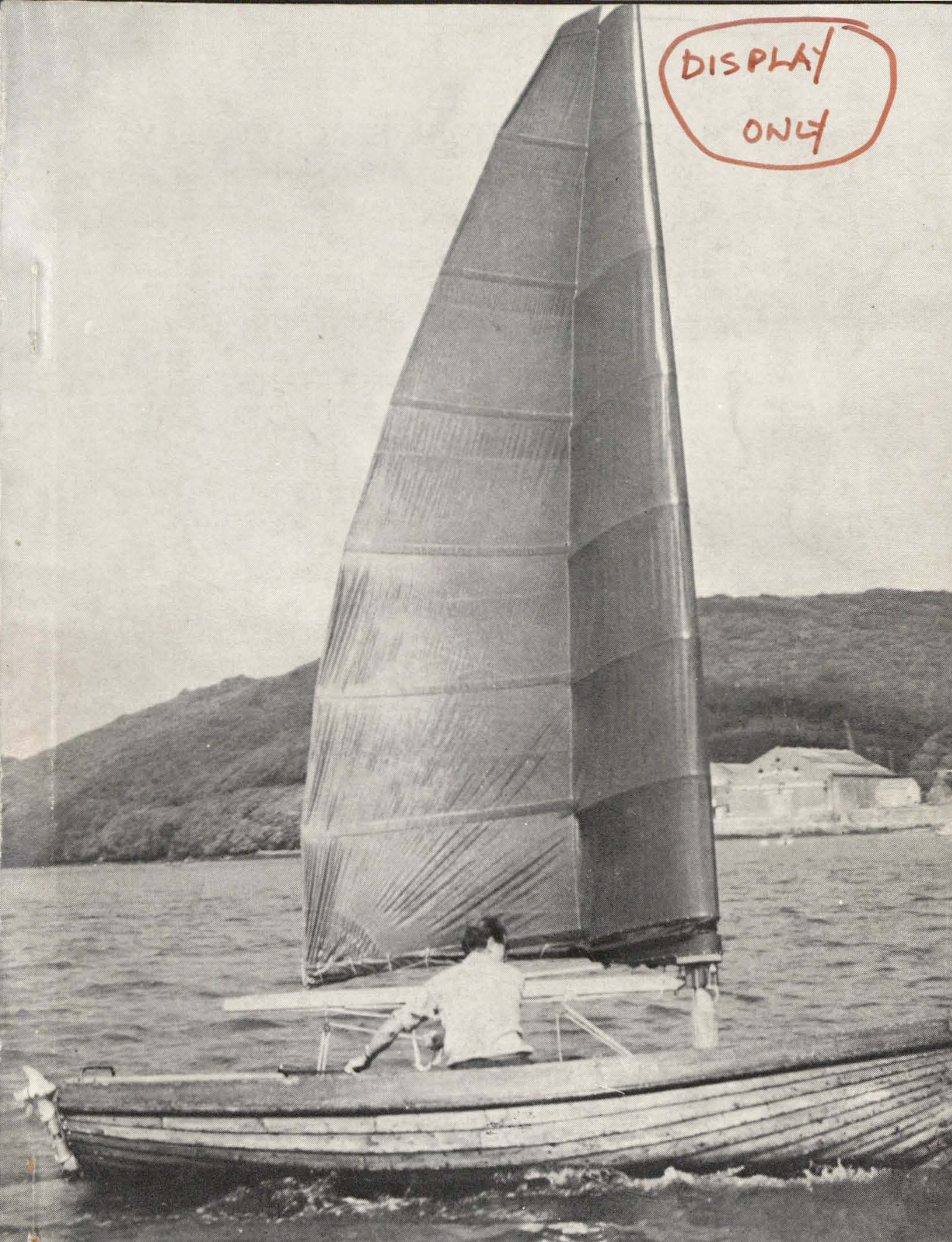

SAIL TRIMMING, TESTING & THEORY

A.Y.R.S. PUBLICATION No. 76

THE AMATEUR YACHT RESEARCH SOCIETY

(Founded June, 1955 to encourage Amateur and Individual Yacht Research)

Editor and publisher:

John Morwood, Woodacres, Hythe, Kent, England.

April 1971

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AYRS AFFAIRS

We are sorry to be late again with this publication. The book No. 74, Sailing Hydrofoils, took so long to go through all the stages of printing and editing that we seemed to live with it for about six months and other work was set aside. We hope to have another book this year "Cruising Catamarans" but will start sooner.

R. B. Smith, Flat 4, 93 Ennisdale Drive, West Kirby, Cheshire, L48 9UF only needs a copy of No. 28 to complete his set of publications. If anyone has a spare copy of this number, it would mean another complete set.

For Sale As One Lot

Publications Nos. 1 to 73 inclusive (6 missing). Contact Dr. J. E. Brindle, 2819, Lakeview Ave., Regina, Sask, Canada for details and price.

Increasing The Membership

We again ask each member to talk about us at his yacht club and generally try to interest people in our work. We need new members not only to make the Society viable but also to press our current projects forward.

HYDROFOIL PROGRESS

At the present moment in 1971, it looks as if the "torch" of hydrofoil progress is in England. James Grogono's hydrofoil *TORNADO* has set off a train of craft, though many, if not most, must have been conceived before James' success. However, the Burnham hydrofoil meeting and the AYRS Hydrofoil Group, both organized most effectively by James Grogono, have had a very stimulating effect on all concerned. The English workers are as follows:—

1 Philip Hansford, whose craft was described in SAILING HYDROFOILS (AYRS No. 74) is perfecting his craft, mostly by attention to the stern foils. James Grogono is co-operating closely with him.

2 Captain Cockburn, who sailed his *Don Nigg* hydrofoil last year, has given it to the AYRS and is now making another craft to his own design, whose details we have not yet had.

3 Joe Hood is modifying his main hull and forward foil from the craft he took to the Burnham meeting but we have had no further news.

4 Bren Ives and John Potts have bought a faster hull and are adding fresh hydrofoil stabilisers to it. Bren and John did drop a hint that they "may add fore and aft foils to make a flyer" but are being a bit 'dark horse-ish'.

5 Chris Rowe: No fresh news since Burnham.

6 Gerald Holtom, having optimised his foils as far as possible, is having a 20 ft *Foiler* built at the time of writing and this should have had its first trials by the time this issue is printed.

7 Dave Chinery, like Gerald, working along the stabilized lines, has used double Bruce foils on his narrow *Mantis* hull with success at full size. He has also, however, a model with fore and aft foils as well which flies and he hopes to fly his full sized craft soon.

8 James Grogono's *ICARUS*, which led all this development, has not been altered from the 1970 version. He has been far too busy helping others with their designs and craft to do anything radical for himself. He hopes to organise another AYRS Hydrofoil Meeting next May.

At the moment, we have had no great progress reports from America since SAILING HYDROFOILS. Edmond Bruce, Don Nigg and Dave Keiper, having got their boats to their satisfaction have, at least temporarily, given up experimenting. Bruce Clark continues to market his hydrofoil stabilisers. In fact, of course, there is a good deal of thought being applied on the quiet. Professor Bradfield has been flying a craft built by his students and studied in considerable depth. Dr. Feldman has also been doing some planning and we follow this section with a letter to him from Edmond Bruce, giving advice on stabilisation.

It has indeed been unfortunate that SAILING HYDROFOILS was delayed by the British postal strike. We feel sure that its summary of work to date will very soon trigger off a new generation of ideas. We also feel that 1971 will definitely be 'the year of the hydrofoil' and look forward to getting the reports of the boats of this year.

Letter from: Edmond Bruce, "Lewis Cove", 69 Hance Road, Fair Haven, New Jersey, U.S.A. 07701
19th September, 1969

Dear John Morwood,

Answering many letters individually has become a burden. Publishing this typical letter might save me much work. Edmond Bruce

Dear Dr. Clayton Feldman,

This is in reply to your letter of 9th September. For the first year and a half after AYRS No. 51 was published, I received no correspondence whatever regarding my article on the critical non-heeling dimensions for the arm of canted foils. Since then, many letters have come in, mostly during 1969. You were a pioneer with your article in AYRS No. 62.

In writing for AYRS, I have tried to keep the mathematics at a minimum, otherwise one will lose many readers. This is unfortunate as simple algebra could keep experimenters, attempting heeling stabilization, out of trouble. I do not believe that those who have sailed a boat truly having the critical dimensions would be willing to accept any compromise, as the non-heeling performance drops so very fast, as I will now demonstrate theoretically.

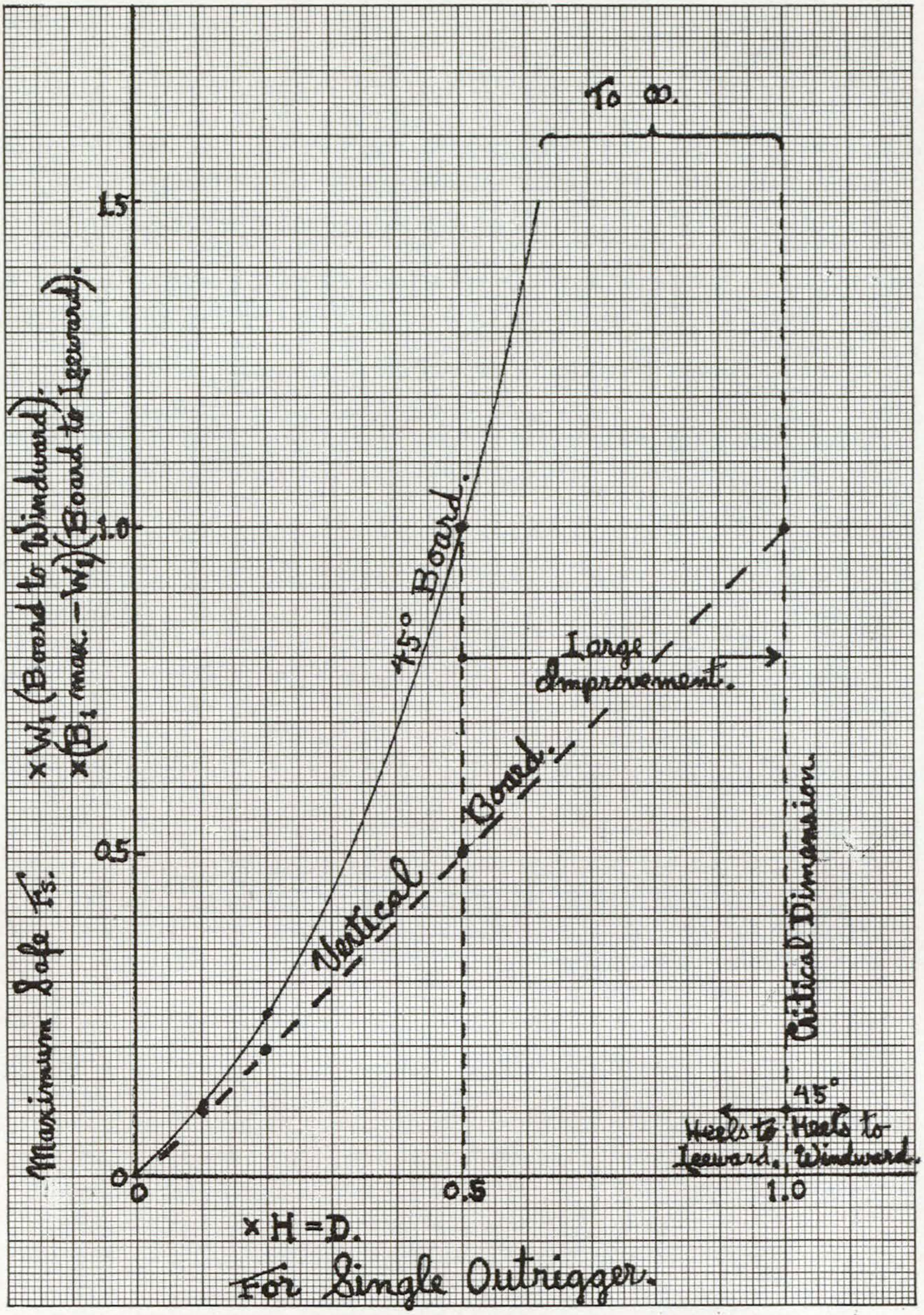
Assume any two parallel hulls in the water (a tri may have one float lifted) called No. 1 and No. 2 with a sail centre of effort of height H. There is a connecting arm of length D to a single 45-degree foil on hull No. 1, as measured from the centreline of hull No. 2. The mast can be located laterally anywhere. Its only performance effect is its contribution to the weight distribution.

First, with the board to windward, $M_2 = 0$ when,

$$F_S \times H + B_1 \times D - F_S \times D - W_1 \times D = 0$$

where W_1 and W_2 are the respective effective weights and B_1 and B_2 are the respective active buoyancies of the two hulls.

Then, with the board to windward, $B_1 = W_1 + F_S\,(1 - H/D)$.



Assume that the safe limit for heeling is when this windward hull No. 1 barely leaves the water, then, $B_1 = 0$. The limiting lateral sail force Fs max. for this case is,

$$F_S \text{ max.} = \frac{-W_1}{1 - H/D} \text{ when board is to windward.}$$

Second, with the board to leeward, the safe limit is when the hull No. 1 is just barely pushed under the surface, thus B_1 is at its maximum. For this case, similar to the previous procedure, the general equation becomes,

$$B_1 = W_1 - F_S (1 - H/D).$$

Thus, its critical value is,

$$F_S \text{ max.} = -\frac{B_1 \text{ max.} - W_1}{1 - H/D} \text{ when board is to leeward.}$$

Plots of the maximum safe lateral sail forces for these two cases are drawn in the attached curve which you requested.

Two further comments are important.

1 If the above type of analysis is extended to cover various weight distributions between the two hulls, this equation results:

$$\text{Critical } D = \frac{H}{1 - r}$$

where r is the ratio of weight of the foils's hull to the total weight of the craft with its crew.

Thus D is smallest when r is the smallest. Therefore, the heavier the hull containing the foil becomes, the longer the critical arm length must be.

2 The lateral resistance in the water must be dominated by that of the board, not the hulls. The higher the lateral resistance of the hulls, the longer the arm D must be to compensate.

Considering all of these facts, the smallest span is achieved by a single outrigger craft having the lightest possible outrigger-board combination compatible with proper static stability considerations. This structure also has the least overall weight, the least wetted surface and the least overall drag. Its critical span is actually less than a corresponding conventional trimaran. It has about half the *critical* span of a canted board catamaran because of the favourable concentration of nearly all of its weight into a comfortable main hull. I currently maintain a demonstration boat of this type, designed for solo sailing, which has thrilled several inquiring sailors. It is beautifully balanced on either tack and it comes about equally well on both tacks. In strong winds, it has no competition by any boat, anywhere near its size.

Some apparent failures that have come to my attention have been by people who insisted on compromises. There have been cases which were due to extremely crude attempts at tuning based on bad "guesswork". One must tune the board in and out for non-heeling then fore and aft so that the craft goes about equally well on either tack.

I always recommend first towing a 15-in. model by hand in a swimming pool. Use a stub mast as described on page 18 of AYRS No. 51. Adjust the board and overall tuning on both tacks. The tow cord should be horizontal and as nearly abeam as the performance will permit. Slide the cord's C.E. attachment point along the horizontal fore and aft rod until a straight course is achieved. When satisfied, transfer the model relative dimensions to the full size boat.

The model's C.E. balance point is bound to be slightly different on the two tacks, if the rudder is fixed. This can be compensated by moving the simulated crew weight fore and aft if the boat is small. If this is not practical, as in a larger boat, the rudder can accomplish this or a variable fore and aft position of the board can be used as discussed in AYRS No. 51.

The best adjustable board that I have seen was a circular board with an off-centre pivot. By simple rotation, nearly half of the board could be placed under water either somewhat forward or aft for windward work on each tack or out of water for running.

My small demonstration craft has a fixed board. It is shaped like a quarter circle segment with the curve forward. It has one-tenth the area of the sail. For running, one sits out opposite the board to lift it out of the water. This is not practical on larger boats therefore their boards should be adjustable.

Good luck and thanks for your articles in AYRS,

Sincerely,

Edmond Bruce

AREA RULE, AEROPLANES AND YACHTS

by Denny Desoutter

Larchfield, Pilgrims Way, Westhumble, West Dorking, Surrey

Amateur designers who were interested in Leonard L. Tieman's note on area rule in aircraft may like to know that this technique was used in yacht design long before the aerodynamicists introduced their "coke bottle" fuselages.

In the original "Elements of Yacht Design," by Norman L. Skene (1927), it is all there, under the term "curve of areas". Oddly enough, the technique is not mentioned (as far as I remember) in the revised modern edition by F. S. Kinney.

Briefly, the idea is to measure the areas of successive sections along the hull, and then to plot those numbers as a curve.

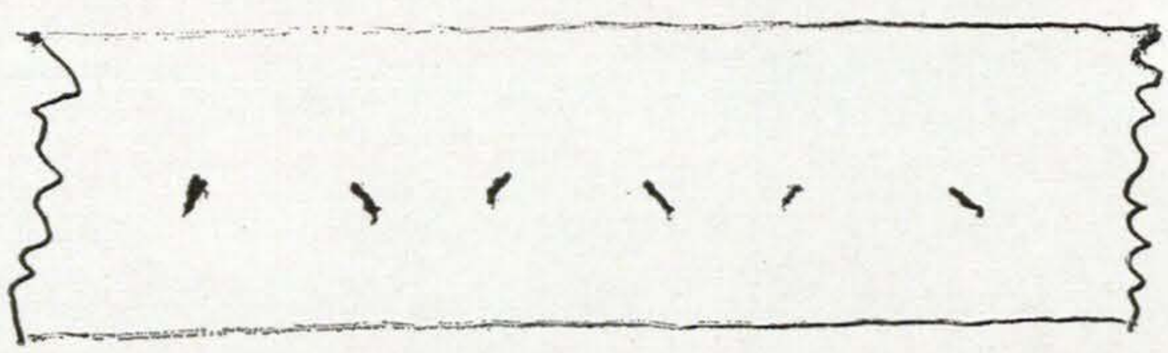
Any sudden increase in sectional area (and displacement, of course) has to be smoothed out. All the immersed body has to be considered, of course, which is what the aerodynamicists discovered. Hence they compensated for the sudden increase of displacement of the wings by waisting the fuselage in that region.

Denny Desoutter

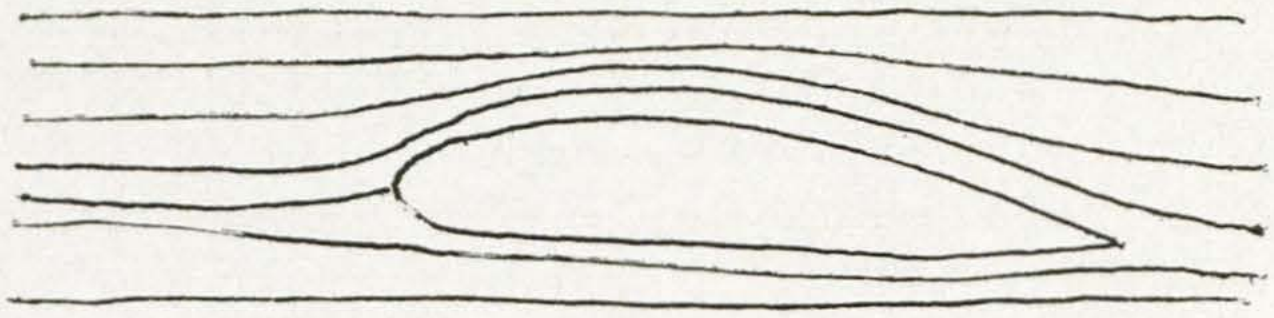
Letter from: J. Robert Williams, P.O. Box 84, Coconut Grove, Florida 33133 USA

Dear Dr. Morwood,

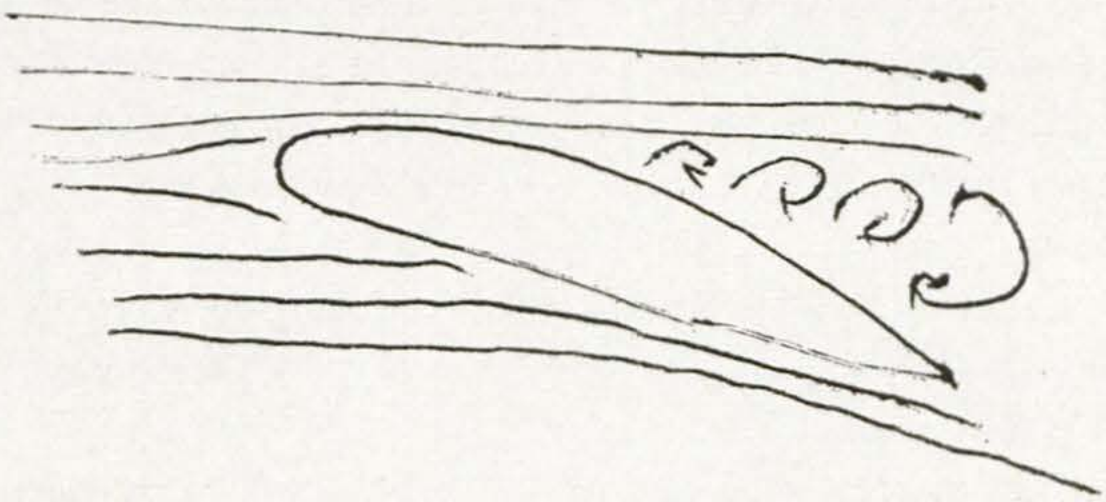
It appears that Mr. Garrett has one of the best retractable foil systems going on his *SULU*.



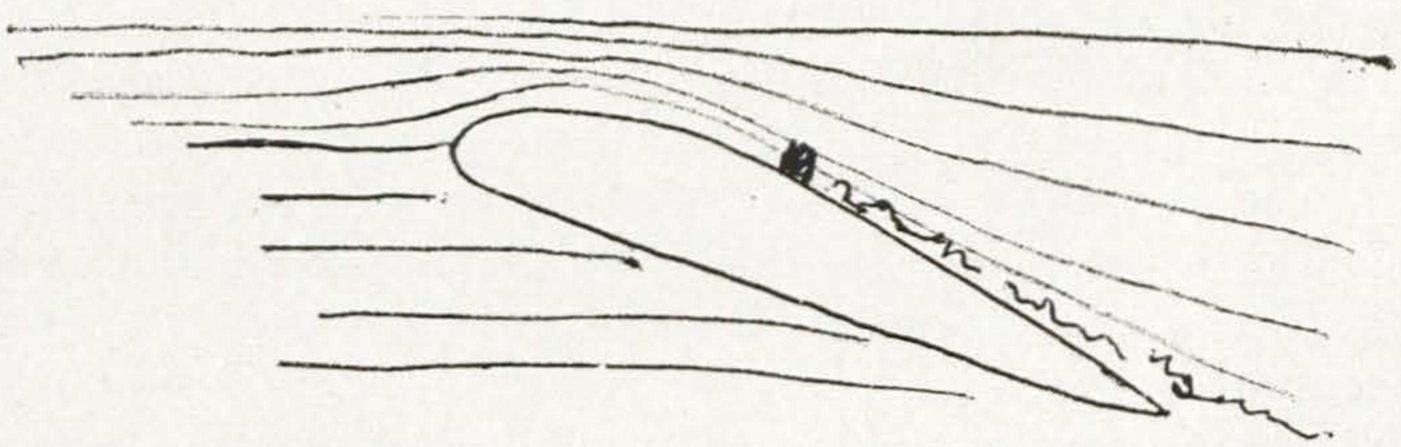
Vortex generators (small upright plates inclined from the direction of normal flow in order to create spiral flow locally)



Foil before stall



Stalled foil



Vortex generators restore energy to the boundary layer to re-attach flow

Has any application been made of vortex generators for boundary layer control in sailing craft, aerodynamically or hydrodynamically?

Generators should be located in an area where the major portion of the blade protrudes into laminar flow in order to be able to extract energy from it. Tuft tests can determine this.

Control surfaces operating on the trailing edge of a foil can be blanketed by a thick boundary layer and have little if any effect. Vortex generators are a possible solution in this type of situation.

Their application to the stall prone wing-mast sails of the hot multihulls might make these sails a bit more tractable.

J. Robert Williams

Letter from: Martin Rosell, Sjogangen 6, V. Frolunda, Sweden

Dear John Morwood,

I would like to make some comments on centreboards. First on the "jybing centreboard". When I tuned up my international canoe for the World Championships last Summer, I made a jybing centreboard of almost the same type as in your issue No. 70. At least it could not hurt, I thought. The boat went out of tune, but I never got the idea of blaming the centreboard. I kept on altering other details. Today I think I know what happened. To angle the centreboard 5° to windward on a well tuned boat means that one has to sail 5° closer to windward than before, so one has to make the sheeting angles 5° wider. Imagine that the centreboard is maintaining its course to windward and the angle of attack of the sails is kept constant and you are just turning the hull to leeward, then you will see what I mean. On a narrow boat, like the canoe, the sheeting points are already on the gunwale and it is already very high pointing.

The hydrodynamical advantage is in fact controversial. The board deflects the water so much that the hull is not "moving straight through the water" anyway, and I think we can only do "armchair guessing" on what is really happening to the boundary-layer and to the surfaces waves on the hull when you are gybing the board.

Then I have a theory to explain the discrepancy between the "Bruce-Morwood" centreboard theory and the common airfoil theory. This is armchair guessing I know, but it could be a clue.

Take two surface piercing foils with different cord lengths but producing the same side force. Let's look at the "leeward" side of the foils. There is high pressure and the water level adjusts to make a transverse wave which follows the foil. According to Froude (or who was it?) such a wave generates energy consuming divergent waves which are worse the steeper the transverse wave is. The same happens on the other side, but it starts with a depression instead. The difference between our two foils is that although their transverse waves are of the same height, the one of the short cord foil is steeper and thus more energy consuming. But under the surface you should still strive for high aspect ratio and you will have to make a compromise which seems to be (according to Bruce) a ratio of 1:1. This theory also suggests that you should match the profile with the pressure gradient of the foil. This will probably lead us to the same "area rule", quoted by Leonard Tieman, which is valid for supersonic aircraft which are also in fact "wave making" vessels. I suggest a Concorde shaped foil for a hydrofoil stabilized craft.

But I still think that a keel or centreboard should follow the old theory as the hull acts as an end plate if it is broader than the cord length of the board. This is also in accordance with common experience.

Martin Rosell

Ed: Martin Rosell's observation here should be noted if hydrofoil stabilisers are "toed in." Sheeting angles should then be so much wider.

Letter from: Greer Ellis, Box 77, Pelham, NY 10803

Dear John,

Right, all the twist doesn't come out even with bendy mast and high sheet loads. But most does. Sheet loads are pretty high. I estimate the maximum load on the clew at around 2,000 lbs. This on a sail with 21 ft luff, 19 ft leach and 8 ft foot. Sailcloth is normally 10 oz Dacron.

Bob Pegel, a leading iceboat sailmaker for many years, tells me that the development of the modern "high rig" skeeter was dependent on the development of stronger sailcloth. Clew loads, of course, have to go up fast as height increases and foot decreases in order to keep that piece of cloth stretched drum tight while operating close hauled in apparent winds of hurricane strength. Present best mast height is 24 ft having crept up from around 19 ft in the last twenty years. Some people are experimenting with 26 ft high masts but so far only have had sporadic success, mostly as you can imagine, in lighter air.

Theoretical calculations show that with everything else remaining equal the speed of an iceboat should be directly proportional to the height of the sail and independent of the sail area as long as you have enough to operate well below the stall. It is interesting that skeeter evolution over the years has resulted in taller, skinnier sails which usually run away from the squatter "low rigs".

A good iceboat sail at work is a beautiful thing to see. Come over some winter for a look and a sail.

Greer Ellis

SAIL TRIMMING

Testing & Theory

EDITORIAL

April, 1971

It had been hoped that, by now in 1971, we would be publishing Polar Curves of yachts. These have still to appear in any numbers in England or America though the German magazine DIE YACHT manages to produce them regularly for a variety of yachts. Perhaps our Polar Curve sheet was so complicated in design that people have been put off from absolutely complete figure studies. This does not mean, however, that partial studies are of no interest to us or that one polar curve, corrected for wind speed, need not be of interest, such as that by Harry Morss.

