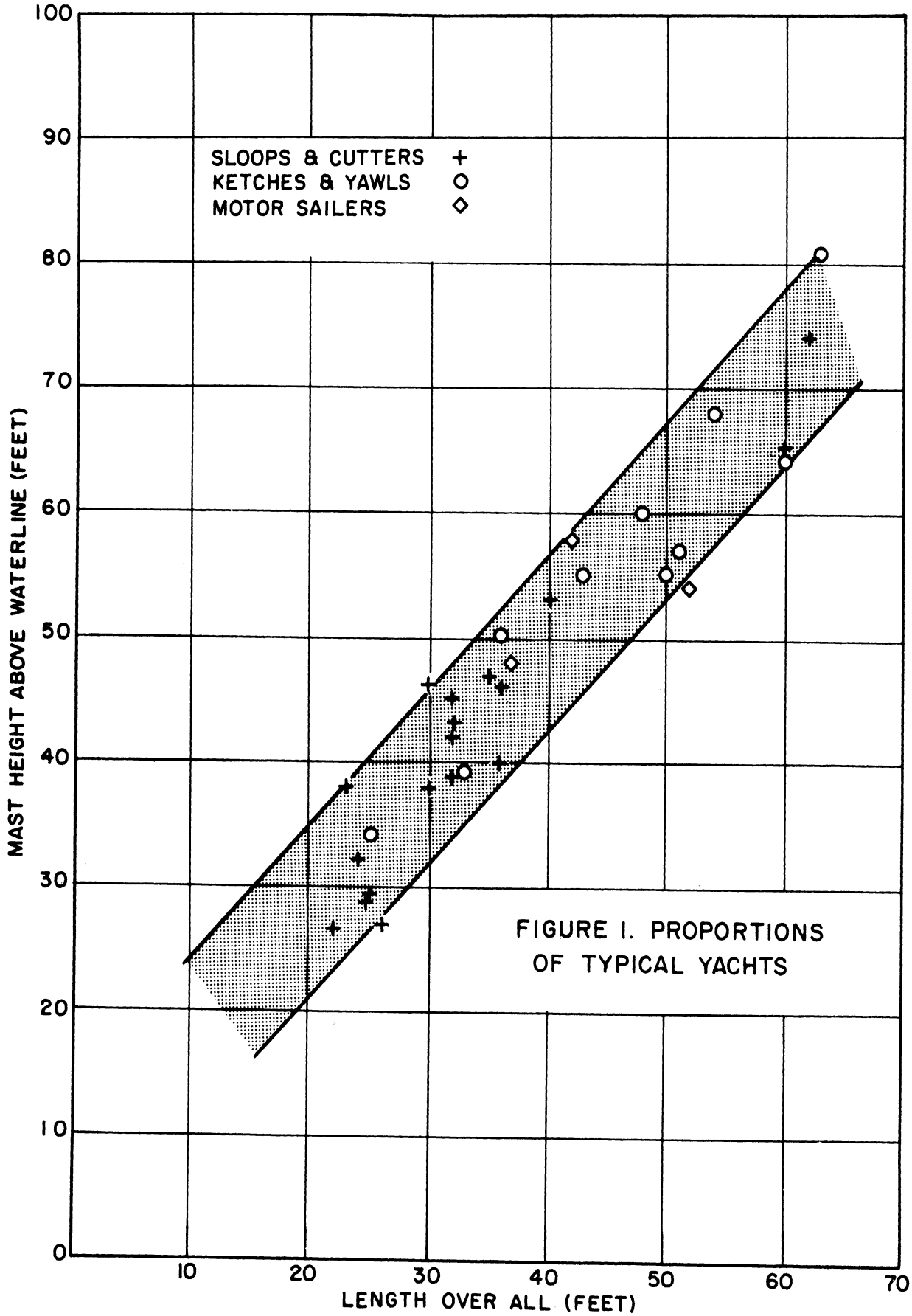


FIGURE 1. PROPORTIONS OF TYPICAL YACHTS

