SAILS & AEROFOILS

A.Y.R.S. PUBLICATION No. 9

P. V. McKinnon's Wingsail

CONTENTS

PRICE $1.00 PRICE 5/-

THE AMATEUR YACHT RESEARCH SOCIETY

EDITORIAL.

The ANNUAL SUBSCRIPTION to the A.Y.R.S. is now due. On the enclosed slip of paper, the amount each member owes or is in credit will be found. It is asked that all subscriptions should be brought up to date and the money for the coming year sent, where this has not been done already. The stand which has been booked for the next London Boat Show has proved rather more expensive than anticipated but it will be well worth it for so many of us to meet. As a result, however, we have only very small funds left which will only just meet our publishing commitments for the next year.

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A CATAMARAN CRUISE

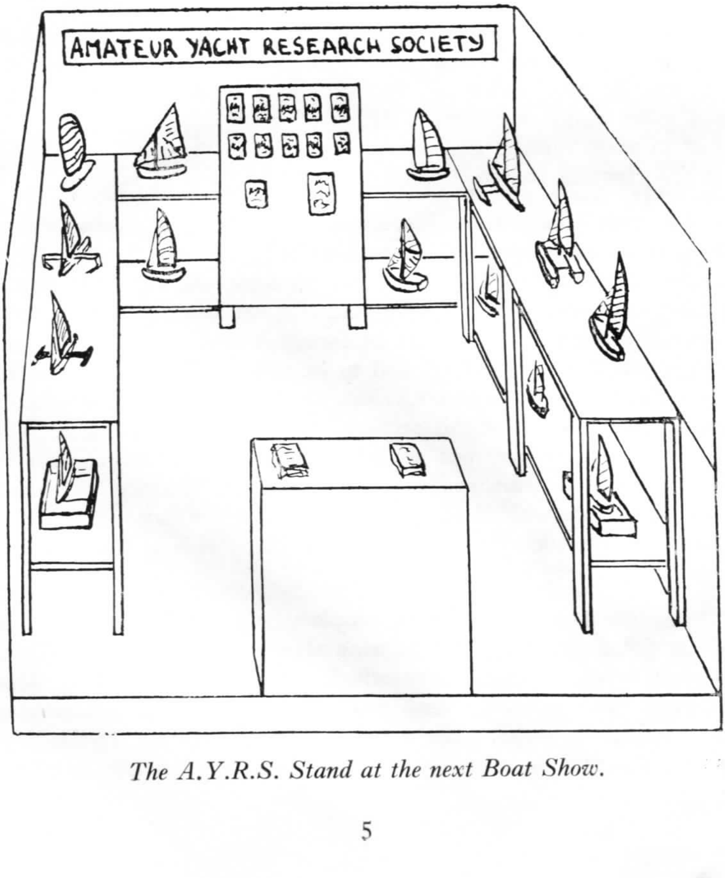
James Wharran, who has so far cruised 2,000 miles in a 20 foot double hulled catamaran, has just written to me. I hope to give details of his craft in a future number on CRUISING CATAMARANS but he has now got to Oporto in Portugal from England, having made a detour by Dusseldorf in Germany. He tells me that in a light gale in the Bay of Biscay, a cup of tea could be put down anywhere with no fear of it moving. He has promised to let us have details of the problems he meets on his cruise and information which could help others. It is only costing him £3 per week for three persons and he is doing things and seeing new places. He has our sincere good wishes. He would like to have books, periodicals and information on the Caribbean sent to him at : S.C. Tangora, Real Club Nautico, Las Palmas, Gran Canaria, Spain.

This number on SAILS & AEROFOILS has been a long time in coming, simply because I have been afraid that the ideas in it might not be practical. However, most, if not all of the suggestions could actually be used to drive a boat and all with very fair efficiency. It is left to readers as to whether or not they would be shipmates with any of them and in time to tell if they are any improvement over the ordinary Bermudian sloop. While assembling this number, I have been lucky enough to get descriptions from Major General Parham, Colonel Bowden and P. V. MacKinnon on their wing sails and these will be published in a future number. If, therefore, any reader has tried any wingsail or knows of anyone who has done so, will he please send as much information about it as he can to me with a photograph, if possible.

THE BOAT SHOW

We have been allotted Stand No. 187 at the Boat Show. This is, unfortunately, on the top floor (the second) at Olympia so it can be expected that people will be a bit foot-sore and weary by the time they reach us. However, we will have a few chairs.

The lay-out of the Stand which is 10′ by 10′ is shown in the drawing. The shelves will allow room for models all round which should make an attractive show if we can get enough of them. We should fit in about 20 models in all and we would like " Wingsails " and aerofoil sails, such as are described in this publication. A scale model of the Prout catamaran will be needed with the various kinds of Outrigger craft. Hydrofoil models of several types should be on display. It would be a great help also to have demonstration



The A.Y.R.S. Stand at the next Boat Show.

models showing how the resultant sail force draws a boat along and models of sail and hull testing apparatus.

The shelves will be 1 foot 6 inches wide and models should not be more than 2 feet long, if possible. Balsa wood models are extremely easy to make and they make an attractive finish when rubbed down with a fine sandpaper between coats of either clear or coloured "Dope." If, therefore, anyone has any model which they would like to display or they are prepared to help the A.Y.R.S. by making a model of one of the craft we need, would they please write to the Editor.

THE SAIL POWER

The Bermudian, or jib-headed rig, was introduced to yachts in a big way in the 1920's. But also in the 1920's, the aeroplane came into its own and wings for aeroplanes became an active study for a great many scientists. Wings of many different kinds were tested in wind tunnels and on flying machines to see which were the best for carrying passengers, freight and weapons of war.

The sails of a boat act just like the wings of aeroplanes, though they pull the boat forwards, instead of lifting it up. Because this is so, a structure built like the wing of an aeroplane has been put on a sailing boat and it sailed quite well. When sailed against boats of an equal sail area, however, its performance was poor. The reason for this was that the aerofoil had to be able to work on either tack so it was made the same on both sides, i.e., it was of a " Symmetrical " section, and aerofoils of this section have a poor performance. One experimenter, however, put an aerofoil on his boat which was *not* the same on both sides and found that the performance was much better than boats with conventional sails when the flatter side was to windward. On the other tack, with the flatter side to leeward, performance was very poor indeed.