We begin this issue by Colonel Bowden's detailed article on foresails which is a mine of information on this sail's shape and trimming. This is followed by John Hogg's note on Genoa sheeting.

Articles on measurement of the wind's velocity gradient by Harry Morss and on figure taking by Edmond Bruce and John Hogg and comparative resistance by Dick Andrews round off the technical side.

We follow this by some theory, the article by K. R. May on "The 'Ideal' Yachts Maximum Performance" being a delightful exposition.

Becoming more practical, we next have an account of George Chapman's wingsail which we all admired so much at Weir Wood and the London Boat Show. This is followed by R. R. A. Bratt's dinghy and sail, then move on to square sails and "Over the top" glider sails by John Hamilton and Albert de Galbert. This section concludes with C. H. Spira's study of models of junk sails, square sails and other rigs.

Ralph Flood's "Positive Drive Cuddy Cabin" deals with abolishing the boom eddy of the mainsail and may well lead to a wider acceptance.

Retirement yacht concepts follow from a variety of members on a variety of subjects. The most interesting new feature to appear is the Stirling Cycle Engine's value as modernized by Phillips of Eindhoven, Holland. Steam engines are eulogized.

We conclude with an article on "Estimating Displacement" by John Darby and an approximate solar Navigation system, using sunrise and sunset.

The various other letters and short articles we have used add colour (and relief from technicalities) to the publication.

A Personal Conclusion (John Morwood)

After some 20 years of trying to conjecture ways of setting canvas to the wind and studying all the ingenious ways which our members have invented, my present view is that the ice or sand yacht rig will give the lowest drag angle to a catamaran, trimaran or hydrofoil especially if the mast is a plank which bends to take most of the twist out of the Sail. Holt-Allen make an alloy extrusion for the *Shearwater* which is excellent.

With a beamy single hulled boat, on the other hand, a sloop with a Genoa cut to have its foot run round the lee gunwale of the bow which, in turn, is of a shape suitable for the sail, will be best to windward.

THE AIRFLOW OVER SOFT SAILS

by Lieutenant-Colonel C. E. Bowden

Norden House, Corfe Castle, Wareham, Dorset

Dr. Morwood's article "The wind in Sails", in the AYRS, journal No. 57, on page 30, prompted this rather delayed discussion concerning the airflow over the top camber of soft sails. Dr. Morwood's statement that interested me was based on John Hogg's now well known hot pen recorder trace showing the type of normal "steady" natural wind in which we sail in good weather. The trace published in AYRS, No. 56, page 51, indicates a considerable turbulent "joggle" in the wind attacking soft sails. This "joggle" means in effect a quick flick from side to side, with peaks up to around 20 degrees or more every so often from a mean line, in a 60 second run. Dr. Morwood's article read—"This smooth flow is of course complete and utter nonsense. The wind is flicking around some 20 degrees on either side of an average direction and full of eddies even before it meets the sails. This explains why streamers tied to a single sail cannot be made to stream aft. They fly all over the place."

John Hogg and I have over the years measured the windward performances of most of the well known Class keel boats from 5-5 Meter *Daring* down to *Flying Fifteen* and *Tempest* in order of size, and as a check on measurements I have sailed or raced each craft measured. I have also wool tufted many sails and smoke streamed many others in a natural turbulent wind with its "joggle".

During our experiments and development of measuring technique, I have made innumerable racing and other checks of the measurements, with different shaped sails and sheeting angles, on my "X" One Design keel boat, which I suppose by now must be one of the most measured boats in the country.

As a result of these odd activities, I find I cannot fully agree with Dr. Morwood's statement, that when individuals mention "a smooth airflow" over certain lee side or top cambers of sails, it is complete and utter nonsense. To limited because the boat's hull and keel requirements unfortunately demand that the sails are working at near the limit of their "smooth" operating angles of attack. The reader may ask—how is this reasonably smooth airflow achieved at the necessary close sailing angles for "optimum Vmg"?

A method of finding sail curvatures that offers a smooth airflow

It is of great value to be able to study sails, and to be able to alter their shape where necessary, with the wind in them on land, where it is possible physically to get at them in an unhurried manner. It is then easy to measure their shape accurately from foot to head, and also try alterations in curvatures etc. by pulling the fabric by hand locally, and noting the airflow. There are, however, certain snags to this method that can be overcome as will be seen below.

When a *vertical* or upright test rig is set up on land, or a moored boat attached to instruments is set to a given angle to the wind, it is found that observations and measurements have to be completed in a few seconds at a time, for apart from definite wind shifts, the chosen angle of attack to the wind changes back and forth in each gust. Therefore constantly changing accelerations and decelerations are recorded on the instruments, and accurate observations of sail shape and airflow are difficult. The sails are at one moment at the correct angle of attack, and the next at either too small an angle for maximum drive, or stalled at too great an angle. Normally a skilled helmsman holds a reasonably constant angle of attack to the wind by feathering his boat to angular wind changes.

This fluctuation of effects when using a vertical sail test rig was the reason why I largely gave it up, and also gave up making measurements on moored craft, except in the running position which is not so affected. Similar windward measurement disappointments were experienced in Holland with moored craft operated from a raft in open water, and on the moored *DRAGON CHOW* at Southampton.

I therefore decided to set my sails (model and full-size) on their side on a *horizontal* sail test rig, for the wind comes along the ground in a nearly directional manner, but with the the vital turbulent "joggle" in it that is encountered when a boat is sailing. Sails can then be set up at a given angle of attack to the wind, and there is sufficient time for measurement and adequate observation, whilst varying sheeting effects can be examined. Different sails are seen to be more affected by sheeting changes in the fore and aft and up and down directions than it is sometimes realised. It is now possible to walk along a foresail (or complete rig) on its side, and measure the exact curvatures taken up at any point of the sail's length or hoist, which is very hard to achieve with a sail in the vertical position. One or more smoke streams can be flowed over the sails from smoke candles obtained from Messrs Brock's Fireworks, or other makers of distress flares. If two or more streams, one above the other are used, it becomes simple to note where the streams flow towards each other. This will indicate where the maximum low pressure effect is taking place. If too far aft it will indicate an imbalance in the boat, and too great side force.

The fabric can be pulled to alter local shape and observe results, such as when the head of a sail has become too full. The amount taken in can be marked for retailoring. A bad sail that can not be altered to advantage can be cast aside.

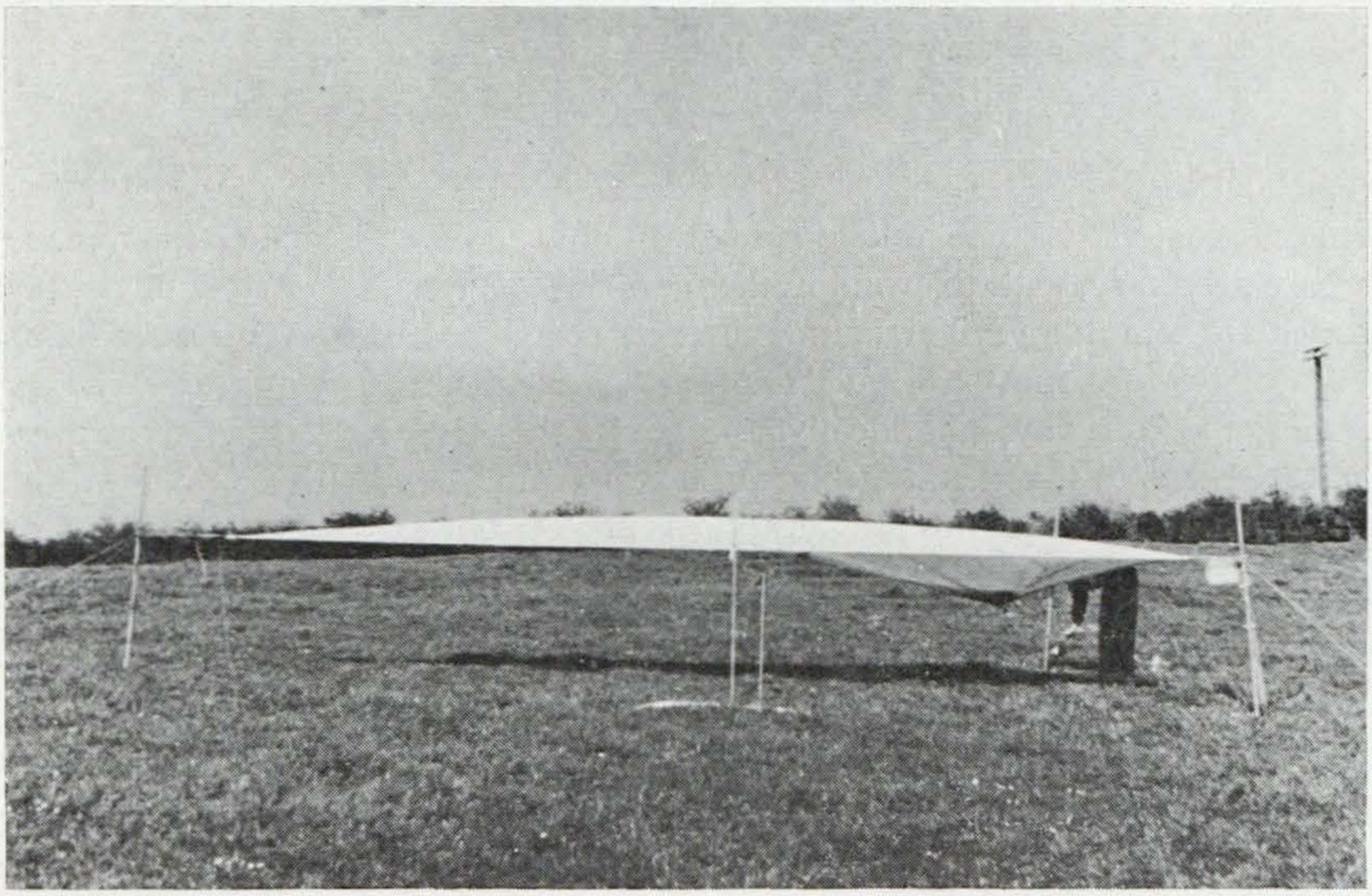


Fig. 1. A foresail set up on its side on the author's Horizontal sail test rig, at the correct angle of attack, and viewed from the head underneath towards the foot, shows a badly hooked leach has developed. It was retailored to provide a good airflow and excellent race results

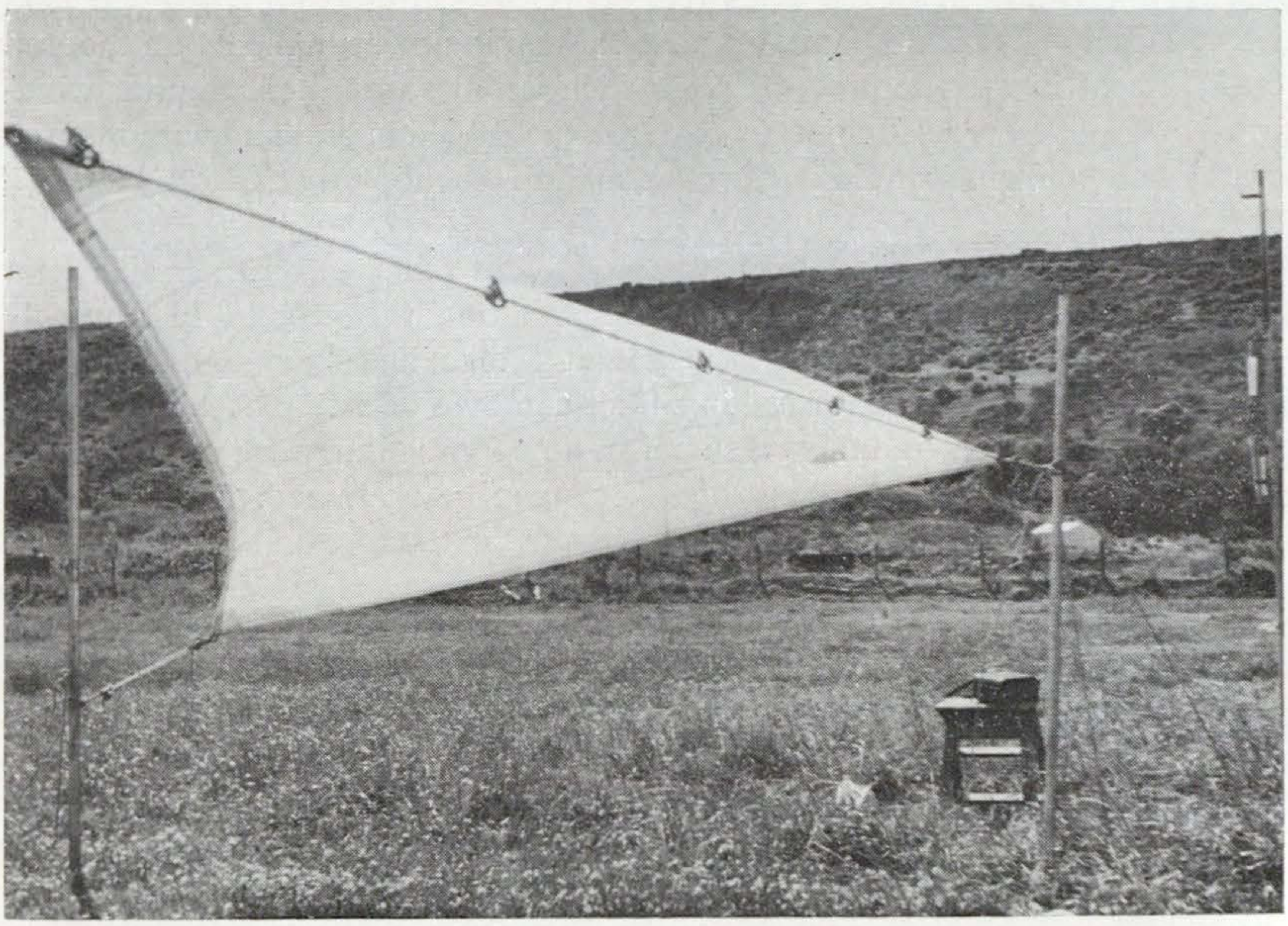


Fig. 2. This 5-5 Meter Daring foresail viewed from a front view with wind in it, indicates a slightly fuller head area than foot. By pulling in the luff by hand to a slight "S" bend in the upper regions it is possible to get a similar airflow from foot to head over the whole sail

As an instance of the above, Fig. 1 is a photograph taken below a foresail set up on its side at its correct angle of attack to suit the boat's top line Vmg and sheeting angle in relation to the centre line of the boat. The view is from the head towards a ledge or flap built into the foot. A severely hooked leach has developed, which under smoke streams indicated that the airflow actually swirled backwards as far as the top of the sail camber. This sail then had its rear seams altered and two short leach battens, permitted by Class rules, fitted. The sail then smoked, measured, and raced well. Fig. 2 shows a 5-5 Meter *Daring's* foresail from the front view. It will be noted that the upper regions of the sail are considerably fuller than the foot. By pulling the upper luff fabric into a slight "S" bend and marking, it is possible to get the same airflow from foot to head. A few minutes on the *horizontal* sail test rig will indicate such and many other matters, instead of wasting a sailmaker's valuable time coming out for a sail.

What smoke streams suggest

These are my personal views, and may not in all cases be accepted by the experts. Let us look at Figs. 3 and 4, which show two "X" One Design keel boat foresails on their side set up to the wind coming along the ground.

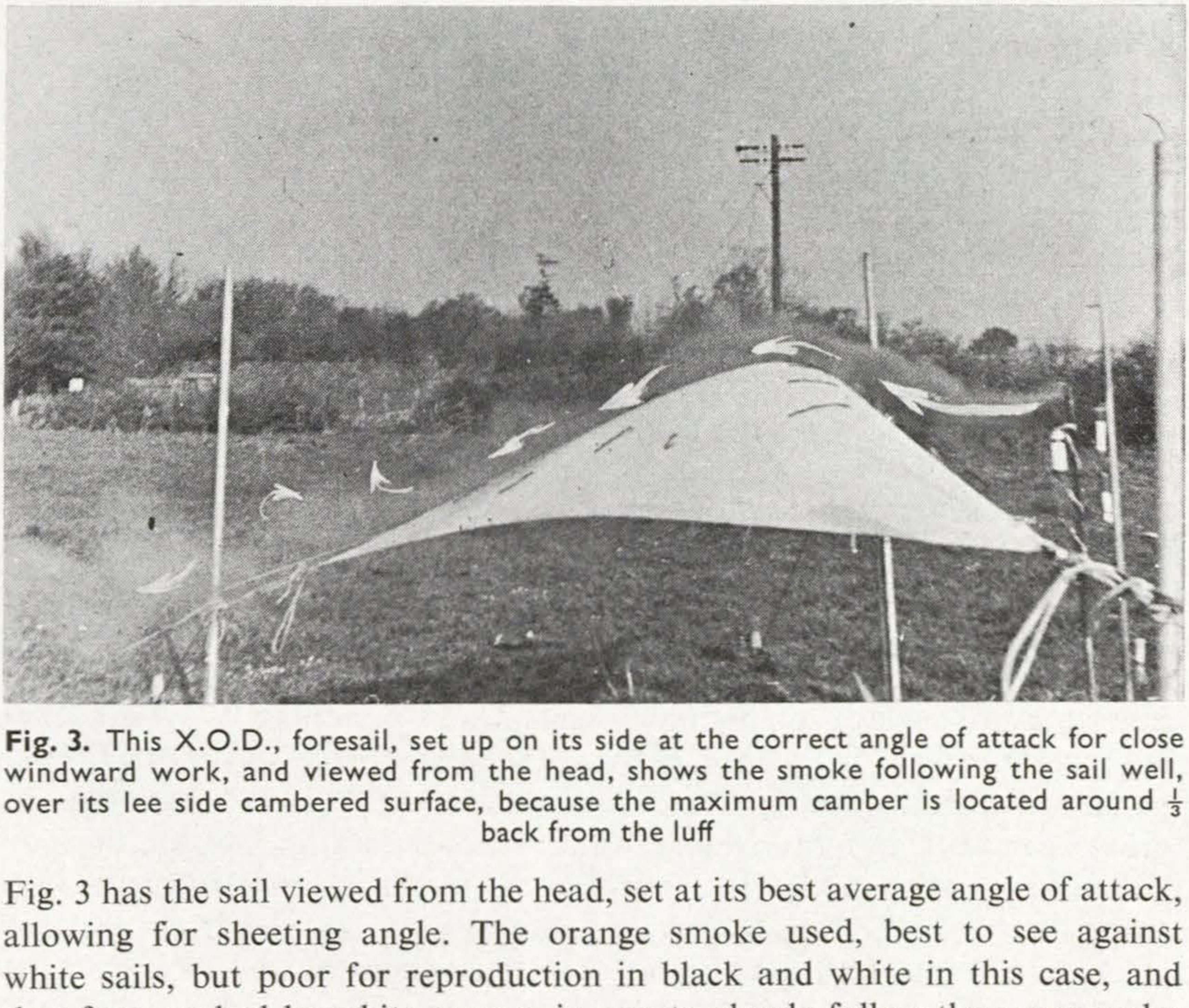


Fig. 3. This X.O.D., foresail, set up on its side at the correct angle of attack for close windward work, and viewed from the head, shows the smoke following the sail well, over its lee side cambered surface, because the maximum camber is located around $\frac{1}{3}$ back from the luff

Fig. 3 has the sail viewed from the head, set at its best average angle of attack, allowing for sheeting angle. The orange smoke used, best to see against white sails, but poor for reproduction in black and white in this case, and therefore marked by white arrows, is seen to closely follow the upper or lee side camber of the sail. Dr. Morwood please note, the air is following the sail with "reasonable smoothness" in spite of the wind's natural "joggle". This is because the maximum camber is located around the 1/3rd back position from the luff, *from head to foot* of the sail. A good airflow is then handed onto the mainsail lee side, and a sound slot effect is created in the gap. A good drive well forward in the sail is indicated, with reasonably low drag, and low side force. The air is seen to speed up over the *tolerant* fore part of the sail's camber. This sail in Fig. 3, measured excellently in Vmg terms, and was a great winner in its day. A helmsman with this type of sail will be able to sail close to the wind at low angles of heel more easily than he will do with the next sail seen in Fig. 4.

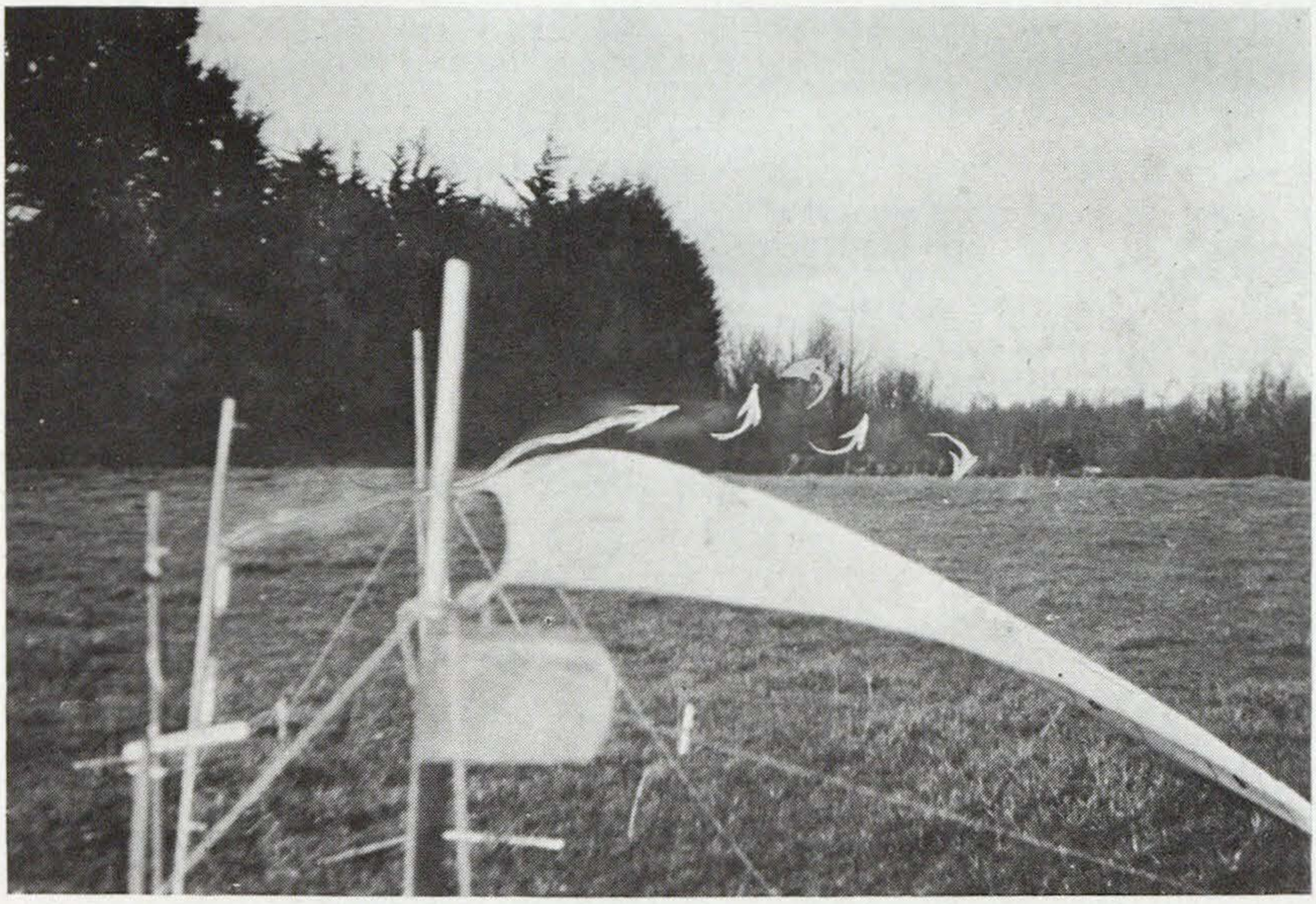


Fig. 4. This X.O.D. foresail, viewed from the foot, has its maximum camber located too near the luff, thereby causing a *critical* sail, with a broken down airflow in lee. It has to be sheeted at too great an angle for a top line windward performance

The foresail seen from a foot view in Fig. 4 has its maximum camber positioned too far forward quite near the luff. The too abrupt "hump" forming, bounces the air away, and then forces it to flow with a considerable swirling mass behind the sail. This drag ridden mass of air is handed onto the mainsail in lee. This sail measured a poor Vmg with wide angle sailing at too great an angle of heel for optimum Vmg. Quite a number of similar type sails with the "flow" too far forward and too abrupt, have appeared amongst the sails tried on my test rig. They usually tend to break in at the luff edge in turbulence upsets, to form a hump further aft momentarily, which also shifts the centre of pressure aft and upsets boat balance. Alternatively such sails have to be sheeted down, as in this photograph, to too great an angle of attack, in order to fill the sail more from the windward high pressure side and less from the suction pull out in lee. They are what I term *critical* sails and make the helmsman's task hard, unless he is a wide angle sailing individual, when the speed gained seldom makes up for closer sailing angle in Vmg measurements. They also make for a poorly balanced boat on the helm if sailed fairly close, for they lack drive in the gusts owing to their critical action.

A number of individuals complain of a bad weather helm developing on their boats, and often suggest that the mast is moved forward, when in fact the mast can remain where it is on a previously well balanced boat, and the sails should be altered to get their drive into the forward area of their shape by locating the maximum camber in the right position. This will provide a balanced helm with just the right amount of encouraging slight weather helm. A useful check when sailing is to sheet in well shaped sails with the battens looking parallel with the centreline of the boat. The sails will then *not* be throwing the wind out to windward from their after area. To do so creates an aircraft condition of "flaps down", which in the case of the boat can cause excessive side force and overheeling, and an abnormal weather helm.

Positioning the maximum camber height in relation to the luff and chord

When sailing displacement craft and certain lighter craft close to the wind, a good airflow in lee is obtained when the foresail has its maximum camber height located around the 1/3rd back position from the luff, and this should be from foot to head of the sail, whilst mainsails are on the whole most effective with the maximum flow around the position just ahead of mid-chord.

A light planing craft, or a very easily driven multi-hull craft (not all multi-hulled craft are either easily-driven or fast) with little wavemaking resistance, can reach higher speeds over water on occasion to make up for a certain lack of close heading angles in Vmg measurements. This may alter sail curvature shape in regard to where the maximum flow is located, but it has to be remembered that any noticeable increase in speed of such craft also alters the airflow characteristics, and even when sailing faster and wider the "flow" too far forward in unbattened soft sails may not pay, because the apparent wind comes forward with the extra speed, and will probably not negotiate a too sudden luff curve even when sailing wide. Fully battened sails with their stiffened surface are a somewhat different problem. The trick appears to be to find the approximate best heading angle in relation to waterspeed by Vmg measurement in a breeze, and then refine suitable sail curvatures to give a good smoke airflow on a Horizontal sail test rig.