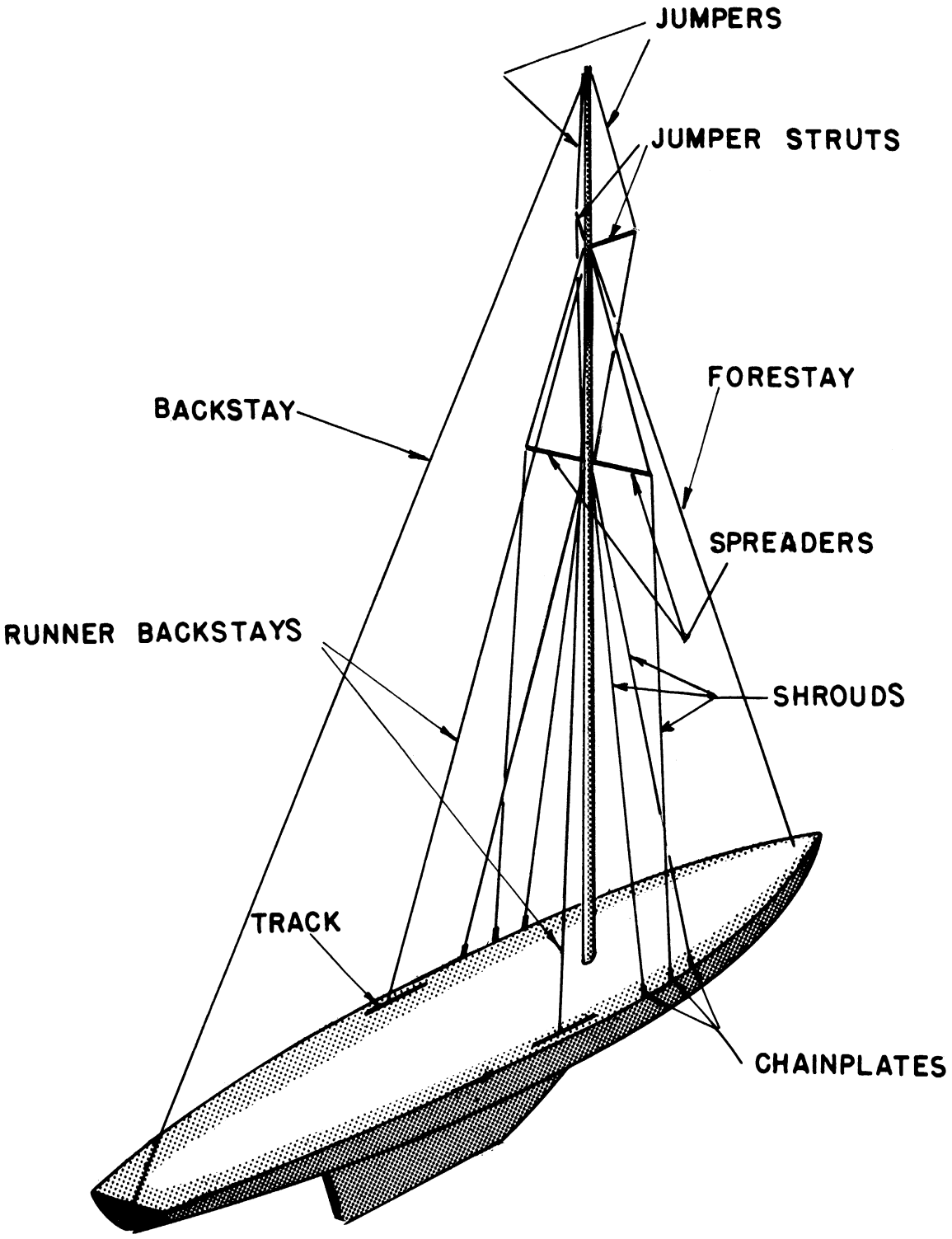
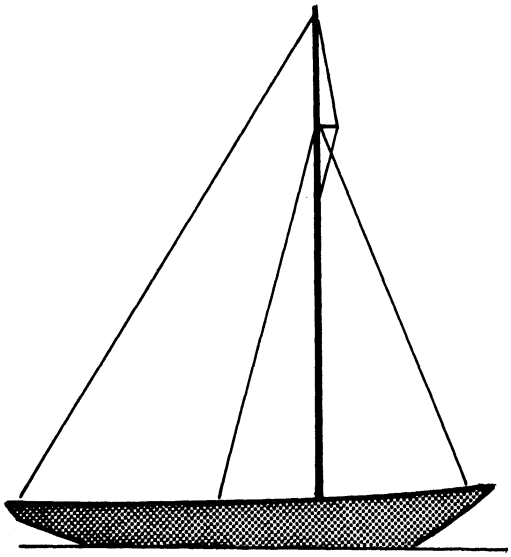
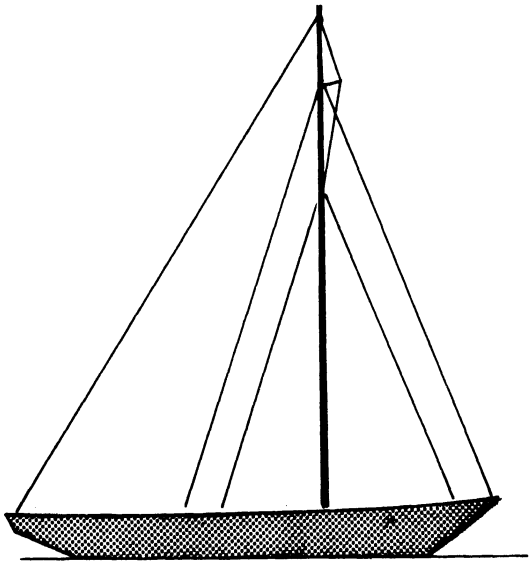