At present, there are many people who can sit down at a desk and draw the exact shape of the wing of an aeroplane which will give it certain flying characteristics which have been asked for. Most of the problems of aspect ratio and wing section can be reduced to mathematical formulae. We can now know nearly everything we wish about aerofoils, of which the sails of a boat are but one kind.

In this article, the possible performance of various kinds of aerofoils, when they are used as sails, will be compared with the performance of the sloop rig so far as this is known. To do this needs a lot of mathematics which need not be given here. What has been done is that the close hauled performance has been reduced to a figure called the " coefficient of thrust " which is the forward acting force produced by the sail or aerofoil per square foot of sail area in a wind speed of 20 land miles per hour with the air at its usual density. (Mathematically, a coefficient is a ratio and not a force at all but readers need not worry about this, if they don't want to).

Altogether, I have worked out some 50 performance curves for sails and aerofoils and these were taken from several hundreds which looked as if they would give good figures. The best close hauled coefficients were as follows :—

GIMCRACK coefficient (Bermudian sloop)	1.2
Manfred Curry's test (Bermudian sloop, estimated)	.37
Thin plate, arch 1 in 13.5 (Eiffel)	.83
,, ,, arch 1 in 7 (Eiffel)	.87
Bird's wing section (Eiffel)	.68
Bird's wing section, R.A.F. 19	1.1
Symmetrical section R.A.F. 27	.59
Symmetrical section, Göttingen 460, thickness 29.26% ...	.61
U.S.A.T.S. 10, a thick, single aerofoil...	1.2
Tandem aerofoils rather like a Fowler flap	1.1
Fowler flap 40%, R. & M. 2180	1.3
R.A.F. 15 with slat	1.0
Leading edge slat of 0.31 chord, R. & M. 2180	1.2
Leading edge slat and 40% Fowler flap, R. & M. 2180 ...	1.3

The Interpretation.

Unfortunately, there are some contradictions in these figures. Undoubtedly, the GIMCRACK coefficient is too high, as Dr. Davison points out when he gives it. This no doubt explains the fact that several yachts have not performed as well as was calculated, though the figures used for the calculations were not given. Manfred Curry's figure is more likely to be correct. Probably, a coefficient of around 0.5 is obtained by a modern, high aspect ratio sloop.

Scale Effect.

Though they have the same transverse sections, large, aerofoils (or sails) in high wind speeds have different coefficients from small aerofoils (or sails) in low wind speeds. This is known as " Scale effect." It is measured in terms of " Reynolds number " (R.N. $= \frac{Vx}{000157}$ V is the windspeed, x is the chord). Modern wind tunnel tests are done at Reynolds numbers of about 10,000,000. Yachts sail at Reynolds numbers of about 1,000,000. The result of this is that many of the aerofoils in the table just given will not perform up to the figures given and some will be better. As a general rule, aerofoils with a hollow windward surface will improve at low wind speeds, for example the Bermudian sloop, the thin sections and the Bird's wing sections. Sections with a convex windward surface and sections with slats and flaps will be worse. Symmetrical sections are very much worse.

Thrust to Side Force Ratio.

This is an important ratio because two aerofoils might have the same close hauled thrust coefficient but, if one of them has a higher side force than the other, a greater area of fin keel or centreboard would be necessary which would slow the boat. Also, the greater this ratio, the greater will be the maximum close hauled speed. As a general rule, a single aerofoil has a higher thrust to side force ratio than one with a slat or flap.

The Amount of Flow.

The third and fourth figures on my list of coefficients are of interest in showing that sails with an arch of 1 in 7 have about 5% more thrust close hauled than sails with an arch of 1 in 13.5. This indicates that full length battens right across the sail should give an advantage, a fact which British yachtsmen do not usually use, though it is common practice in other countries.

Conclusion.

With quite a number of if's and but's, it should be possible to put an aerofoil on a yacht which will give almost three times the thrust close hauled than an equal sail area in the sloop rig.

THE BERMUDIAN OR JIB-HEADED SLOOP

This rig loses efficiency for the following reasons :—

The Mainsail.

1. Eddies form behind the mast on both sides of the sail for about the fore 10%. This is the part of an aerofoil where the forces are most powerful so a great loss of power occurs. In Warner and Ober's test, the loss of thrust of a mainsail from mast eddies was found to be 18% of the total force. No jib was used and it is possible that a jib prevents at least some of this loss by smoothing out the air flow on the lee side of the mainsail.

2. Manfred Curry's examination of a mainsail showed that a mainsail without a jib is sailed " Stalled," i.e., there are eddies all over the lee side of the sail. He also showed that, when the jib is set, the air flow on the lee side is smoothed out and the sail is no longer " Stalled." This would make one think that the jib was acting like a Handley Page " Slat " except for the fact that the thrust force produced by a jib and mainsail, close hauled, is less than the thrust of a mainsail alone of equal area. When a jib is used, 75% of the force of the mainsail comes from negative pressure on the lee side.

3. A mainsail has a twist of 10° to 20°. It may even have a twist of 45° when the sheets are eased. This produces a varying " angle of attack " up and down the luff of the sail so that, if one part is properly trimmed to the wind, other parts will not be. The " Wind velocity gradient " calls for a slight twist of about 4° in theory but Major General Parham has shown that this does not appear in practice.

The Jib.

Warner and Ober showed that, when both jib and mainsail were on a boat, the forces on the jib were relatively greater than those on the mainsail. This has lead many people to give the jib credit for a greater efficiency than it, in fact, possesses. The reason for the larger relative forces on the jib in the tests was the fact that the mainsail acts as an obstruction to the windflow and increases the speed of the wind on its lee side, *even up to windward*. This extra wind speed then increases the forces on the jib. An analogy which is perfectly valid is the case of the " Safe leeward position " where the yacht which is behind and to windward increases the windspeed and frees the wind's direction for the boat on its lee bow. The jib is, after all, on the " Lee bow " of the mainsail.