Fig. 5 shows a *Dragon* genoa, viewed from the foot, with a highly "stretch luff". This particular luff has been hauled bar taut on the test rig, and contrary to expectations in this case the "flow" has not been brought forward, for the stretch has been so great that the fabric has become flat with virtually no luff curvature. The foot has also become flat. Like most "flatplate" airfoils, it is seen by the smoke that little or no speeding up of the air is taking place over the top surface, for there is no camber to bend the wind. In effect there is virtually no low pressure "suction" drive occurring behind the sail, and the smoke shows that the "joggle" in the wind is *not* smoothed out, for there is no pull out of the fabric. An indifferent flow is being handed onto the mainsail rear side. The great area of this most important sail without any mast interference is only working on the windward side, ignoring the most important lee side "suction" drive. A new genoa was cut for this *Dragon*, which then won its Class points for that particular Cowes Week. Many foresails and long

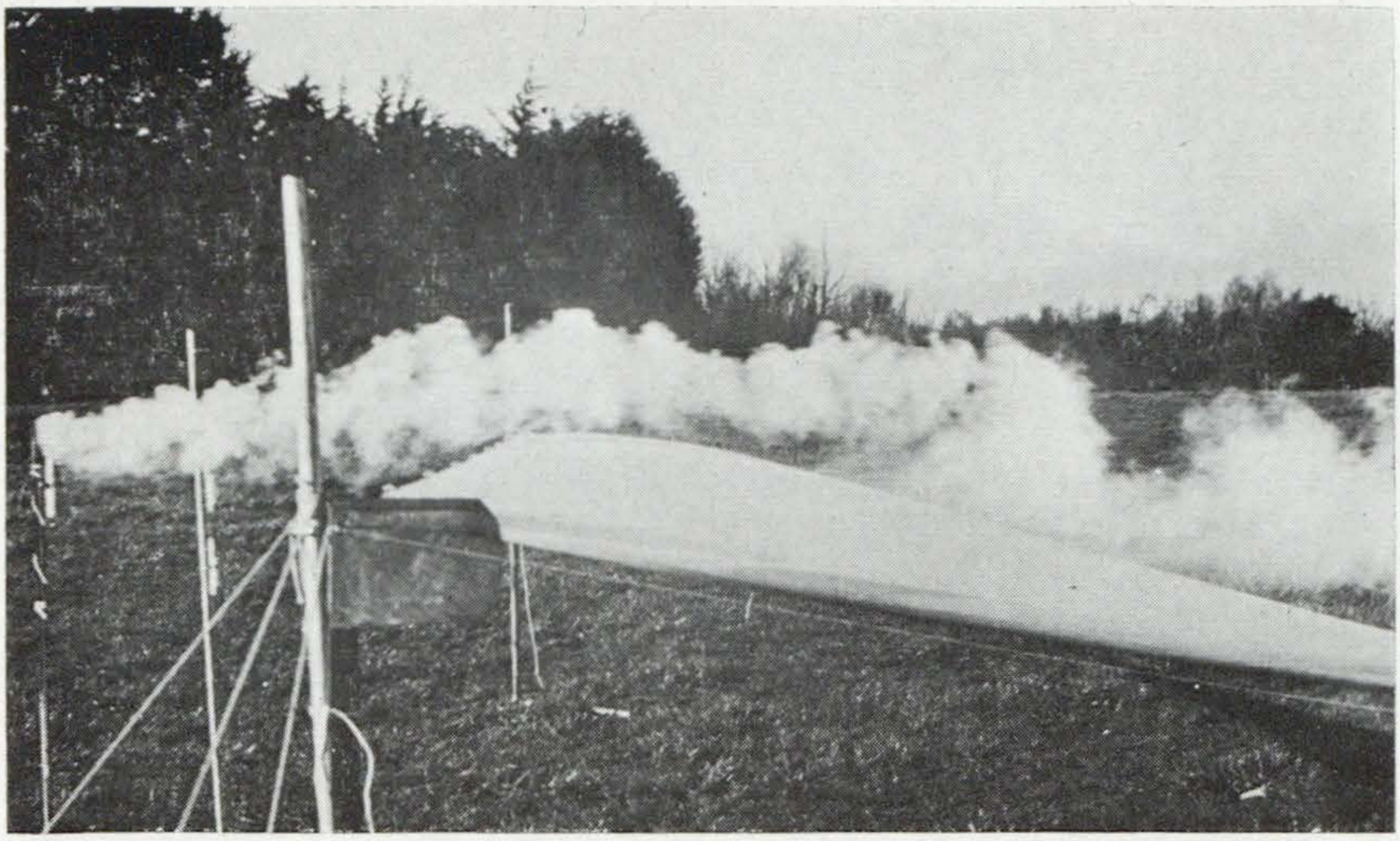


Fig. 5. This highly "stretch luff" Dragon genoa when hauled up bar taut at the luff, formed a "flat" luff curvature and a "flat" foot. Having little curvature, it fails to bend the wind properly. The smoke can be seen to be virtually unaffected, with all its natural turbulent "joggle" in it. The sail is only working usefully on its windward side

overlap genoas, have too flat a foot even when they have a good middle and head area.

It should perhaps be mentioned that if a helmsman's technique is to sail slightly wide and free, which might also suit the boat's speed and wavemaking characteristics, the sails can be fuller, but the luff curvature must still be tolerant to hold the airflow, and not bump it away by having the maximum flow located too far forward. Also, boats that rely upon sailing fast and very free to windward at a wide angle of heading with very full sails are not so worried about a smooth airflow in lee. The sails are now at a very big angle of attack and slightly stalled with maximum drive but corresponding extra drag.

Why does a good sail's curvature suck out to shape?

Air will not follow a sudden deflection by an unfair curve or "hump" forming in a soft sail. A rigid curved surface will bend the wind over a greater curvature more easily. In the case of a soft sail the air has to be more gently persuaded to flow over a relatively easy bend and in doing so, it is speeded up. The speeding up action creates a low pressure "suction" which then strongly pulls out the soft fabric to its curvature shape. Any attempt to locate the camber hump too near the luff creates a too sudden curve. The turbulence in the wind soon refuses to follow this abrupt "hump", the speed up action is lost, and the entry curve of the sail all too frequently drops in for lack of a strong suction pull out. A larger curve forms further aft in many cases, creating a breakaway of the airflow as seen in Fig. 4, which is not only handed onto the mainsail but creates great drag and ruins all attempts at really close windward sailing. The sail has then either to be sheeted at a greater angle to the wind, or the boat sailed wider to achieve the same effect, in order to fill the sail by greater pressure from the windward side and less lee side low pressure suction pull out.

I have experience of two foresails made specially for experimental comparative work. Both sails were of the same general curvature, but one had the

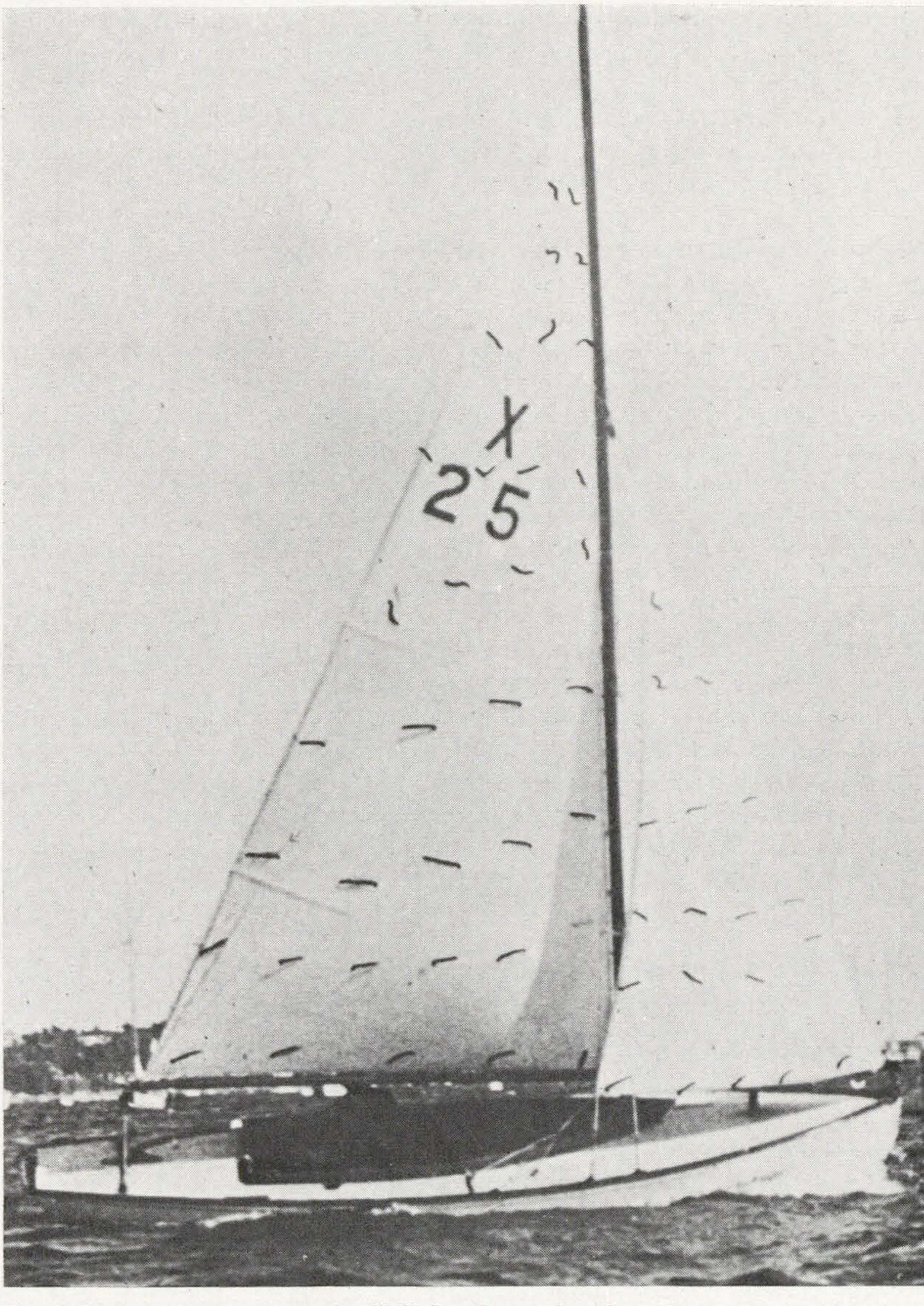


Fig. 6. Ribbon tufted sails on this "X" One Design keel boat show a reasonably smooth "attached" airflow in lee of the foresail, and in lee of the mainsail where the jib is creating its slot effect. Above the slot effect, the mainsail has a broken down airflow due to "mast interference", with the flow smoothing out near the leach

maximum camber point extended nearer to the luff with wind in it as seen on my test rig. We then carefully Vmg measured the boat with these sails. The normal 1/3rd back flow sail not only measured better, with an edge on its windward performance, but the recorder showed it was more tolerant in gusty conditions.

I have noticed that when a sail has a tolerant airflow with the maximum flow in the right place, the general camber can be slightly greater, for the pull out suction is greater, and yet the boat can sail as close, and have greater drive through waves.

It appears that a foresail with its maximum camber height located around the 1/3rd back position offers a happy compromise for turbulent winds so that an easy entry curve is presented to the air.

Airflow seen, with and without the slot effect

Fig. 6 shows my "X" boat sailing to windward, but with slightly too much mainsail "twist" which was later improved, together with greater flow at the foot of both sails. However, the wool tufts clearly indicate certain general characteristics seen on most well shaped soft sails working close to the wind, namely a smooth airflow in lee following the camber of the sails, except where the gap narrows unduly at the head of the foresail. The flow is upset in this area. A hollowed leach on bigger craft like a 12 Meter helps at this point. The mainsail on the "X" boat can be seen to have a reasonably smooth flow where the slot effect is in operation, with its usual foot downflow. Mast interference at the head of the mainsail is seen to upset the flow in lee until it smooths out near the leach. The foresail, with no mast interference, and with its maximum camber 1/3rd from the luff, is dealing with the wind's natural turbulent "joggle" smoothing out the flow in lee and handing on the smooth "attached" airflow to the mainsail lee side. The same smooth airflow was seen on a forsail by itself in Fig. 3.

Fig. 7 shows a large 1/9th scale 12 Meter model controlled by radio, sailing close to windward in a scale wind, at a correct angle of heel, registering a good Vmg. We can now accurately measure Vmg on models by a slightly modified technique. The full-scale X.O.D., and this radio model, should answer Dr. Morwood's doubts about the possibility of a reasonably smooth airflow over soft sails, although the natural "joggle" in the wind is obviously greater in effect on the 8 ft 6 in tall model than the larger full-size craft. The genoa of the model is properly shaped, having its correct positioning of the maximum camber around the 1/3rd back position. Some years ago we also ribbon tufted a full-scale 12 Meter genoa and when sailing, found the comparative flow the same between model and full-size craft. Unfortunately the general concensus of opinion at the time of the *SOVEREIGN-KURREWA* Americas Cup disastrous period, was to locate the maximum camber too near the luff of the genoas together with an overfull sail, in the mistaken belief that this gave better speed through the water which was thought to be advantageous even at the expense of close heading angles. The radio controlled model experiments I made around this period were not in those days considered to be reliable, for in all fairness they were rather a novelty. However in the event, it turned out that the Americas Cup winner *CONSTELLATION* pointed far higher

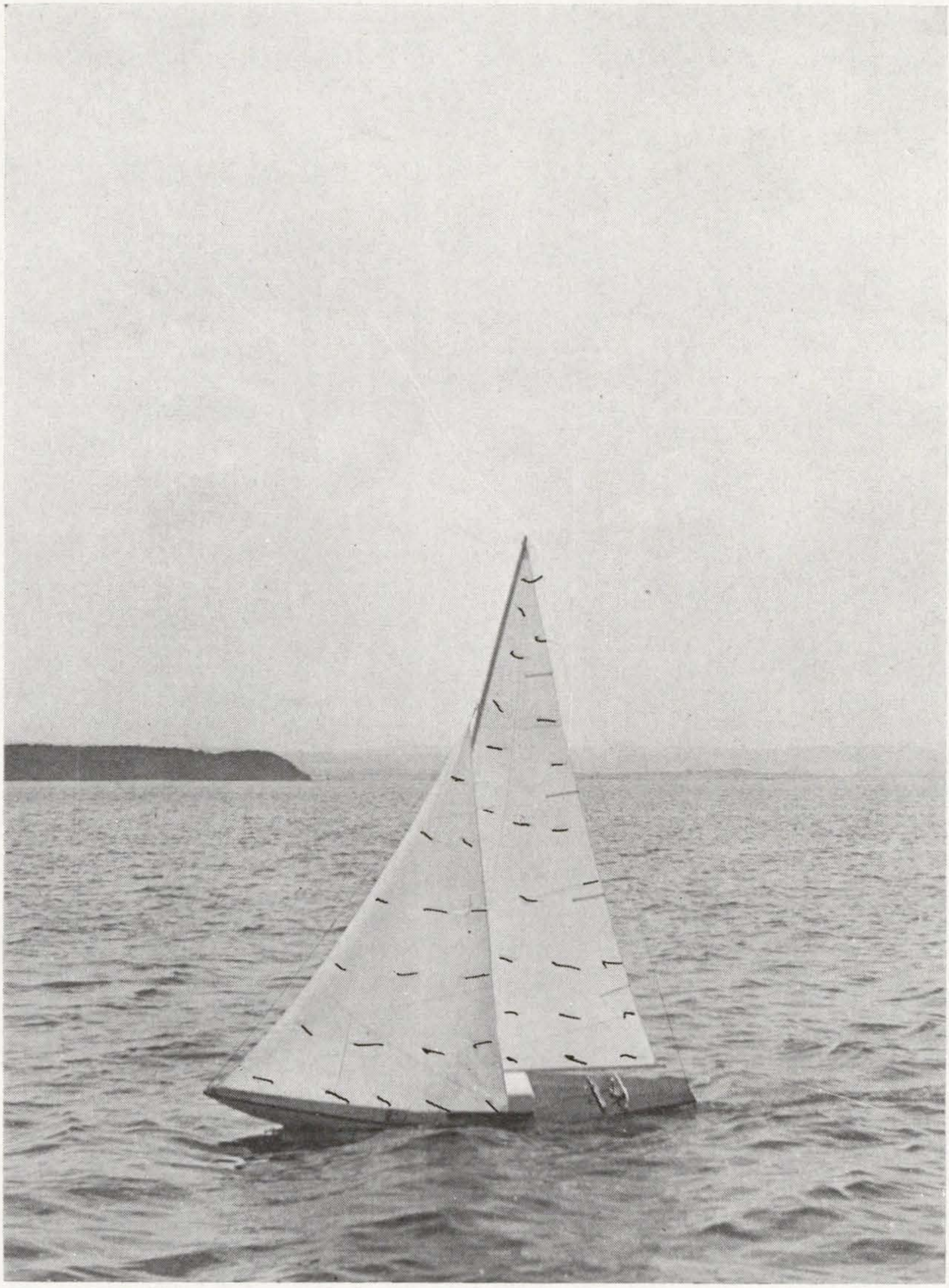


Fig. 7. This large 1/9th scale radio controlled 12 Meter model is sailing correctly close to the wind at a proper low angle of heel in a scale wind. The correctly shaped genoa has a smooth airflow in lee. The mainsail has a good flow in lee behind the slot gap, and breaks down due to mast interference at the head. Note the flow returns near the leach at the head. Also note the usual downflow at the foot of sails

than any previous 12 Meter with a vastly superior Vmg gained at a lower angle of heel, and she had the important maximum camber properly located in her sails as the model had predicted. We subsequently found that a large 1/3rd scale X.O.D. radio controlled model provided extremely similar airflow conditions to the full-scale craft, and in comparative Vmg measurements in scale winds proved to be more accurate than the tank tests indicated, particularly in the upper wind speed performance curve area. The latter has often been over optimistic in the case of the tank on different type craft, probably due to wind and wave turbulence differences outside in natural conditions. I am convinced that large radio models can provide many useful pointers, quickly and reasonably cheaply.

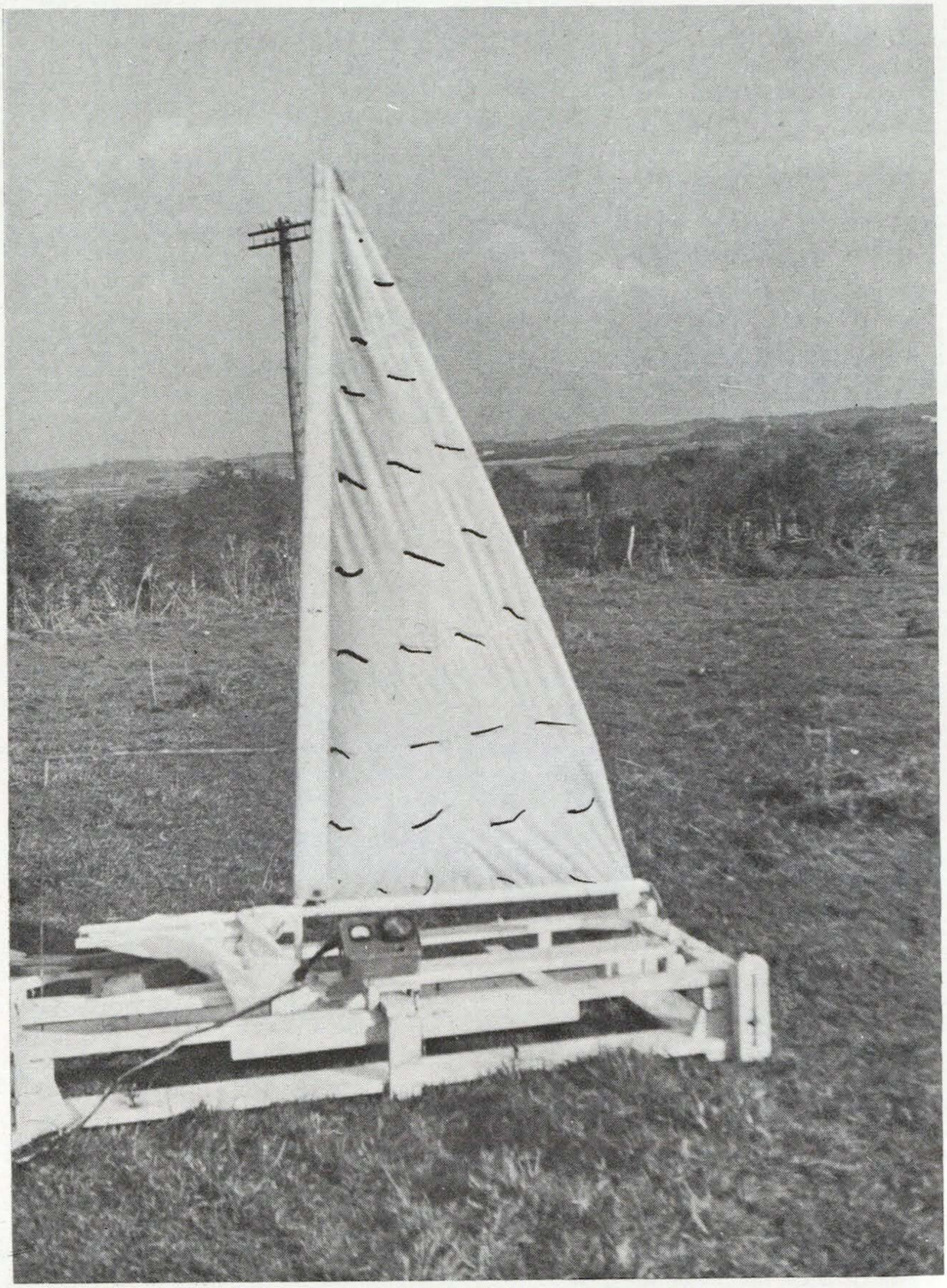


Fig. 8. This Una rig has a rotating "forewing" mast. Because the mast is looking into the wind, the airflow in lee of the soft aftersail is smoothly following the curvatures. When the mast is locked fore and aft in a straight line the airflow breaks down

Because the streamlined rotating forewing mast of the large model rig seen in Fig. 8, looks into the wind, the purposely unbattened soft afterpart of the sail shows a smooth airflow in lee in the windward sailing attitude. When the "mast" is locked fore and aft and set to "sail" at a windward angle of attack, the airflow in lee breaks down. Non-rotating streamlined masts create a greater mast interference than round masts when sailing to windward, because the pear shape is being dragged through the air offering a greater and even

Fig. 9. The weather side of a tufted sail

more unfair area of disturbance. A long way back in AYRS, Journal No. 14, the front cover showed my early experimental semi-wingsail rig mounted on the six ton cruiser *TENTATIVE*. The wide chord streamlined "mast" on this first semi-wingsail Una rig cruiser was able to rotate into the wind, but I fitted a drum brake at the foot to lock the mast fore and aft at moorings. I wool tufted this rig, finding a smooth airflow in lee when the wing mast looked into the wind, but when I locked the mast fore and aft along the centre-line of the boat when sailing to windward the airflow in lee was broken down. Similar trials found similar results on the very large 9 ft long hulled twin rigged radio model seen on the cover of AYRS journal No. 12. Both winglike masts were easily rotatable or locked as desired.

Summary

It can therefore be said that the peaky turbulent "joggle" in the wind can be absorbed by tolerant sail curvatures, having the right entry curve to speed up the wind sufficiently to create a strong low pressure "suction" pull out in lee, when there is no mast interference, such as in a foresail or a genoa. When there is mast interference, the smooth airflow in lee is broken down on a single sail, unless a rotating "forewing" type of mast is used, free to look into the wind. In this latter case a smooth airflow can be obtained, for the rigid cambered entry speeds up the air to suck out the rear sail.

Any over abrupt curvature tailored into a headsail luff area, such as when the maximum camber is located too far forward, will cause the air to bounce away from the "hump" formed. The pull out of the soft fabric then suffers, requiring the whole sail to be sheeted at a considerable angle of attack, often too great for close windward sailing which is necessary for hovering around "optimum speed made good to windward."

GENOA SHEETING

by John Hogg

Parklands Cottage, Curdridge, Southampton, England

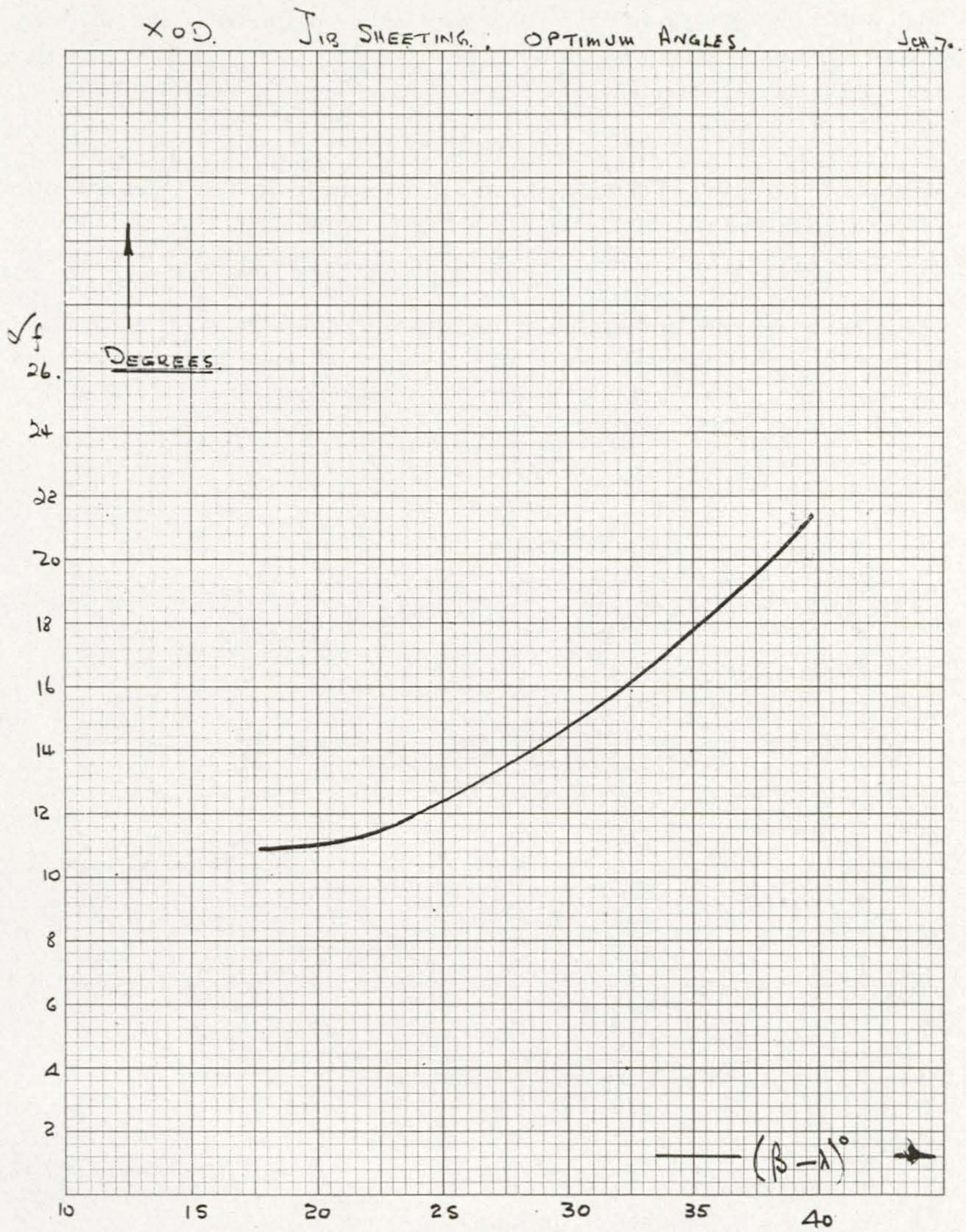
The optimum sheeting angle (αf) for a Genoa depends on two limiting factors:

1 The cut of the sail because unless the sail is cut well it is impossible to obtain drive at the minimum sheeting angle and so obtain high Vmg figures. and

2 The width of the deck, eg the average 12 Metre is unable to sheet to a greater angle than 12° owing to deck width. This is a disadvantage on average cut sails but not bad on good sails. 15° would give a less critical setting.

The accompanying graph shows the optimum angles for an overlapping jib on the X.O.D. based on our full scale measurement tests and wind tunnel results on a $\frac{1}{3}$ scale sail.

A point should be made that a well cut (high pointing) jib may be retarded by an accompanying main which is cut too full with a result that the main is backwinded. 12 Metres often sail with the main partially backwinded in stronger winds allegedly without loss but in my opinion in an attempt to make two wrongs into a right, ie to obtain high pointing with insufficient gap to pass the required *volume* of wind.



A NOTE ON WIND SHEAR (VELOCITY GRADIENT)

by Henry A. Morss, Jr.