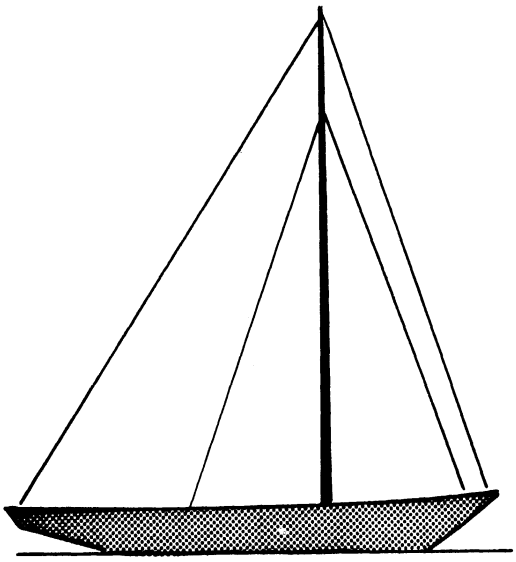
FIGURE 2. BASIC STANDING RIGGING OF A SLOOP



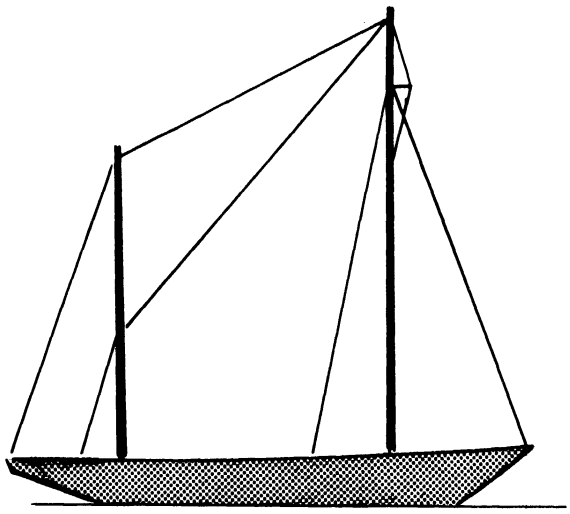
STAY ARRANGEMENT FOR SLOOP



STAY ARRANGEMENT FOR CUTTER

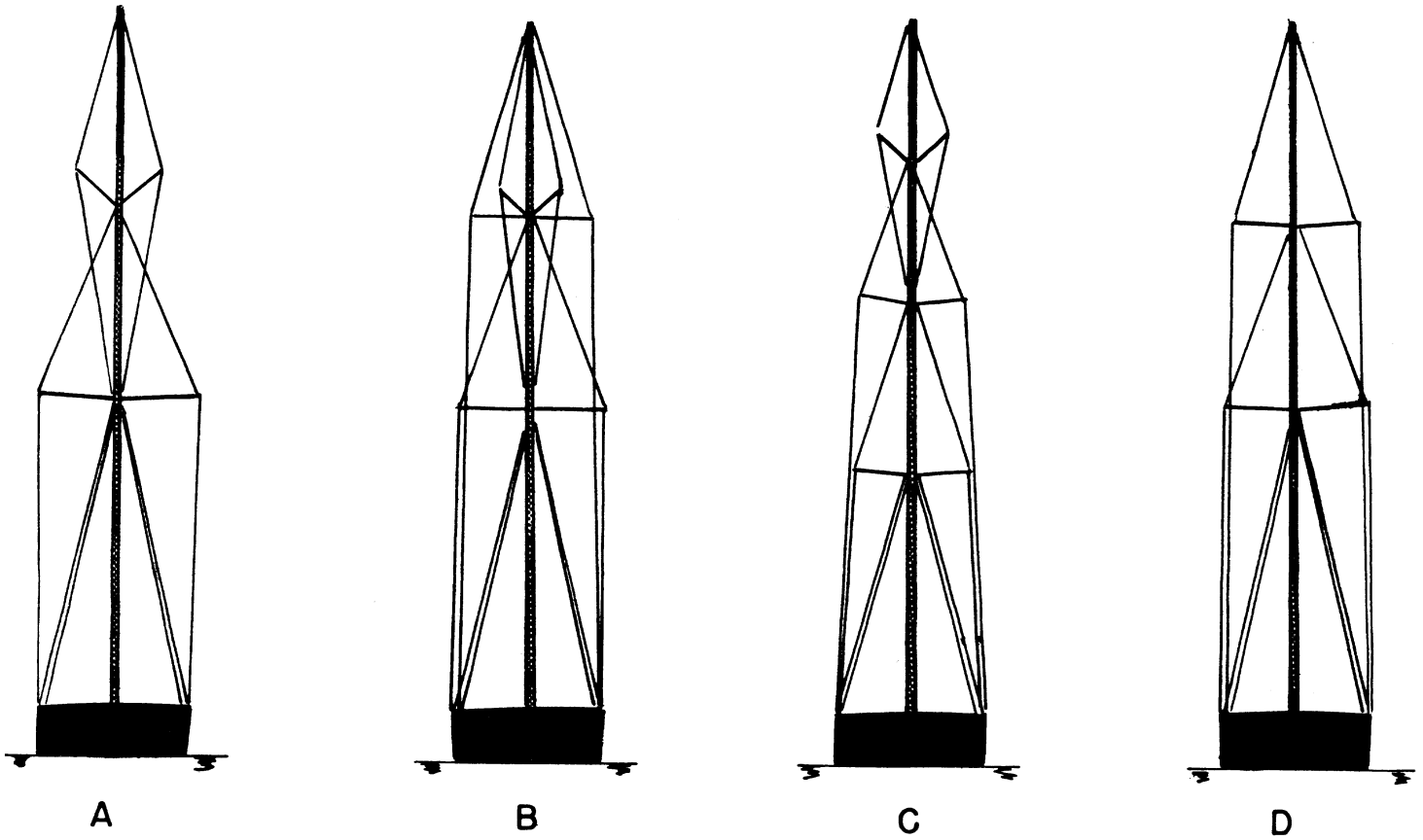