Lord Brabazon showed in 1948 that a Genoa jib, if properly set, is more efficient on all courses than the sloop rig of the same sail area. It is also known that, for the same area, a mainsail alone is faster to windward than a sloop but, when the sheets are eased, the sloop is faster. These facts indicate that there is no value in having two sails on a boat if there is no twist in the mainsail and no mast eddies. Both these faults can be partially corrected by a jib.

Jib and Mainsail.

The most efficient plan form for any aerofoil is an ellipse, or, for the aerofoil of a boat, half an ellipse. The triangular plan form of the Bermudian rig, especially with the hollow formed by the jib is very far from this and causes losses in the region of 10%. It is this fact which creates the need for a taut luff to the job, and, indeed, the jib luff would be better convex.

Aspect Ratio.

The wind eddies which come off the leeches of the sails, the " Trailing edge vortices," all gather together to form one eddy coming off the peak of the rig and a much larger eddy swirling around the boom. These eddies produce a great loss of power and I do not think that a device like a wide flat boom would help them. Both jib and mainsail act together to make the eddies so they must be taken together. It is no help to examine either sail by itself.

The value of high aspect ratio is to be found in the greater sail area which is then present, relative to the loss of power in the peak and boom eddies.

For aeroplane wings, to bring values of aspect ratio into accord with the rectangular plan forms which are commonly studied and to take into account various shapes, aspect ratio is taken to be $\frac{\text{Span}^2}{\text{Area}}$.

The presence of the boat's hull and the sea surface keep the boom eddy from developing fully so the sails' aspect ratio must be given a higher figure than that of the above formula. If there were no boom eddy at all, the aspect ratio would be twice that calculated. An estimate by P. V. MacKinnon, which is probably not far out, is that the aspect ratio of the above formula should be increased by 50% to be comparable with aerofoil tests.

The aspect ratio to be aimed at which will give the greatest power with the least weight and heeling moment is 6 : 1. This means that the figure for $\frac{\text{Luff}^2}{\text{Sail Area}}$ must be 4 : 1 to allow for the improving effect of the hull and sea surface. A truly triangular rig with this figure would be twice as long in the luff as along the base of the sail plan.

The aspect ratios of yachts are often low due to the rating rules and tradition. The ratios of four yachts are as follows :—

		$\frac{\text{Luff}}{\text{Area}} \times \frac{3}{2}$ Aspect ratio
REDSTART, Bembridge Redwing, Rig unrestricted		7.4
International 14 foot class	(measured sail area) ...	5.1
	(total sail area)	3.7
International Canoe	(measured sail area) ...	4.3
	(total sail area)	3.2
ENDEAVOUR, J class yacht		4.2

It will be seen that these ratios are low with the exception of the Redwing where there are no restrictions on mast height and the aspect ratio is very good.

It is a common fallacy to suppose that a low rig will heel a yacht less than a high rig. The rating rules often show penalties on high aspect ratio in the belief that they help to produce a better boat, the recent R.O.R.C. rules being the latest example. The C.C.A. rule is even more severe. Actually, a rig of low aspect ratio will cause a boat to heel *more* than one of the ideal ratio. Until we can get precise experimental figures at full scale, the aspect ratio when worked out to the formula $\frac{\text{Luff}^2}{\text{Area}} \times \frac{3}{2}$ should always be 6 : 1 for maximum efficiency.

THE POCKET LUFF MAINSAIL

This rig is shown in section in the left hand sketch of Fig. 1. It has the virtue of being the cheapest possible rig for a boat. The depth of the pocket must be at least three times the diameter of the mast, otherwise the sail will stick to the mast if it gets wet. Indeed, this and the fact that all stays must run to the masthead are the only faults with this rig.

As developed by the Prout brothers for use on their folding sailing dinghy, the mast must be lowered to get the sail off the boat. In a version which I tried in 1932, there was an incomplete " pocket " with the sail passing around the mast to be tied to itself on the other side as shown in the middle sketch of Fig. 1. This was satisfactory in allowing the sail to be taken from the boat but the airflow was not so good as with the complete pocket. This sail was still not above being difficult to get down when wet.

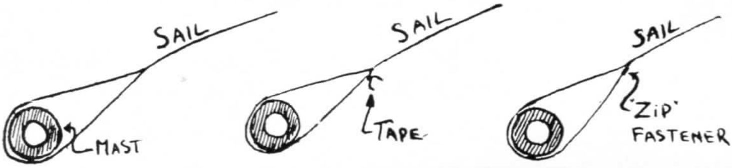


FIG. 1. *Sections of Pocket Luff Sails.*

Perhaps the last sketch of Fig. 1 would be the best way to use this principle. Here, the sail passes around the mast as in my 1932 rig but is attached to the sail on the other side by a " Zip " fastener.

Efficiency.

The thick leading edge caused by the mast causes no loss of power. There are no mast eddies so the 18% loss from that cause does not appear and thus, this sail is equivalent to one with 22% more canvas with a normal mast. With an aspect ratio of $\text{luff}^2/\text{area}$ of 4 : 1, the coefficient of thrust equivalent to the figures given earlier would be about 0.6.

A jib is neither necessary nor desirable with this sail for the reasons given already. Full length battens across the sail might increase the close hauled thrust force by some 5%.

THE PROUT WINGSAIL

This is a semi-rigid " wingsail " which has been developed by Roland Prout for use on his catamarans. The arrangement is shown in Fig. 2. The mast is 5 inches broad by only $1\frac{7}{8}$ inches thick and is revolving. The boom is attached to the mast by a goose neck

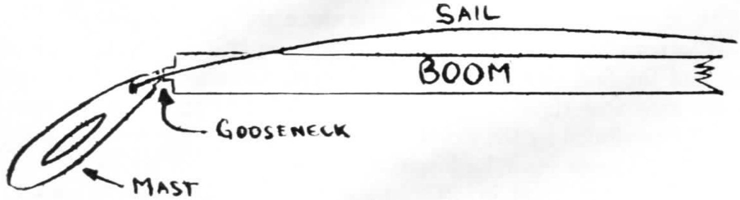


FIG. 2. *The Prout Wingsail.*

so that the mast can be revolved more than the boom to allow the sail to come off the mast's lee side in a smooth curve. In the Finn and other classes with revolving masts, the boom turns the mast but it is not turned far enough and there is a vertical hollow on the lee side of the sail. In this sail, there is no such hollow.