6 Ballast Lane, Marblehead, Mass. 01945, USA

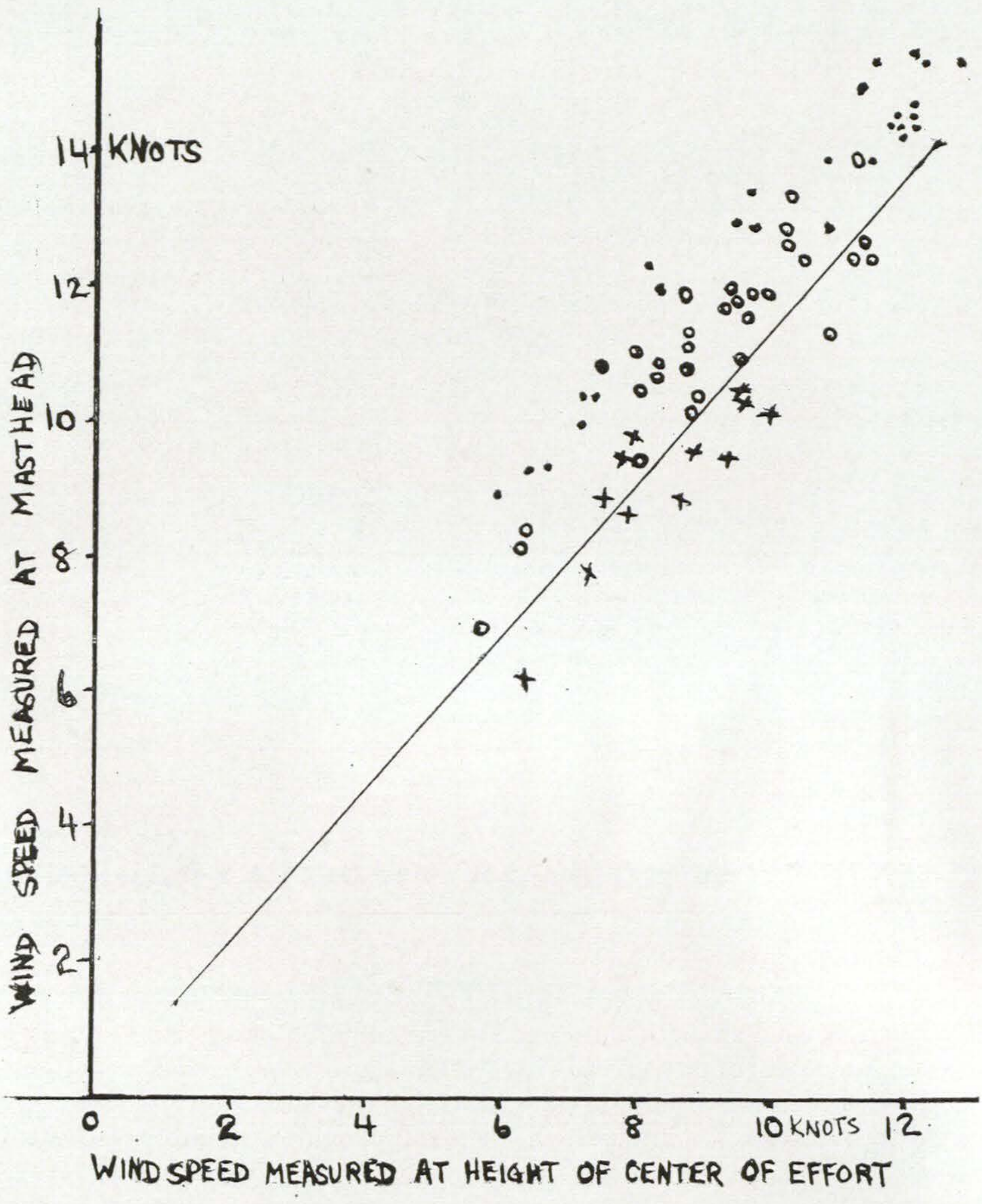
Variation in wind strength and direction is a common observation of sailing people. The extent of the variation itself varies a great deal. In some conditions the wind is relatively steady; in others it is "all over the lot."

Off Marblehead, for instance, the steadiest conditions occur in moderate easterly or southeasterly breezes, an on shore wind. The northwest winds which follow the passage of cold fronts vary widely in direction and as much as two or three to one in strength.

In AYRS No. 56 John C. Hogg reproduced a recording which showed the variations dramatically.

What can be said of the wind shear, or the rate of change of wind speed with height above the water? Does it also jump all over the place? The publications of the AYRS do not seem to have much to say on this subject. They do mention more than once the typical logarithmic nature of the wind shear—wind speed proportional to the sixth or seventh root of the height above the sea surface.

To those of us who try to measure the performance of sail boats it is tempting to assume that the wind shear remains constant even though the wind itself does not. If this is correct, then the wind sensors can be put at the masthead. The resulting data can be corrected to allow for the wind shear.



If this is not correct, the sensors should be at the height of the centre of effort of the rig, awkward as that may be, because that is the best level for estimating the average wind felt by the sails.

But all this is not likely to influence the facts of the situation. One had best assume that if the wind varies in strength and direction, then the wind shear varies also.

It does.

In the course of extensive measurements in the lower layers of the atmosphere, made as part of a study of "air-sea interaction", Professor E. L. Mollo-Christensen of M I T and the group working with him found that the wind shear varies with the type of weather and the state of the sea and often does not follow the logarithmic rule (or any other simple formula) unless ten-minute averages of wind speed are used.

For several weeks during the summer of 1969 I had one anemometer at the masthead of *COQUI* and another at the height of the centre of effort of the rig, held by a special "mast" at the bow sloping out forward away from the jib to keep the instruments in free air or nearly free air. These two instruments had electrical circuitry to produce ten-second averages, very short by Professor Mollo-Christensen's criterion. In the figure are plotted some simultaneous readings. All those marked with dots were made on one day, those marked with circles on another day, and those marked with crosses on a third day. All the points would fall on the sloping line if the wind strength increased with the seventh root of the height off the water. It can be seen that ten per cent deviations were not uncommon.

Since wind force is proportional to the square of wind speed, errors of twenty per cent in estimates of force would be made. Sizeable errors in boat speed could result. In effect, a given boat speed would be correlated with an incorrect wind speed. Thus it must be assumed that if the wind sensors are at the top of the mast, a significant "scatter" of data points will occur. Of course this will be superimposed upon the scatter which is inevitable at best when the wind and other things are not perfectly steady.

Conclusion—Wind shear varies greatly.

Letter from: Edmond Bruce, "Lewis Cove", 69 Hance Road, Fair Haven, New Jersey, USA
14th January, 1970

Dear John,

Now that the AYRS programme for Polar Performance Curves has been launched, I hope that members do not think that one has to wait for a specific value of apparent wind velocity before making measurements. This would be almost impossible to do accurately. A cross-plotting technique of all the random measured bulk data can be employed to obtain the desired values of V_B versus β for a fixed apparent wind velocity V_A as described below:

The only parameter choice possible is the steered course β, to the apparent wind, as shown by the wind-vane plus the leeway gauge. The resulting boat velocity V_B and the existing apparent wind velocity V_A must be accepted after the optimum sail adjustments, etc., are made.

These data may be plotted on rectangular co-ordinates for each of a number of selected apparent course angles β, as shown in Fig. 1. Many measurements are preferable in at least three different wind conditions, namely in light, medium and strong winds.

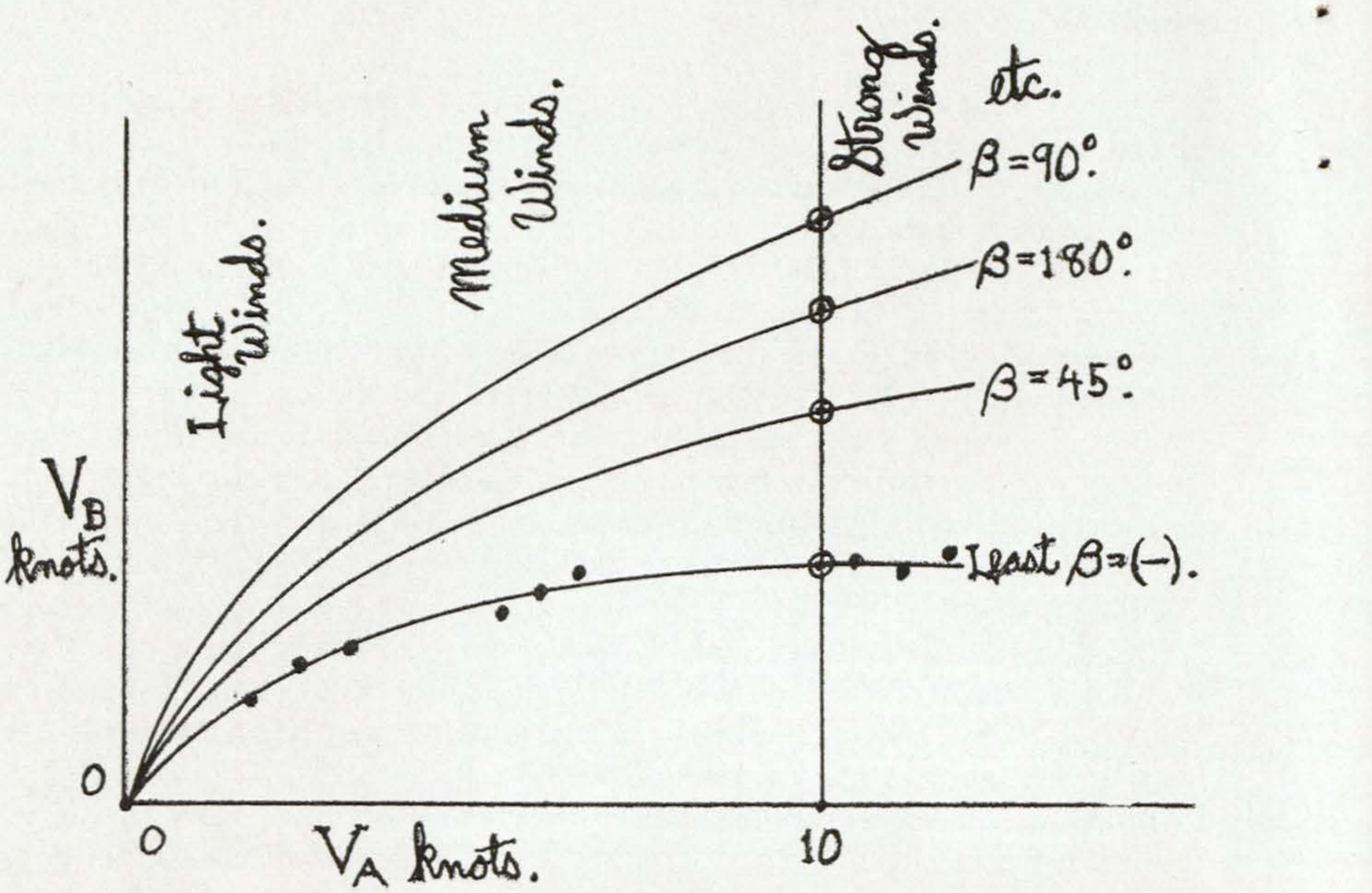


Fig. 1.

If one desires to obtain the boat velocity V_B for a definite value of the apparent wind velocity V_A, on each of the given steered courses β, a vertical line, such as at $V_A = 10$ knots in Fig. 1 will provide the answers by its intersections with the plots representing the various selected apparent courses β. Thus the necessary data can be obtained for plotting the apparent wind portion of the AYRS polar diagram of performance.

The data for the true wind portion of the AYRS polar diagram can be derived from the previous data as follows:

For all the original apparent wind measurements, calculate the corresponding true wind velocities V_T from the formula,

$$V_T = \sqrt{V_A^2 + V_B^2 - 2V_AV_B\cos\beta}$$

These V_T results should be plotted on rectangular co-ordinates versus boat speed V_B for each of the previous *apparent* courses β as shown in Fig. 2. In a manner similar to that already described, the boat velocity V_B for a fixed true wind velocity V_T and *apparent* course β can be determined by the curve inter-sections with a vertical line drawn along a desired value of V_T as shown.

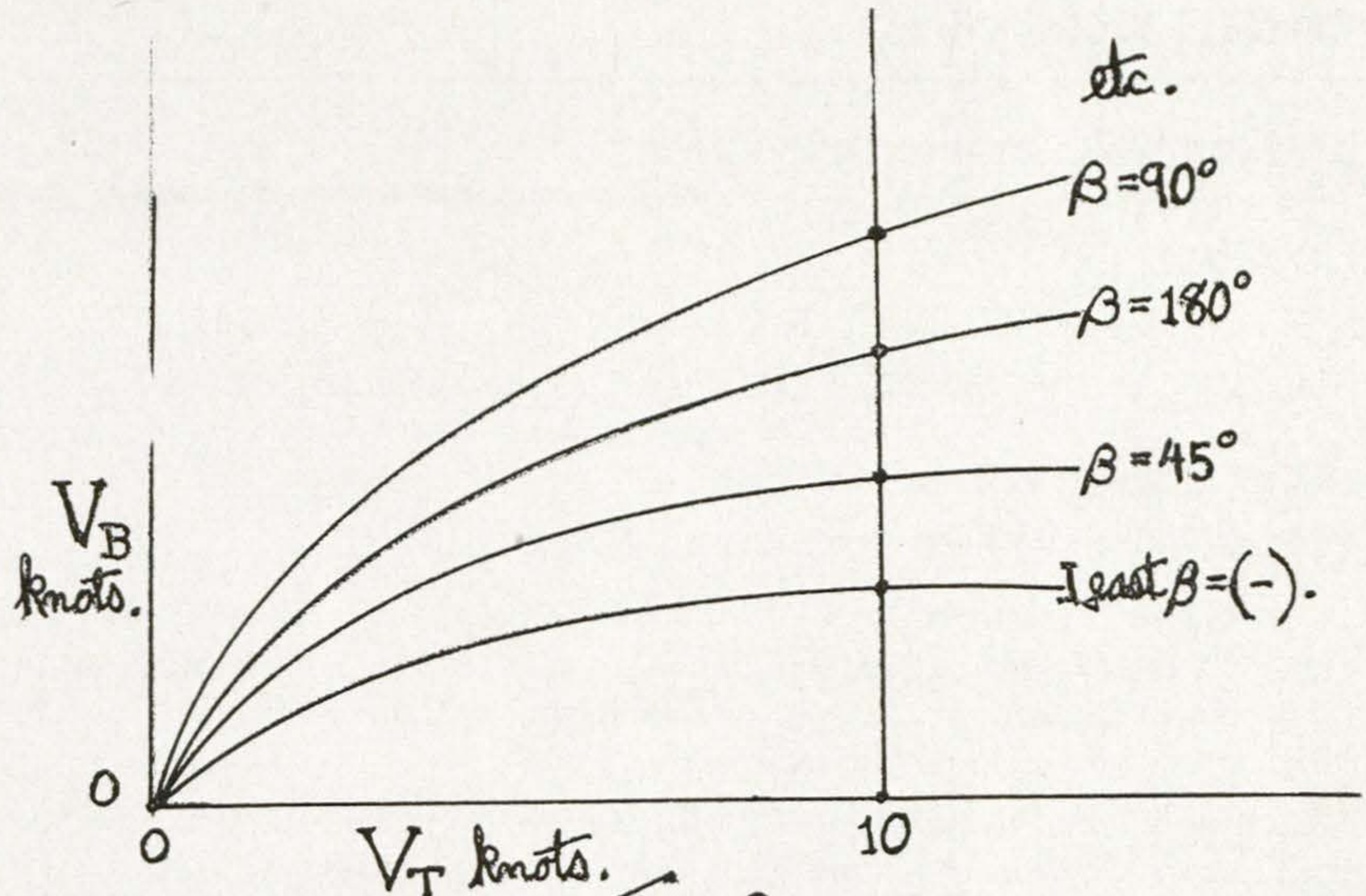


Fig. 2.

Next calculate the corresponding course to the true wind γ for each of these intersections using the formula,

$$\tan \gamma = \frac{\sin \beta}{\cos \beta - \frac{V_B}{V_A}}$$

Thus one obtains the boat velocities V_B versus courses to the true wind γ for each of the fixed true wind velocities V_T, as chosen. These are the data required for the true wind portion of the AYRS polar diagram of yacht performance.

A good polar performance diagram contains much hidden information of value. I hope to prepare a future article on how to extract this knowledge from the diagram.

As one example of the previous statement, one can rate the merit of a yacht by its minimum possible course angle β and on its percentage Vmg compared with the ultimate possible at that angle, in a given true wind velocity V_T.

Another example of extracted information is that optimum sail areas for best Vmg can be calculated readily when heeling is not the sail area limitation.

Edmond Bruce.

COQUI IMPROVED

by Henry A. Morss, Jr.

6 Ballast Lane, Marblehead, Mass. 01945, USA

L.O.A. 24 ft	Rig	Sloop
L.W.L. 19 ft 4 in	Sail Area	235 sq ft
Beam 14 ft	Est. weight, sailing, including two people	1,600 lbs

Designer: Robert L. Taber

Builder: Warren Products, Inc., Warren, Rhode Island, USA.

"Of course" was the instant reaction of Edmond Bruce when I told him that the *COQUI* sailed at least 25 per cent faster (except before the wind) in 1970 than in previous years. My own reaction, as the facts began to unfold early in the summer, was "incredible."

Even now I find it incredible. I'll give the story and all the explanations I can think of. Can any of our readers improve the explanations?

The earlier story of *COQUI* has been given in publications 70 and 74. For this report, we'll ignore the results in "*COQUI*—1969" as found in No. 74

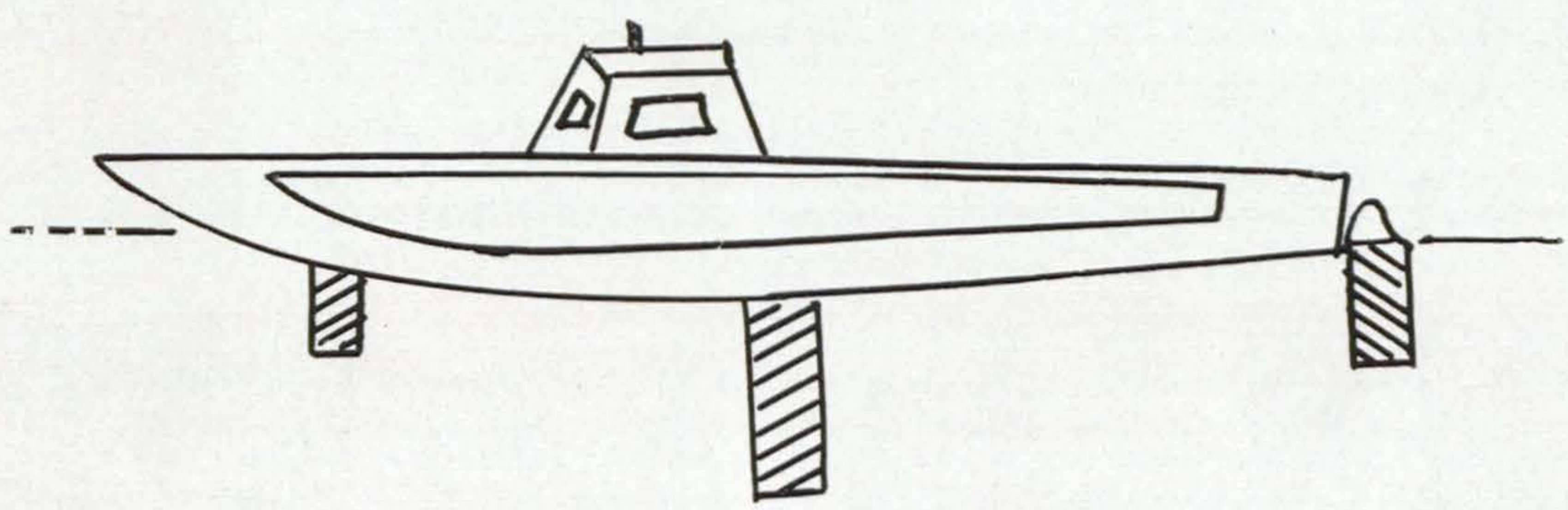


FIG 1.

since speed was not good. There was too much parasitic resistance from the mechanically crude arrangement.

Design

The changes in the boat which have to explain the enormous improvement in speed are entirely in the underwater profile. Fig. 1 shows the configuration with which we sailed in 1968 and earlier years. Fig. 2 shows the configuration with which we sailed in 1970, the one which was much faster.

In 1968 the *COQUI* had two pivoted boards on the centre line. The main board had an aspect ratio in the neighbourhood of 2·5. In 1970 she had a "keel" made of $\frac{3}{4}$ in plywood and a larger rudder than before.

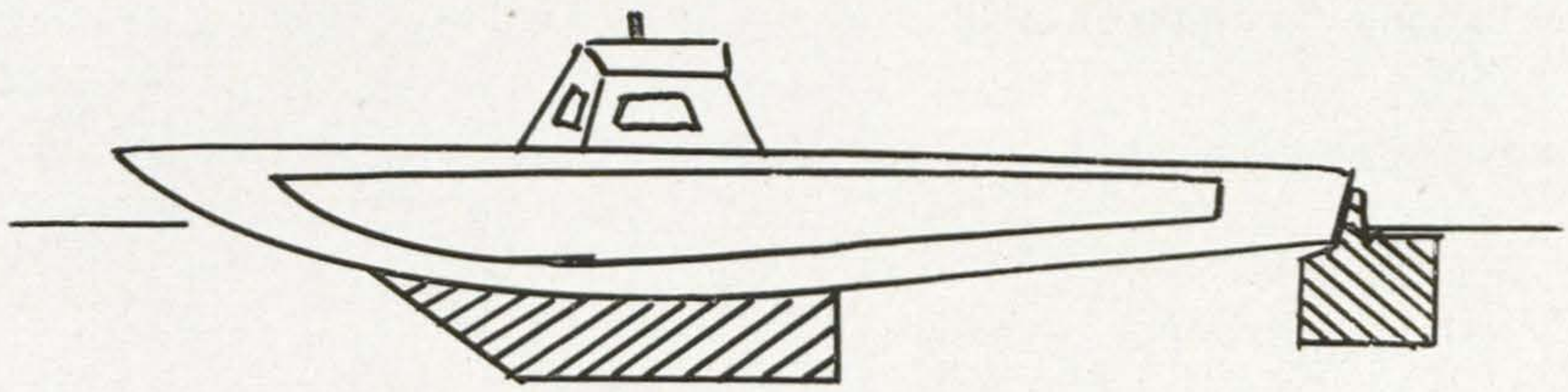


FIG. 2

Differences

The following seems to be a complete catalogue of changes:

1 The keel has an area nearly double that of the two boards in the earlier design.
2 The keel is centred well forward (almost two and a half feet) of the position of the original main board.
3 The keel has a very low aspect ratio.
4 With keel in place of pivoted boards, there is no centreboard box to produce turbulence and absorb energy. Instead, there is a nice, smooth fillet at joint of keel and hull. The bottom is "clean."
5 Rudder area has been more than doubled.

Corollary Differences

Those physical differences produce the following:

1 Wetted surface is appreciably increased. (At least 20 per cent for main hull and appendages and perhaps 15 per cent for the entire underbody in a typical sailing situation with one outer hull clear of the water.)
2 Reduced leeway angle surely helps. "Induced drag" is proportional to the square of the leeway angle, other things being equal. In this case other things are not equal, but probably this is an important gain nonetheless.
3 With the immersed lengths of keel and rudder both greatly increased, the Reynolds Numbers for flow of water by these appendages, considered separately, will be much increased and resistance coefficients somewhat reduced.
4 The elimination of lee helm presumably contributes significantly to improvement in windward performance. It probably does only a little for speed on a reach.

Qualitative Behaviour

That the performance was greatly improved is evident from the following observations:

1 *COQUI* kept up with some boats and outsailed others which had been faster than she in previous years.
2 Sailing to windward was a pleasure. It was easy. We quickly acquired a whole new confidence.

3 Tacking was *no* problem. She came about as handily as most good sailing craft.

4 The process of approaching the mooring was like that of ordinary good sailing boats. We came in to leeward of the mooring, headed into the wind, and "shot the mooring." (A short "shoot," but a real one.) In previous years we were much more likely to sidle up to it.

5 She did well on every point of sailing under jib alone. The extreme demonstration of this came on a breezy day early in the summer. In at least twenty knots of wind and a steep, short head sea we got to windward satisfactorily under the jib alone. While tacking was accomplished with little to spare, it was successful every time we tried. On that same day we had no trouble picking up our mooring in a crowded anchorage under jib alone. (In the harbour the water was smooth and the breeze more moderate.)
In short, we now had a trimaran which was a delight to sail.

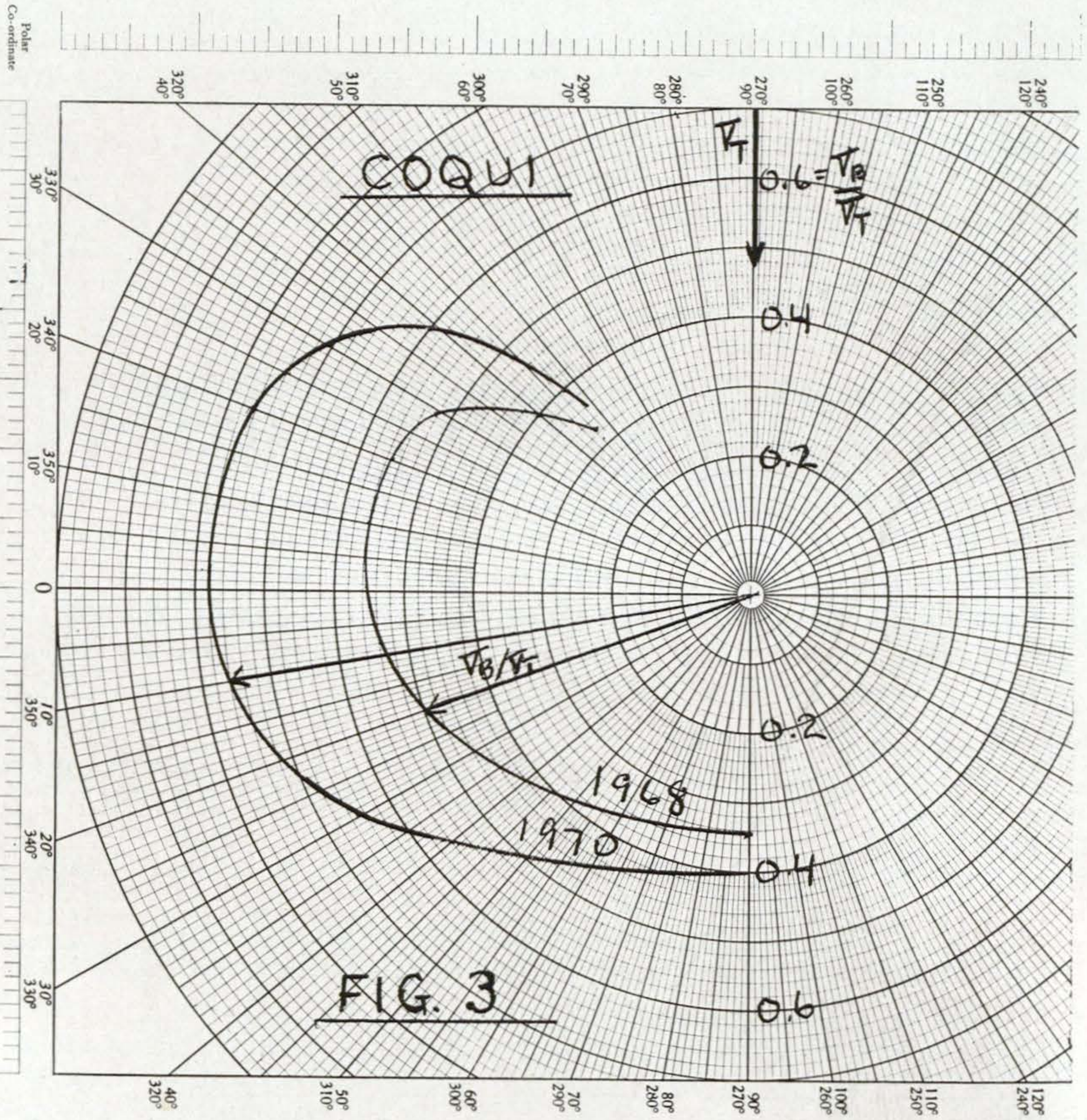


FIG. 3

Quantitative Performance

Fig. 3 reproduces as the inner curve the one given for the old configuration of the *COQUI* in AYRS 70; the outer curve gives the performance in 1970. In both cases the length of the vector from the centre to a curve is the ratio of boat speed to true wind speed. The curves are fairly representative of speed in smooth water in true wind speeds up to ten knots or so.