MASTHEAD CUTTER



KETCH WITH MASTS STAYED TOGETHER

FIGURE 3. TYPICAL STAYING ARRANGEMENT



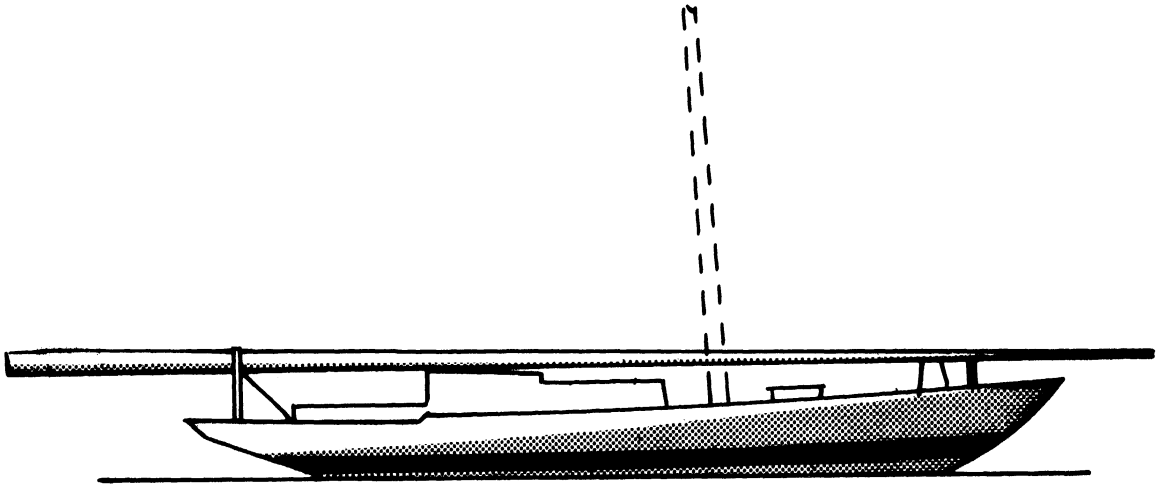
A BASIC SHROUD ARRANGEMENT FOR SLOOPS

B IMPROVED VERSION OF "A"