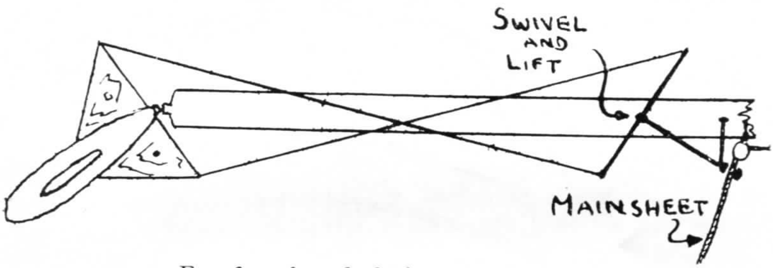


FIG. 3. *A method of turning the mast.*

The manual turning of the mast is a drawback to this rig but it should not be too hard to devise some automatic method for doing this. A way of turning the mast by the alteration in the direction in which the sheet comes from the boom is shown in Fig. 3 and other methods can be used.

One would naturally want to increase the fore and aft dimension of a mast like this because it should increase the drive from the sail. It would be unwise to go too far in this direction, however, because Roland Prout tells me that, even with the 5 inches he uses, there is quite a lot of windage and his catamaran is blown about in strong winds by it when no sail is set. A larger mast might, therefore, cause even a catamaran to capsize at moorings, unless the mast was very freely revolving.

As with the pocket luff sail, a jib should not be necessary and full length battens across the sail would help.

THE SQUARESAIL

The squaresail has never been geometrically square in shape. The word "Square" refers, as far as one can gather, to the fact that the yards can be put at right angles across the boat. This sail was described in OUTRIGGERS but I have again included a sketch of it for completeness.

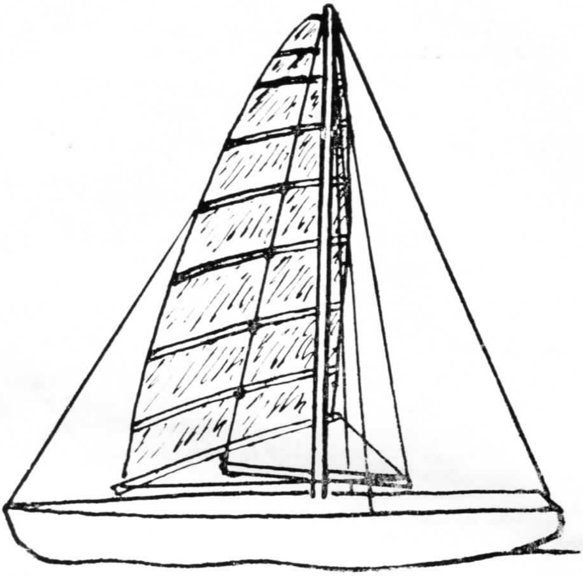


FIG. 4. *A Square Sail.*

The sail is half an ellipse with a $\frac{\text{Luff}^2}{\text{Area}} \times \frac{3}{2}$ value of 6 : 1. The full length battens give an arch of 1 in 7 and the sail is trimmed to have the luff slightly aback. There is no twist in the sail. This sail would be as efficient as it is possible to get any sail. The only loss is due to the parasitic wind resistance of the mast which lowers the thrust to side force ratio somewhat, though it may actually increase the thrust force. No jib is necessary.

The sail could be taken from the boat by having the fore side of the battens grooved, like the luff grooves of masts. Ropes sewn horizontally onto the sail with a tag of canvas could slide in these grooves and the sail could be slipped off the battens sideways.

It is not believed that putting about would be difficult with this sail. It would probably be closer winded than a normal sloop rig and on luffing, when the sail came back, it should only need a quick tug on the sheet to swing the sail onto the new tack.

On all courses the sail should sit well and be free of twist. Because of this absence of twist, the boom should lie at about 13° from the centreline of the yacht when close hauled four points from the wind rather than the normal 6° for a boom, thus giving much more drive. With free winds, the sail would also give much more drive and, when running dead down wind, it would almost be self steering with no possibility of a gybe.

The advantages would be partially offset by the risk of being " taken aback."

THE MAST AFT RIG

This rig has been independently invented by Victor Tchetchet, Paul Richards (DINGHY DESIGN, No. 8) and myself. Probably others have invented it as well. The basic idea is that the mast at the fore edge of the mainsail destroys power while, if put on the weather

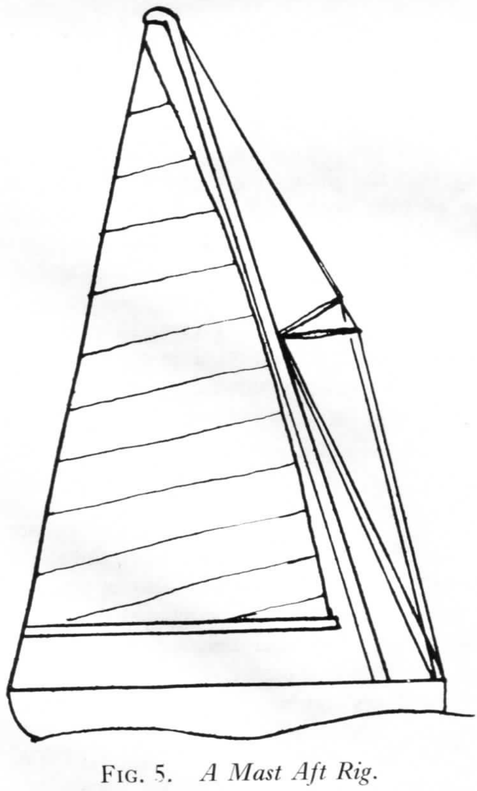
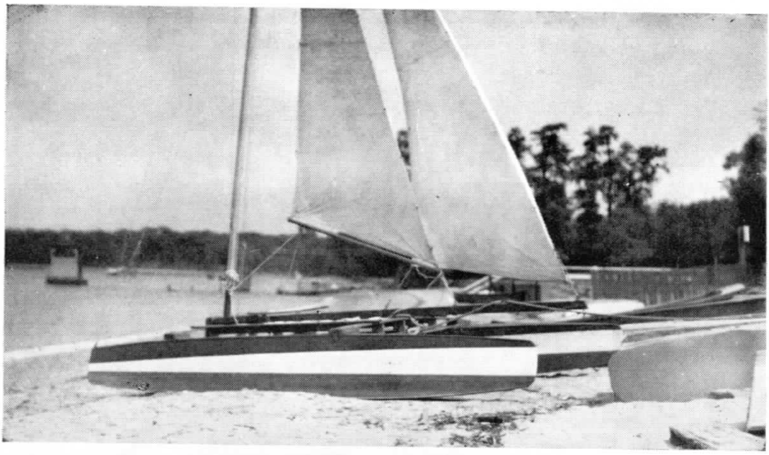