A comparison of the curves shows that with her new underwater profile the *COQUI* is closer winded, can "make good" to windward a speed roughly 25 per cent greater than she did earlier, and is something like that degree faster on all courses except before the wind.

The data come, as in previous seasons, from readings made with instruments patterned after those described by Edmond Bruce in AYRS 56. I did change to a different speedometer, a small "paddle-wheel" type mounted through the hull.

Unfortunately, I do not have great confidence in the data. On two or three days in the middle of the summer the data looked better than those in the attached curve. Later in the summer the performance seemed to back off somewhat—to values plotted here.

After the close of the sailing season I started to look for an explanation. The obvious one to expect was that the boat's bottom was not clean. In fact she was pretty clean when she came out of the water.

But another trouble appeared in a rather thorough checking of the instruments. The new "paddle-wheel" type boat speedometer is battery powered. It turns out to be much more sensitive to changes in battery voltage than I had realized. Perhaps, then, the lower measured speeds toward the end of the season can be attributed to a gradual running down of the battery, a dry battery which was not renewed all summer.

Needless to day, this trouble will not be allowed to continue in the future.

These rather minor difficulties do not alter the fact that the *COQUI* is now a vastly better sailboat.

Summary Explanation

Mr. Bruce to the contrary notwithstanding, I feel the need to try to understand the very great improvement in the performance of the *COQUI*. This has led me to list all the things which have contributed. My present list, which hardly seems adequate, is as follows:

1 Enough area of underwater profile.

2 Proper position of the "keel".

3 Smooth fillet at point where keel joins hull.

4 "Clean," fair bottom.

These offset the effect of an increase in wetted surface to produce proper balance, reasonable leeway angle, and reduced resistance. To me, the result is spectacular. What next?

PERFORMANCE MEASUREMENT AT WEIR WOOD OCTOBER 1969

by John Hogg

Parklands Cottage, Curdridge, Southampton, England.

Weir Wood weather in 1969 was not ideal for measurement. The fluky wind hardly got the boats going, but the quiet conditions did enable helmsmen to get used to the idea of the measuring course and it is hoped that next time in stronger winds they will cover the required range of sailing angles at more indicative speeds.

The following results are from some 50 test runs, some taken on board by the "Dynamic" method (see Publication No. 56). Others taken over the "Static" course method which is described below.

The "Static Course" Method

This method of yacht performance measurement is designed to produce a polar curve diagram of the yacht's speed in a given wind range. The method is to sail the yacht past a fixed measuring point or Pivot (eg moored dinghy) on a number of random courses to the True wind from close hauled to running free. At the Pivot the True Wind speed V_T during the test run is measured, also the yacht's course angle to the True wind (γ with the recording wind vane and angle sight), and the Time to cover a given distance (observed by range finder) is taken. From this the speed V_s (V_B) on each course is obtained and

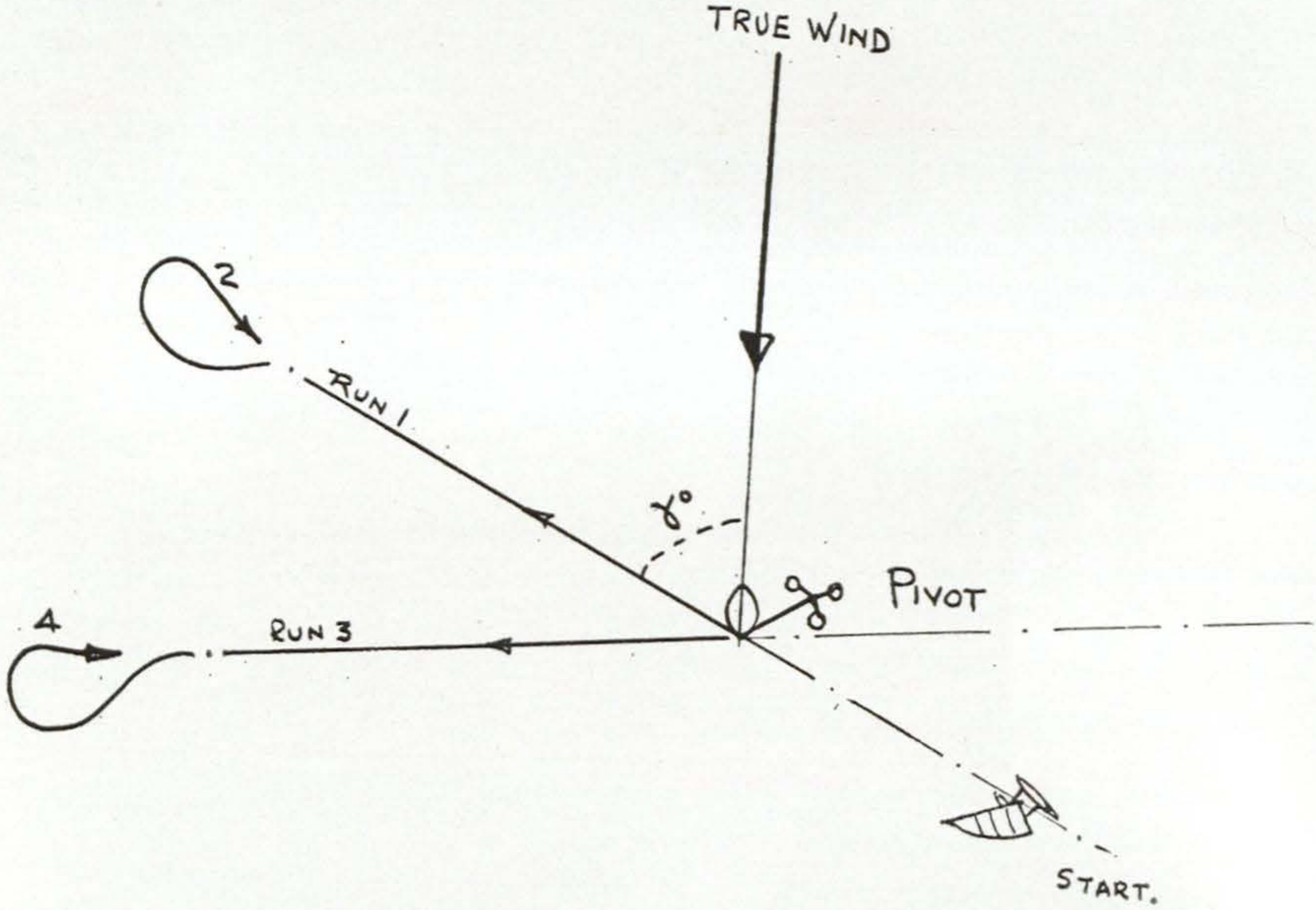
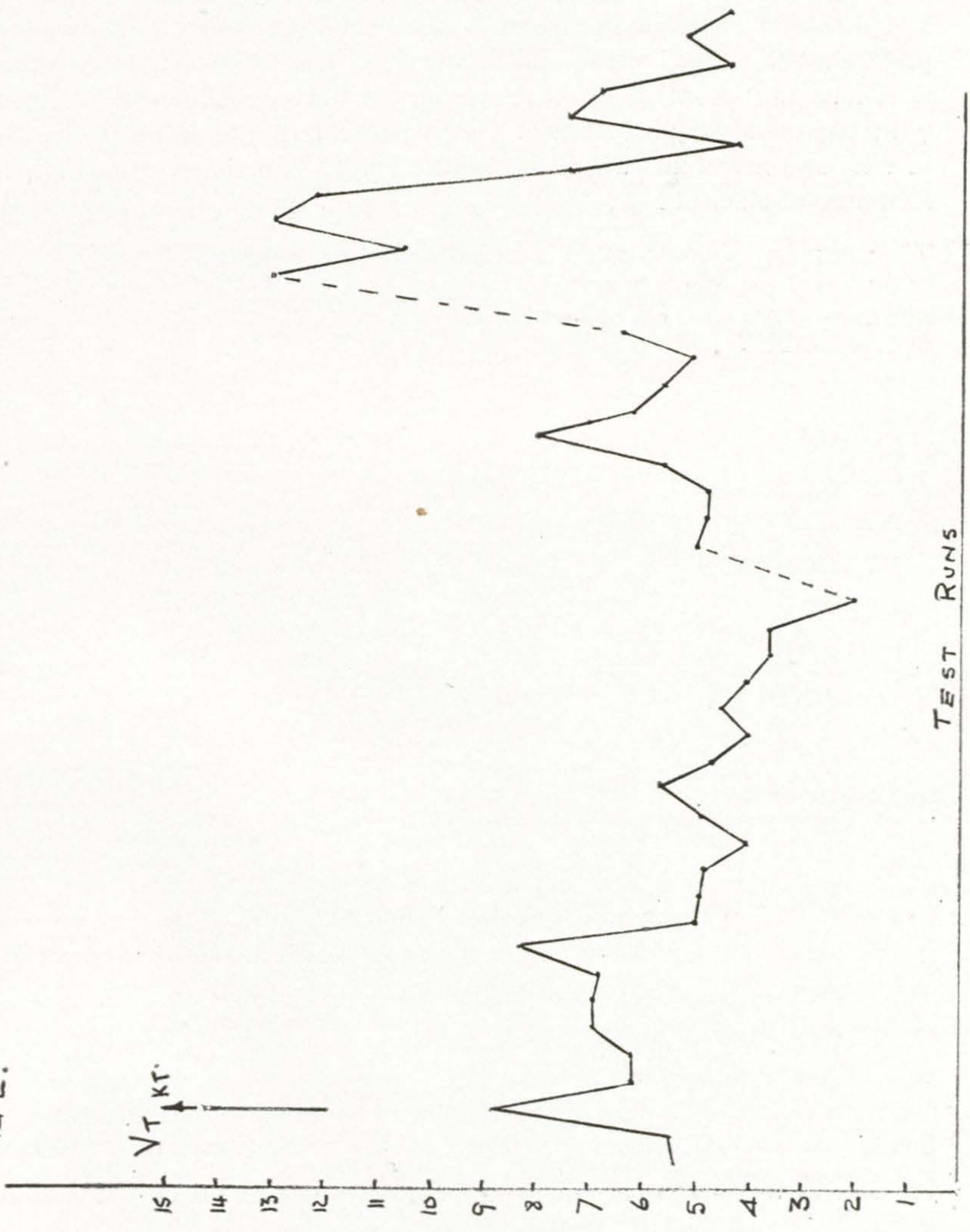


Fig. 1. The static course method. Starting for Run 1 the boat gets up to speed and passes the pivot point closely and is then timed over the first course of 60 yards. After a signal from the pivot she goes about, gets up to speed and heads for the pivot to complete Run 2

this data can be plotted on the Polar chart. From this data also the Course Angle to the Apparent wind β, the Apparent wind speed V_A, and Speed Made Good to windward, Vmg can be quickly calculated, or obtained graphically (Publication No. 61).

In order to save time, a yacht after completing a test run to windward should go about and come back on a roughly reciprocal course so as to pass the Pivot again. (Fig. 1). This enables another test run to be taken in the down wind direction without loss of time. At least ten test runs are needed to form a good polar (the more the better) in each wind range. On the Sunday, most tests lay in the 5 knot range (3 to 7 knots). Fig. 2 shows how the True wind speed behaved during the testing period (10.30 to 3.30).

FIG 2.



Helmsmen please note

Two important points for accurate results:

1 The Yacht must pass as close as possible to the Pivot boat at the start (or finish) of a Test run.

2 The yacht must be brought up to speed and set on a fixed course before the start of each run and thereafter should not deviate during the 60 yard test run. This takes quite a little practice and those interested should try it out on a mooring buoy or post until they can pass it on any course, as closely as possible with the minimum of deviation and sailing on, in a straight line. Weir Wood is ideal for this, no allowance or adjustment for tides being necessary. In tides the method of adjustment is to have a small dan buoy on a line at the Pivot boat (weighted to float awash) and to note its distance and direction travelled during each test run. This works well though I prefer the "Dynamic" method for tidal waters. The "Static Course" method does have an advantage in respect of leeway angles because in measuring γ directly the leeway is included. This is particularly important in the case of foils and multihulls where big leeway angles sometimes offset the performance of efficient rigs!

The summary of boats tested is as follows:

	Number of runs	
Name	Dynamic	Static
CALCULUS	9	4
SULU	14	4
THISTLE	—	6
GOONRAKER		7
MANTIS		1
WINDCHEETAH		1
KELEK		3
CHEROKEE		1
MAPHEHUKA		1

Brief comments

1 In one or two cases there was a fair amount of Twist even in fully battened sails.

2 In one case (*SULU*) an adjustment of batten curvature at the foot gave an increased speed of 0·35 knots, (9 per cent) well worth further measurement.

3 The AYRS Burgees were conspicuous by their absence. Pity, its a good occasion to "show the flag."

4 Naturally not all the tests were satisfactory — wind flaws, wrong positions etc. but if owners are interested I can let them have details of results for their boats.

5 My thanks to owners for submitting to the tests and for enduring some instruments and mud on board.

Name: *CALCULUS* **DYNAMIC COURSE** Series: Weir Wood 19.10.69

Run No.	c	V_A	V_S	$(\beta - \lambda)$	$(\beta - \lambda)$	θ	λ	β	γ	Vmg	V_T	NOTES
1		1·7	3·68	180	—	–	0	180	180	—	5·4	Goose winged. C. Newton. *Lynx* Cat. LOA 14 ft Beam 6 ft 6 in SA 160 f^2
2		1·7	3·8	180	—	–	0	180	180	—	5·5	Goose winged
3		5·7	3·75	135	—	–	0	135	152	—	8·8	
4		5·2	4·45	80	—	–	0	80	124	—	6·2	
5		5·2	4·28	80	—	–	–	80	123	—	6·2	
6		7·8	5·2	50	—	–	2	52	89	—	6·9	
7		7·8	5·25	50	—	–	2	52	90	—	6·9	
8		8·7	4·95	50	—	–	2	52	86	—	6·8	
9		9·5	5·2	60	—	–	1	61	94	—	8·3	
10		8·2	4·65	31	—	–	3	34	66	—	5·0	
11		—	1·57	—	—	–	–	—	100	—	—	Wind Flaw
12		6·8	4·87	42	—	–	3	45	91	—	4·8	
13		6·7	4·35	42	—	–	3	46	89	—	4·8	

Name: *SULU* **DYNAMIC COURSE** Series: Weir Wood 19.10.69

Run No.	c	V_A	V_S	$(\beta - \lambda)$	$(\beta - \lambda)$	θ	λ	β	γ	Vmg	V_T	NOTES
1		<1·5	3·5	180	—	–	–	180	180	—	5·0	Rodney Garratt. Trimaran LOA 18 ft Beam 10 ft SA 178 f^2 (with retractable foils).
2		1·7	3·5	135	—	–	–	135	165	—	4·9	
3		1·8	3·45	135	—	–	–	135	165	—	4·8	
4		2·2	3·33	90	—	–	–	90	147	—	4·0	
5		2·2	4·45	90	—	–	–	90	134	—	4·9	
6		3·9	4·9	80	—	–	–	80	137	—	5·65	
7		6·1	4·74	47	—	–	–	50	98	—	4·7	
8		4·4	5·15	50	—	–	–	50	124	—	4·0	
9		5·5	5·26	50	—	–	–	50	112	—	4·5	
10		6·1	5·2	45	—	–	–	45	102	—	4·4	
11		7·8	5·1	26	—	–	5	31	74	—	3·8	
12		8·3	4·9	26	—	–	5	31	64	2·3	4·8	
13		5·65	3·8	95	—	–	–	95	127	—	7·1	
14		4·35	4·15	95	—	–	–	95	136	—	6·2	Repeat of 13 with tighter battens at foot of main

STATIC COURSE

15		6·2	3·2	29	—	–	3	32	58	1·7	4·0	
16		3·2	2·92	71	—	–	–	71	122	—	3·6	
17		8·6	3·34	22	—	–	4	26	51	2·09	3·6	
18		1·35	1·98	108	—	–	–	108	140	—	2·0	

Name: *THISTLE* STATIC COURSE Series: Weir Wood 19.10.69

No.	c	V_A	V_S	$(\beta - \lambda)$	$(\beta - \lambda)$	θ	λ	β	γ	Vmg	V_T	NOTES
1		9·4	6·1	30	—	–	5	35	75	1·6	5·6	
2		8·0	5·4	69	—	–	–	69	110	—	8·0	
3		7·4	1·78	37	—	–	5	42	54	1·1	6·2	Wind Flaw. Not Straight
4		9·5	4·85	23	—	–	5	28	51	3·04	5·6	
5		4·7	1·75	97	—	–	–	97	116	—	5·2	Wind Flaw.
6		10·1	5·6	31	—	–	4	35	66	2·3	6·4	

Name: *GOONRAKER* **STATIC COURSE** Series: Weir Wood 19.10.69

Run No.	c	V_A	V_S	$(\beta - \lambda)$	$(\beta - \lambda)$	θ	λ	β	γ	Vmg	V_T	NOTES
1		12·0	3·28	85	—	–	–	85	100	—	12·2	Don Rigg's 14 ft Outrigger SA 65 f²
2		8·3	3·85	62	—	–	–	62	90	—	7·4	
3		8·4	5·46	21	—	–	5	26	60	—	4·2	Not straight.
4		9·8	3·94	37	—	–	5	42	63	—	7·4	
5		7·5	2·21	89	—	–	–	89	106	—	6·8	

Name: *Various* (*see below*) **STATIC COURSE** Series: Weir Wood 19.10.69

Run No.	c	V_A	V_S	$(\beta - \lambda)$	$(\beta - \lambda)$	θ	λ	β	γ	Vmg	V_T	NOTES
Mantis		5·5	1·78	36	—	–	8	44	61	·86	4·4	D. Chinery. Trifoil 16 ft LOA 10 ft 0 in Beam 100 f²
Windcheetah		6·3	1·83	40	—	–	5	45	61	·89	5·2	D. Banham. Trimaran. LOA 18 ft 0 in Beam. 12 ft 0 in SA 170 f²
Cherokee		8·1	3·2	40	—	–	4	44	66	1·3	6·2	John Pertigh. Trimaran. LOA 15 ft 8 in Beam 8 ft 6 in SA 110 f²
Kelek 1		15·4	6·35	5·2	—	–	3	55	80	1·11	13·0	Kenneth May. Trimaran inflatable. LOA 16 ft 4 in Beam 10 ft 0 in SA 120 f²
2		11·1	3·32	71	—	–	–	71	90	—	10·6	
3		17·7	8·32	40	—	–	3	43	71	2·76	13·0	
Maphehuka		4·0	1·5	96·5	—	–	–	96·5	116	—	4·4	Heavy laden. Paul Dearling Trimaran LOA 22 ft 6 in SA 225 f²

THE TEN INCH MODEL BOAT RACE

by Dick Andrews

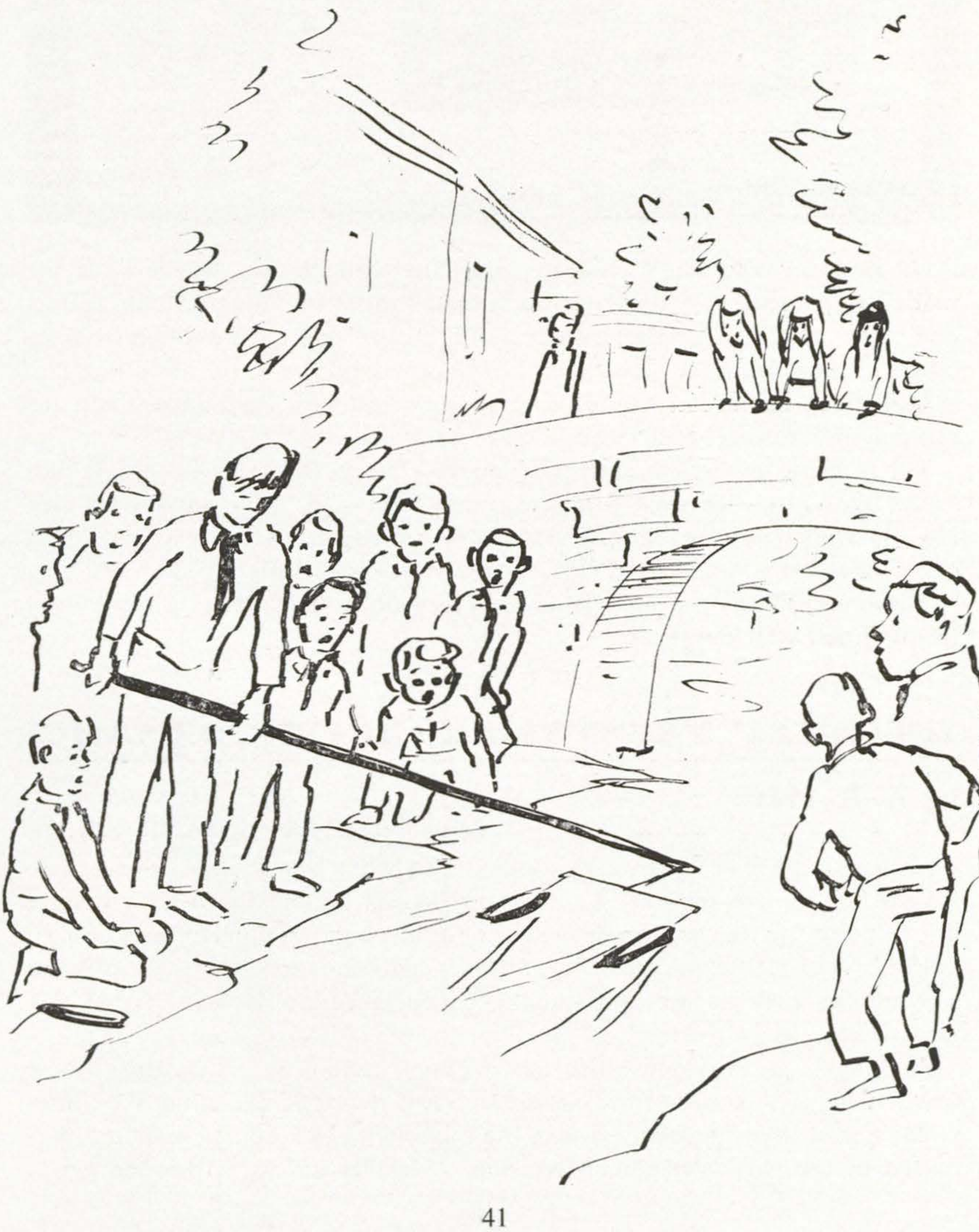
25 Audubon Drive, Ossining, NY 10562

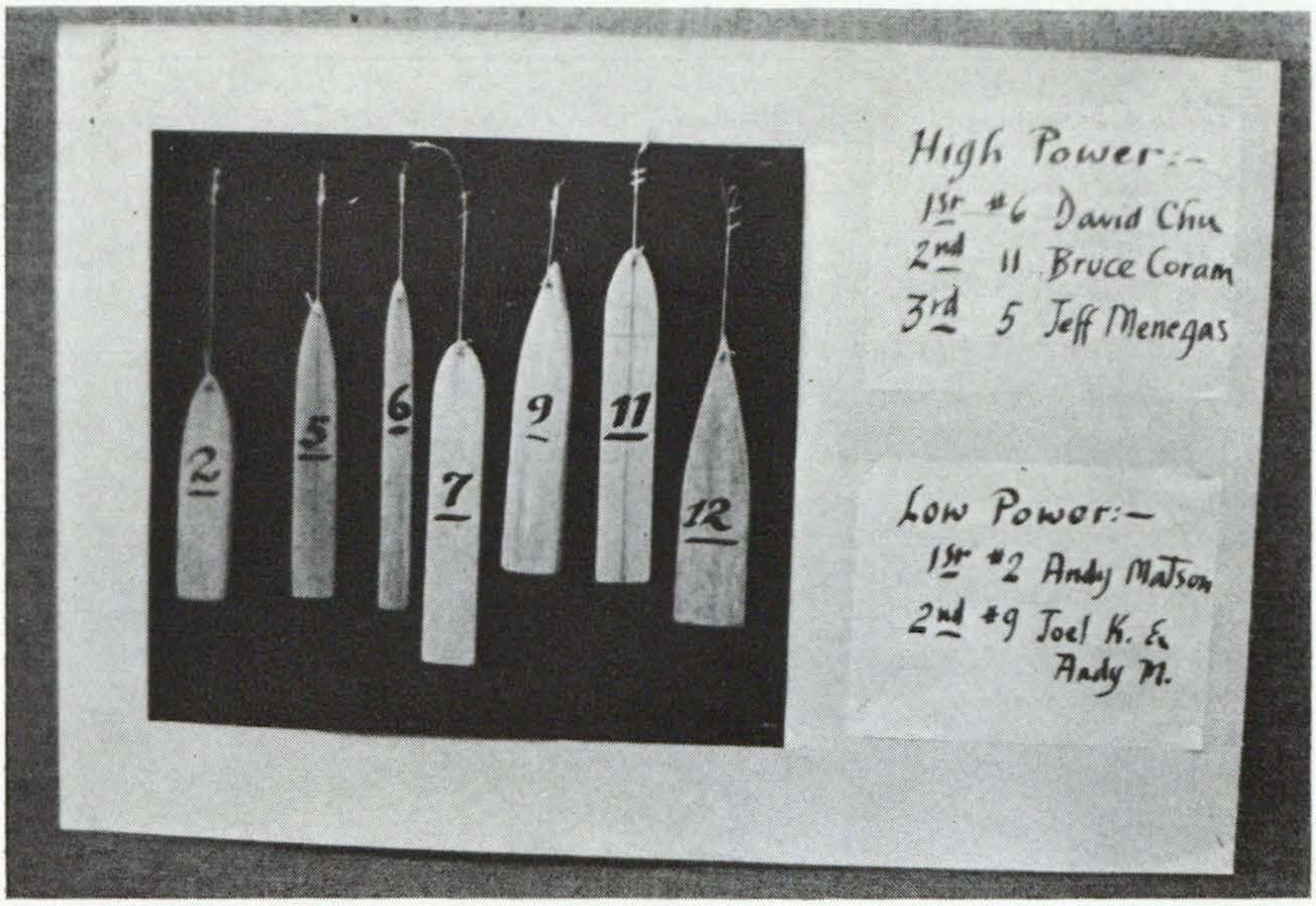
Scarborough School in Scarborough, New York, where I have taught some years, is favoured with a delightful brook winding through the campus—just right for floating small wooden boats carved from pine wood.

This year the ten year old boys competed in a "designer's race" in the brook.

The only limitation imposed on full design was that no hull could exceed 10 in in length overall.

The boys worked away and put a good deal of time into their models, sanding them to a fine polish.





On race day, the whole class thronged the banks of the brook while the models were raced in two events. Each model raced in match fashion against one other, towed on a balanced bar which in turn was moved along from its centre by a rod from the race committee chairman on the bank.

One sweep of the rod would be very gentle and slow (low power) and the other at about model hull speed (high power).

The ultimate winners in each category very nicely followed theory. At hull speed, the craft with least form resistance won—(the very narrow-beamed No. 6)—while ghosting along at very gentle low power, the race went without question to minimum wetted surface (the sweet-lined little No. 2).

The photo shows the models as displayed on a wall, hanging from their towing lines, after the races.