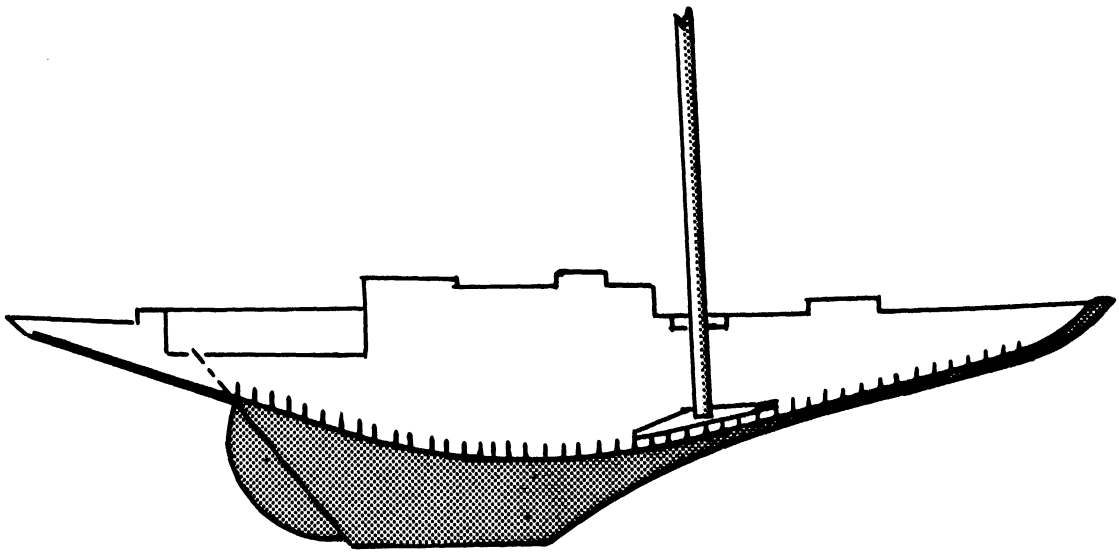
C SHROUD ARRANGEMENT FOR TALLER MASTS

D SHROUD PLAN FOR MASTHEAD RIG

FIGURE 4. TYPICAL SHROUD ARRANGEMENTS

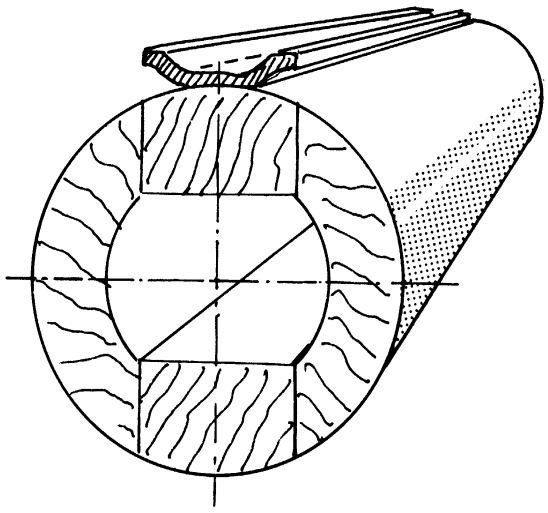


50' CUTTER CARRYING SPAR ON DECK