FIG. 5. *A Mast Aft Rig.*



Victor Tchetchet's Mastaft Rig.

stern end of the sail, it behaves like the split flap of an aeroplane wing and increases the thrust force. Another way of arguing the point is to say that the jib is much more efficient than the mainsail so, to get the greatest power, all the sail area should be in the jib. However, it is as well to remember in this connection that part of the extra power of the jib is due to the mainsail and disappears when the mainsail is not set.

The photograph is that of Victor Tchetchet's twin foresail, " Mastaft " rig. The construction I suggest is as in the sketch. The aspect ratio is 6 : 1, aerodynamic (span to boom is 2 : 1). The main trouble with this rig is in getting enough support for the mast.

Efficiency.

This rig would not be as good as the squaresail described previously. The triangular plan form with the slightly sagging luff would lose power, while twist would also appear. The flattening of the sail by the boom would also be against it. However, it should be slightly better than a normal Bermudian sloop and be easier to handle. When reefed, the centre of effort would move forward which might be disagreeable.

A TRIANGULAR LUGSAIL

This is a triangular sail set on the lee side of the mast but not attached to it except at the peak and boom. The luff is made as taut as possible by a winch on the mast pulling the boom forward against the luff wire and a down haul to the fore end of the boom.

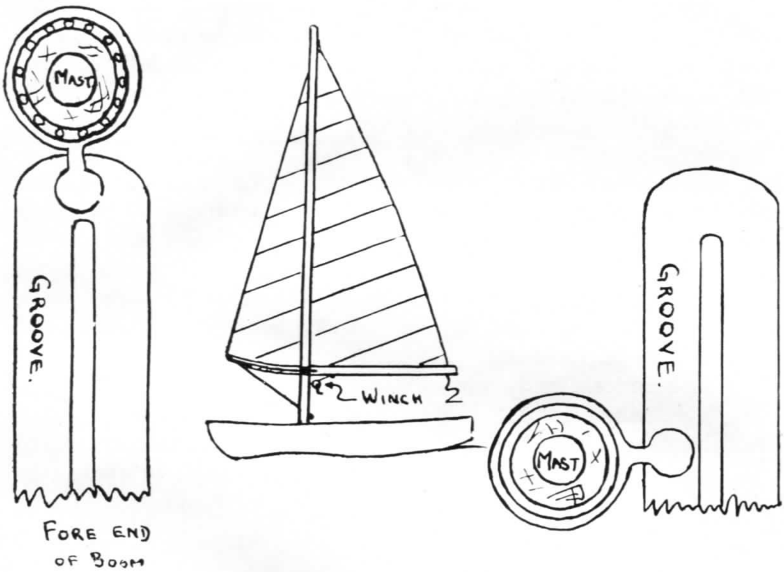


FIG. 6. *A Triangular Lugsail.*

Lugsails are less efficient on the wind when the sail is on the weather wide of the mast so the traditional lugsail with a yard is " dipped " when going about and the yard and sail are put on the lee side of the mast on each tack. With this triangular lugsail, both the sail and boom are " dipped " horizontally, being pulled back and put on the lee side when going about. To do this, the winch on the mast is slackened off, the boom is pulled back, though it is kept under control by the ball on the mast running in the groove in the boom and it is put on the lee side. The boom on the fore side of the mast is curved to an arc of a circle whose centre is at the masthead so that the luff does not flog about, when the sail and boom have been pulled aft.

Efficiency.

This sail should be better than an ordinary sloop rig of the same sail area and aspect ratio. Lord Brabazon's experiments in 1948 showed that a large Genoa jib was far more efficient on all course, if properly set, than a sloop and this sail is, in effect just a large Genoa.

A DOUBLE LUGSAIL

This is a handier version of the previous sail. To avoid the difficulty in putting about, two sails are set, one on each side of the mast. Again, there should be extreme tension in the luff wire and this could be taken by either the halliard or downhaul winch.

Efficiency.

When sailing, the weather sail would lie up against the lee sail except at the mast where it would lessen the parasitic wind resistance and thus probably make this sail a little more efficient than the sail of the last article. Like that sail, this one would be better than a Bermudian sloop rig for the same *projected* area, if the aspect ratios were the same. It would obviously *not* be better if the area of *both* sails were to be measured.

Commander Gandy uses a version of this rig in his "GIG, RIG," described in A.N.U.S.C. Technical Papers Nos. 6 and 7 (available from Hugh Barkla, 15, Howard Place, St. Andrews, Fife.) His aspect ratio is low, however, to lower the centre of effort. In

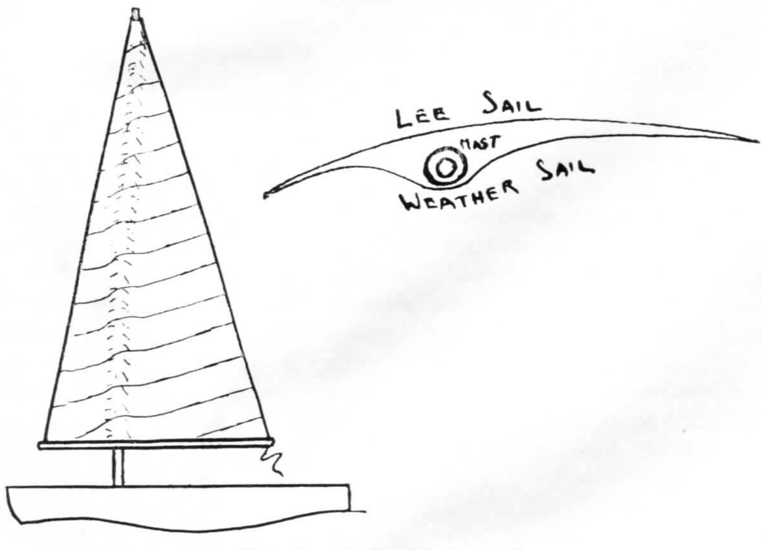


FIG. 7. *A Double Lugsail.*

my opinion this use of a low rig actually *increases* the heeling moment for a given amount of thrust because of the greatly increased side force produced.