THE "IDEAL" YACHT'S MAXIMUM PERFORMANCE

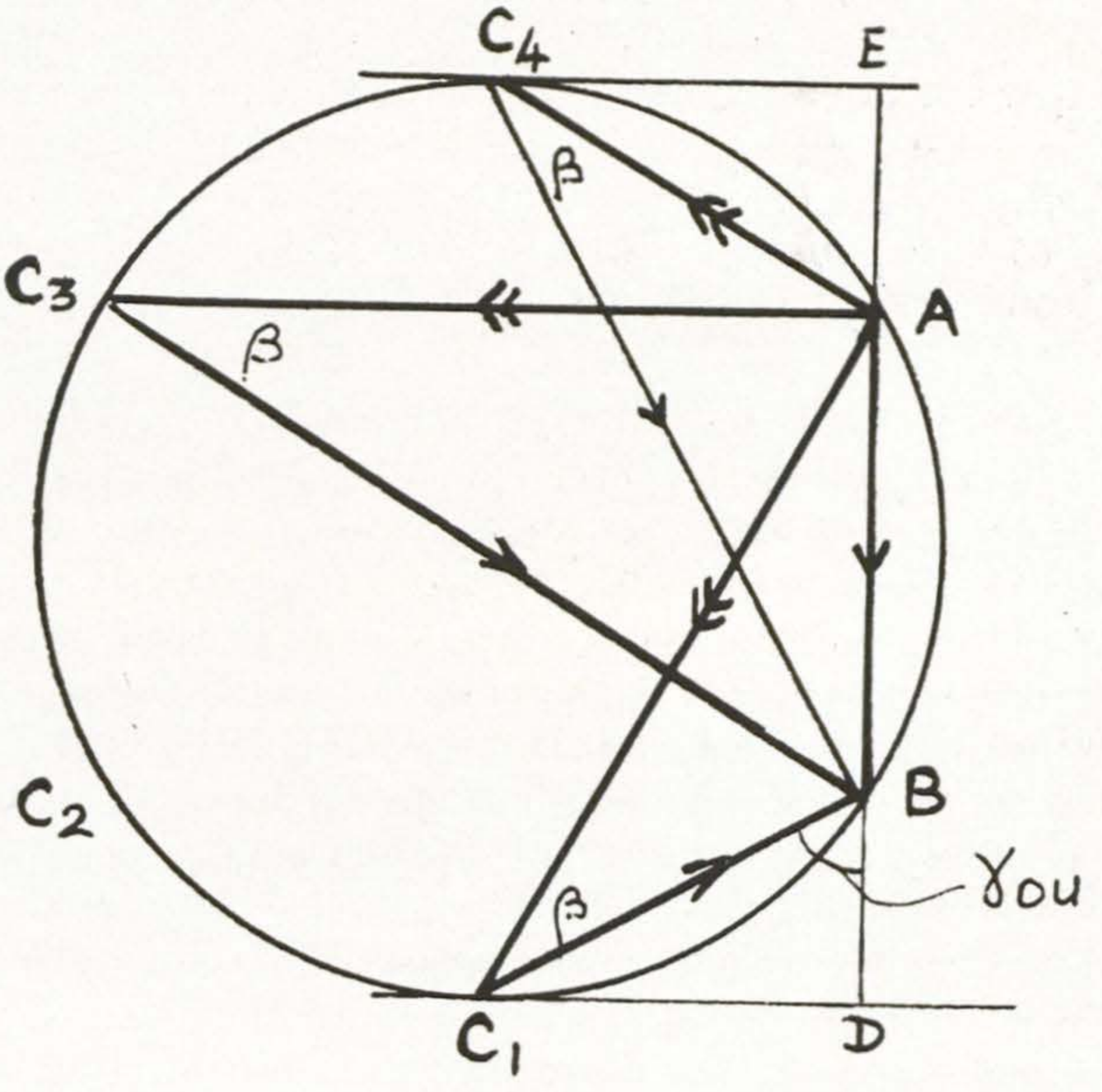
by K. R. May

Brook House, Middle Street, Salisbury, UK

This note is no more than a re-statement of what has already appeared in AYRS Publications (eg Nos. 61, 66a and 70) and my only excuse for writing it is to point out that we can define the absolute maximum performance of an "ideal" yacht with complete certainty. This enables us to dismiss out of hand any claims, such as are occasionally encountered, to have exceeded this performance.

An "ideal" yacht is one which sails without friction or leeway and, by the drive of its sails, continues to accelerate until the apparent wind V_A comes so far ahead that the yacht reaches the minimum close hauled course β permitted by the particular sails it is using. A further luffing up beyond β will lose sail drive and the boat slows. Ice boats achieve the nearest approach to the ideal performance (how near would be interesting to know) and land yachts would be runners up. Foil borne craft might also make some approach to the ideal maxima, but no monohull, bihull nor trihull craft could ever get anywhere near the ideal. Perhaps it would be useful to define an overall yacht efficiency which would be the ratio of its actual speed on any particular course made good to the ideal maximum for the sails in use.

I will use the symbols as defined in AYRS No. 61 for yacht performance (but V_B instead of V_s for the boat velocity) and V_{BOU} will be the boat velocity for optimum upwind velocity made good (Vmg max.). γ_{OU} will be the optimum upwind course angle to V_T. Similarly for optimum downwind velocity made good we have V_{OD} and γ_{OD}.



In the figure, AB is the wind velocity vector V_T, CB is the yacht velocity V_B and AC the apparant wind velocity V_A. Triangle ABC_1 shows the situation for optimum upwind performance because BD = Vmg max. is clearly reduced if C_1 moves round the circle to left or right. When we bear off from this course γ_{OU}, our yacht accelerates and, as we keep the angle of the apparent wind ACB = β constant, the locus of C describes the circle shown, from the principles of elementary geometry. When our course reaches C_2B we no longer make any ground to windward, although still close hauled and thereafter on further bearing off from V_T we make ground downwind.

At C_3 our yacht is making its maximum possible speed V_B max., because C_3B is now the diameter of the circle. Here we have brought the apparent wind 90° off the true wind (the angle in a semi-circle is a right angle). Peeling off still further from the true wind our ideal yacht slows as CB shortens, but at C_4B we have the vector V_{BOD} at γ_{OD} for maximum ground made good downwind, i.e. our best tacking course on each side of V_T to get downwind quickly. The bearing-off cycle is complete when C coincides with A and we drift downwind at exactly the wind speed—a situation which clearly shows, if nothing else, that the "ideal" yacht performance can never actually be attained.

Calculations of the optimum performance figures in terms of V_T and a range of values of β is simple and the geometry of the circle yields the following equations:

$$V_B \text{ max.}/V_T = C_3B/AB = \text{Cosec } \beta$$
$$\text{Vmg max.}/V_T = DB/AB = \tfrac{1}{2}(\text{cosec } \beta - 1)$$
$$V_{BOU}/V_T = C_1B/AB = \text{Vmg max. Cosec } \tfrac{1}{2}(90 - \beta)$$
$$\gamma_{OU} = \text{Angle } C_1BD = \tfrac{1}{2}(90 + \beta)$$
$$V_{OD}/V_T = EB/AB = 1 + \text{Vmg max.}/V_T$$
$$\gamma_{OD} = \text{angle } C_4BD = 90 + \gamma_{OU}$$

We can now obtain the following table of limiting performance of an ideal yacht.

β	γ_{OU}	V_{BOU}/V_T	Vmgmax/V_T	$V_B\text{max}/V_T$	V_{OD}/V_T	γ_{OD}
40°	65°	0·66	0·28	1·56	1·28	155°
30°	60°	1	0·5	2	1·5	150°
20°	55°	1·67	0·96	2·92	1·96	145°
15°	52½°	2·35	1·43	3·86	2·43	142½°
10°	50°	3·7	2·38	5·76	3·38	140°

Actual yacht speed is of course obtained from the table by multiplying the appropriate figures by the prevailing wind speed. AYRS work suggests that few if any mono or multihulls can expect to do better than 25° for β and they rarely approach it. Column 5 shows that their chance of sailing faster than the wind is thin, and limited to a course not far off 90° + β (angle C_3BD) from the true wind. Ice yachtsmen are well aware of the necessity of being able to sail exceedingly close to the apparent wind—a point well brought out by the table.

Boat velocities at intermediate angles can be found from the simple expression $V_B/V_T = \text{Sin}(\gamma - \beta)/\text{Sin } \beta$, where γ is the angle between the boat's true course and the wind. The expression holds for any boat (or moving object) for any value of γ and β. $\gamma - \beta$ is the angle between the true and apparent winds.

Ed: We have also had an article by Bert Goldstone on this subject but too long for this publication.

HOW SMALL SHOULD BETA BE?

by Henry A. Morss, Jr.

6 Ballast Lane, Marblehead, Mass. 01945, USA

Our editor, for AYRS 70, wrote a piece entitled "How Small *Can* Beta Be?" (My italics.) One conclusion was his own opinion as to how small beta *should* be. In a letter following, Edmond Bruce made constructive comment, then suggested a goal (*should* be?) of zero. In another letter, John Hogg expressed doubt that beta *should* be brought down too far. He pointed out that when a boat is sailed very high, its Vmg, or windward performance, is not at its best.

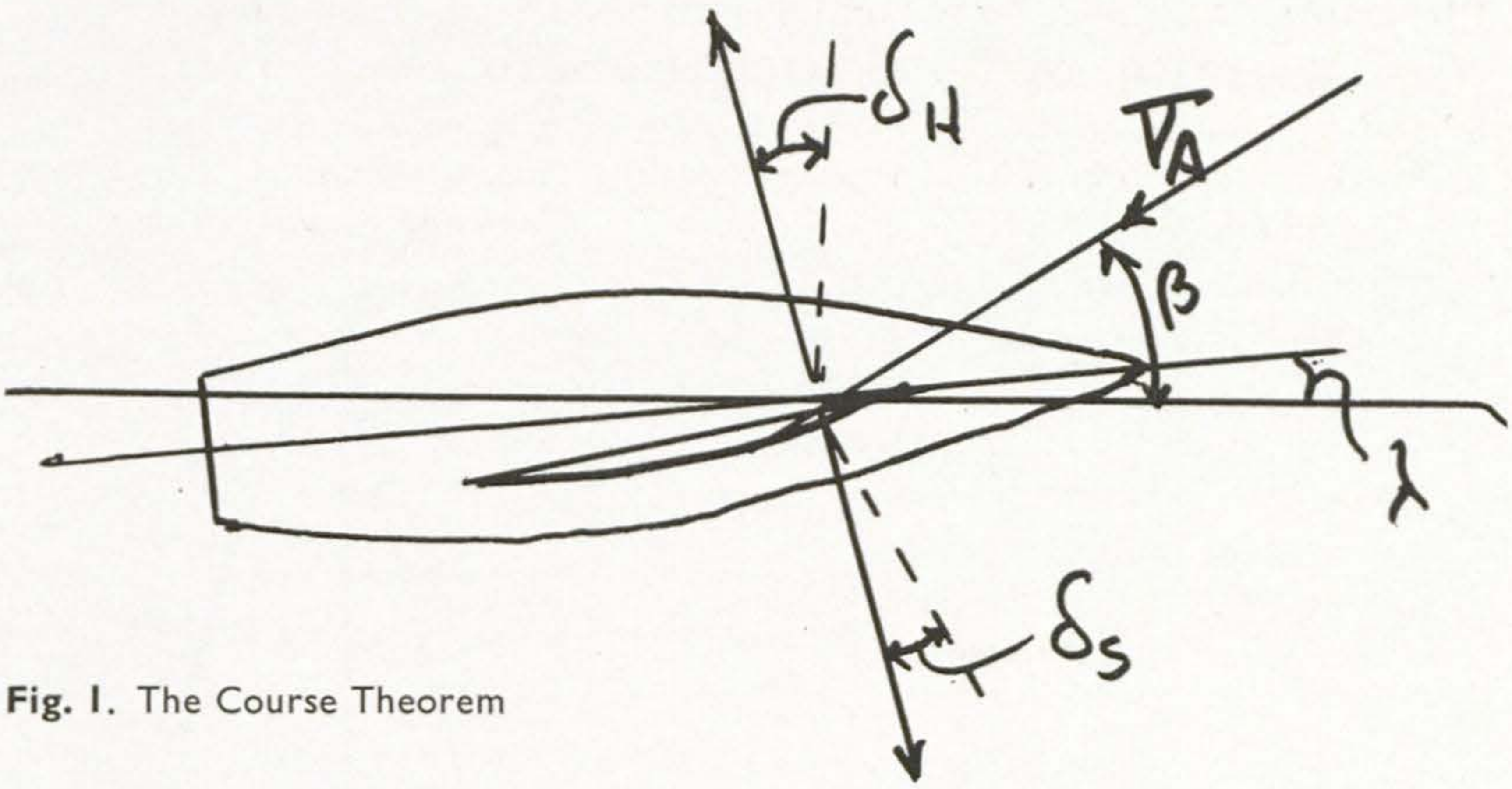


Fig. 1. The Course Theorem

Off and on for over a year I have been working over various aspects of this problem and have been led to the conclusion that, in particular, the hull-drag-angle-component of beta does not want to be forced down too far if the best windward performance is sought.

The Course Theorem

The course theorem states that on any course of sailing the angle between the course and the apparent wind, beta, is equal to the sum of the drag angles of hull and rig, δ_H and δ_S (Fig. 1). Sailing to windward is sailing at a low value of beta. From these facts alone it is tempting to conclude that one way to improve windward performance is to reduce one or both of the drag angles. Is that correct?

Pinching

Obviously it is not reliable if it is pushed too far. To every sailor, "Pinching" is a familiar enough practice, as John Hogg suggests. An imaginable explanation of pinching is that it constitutes sailing closer to the true wind but at unchanged angle to apparent wind. Fig. 2 shows a pair of sailing triangles which illustrate how this might be. The boat which is "pinched" is sailing at lower speed through the water and is realizing less speed to windward, Vmg.

Tests show that ordinary pinching is not fully explained in this way. An "apparent wind vane" tells this. When the boat is pinched, she sails in fact at smaller beta. (To be more precise, $\beta - \lambda$, where λ is leeway angle, is what is indicated by the wind vane. During pinching it may well decrease more than γ could change. Thus it is fair to say that a boat when pinched sails at a reduced value of beta.)

Since beta is the sum of the two drag angles, one or both drag angles must decrease when beta decreases. With a bit of thought we can see that it is possible for either of them to decrease. The possibility for drag angle of rig can be deduced from Edmond Bruce's curve of sail force measured in his "tethered-

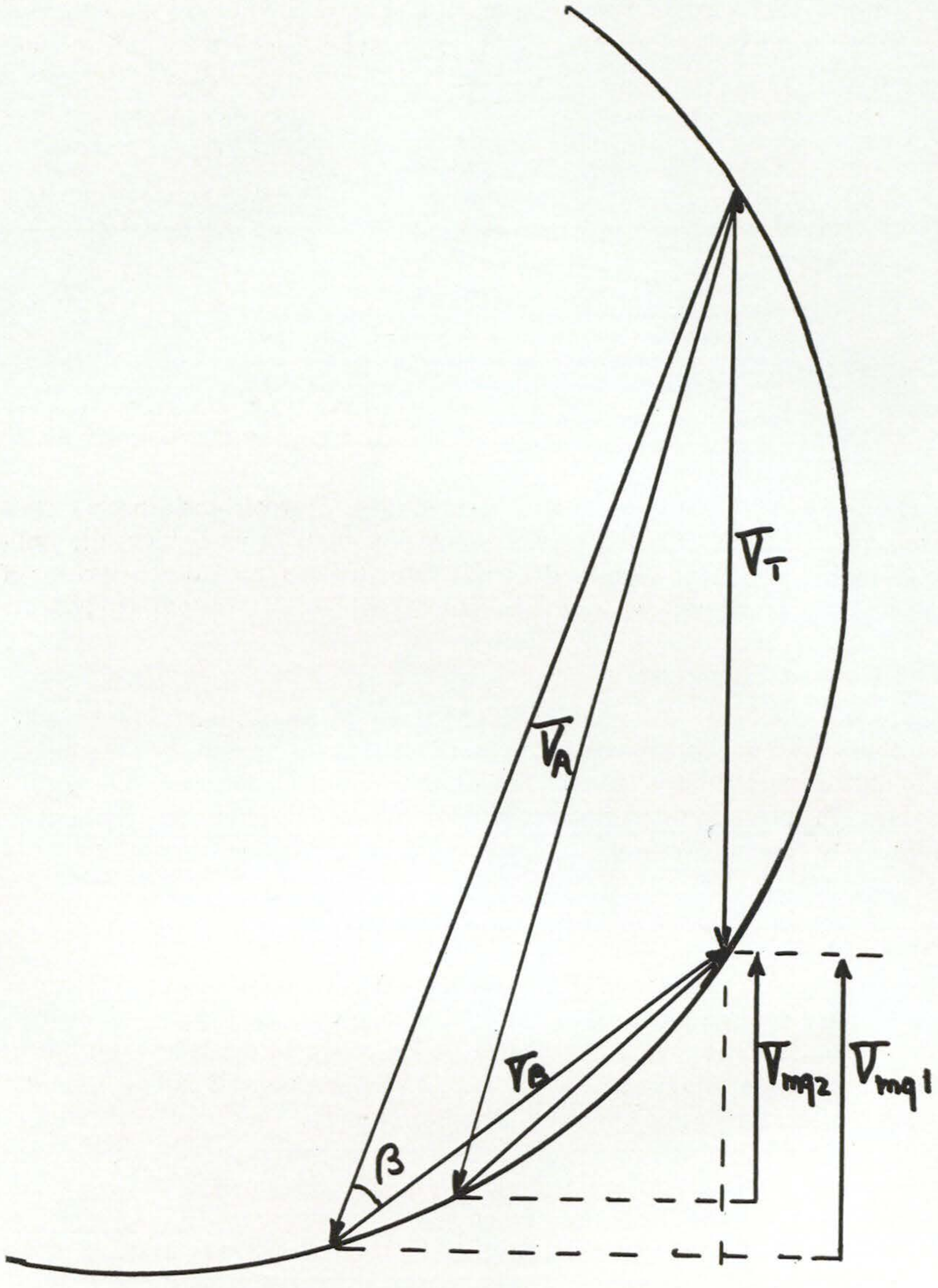


FIG. 2

boat test" (AYRS 40, page 35, fig. 7). The optimum does not occur at the smallest value of δ_S at which the boat can sail.

The possibility for drag angle of hull can be found in the fact that the "wave-making" part of the forward component of total resistance may be expected to drop off more rapidly with declining speed than will the side component (lift). As it does, drag angle of hull will decrease slightly.

It is not justified, then, to assume that in every case a reduction of one or both of the drag angles will improve the windward performance.

Hull Drag Angle

Another way to look at this has been explored. It derives from the fact that the forward driving force, or the forward component of the total sail force is equal to the magnitude of the total sail force multiplied by the sine of the drag angle of the hull.

Consequently, if the hull could have a *very* small drag angle, the forward driving force of the sails would be very low, and the speed to windward would necessarily be low.

If, on the other hand, we visualize sailing at a relatively high value of hull drag angle, we see that we could come to the point where the sailing angle to true wind would be so great that little progress would be made to windward even at relatively high boat speed. (See Edmond Bruce's article on page 59 of AYRS 70).

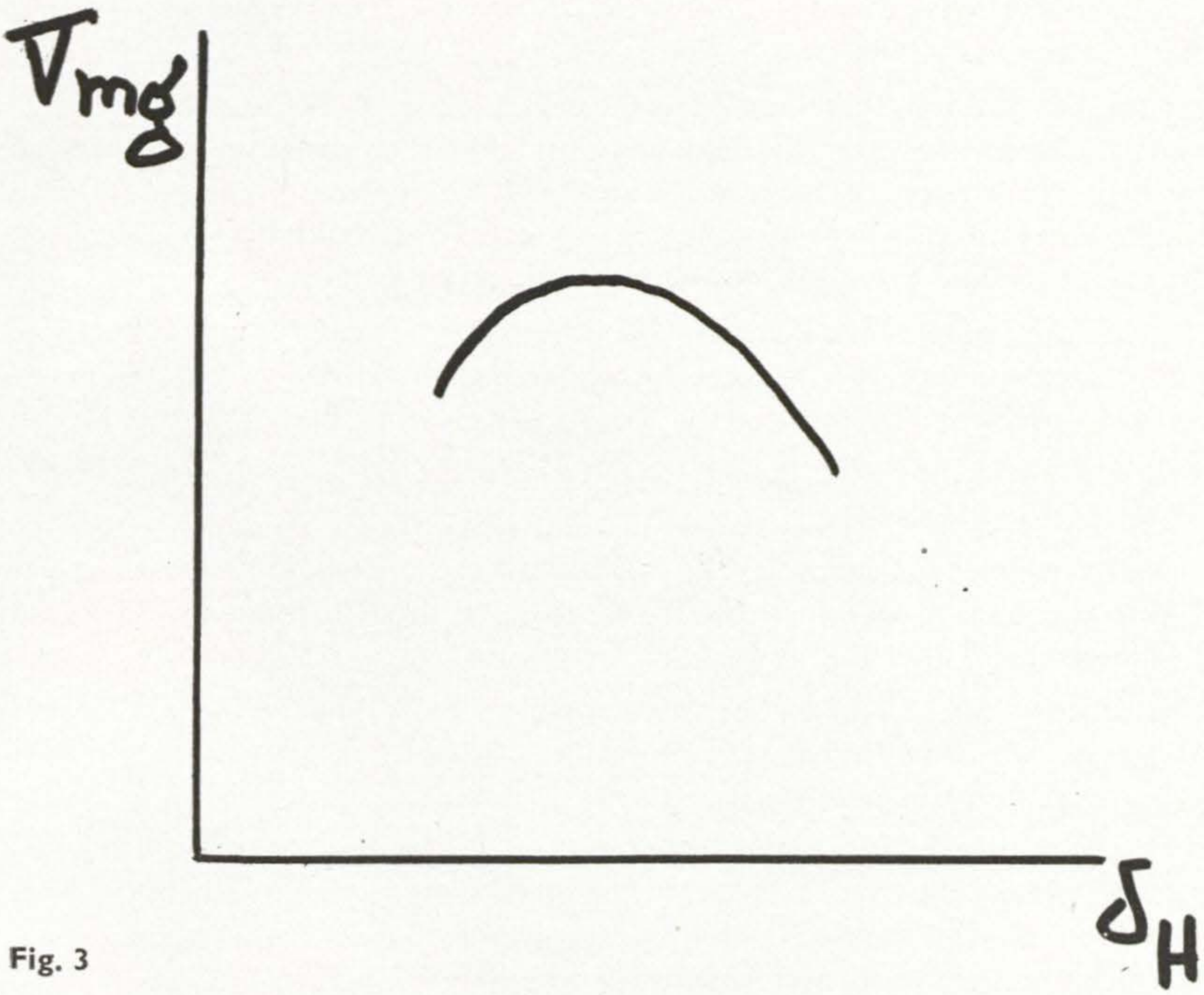


Fig. 3

Somewhere between these two extremes there must be a point which produces optimum speed to windward. Qualitatively, if we plot speed made good to windward against drag angle of hull, we shall expect a curve of the character of that drawn in Fig. 3. It will have a maximum at some value of δ_H and will slope down from the maximum on both sides in some fashion.

In these terms, it seems reasonable to suppose that the highest "pinching" is the point of sailing at minimum drag angle of hull. As the helmsman heads off slightly, he forces the hull drag angle to a higher value. The boat picks up speed. For best speed to windward the helmsman should aim for the value of δ_H at which the high point of the curve in Fig. 3 lies. If he sails at lower δ_H, or to the left of the maximum of the curve, he is pinching. If he is sailing at higher δ_H, he is too "wide" for best speed to windward.

How Small Should Beta Be?

For best Vmg, one answer is that δ_H should not be smaller than its value at the high point of the curve in Fig. 3. Beta should not be less than this value of δ_H plus δ_S, whatever is appropriate for that. A study would be desirable.

Some calculations

This line of reasoning throws some importance on the particular value of δ_H at which best windward performance is realized. So far nothing has been said to indicate whether the value is large enough to be of interest or not. If it is smaller than the value of δ_H at which boats can sail, then we have not really learned anything.

I tried to find out, therefore, what the curve of Fig. 3 may look like in some real situations. Toward this end, various combinations have been figured through. The detail of the calculations will be omitted. Necessarily, each single series of calculations (one curve) involves simplifying assumptions. Hence, any single curve can not be relied on very much.

From the group of these curves which has been derived (in which the most important assumptions have been tested through a range), it does seem fair to draw some conclusions.

1 Every one of the curves resembles the one in Fig. 3.

2 For boats sailing fast in relation to wind speed (fast racing catamarans or twelve-metres, for example) the position of the high point of the curve is probably at a value of δ_H lower than that realized in ordinary windward sailing.

(It is safest not to apply these calculations to an ice boat. This belongs in a category of its own. The assumptions used do not fit very well.)

3 For many boats which are not very fast to windward (that is, those which do not fit the description in the preceding paragraph), it appears that the high point of the curve falls at a value of δ_H close to that at which the boat usually sails to windward or even at a value slightly higher than one at which the windward performance is considered satisfactory.

Some numerical values

Because of the simplifying assumptions which underlie the computations made in this study, it is best to use the numerical results with caution. The numbers suggest that:

a Only the fastest boats (relative to wind speed) can benefit by sailing at hull drag angle below 10°,

b Ordinary good boats of today should probably sail at hull drag angles in the range of 15°, say between 12° and 18°.

c Boats with lower *sail* drag angle should sail at slightly higher hull drag angle. (A surprise, too!)

What Practical Deductions?

Within the limits set by the underlying assumptions, the things said so far are probably about correct. Now we must ask what bearing they have on two separate and distinct problems.

a *Handling a Given Boat.* For this section let's think of a boat with a fixed underbody. If she is a centreboarder, we shall consider the centreboard to be fixed in one position.

Here, then, the helmsman has freedom to adjust sails and to steer as he wishes. By his steering he can hold the boat at any value of δ_H at or above a certain minimum value which is a characteristic of the design. When he holds at that minimum he is pinching. As he heads off from that value, boat speed will pick up and Vmg will increase, as indicated in Fig. 3. For best windward performance he should aim for the angle which gives the maximum of the curve for Vmg in Fig. 3.

This sets a value on beta which is bigger than the minimum achievable value.

b *Altering Design.* At first sight it is not evident just how to apply these thoughts in altering the design of a boat—in improving design. The hint that beta should not be forced down too far surely does not mean that any effort should be spared in reducing drag or resistance in every possible way.

Even in the simplest change in design, namely, a change in board area of a centreboard boat, it is not obvious that we have a new criterion with practical value.

How Small Should Beta Be?

The argument outlined here leads me to conclude that, if best windward performance is the objective, the drag angle of the hull *should not* be forced down too far.

All of this seems to throw some light on the Course Theorem and its implications, also on pinching. It leaves many interesting questions unanswered. One hopes it will bring further comment on the subject. If what is written here is wrong, it will still serve a useful purpose if it stimulates someone to find better answers!

Letter from: Norman Riggs, 13 Russell Road, London N13
22nd April, 1970

Dear John Morwood,

Re: "How small should β be?" "10° yachts" etc.

Having read my AYRS journals I feel compelled to make some observations.

AYRS No. 67, page 86, Figure 14, must be, I feel, a source of misconceptions. The diagram seems to suggest that Fx is the driving force which of course it is not, unless there is no leeway. The driving force is in fact L sin β $-$D cos β, so that even when Fx $=$ O and Fy acts abeam, there will still be a driving force provided there is leeway. Drive acts along a line $\beta°$ from the apparant wind NOT $(\beta - \lambda)°$.

In this connection I must point to errors on page 83 of AYRS No. 70. If as the author of the article states: $\beta = 30°$ and $\lambda = 2°$, the angle between the heading and apparant wind is 28°, not 30° as stated in the opening paragraph. In the diagram at the bottom of the same page, the angle $\beta - \lambda$ is incorrectly marked β.

Perhaps those taking figures for polars should be reminded that β is the angle of the apparent wind to the bow $+$ leeway angle.

Yours sincerely,

Norman Riggs

P.S. I think $\beta = 10°$ may be possible as Edmond Bruce suggests.