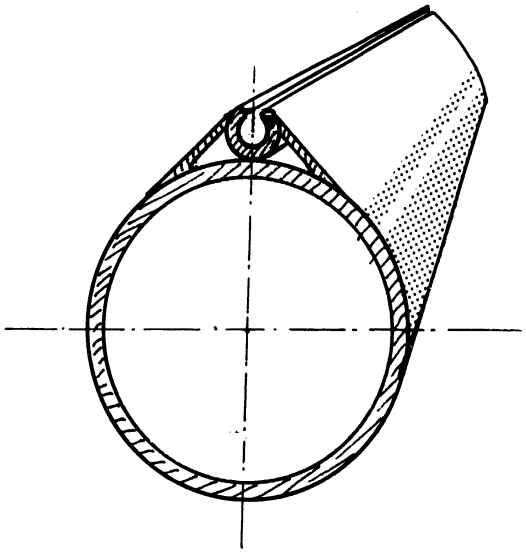


INSTALLATION OF STEPPED MAST

FIGURE 5. NORMAL INSTALLATION FOR STEPPING AND METHOD FOR TRANSPORTING UNSTEPPED MASTS

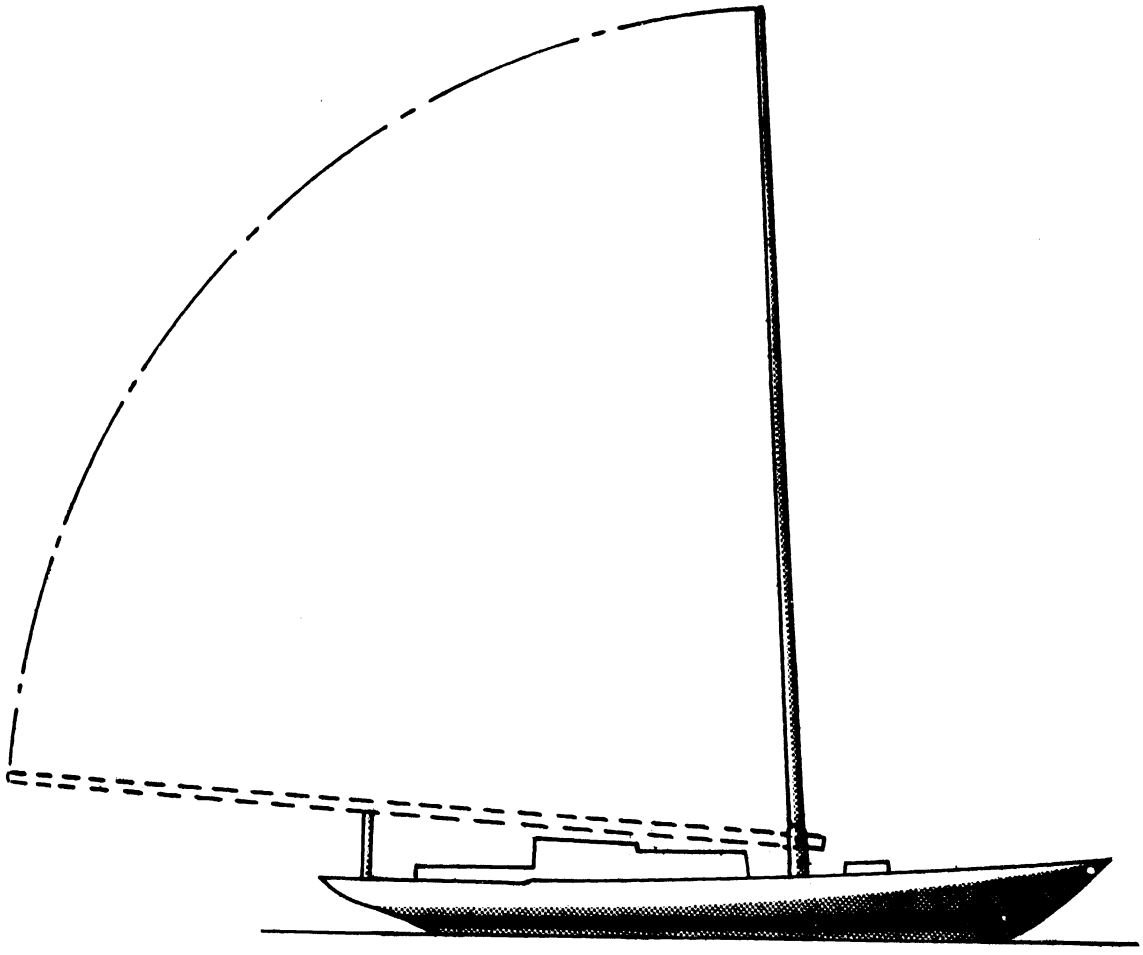