AEROFOIL SAILS

There is no doubt from the calculations about aerofoils, some of the results of which are given earlier in this issue, that an asymmetrical aerofoil, i.e., one which is not the same on both sides will give far greater speeds to a sailing boat than conventional sails. Such an aerofoil would never need to be reefed. Simply by setting it at a smaller angle of attack to the windflow, the forces on it can be reduced to small proportions even in a gale. If allowed to " weathercock " freely, there would be less windage than from a mast and rigging so it could be left on the boat at all times. However, most yachtsmen

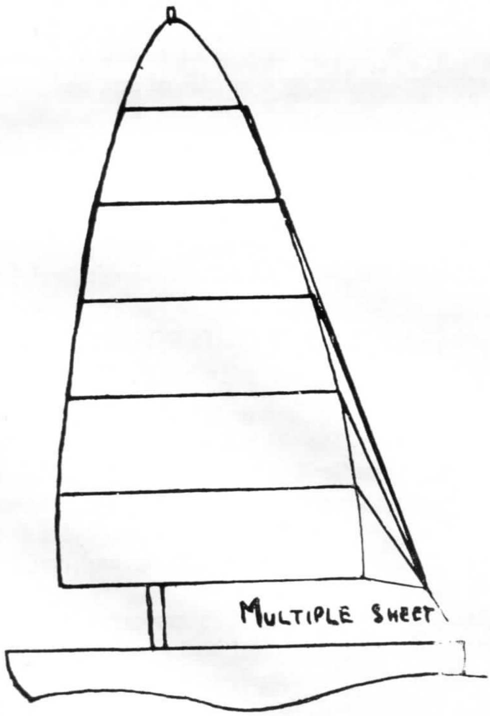


FIG. 8. *An Aerofoil Sail.*

would want to be able to take the sail home and this is thought to be a reasonable need for a successful sail of this kind.

Construction.

An aerofoil sail could consist of many " Formers " which would be made to the aerofoil section and be placed at regular intervals up the mast. The sail would be placed around these formers so that the free edges would meet behind where they would be laced together. The cloth could be attached to the formers by ties or by ropes in grooves.

Erecting the Aerofoil.

Each former would first of all be put on the mast by a slot stretching in from the side and locked in position. The canvas would then be put around the front of the formers and tied to them at either side. Then the after edges would be laced together and the lacing would pass through the after tip of each former. When all this has been done and it is not likely to be a very difficult job, the sail would be ready for hoisting by the halliard attached to the top former.

Sheeting.

Ideally, a multiple sheet of the Chinese pattern with parts to every former would be best but, of course, it has a lot of windage. A vertical leech pole in the leech lacing would allow the number of parts to be reduced but it might not pay for its weight.

ASYMMETRICAL FORMERS

It has been suggested by a member that the aerofoil section known as N.A.C.A. 63015 is worth trying on a yacht. This is a high lift section rather like U.S.A.T.S. 10, whose figure of close hauled thrust is given earlier but there is a hollow on the under surface and it improves its performance at the low Reynolds numbers where yachts sail. It will give a better thrust force and a better thrust to side force ratio than a Bermudian sloop rig and could be combined with a slat or flap (see later).

Constructionally, N.A.C.A. 63015 has one very useful feature in that the after 2/3rds is symmetrical and, for this reason, can be used to show two extra ways of producing asymmetry.

When this aerofoil is in use, forces acting inwards, which would tend to collapse the aerofoil, are only to be found over the windward surface and the " Stagnation point " which is usually on the windward surface but may be exactly at the leading edge or even extend slightly onto the lee surface. All over this part, therefore, there has to be a continuous structural backing for the canvas to make the airflow smooth. On the lee side, however, all the pressure forces act outwards so as to keep the aerofoil " Blown up." Over this surface, therefore, a gap in the structural backing for the canvas will not produce a hollow. It is not possible to attach the canvas all along the sides of any asymmetrical former which I can think of, so the canvas would have to be unstretchable in order to bridge one or more gaps in the former's lee side.

There are four methods of making asymmetrical formers which are :—

1. *Revolving Nose Former.* Owing to the symmetry of the after part of the aerofoil, only the nose part need be altered when putting about. If, therefore, the asymmetrical nose of the former is made separate from the symmetrical part and is joined to it by a bearing whose axis is in the long axis of the former, the nose can be

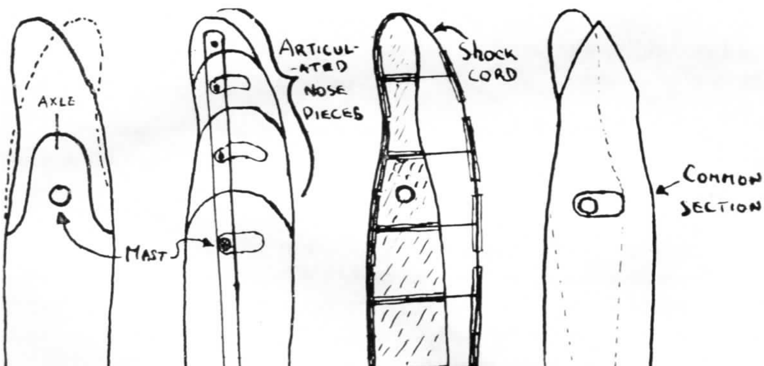


FIG. 9. *Four types of Asymmetrical Formers.*

simply revolved when putting about. Unfortunately, the revolving must be done by some system of lines which would be rather difficult. The canvas would be attached to the sides of the symmetrical part of the former but forward of this, it would be free.