LEE HELM and WINDWARD PERFORMANCE

by Henry A. Morss, Jr.

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From time to time, one or another of us makes some comment about the effect of leeward helm in windward performance. Recently John Morwood, in AYRS 70, spoke of finding that the *KINNEGOE* carried a lee helm. He disliked it and eliminated it by moving the keel farther forward.

Surely there are various reasons for thinking that lee helm impairs windward performance. Perhaps there is merit in writing some of them down.

The helmsman

By definition a boat carries a lee helm if, while sailing by the wind, she tends to head off when left to herself. The helmsman must oppose this tendency continuously in just the right degree. This is not so easy or natural as it is to hold the boat against the opposite tendency to head up which characterizes weather helm. The evidence says that most helmsmen can not do it as well. They simply do not guide a boat with lee helm as effectively to windward as they do one with weather helm.

Forces

A study of the forces is revealing. Fig. 1a is intended to show a horizontal section of keel and rudder of a boat sailing "by the wind." V_A is the direction of the apparent wind. F_S is the horizontal component of the force it produces, the "sail force," projected down to the plane of the drawing. F_K and F_R are forces (horizontal components) on keel and rudder by the water. (Strictly, F_K is the horizontal component of the entire "water force" exerted on hull and keel, all except the rudder.)

For steady sailing, the (vector) sum of F_K and F_R is equal and opposite to F_S (Fig. 1b).

Fig. 1 pictures a boat with weather helm. Fig. 2 pictures a boat with "slight weather helm," one with rudder amidships feeling a force which would tend to put the boat into the wind if she were left to herself.

These two examples of a boat with weather helm we compare now to one for a boat with lee helm as pictured in Fig. 3. Here the force on the rudder tends to add to the sail force. The combination of the two (vector sum) must be opposed by F_K (as in Fig. 3b). which therefore will be larger than in the

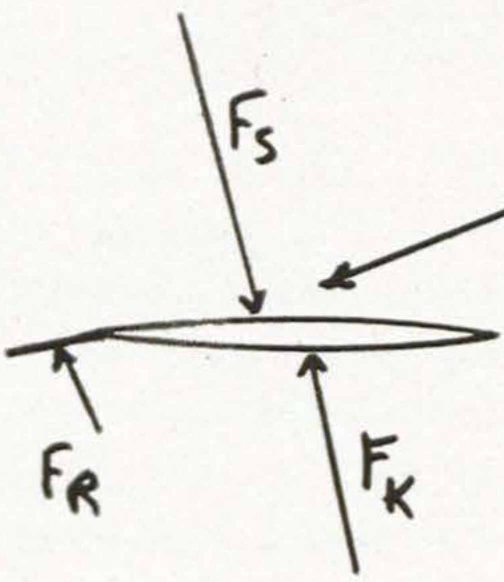


FIG. 1a

FIG. 1B

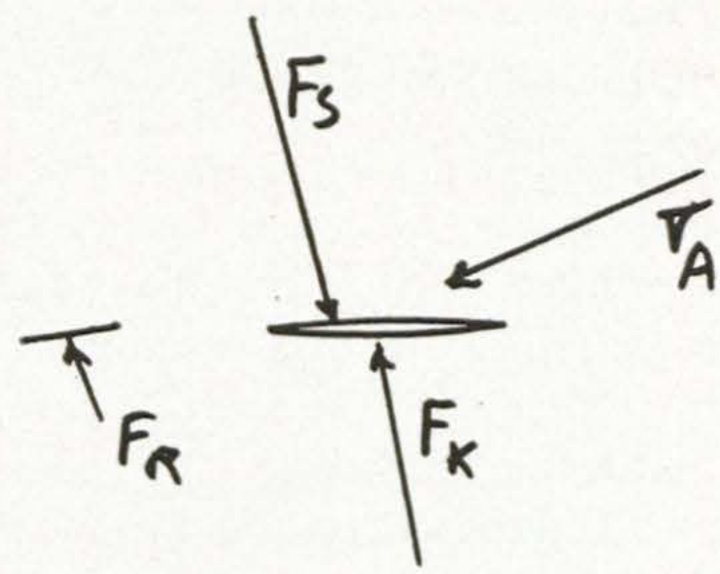


FIG. 4

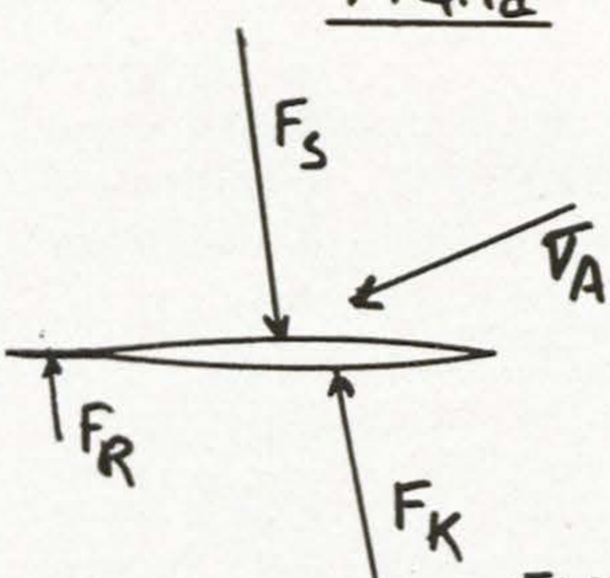


FIG. 2

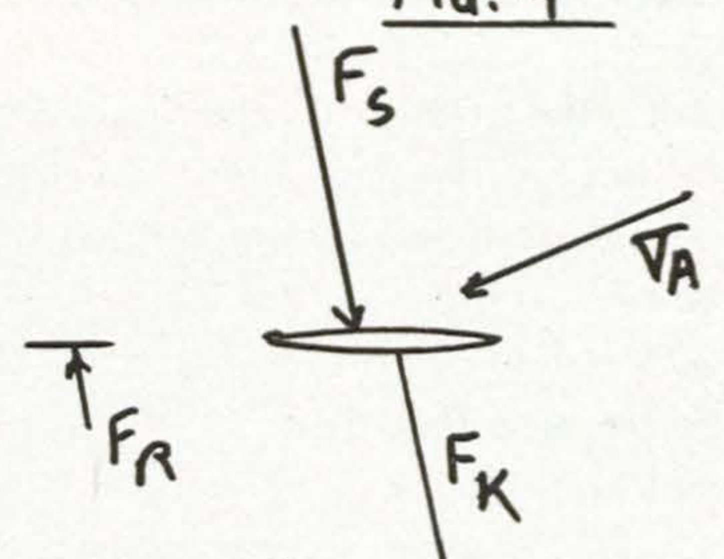


FIG. 5

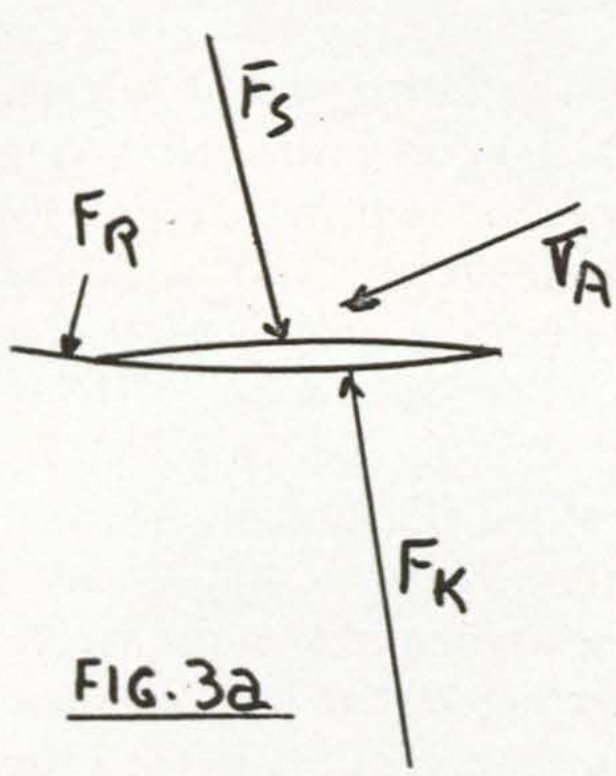


FIG. 3a

FIG. 3b

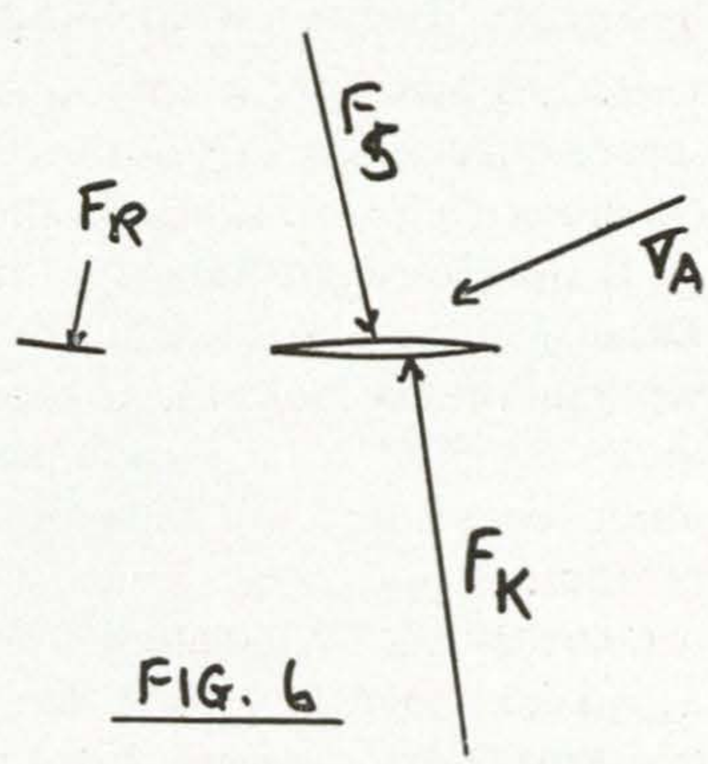


FIG. 6

situation of Fig. 1 or Fig. 2. The boat creates this larger force through increased angle of leeway. This in turn increases the "induced drag," that drag which does not exist when the boat's motion is parallel to her centre line but is added or "induced" by the side force from the wind and the consequent leeway. Induced drag rises roughly with the square of the angle of leeway. Hence the lee helm will cause a significant increase in total drag and thus will impair the performance.

It is worth noting that with the rudder off centre, as in Figs. 1 and 3, the direction of F_R points farther aft than that of F_K. Thus its aft component, or drag, is increased. Perhaps also the angle of attack is increased and with it the magnitude of F_R. Thus we see a double effect: increased drag both because F_R itself is larger and also because of its direction. This is not the way to improve speed.

"Curved-Foil Effect"

Some people argue that a small angle of helm as in Fig. 1 has the effect of making the keel and rudder together into a curved foil. This may be an advantage, especially if the rudder is nicely faired to the keel to make a smooth curve, since one may assume that a proper, curved foil will produce the necessary force with less drag as compared to a flat or straight foil. (Memory says that Roderick Stephens, Jr., came close to this in a description of *COLUMBIA* in YACHTING magazine in the spring of 1965. He said that *COLUMBIA* was designed to carry a five-degree weather helm when sailing by the wind and that her rudder was beautifully faired into the keel to make a smoothly curved surface on each side.)

To the extent that the "curved-foil effect" will be an advantage with weather helm (Fig. 1), it will be a disadvantage with lee helm (Fig. 3). In this case the curvature is the wrong way. It will enhance side force to leeward, not to windward.

Separate Rudder

Figs. 4, 5 and 6 show the situation for a boat with rudder separated from keel or centreboard. The forces look much the same. The conclusion is the same.

Separate Rudder with Skeg

Figs. 7, 8 and 9 show the situation for a boat with rudder attached to skeg separate from keel. Again the forces look much the same and the preliminary conclusions are the same. In this case, however, the "curved-foil effect" may be a significant advantage with weather helm, disadvantage with lee helm. Because of the possible gain from the "curved-foil effect," a skeg in front of a separate rudder looks like a good idea. The common "spade" rudder of today looks less good. If the area of the skeg, is less than that of the rudder, the maximum "curvature" will be toward the forward end of the assemblage, where it belongs.

One may ask "What about a small 'trim-tab' on the trailing edge of the keel?" This is sketched in Fig. 10 for the case of weather helm. The kind of logic developed here suggests that it may do more harm than good. It is both too

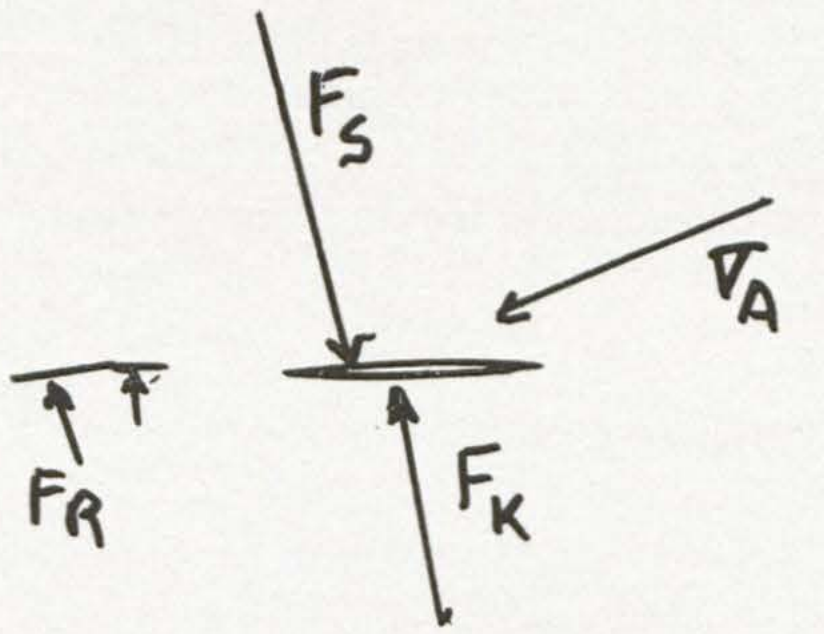


FIG 7

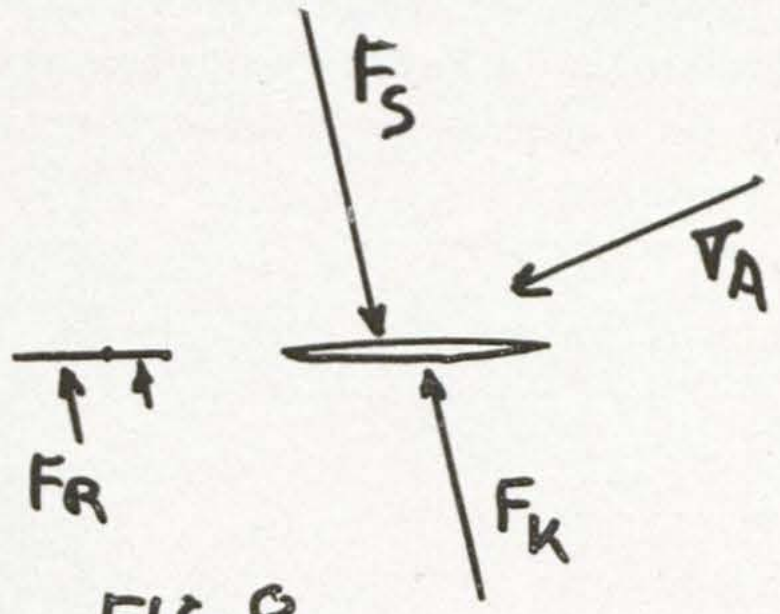


FIG.8

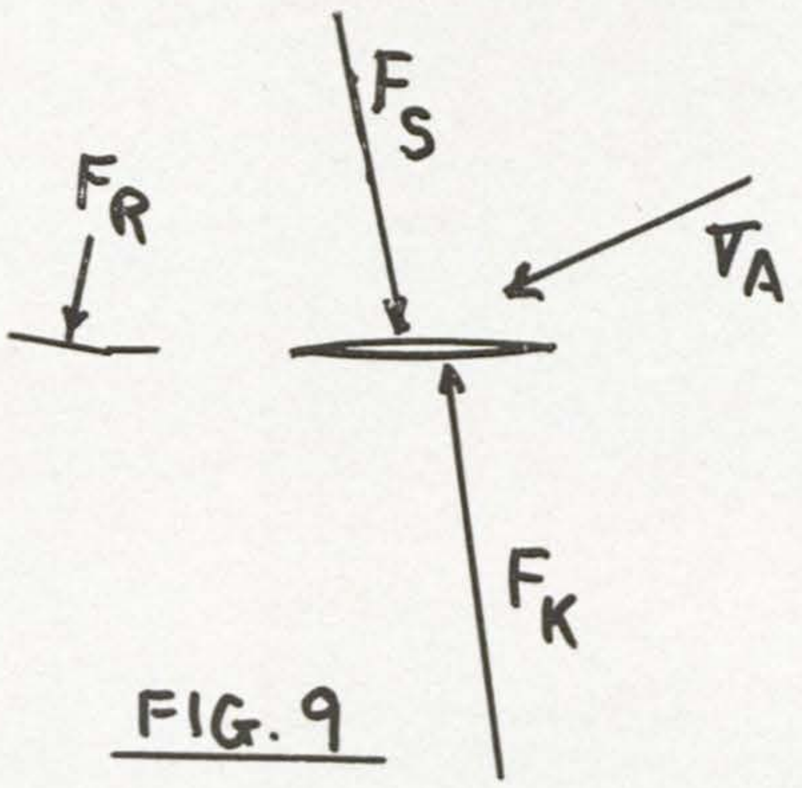


FIG. 9

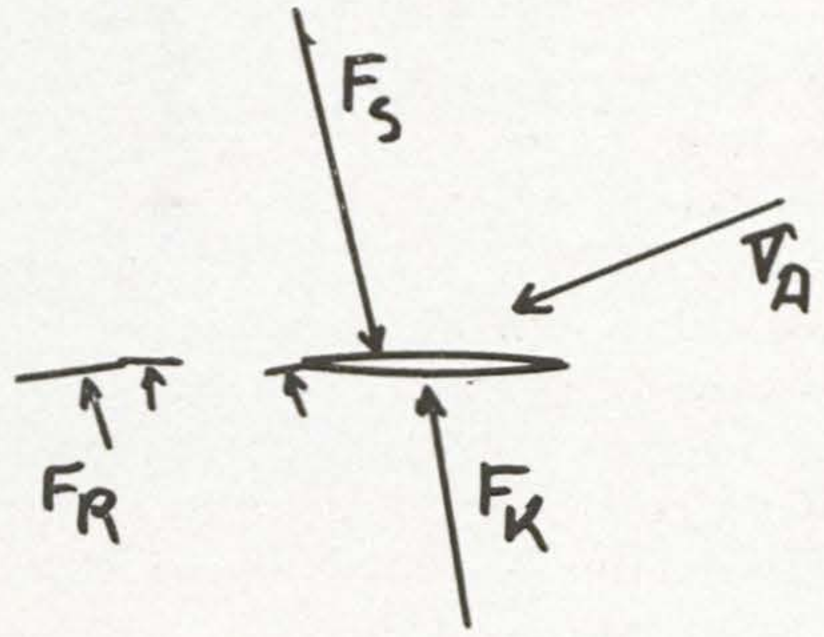


FIG. 10

far forward and, by definition, too small to do much for steering. Yet the direction of its "side force" is farther aft and increases resistance. If its angle is more than very small, the addition to resistance may be severe. (That is the case with wing flaps on airplanes. They are used only when more "lift," comparable to our side force, and less speed are desired.) With a small "trim-tab," a "curved-foil effect" will contribute little.

Conclusion

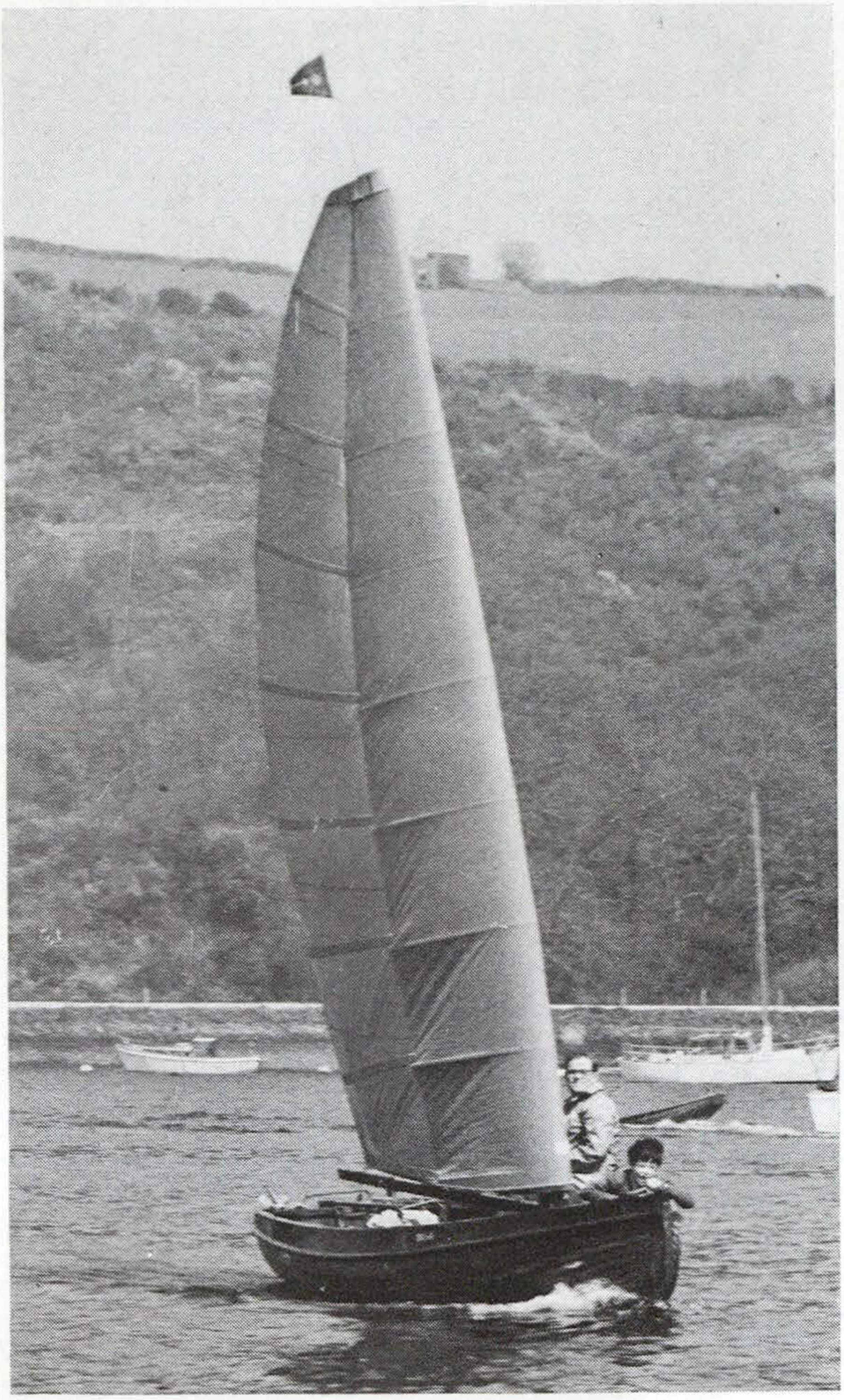
This line of reasoning certainly suggests that a lee helm is a real disadvantage in sailing to windward.

WINGSAILS FOR PLAIN BOATS

by Commander G. C. Chapman RN

The advantages of the wingsail, apparently enjoyed only by the C Class catamarans, can also be experienced in humbler boats. Initial experiments proved the type of structure described below, using a sail whose wing was of uniform chord, and in 1970 I changed to a wingsail whose shape derives largely from the wingsails devised by Austin Farrar and General Parham.

My sail structure differs from their's in that the wing is a sailcloth tube stretched over wing battens (shaped plywood formers) which can slide up and down the keyed cylindrical mast. This means that the sail can be lowered, to allow gales to pass, and it can easily be reefed, handled and transported.

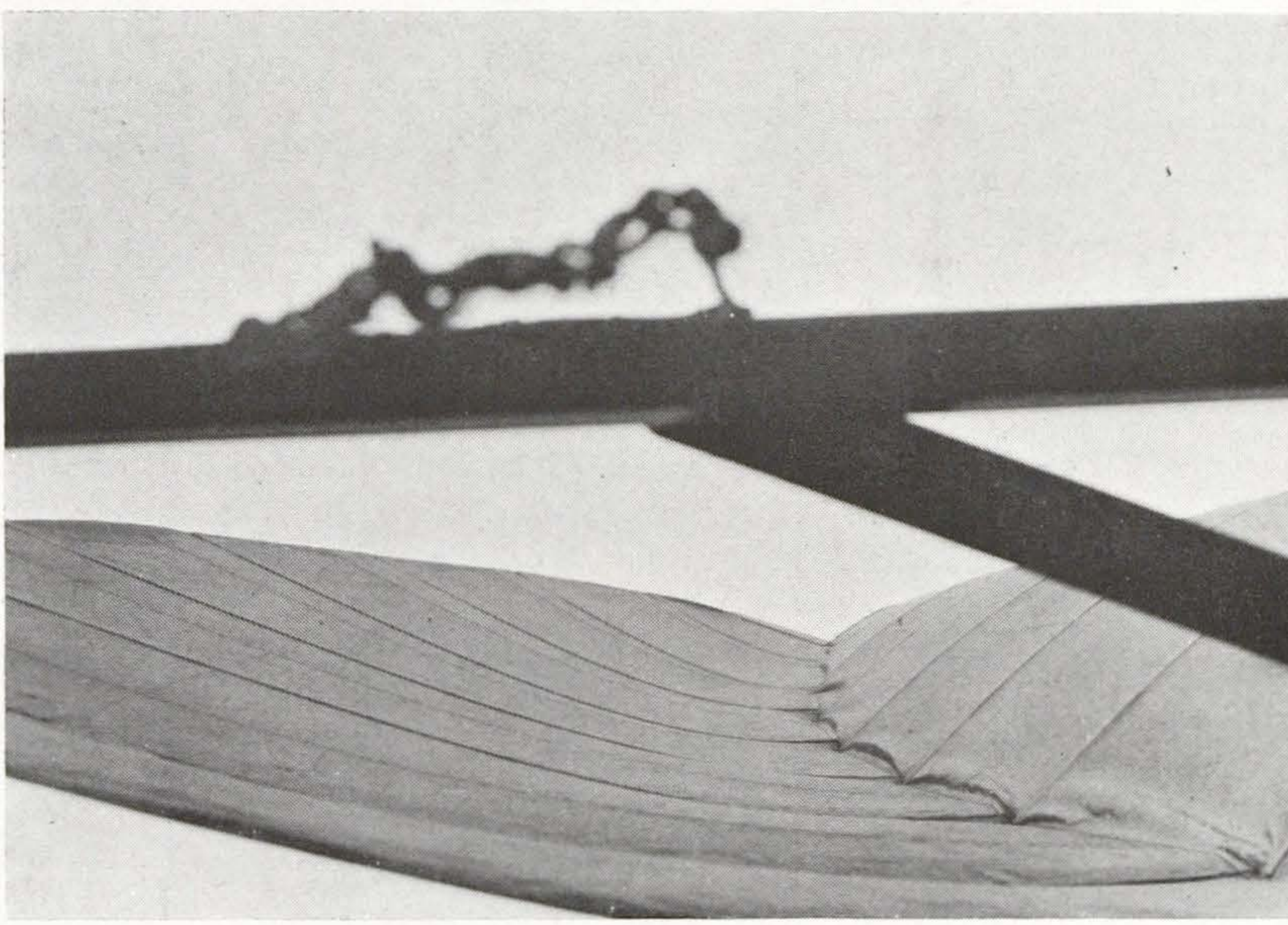


The *Chapman Wingsail*, close hauled

The merits of the shape chosen are that the aerofoil section is the same at all heights (and is I hope chosen to be an optimum!). There is very little twist so the angle of attack is uniform at all heights, and drag is reduced to a minimum. The distribution of area is approximately a semi-ellipse, with an aspect ratio of 3:1. The wing itself has a chord/thickness of 3·8:1, and the single-thickness part of the sail (or to the aircraft designer, the flap) has a chord 1·5 times that of the wing. The draft of the complete sail can be varied from nothing—ie feathered—to a quarter of the total chord.