SECTION OF HOLLOW WOODEN MAST WITH SAIL TRACK



SECTION OF LIGHT ALLOY MAST WITH RECESSED SAIL TRACK

FIGURE 6. TYPICAL MAST SECTIONS



CRUSING SLOOP WITH MAST TABERNACLE

MAST TABERNACLE
FOR SMALL BOATS

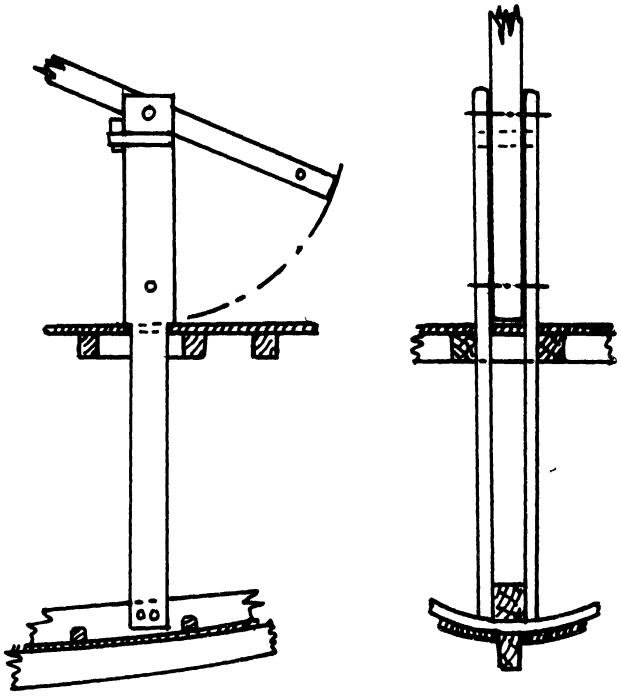


FIGURE 7. TYPICAL TABERNACLE ARRANGEMENT
FOR LOWERING MAST

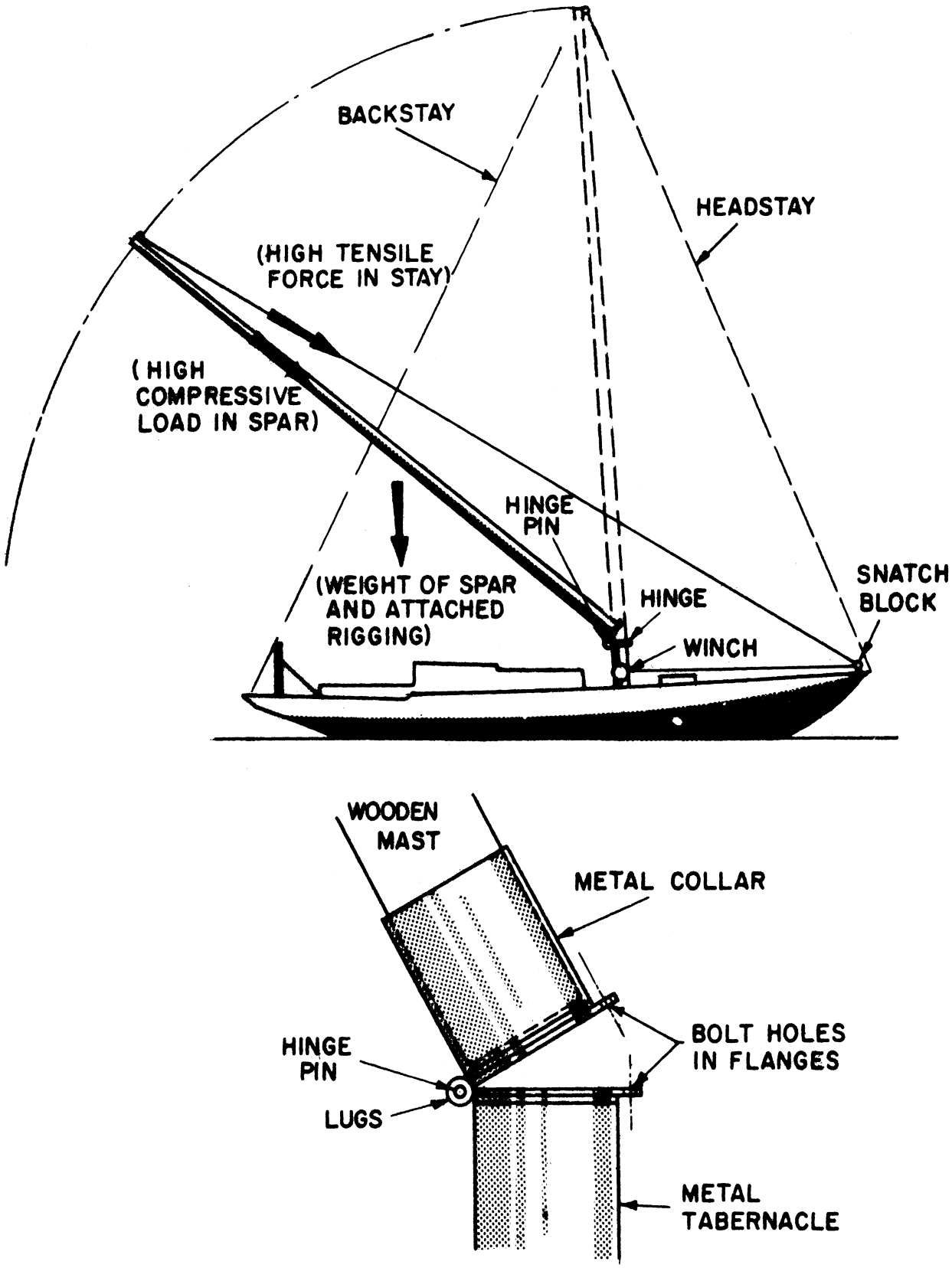


FIGURE 8. TYPICAL HINGED MAST DETAILS AND LOADING IN INTERMEDIATE POSITION