2. *Articulated Nose Former.* With this former, the after part is treated in the same way as with the " Revolving nose former " and the canvas is attached to the sides. For the asymmetrical part, however, the system is very different. There are from one to four parts here, depending on the aerofoil section used, each one fitting into the one aft of it by a semi-circular articulation. Two planks at both sides of these pieces keep them in place and, by stops, in slots in them, limit their movement from side to side. The planks are attached to the end piece near the leading edge and fairly far aft in the symmetrical part by bearings. The mast passes through a hole about their centres. There is a slot in the symmetrical part of the mast to move a little from side to side, and when it does so, it carries the leading edge piece to windward and the other little pieces in the nose take up the aerofoil shape. This system has two advantages over the revolving nose former. Firstly, the asymmetry is automatic and secondly, the aerofoil can be made symmetrical which would be useful in gales.

3. *Slide over Former.* The basic strength of this former comes from a symmetrical bar which stretches from the leading to the trailing edges. Each side of the bar is shaped to the curve of the *windward* side of the aerofoil. Across this bar slide rods, each one of which is the length of the thickness of the chord at that place. The canvas is again only attached to the after part. When the wind blows against the weather side of the aerofoil, it pushes the rods across the bar to give the shape to the lee side. Small, articulated pieces at the ends of the rods protect the canvas from damage and, if these pieces are tubes, a light shock cord threaded through them would prevent the formers fouling each other when the sail was furled. This system is fully automatic, it can take a symmetrical section and the formers are light and should stow nicely on each other.

4. *Common Section Slide over Former.* I think that this is the best of these four systems. It uses the same principle as No. 3 but both the symmetrical after part of the section and that part of the nose which is used on both tacks slide from side to side. When the section N.A.C.A. 63015 is used, only two small places on the lee side of the sail are left unsupported and the negative pressure

there should keep the aerofoil in shape. The canvas may be attached to the sides of the symmetrical part either by three ties or by a rope in a groove but it must be free over the asymmetrical part.

The ordinates of N.A.C.A. 63015 are :—

Station	1.25	2.50	5.00	7.50	10.	15.	20.	25.	30.
Upper	5.51	6.94	8.91	10.29	11.21	12.20	12.46	12.40	12.16
Lower	–0.73	–0.88	–0.62	–0.51	–0.58	–1.15	–1.91	–2.49	–2.89
Station	40.	50.	60.	70.	80.	90.	95.	100.	
Upper	11.28	10.00	8.40	6.61	4.64	2.49	1.36	0.16	
Lower	–3.28	–3.30	–3.03	–2.56	–1.94	–1.13	–0.65	–0.16	

Leading edge radius : 2.48. Slope of radius through end of chord 0.915.

SLATS AND FLAPS

A " Slat " is a narrow auxiliary aerofoil put at the leading edge of a larger aerofoil and a " Flap " is either an auxiliary aerofoil or part of the main aerofoil at the trailing edge. Both of them delay the " Stall " and hence allow greater forces to be produced. They would increase the thrust force with a free wind and also close hauled in light winds. Both would be quite easy to make for a rigid aerofoil but I doubt if a practical way to use them with the type of aerofoil described here would be possible.

THE KITE RIG

Cody, who did so many experiments with kites at the beginning of this century, once attached one of his kites to a boat in Dover Harbour. The course was more or less down wind and, before the boat had gone far, the kite had fallen into the water. The Polynesians were more successful with kites towing boats and used the method several times according to their traditions. However, all these kites flew " Stalled " and could only fly directly down wind so they can be of no use to us. On the other hand, if a kite were to be made into the shape of an aeroplane and be capable of flying at an angle *from* the wind's direction *under the stall*, it is certain that greater speeds would be obtained by a sailing boat than with any other arrangement.

It is perfectly possible for a kite to tow a boat on a close hauled course and so get to windward. This seems to be a very difficult thing for many people to understand because, of course, the string of the kite cannot pull to windward. However, if the string were to pull at an angle of, say 80° from directly down wind, the kite would be pulling in about the direction that a good sloop rig pulls a boat. It is because the force pulls forwards of the beam that the yacht goes to windward. The diagrams show the forces.

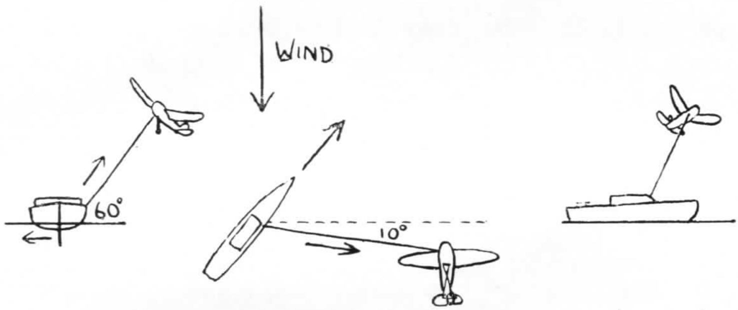


FIG. 10. *How a Kite could pull a boat to Windward.*

A model glider will not fly as a kite. It will rise well enough and it will climb till it is more or less straight overhead. Then it will side slip to the ground. The reason for this is that the tail must be large enough to bring the centre of lateral resistance aft of the string's axis to make the kite point into the wind. It can only fly in unstable equilibrium, therefore, because, if a slide slip starts, it will be kept going by the tail.

My successful model is shown in the sketch. It was made from one of the construction kites for a glider but the nose weight was not, of course, used. The tail was modified to have a steering rudder acting on thread hinges and this rudder was fitted with a cross bar. A light alloy tube passed through the fuselage at an angle of 45° being held in bearings at the top and bottom. Below the fuselage, the alloy tube was bent so that its lower part was vertical and its lower end was weighted. At the upper end, there was a cross bar which was linked to the rudder bar with crossed strings.

In operation, if the starboard wings starts to drop and a side slip begins to the right, the weight also moves to the right and this gives port rudder and steers the kite back to the top. The cross bar on the alloy tube must be much shorter than the cross bar on

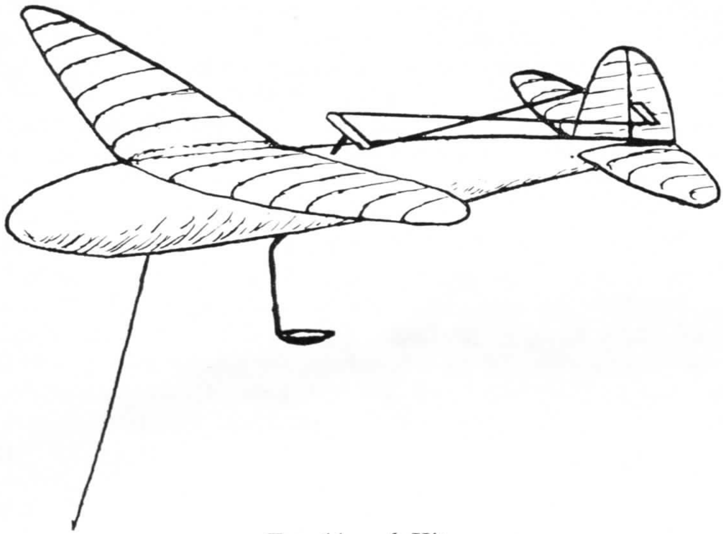


FIG. 11. *A Kite.*

the rudder, otherwise the movements are too jerky which may bring the kite down.

Unfortunately, my own experiments have only reached as far as the kite which has been described. All that would be needed to produce a kite to pull a boat would be to put a mechanism in the control strings to the rudder so that it could be controlled from a yacht. The weight would then stabilise the kite at different angles from the wind.

Operation. The kite should be made to have a " Lift to drag " ratio of about 20 : 1. When going to windward, it would be controlled to take up an angle of about 60° from the vertical and this would put the string at an angle of about 80° from down wind. The yacht would then be able to make a course of 45° from the wind with great ease. Various " Relief " mechanisms would be needed to spill the wind in very strong gusts and also to control the speed of the boat below, though this would usually be done by varying the angle of the boat from the string.

If the kite were flying at a height of 200 feet, it would get stronger winds than at sea level. No stability would be needed in the yacht and, of course, no ballast, so great speeds should be attained. Self steering should automatically occur because the string would always be put on the leeside of the centre of lateral resistance.

Putting about. This should not be difficult. The kite would simply be trimmed to go from one tack to the other which it would do by executing a sweep through the sky *downwind.* At the same time, the helmsman would steer his boat from one tack to the other *through the eye of the wind.* This should be the only time when it would be necessary to steer the yacht. It would also be possible to wear the boat round.

Summary. In all, the kite rig has some very interesting possibilities. Both hull and sail efficiency should be the greatest possible and the windspeed acting on the kite would be greater than at sea level. There is only one fault. This is that when running dead down wind or when the wind falls light, the kite would drop into the sea. The only way to avoid this would be to have a streamlined fuselage filled with hydrogen, and yachts would then need to have a cylinder of that gas as part of their equipment to " top up " the fuselage when the gas leaks out.

Perhaps the moorings of the future will be occupied by yachts rather like to-day's motor boats with a kite flying from each. Such kites would have little more windage than the masts and rigging of modern yachts but, if they broke loose, they could cause trouble with the aviation authorities. It might be better if the yacht yards of the future had " Hangars " in which the yachtsman, after his weekend cruise to Spain and back could put his kite.

LETTERS

Sir,

I enclose a photograph of a wingsail I have used on an American class R model yacht which usually spreads a sail area of 1,200 sq. ins. The wingsail has only 800 sq. ins. which is 2/3rd of the class area. As you will see, the sail was hinged in its first third as, at the time I designed it, I thought it was necessary to change the shape of the profile for either tack. The strut of the wing was stepped on deck in a socket.

Our experiences with this sail showed that she could not be sailed close hauled without using a vane steering gear. Under usual rig, the boat was very well balanced and did not need the vane. The C.E. of the wing was made to coincide with the C.E. of the cloth rig at first but her behaviour improved when it was moved slightly forward. The reactions to change of wind direction and speed were tremendously violent. The heeling was less than with the cloth rig.

Fritz A Rabe's Wingsail.

With a free wind, the boat sailed much steadier. Once, on a broad reach, the heavy hull, weighing 32.5 lbs. rose visibly and, began to plane for a period of about 10 to 15 seconds, a thing which never was attained with a cloth sail.

We tried the model against another model of the same class which always had been faster and the rigid sail beat her regularly. We even tried starting the experimental boat 10 or 15 feet behind and to leeward and she regularly caught her and sailed clean through her lee. We thought that perhaps the hull used was especially suited to this type of sail and so reversed rigs and the results were reversed too.

To my mind, this type of sail has immense possibilities and ought to be investigated thoroughly.

FRITZ A. RABE

c/o YACHTING,
Casilla de Correo No. 1551,
Montevideo,
Uruguay.

Sir,

I have become interested in whether the kite type sail rig with no overturning moment has been applied to the planing type hull. Presently, we are planning some modest experiments with kite propulsion of a light, Hawaiian type surfboard, using leeboards of cambered section to take the underwater side force. We would be very happy to correspond with anyone with similar interests, or learn of similar experiments.

FRED C. GUNTHER.

3689 N. Fair Oaks Avenue,
Altadena,
California, U.S.A.

Sir,

A friend and I are at present building a "Cat" which we hope to have ready early next year. Our intention is to try it out first in hull form with an outboard and get as much information as possible re seakindliness, going about ability etc., and then try her with a normal suit of sails. We will then try a "Wingsail" which we hope to construct either during or after the construction of the "Cat." I have ordered 90% of the material for the "Wingsail" so with good luck and hard work we hope to further the work of the A.Y.R.S. in our own little way.

I would like to mention that our reason for outboard and sailing trials before fitting the "Wingsail" is that the hull design is considerably novel (evolved by D. H. Cockburn and subject to patent rights). So it looks as if it is going to be an interesting 1957 for us.

Do you know of anyone who would sell an impoverished experimenter a mainsail (luff rope track) ex International 14 ft., Flying Fifteen, Hornet or Merlin for a *very* reasonable figure ? If so would you ask them to contact me ? Wishing every success to the A.Y.R.S.

A. JEFFERY,

27, Roseworth Avenue,
Gosforth,
Newcastle-on-Tyne 3.

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