These proportions are close to the ideal for an aerofoil which is to have a low drag angle when sailing close-hauled (particularly compared with a conventional "draggy" rig), and a high value of drive (lift in an aircraft) when broad reaching or free.

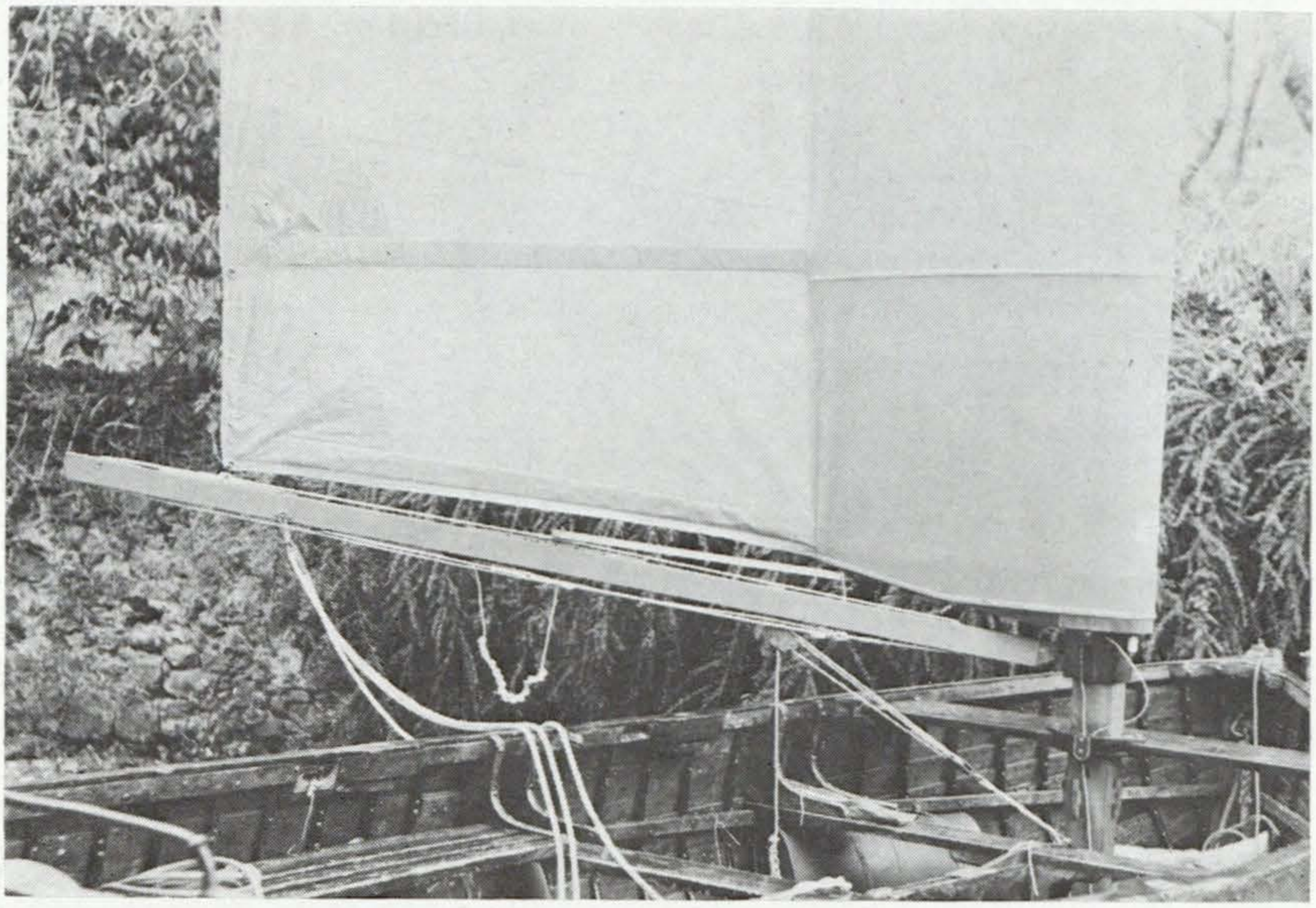
The sail shown in the photos has a lower aspect ratio than the sails used in C Class cats: not surprisingly, as *DISA* is a monohull (RNSA 14 ft dinghy) with a wooden centre plate. Even so, the centre of effort is 18 in higher than it was in the original Bermudan rig; but the area is 12¼ per cent less, and the boat heels, when close-hauled, very much less. As with gliders, increasing the aspect ratio helps to improve the drive/drag ratio, but for aspect ratios above 3:1 the rate of improvement falls off.



The *Chapman Wingsail* from below. Note boom linkage to give a fair curve between the wing and the sail

Draft (or camber or belly or flow) is controlled precisely by ropes and elastic on the boom. A linkage between wing, boom and clew at all settings preserves the fair curve from the wing into the sail. Close hauled a draft/chord ratio of 1:6 seems about right—in apparent winds up to 20 knots—and broad reaching and free the draft is profitably increased to 1:4. The flexibility of the rig allows the sail to preserve a satisfactory shape over the full range of drafts, from 1:4 to fully feathered.

Comparisons of performance based on measurements of apparent wind speed and direction and boat speeds—reduced to give speed made good to windward—and on the results of races, indicate that the 12¼ per cent reduction in sail area (from the Bermudan rig) has reduced speed by about 4 per cent, as an average over all points of sailing and a practical range of windspeeds. If drive is proportional to sail area and $(\text{windspeed})^2$, and boat speed varies



DISA's boom showing camber control mechanism

as the square root of drive, then one might expect a speed reduction of between 9 per cent and 11 per cent. The fact that the speed loss is not so much indicates that the wingsail is more efficient in terms of drive per square foot.

As stated earlier, heeling is less, and as there is only one sail—no jib or spinnaker—handling is easier, though instruments are necessary if one is to sail the rig successfully, quickly.

Only in weight does the rig compare unfavourably with the Bermudan: the wing is 0·49 lb/sq ft compared with 0·43 lb/sq ft. It so happens that the

areas (114 and 130 sq ft) are such that the weights of the two rigs are the same. Modern Bermudan rigs are lighter and compare with manpowered aircraft wings at around 0·3 lb/sq ft. An improvement of 15-20 per cent would be possible using a metal mast and reducing scantlings.

The rig is fairly flexible, both in that the upper part of the sail feathers to spill puffs automatically, and the mast (hollow spruce) bends to help this feature, which makes for comfort at the expense of drive. A metal mast of tapered wall thickness could be stiffer for the same or less weight and improve the drive, with the penalty of more frequent heeling.

Close hauled in 15 knots of apparent wind, gusting to 20 knots, stability is remarkable and I now have no hesitation in cleating the sheet under those conditions.

Instruments which read apparent wind speed and angle, and boat speed, as well as scales to show draft and sail angle to the centreline, have proved invaluable in finding out how best to sail the boat, before racing, and in sailing to best advantage all the time during races. But one can become too dependant on the instruments!

The *Chapman Wingsail*, running. Note instruments forward

Design and construction of the rig is quite straightforward, in particular the lofting and cutting of the single-thickness part of the sail is an entirely straightforward piece of mechanical drawing 'development' work. There is no need to invoke any cunning sailmakers' "rules"! Manufacture is also simple, using spruce, ply, a little GRP, brass strip, terylene and a domestic sewing machine. I suspect a heavier rather than a lighter weight of cloth would be advantageous. Full details of construction of the first version were described in AYRS Journal No. 58. The principles used then still apply, though there have been some minor refinements.

In *DISA* the mast is self-supporting and fully rotatable. A stayed mast would be possible, and on a cruiser the key on the mast could be a track, to take normal sliders if one wanted to hoist a conventional sail in place of a furled wingsail. *DISA's* sail is fitted with reefing of the lower section of the sail only: further sections could be fitted if desired.

The 8 ft model which I made to prove the principle, before making the full-size sail, was on the AYRS stand at the 1971 London Boat Show.

DISA's INSTRUMENTATION

by Commander G. C. Chapman RN

Summary
This article describes the simple instruments used to measure *DISA's* performance (in terms of V_A, V_S (V_B), and $\beta - \lambda$) and to calculate V_T and Vmg on windward courses, and updates the performance figures given for her wingsail—see AYRS No. 58.

Requirements
I have accepted the following limitations on instruments in order to keep down complication and cost—both in time and money.

Restricted Range Of Values
$\beta - \lambda$—wind direction relative to ship's head—is measured from 0° to 50° only, and is accurate to about ½° from 20° to 40°. I have to determine for myself which tack I'm on! V_A—apparent wind speed—is indicated from 4 knots to 30 knots.

Reduced Weather-Proofing
I take my $\beta - \lambda$ and V_A instruments ashore when not sailing. They are therefore exposed to salt water and rain only when actually sailing: also wear is saved by the very reduced usage compared with an ocean racer's sensors which remain at the mast-head all season. However the use of cheap, but strictly unsuitable materials means that despite the forgoing, some maintenance is required.

Increased Size and Drag
The $\beta - \lambda$ sensor needs a 15 in long by 6 in diameter windsock to rotate its potentiometer with adequate sensitivity: the sensor is fitted on a portable

"bowsprit" necessitated because the mast rotates and so masthead fitting is not possible. This windsock and the bowsprit must cause some drag—though by way of bonus the windsock is held well forward in clear air. The anemometer head is 3½ in high by 1¼ in × 1¼ in, with the cups above that, and is larger than most commercial models: even so its drag must be small.

Cost

The wind speed and direction instruments, made using some ex-Government surplus and some new, plus odds-and-ends from my workshop, have cost under £10 in materials and parts.

Water Speed Indicator

My water speed indicator is a Smith's instrument, comprising a simple pitot-tube unit which clips on the transom, and a pressure gauge unit (calibrated in mph and knots, to 10 knots) connected by flexible tube, together with a simple home-made pressure release valve to equalise pressures at the start of a day's sailing. This instrument cost £6·75 in 1957, is fully weather-proofed, and appears to be as accurate and reliable as when new. It remains in the boat on her mooring, the pitot unit is unclipped and stowed inboard when not in use. The meter is permanently mounted under the stern thwart, where it can be seen by the helmsman on either tack.

Wind Speed and Direction Indicators

The two meters are mounted side-by-side in a wooden box, under a perspex cover, arranged so that the box sits on the stern thwart, and the meters are then visible close to the water speed meter. The box contains the electronics and batteries, and houses the anemometer unit and cups when not in use.

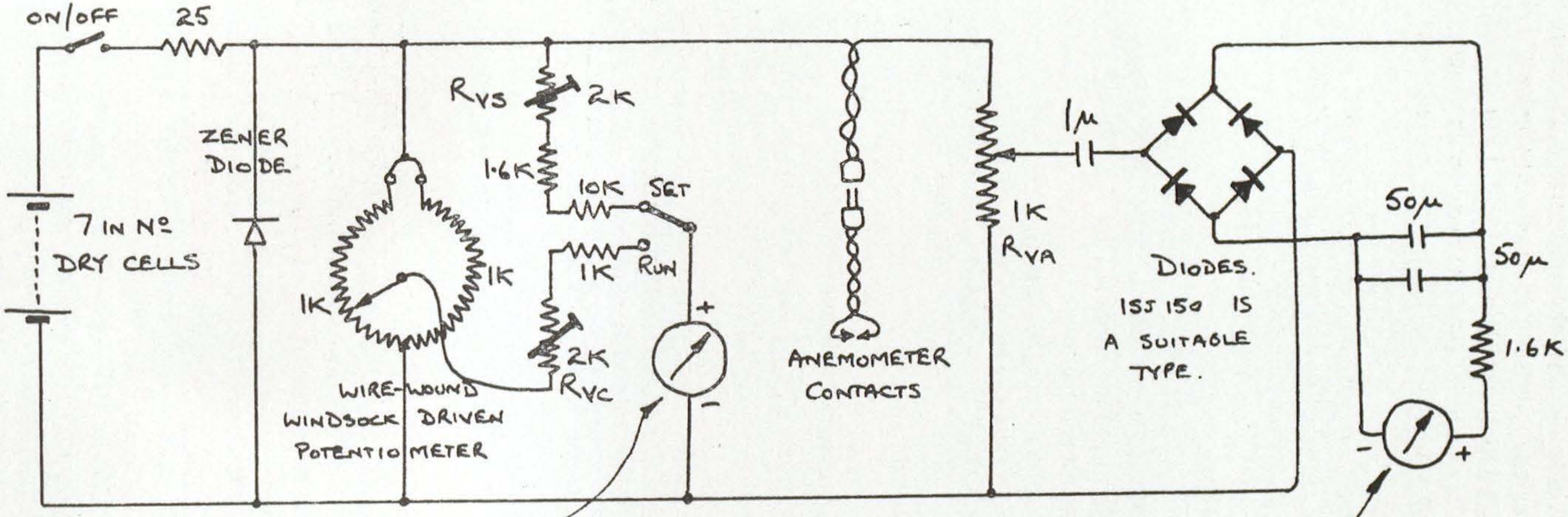
Both indicators use the same electrical power source, seven U2 cells whose total voltage (varying from 10·5 volts for fresh cells to 8·6 volts when exhausted) is controlled by a 25 ohm resistor and a nominal 8·2 volt Zener diode to give a constant output. The exact value is unimportant, what matters is that the Zener keeps it constant. The V_A meter can be used to measure the Zener voltage, as a check that the battery has not run down.

Wind Direction Indicator

The sensor is a wire-wound, centre-tapped, 1,000 ohm plus 1,000 ohm, potentiometer. This had to be dismantled and carefully re-fitted to reduce the friction of the plain bearing and wiper arm sufficiently. The body of the potentiometer is clamped to one disc of ⅛ in paxolin, which can be rotated by a screw-driven eccentric cam for fine zeroising, relative to another paxolin disc which is mounted horizontally at the forward end of the bowsprit. Once aligned, the first disc is clamped to the second by three bolts. A plastic bowl (ex-lemon sqeezer) is bolted on top as a rain cover, and carries a scale (divided 50°-0°-50° in 10° steps), also adjustable. The windsock boss is held to the potentiometer spindle by a set-screw, and is located by a spigot: the sock is removed for transport. Permanently fixed to the spindle is a pointer used for setting-up, using the adjustable scale.

DISA's WIND-SPEED/DIRECTION INDICATOR

(JUNE 1969)



<u>β-λ METER.</u>

CALIBRATED 0° TO 50°
3/4 mA FULL SCALE DEFLECTION
75 OHMS. R_{VS} SET SO METER
READS 30 FOR 8 VOLTS BY ZENER.

<u>V_A METER</u>

CALIBRATED 4 TO 30 KNOTS
3/4 mA FULL SCALE DEFLECTION.

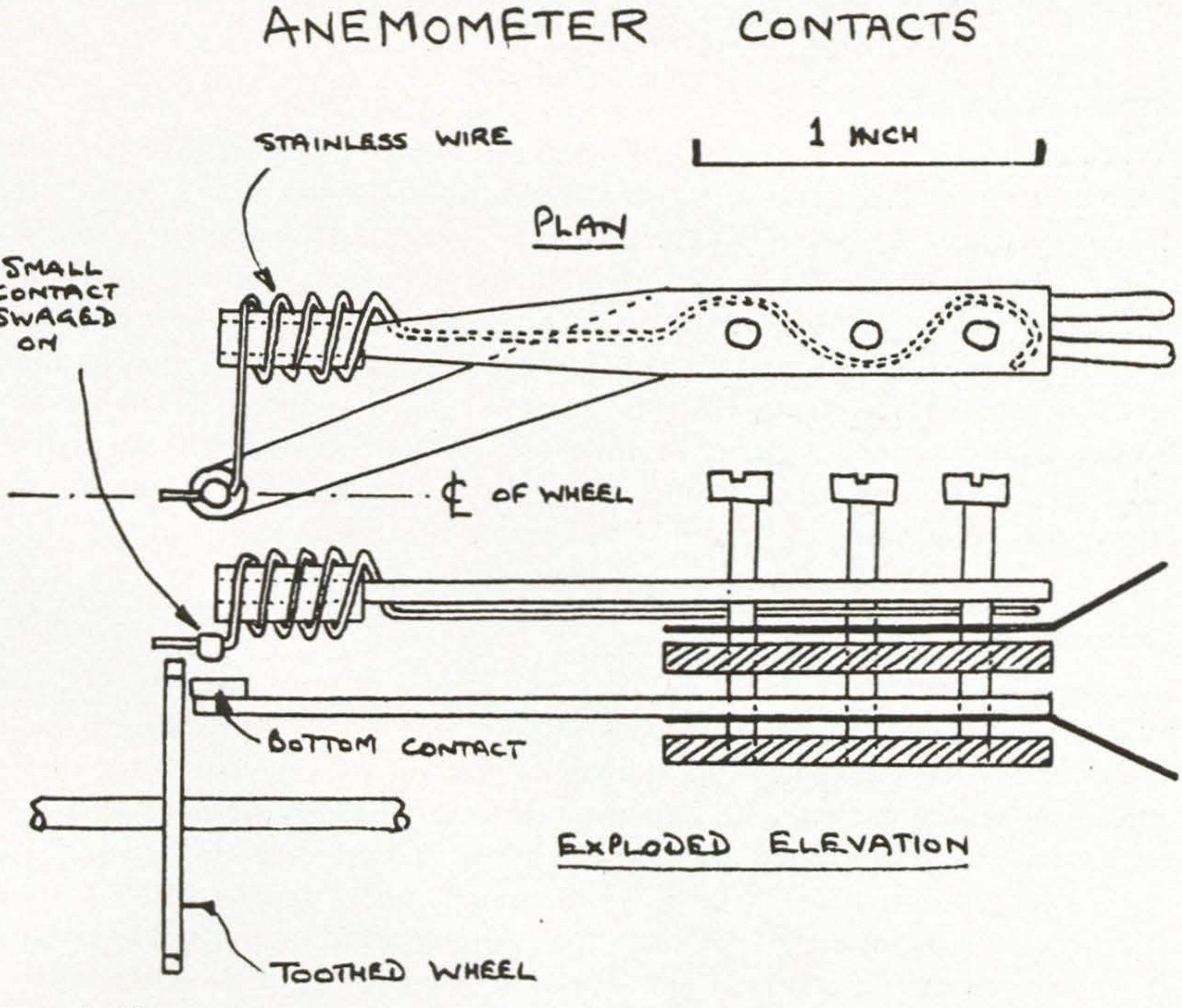
It is prudent, before mounting the potentiometer, to set up a simple rig using a protractor and either an ohmmeter or the final electronics to check, as far as possible, that the response of the potentiometer is in fact linear over the arcs of interest. Mine is sufficiently linear from the centre-tap position (0°) to 130° either way, but from choice the associated meter is driven to full scale at 50°, either way. At greater values of $\beta - \lambda$, the needle remains hard over, but without suffering damage.

The value of the components in the two resistor chains will depend on the Zener voltage, resistance of the potentiometer, and meter current for full scale deflection. In the very simple circuit shown, linearity of response will be affected if a meter is used which draws a current which is a significant proportion of that flowing in the potentiometer.

Setting up is a matter partly of careful mechanical alignment, and partly of electrical adjustment using R_{VC}. Remember also that the meter needle zero can be adjusted, and should read zero when the windsock is central and power is ON.

Wind Speed Indicator

Three half ping-pong balls mounted on wires, emanating from a central boss, drive the unit. The centres of the cups are at 2¾ in radius. The boss is held by a



Notes: 1. Upper contact wire loosely wound on cylinder of insulation, mounted on insulating strip
2. Bottom contact must be mounted on stiff metal arm to eliminate resonnance
3. Assembly fits standard G.P.O. relay contact mounting

set-screw to the top of a 6 in knitting needle shaft, which in turn is supported by two plain bearings (holes in $\frac{1}{16}$ in thick plastic—PTFE or Roulon or Formica) and a needle point at the bottom, resting on plastic. Araldited on the shaft is an eight-toothed formica wheel, about $\frac{5}{8}$ in diameter. This wheel operates a stainless steel wire contact arm which carries a small silver contact, which in turn bears on or is lifted from a fixed, heavier contact. (See sketch). The pulsating voltage thus produced (whose frequency is proportional to rotation speed) is fed through an adjusting potentiometer and a capacitor to a full-wave rectifier (ideally an instrument rectifier made as such) and then through a smoothing circuit to a meter. The values used are a compromise to give adequate sensitivity with the voltage available, and a sufficiently steady reading of the meter at low wind speeds. Care is necessary to ensure that the steel wire does not resonate at higher speeds and give false readings. The unit is made from $\frac{1}{16}$ in sheet alloy, and is bolted to the male half of a two pin plug, pins downwards. It can thus be plugged into a socket fitted into the headboard of the wingsail, before hoisting. The twin flex passes down inside the wing to a similar plug fixed at the wing boom, to which is connected a further socket on the end of a flex from the meter box. Because this simple make-and-break device is liable to be unreliable I plan to make an improved version in which the two poles of a rotating magnet will operate three reed relays (magnetic reed contacts in evacuated glass tubes) giving six pulses per revolution.

Anemometer Facts

A cup unit which is frictionless will rotate in wind at a speed such that the force exerted by the wind on the concave cup (going downwind) equals the drag experienced by the convex cup (going upwind). This applies regardless of the number of cups—usually three, but may be four. The circumferential cup speed (taken at the mean radius) for hemispherical cups will be 1/2·75 times the wind speed, and for conical cups 1/3 times wind speed. For a radius of $2\frac{3}{4}$ in, the former gives 25·5 rpm per knot of wind speed. However any friction will reduce this speed, and the effect will not necessarily be linear with wind speed, or constant with time. Naturally, more cups will generate more output torque, so four cups should be better in this respect than three.

Calibration

It is therefore necessary to ensure that the cup unit is as free as possible, and by choosing stable materials, that its friction will not increase: and then to calibrate it. If you have no wind tunnel, calibrate a car's speedometer (using milestones and a watch), and then using the car to carry the anemometer—on a windless day—calibrate the anemometer. To engrave the scale of the meter itself you need the curve of wind speed in knots against meter current in mA: from this one can make a new meter dial marked in knots. The resistor R_{VA} in the circuit diagram is used to set the meter to full scale at the desired windspeed (I chose 30 knots, achieved at an indicated car speed of 36 mph): calibration by travelling at various intermediate speeds and reading mA must follow, while the dial still shows mA. My meter scale of knots is more open between 5 and 15 knots than between 15 and 30: this is an advantage as most of my sailing is done in apparent windspeeds below 15 knots.

It is instructive after calibration to use a variable speed motor to rotate the shaft and wheel, and plot the meter current (in mA) against rpm: and to derive and plot the cup's rpm against actual windspeed in knots. The former will probably not be a straight line: nor will the latter, due to friction and possibly due to the onset on resonance effects from the steel contact wire; and the theoretical rpm per knot will not be achieved. Periodic check calibration is necessary to confirm that there has been no change in characteristics.

Leeway Angle (λ)

Generally, leeway angle when close-hauled remains within a degree or two of a single value. This can be determined by the use of a simple protractor calibrated to 10°, towing a string with a drogue on the end. I used a practice golf-ball, slightly weighted, which towed in a stable manner. Having established λ at 5°, this is the value I always use.

Sail Angle (δm)

The principle variable in the boat is the sail angle to the centre line. A rotating mast lends itself to ease of reading as a scale of degrees can be fitted to the mast. My wing sail additionally requires a scale to read the boom angle relative to the mast—a measure of draft—in order completely to read the sail setting—assuming the downhaul (kicking strap) is always set at a uniform tension.

Taking Readings

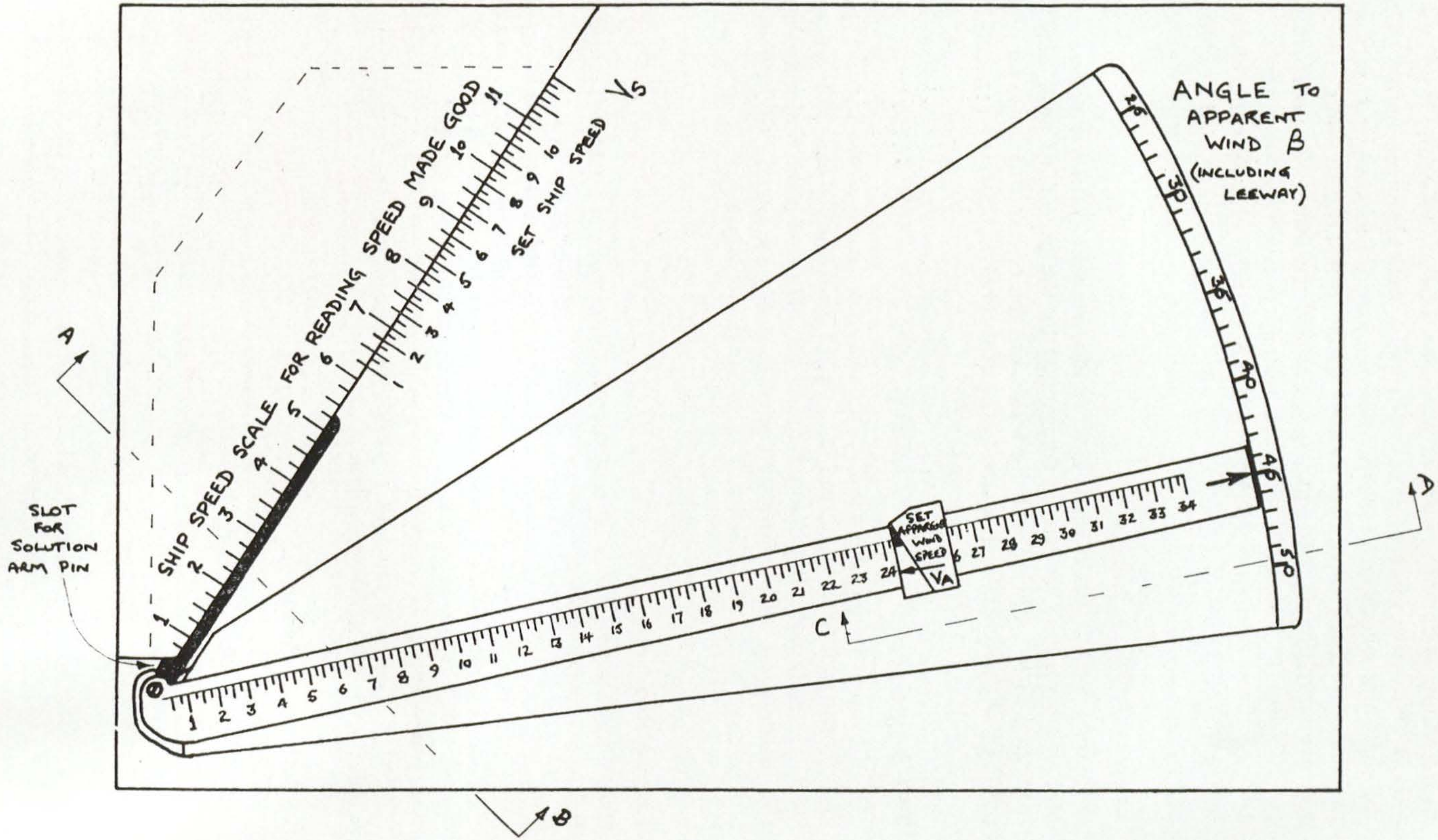
Once I have set the sail to a particular setting, I get the boat sailing in what I feel is a satisfactory manner, to windward. When conditions appear to be stable—and it is variation in true wind speed which introduces most variation—I read the three meters and write down the figures. An hour's sailing will produce 30 to 40 readings, divided between port and starboard tacks, perhaps spread over a range of values of $\beta - \lambda$, or whatever it is desired particularly to investigate: and of course over the range of true wind speed that prevailed. With experience one can take readings more accurately (honestly?) and take readings directed to investigating some particular aspect.

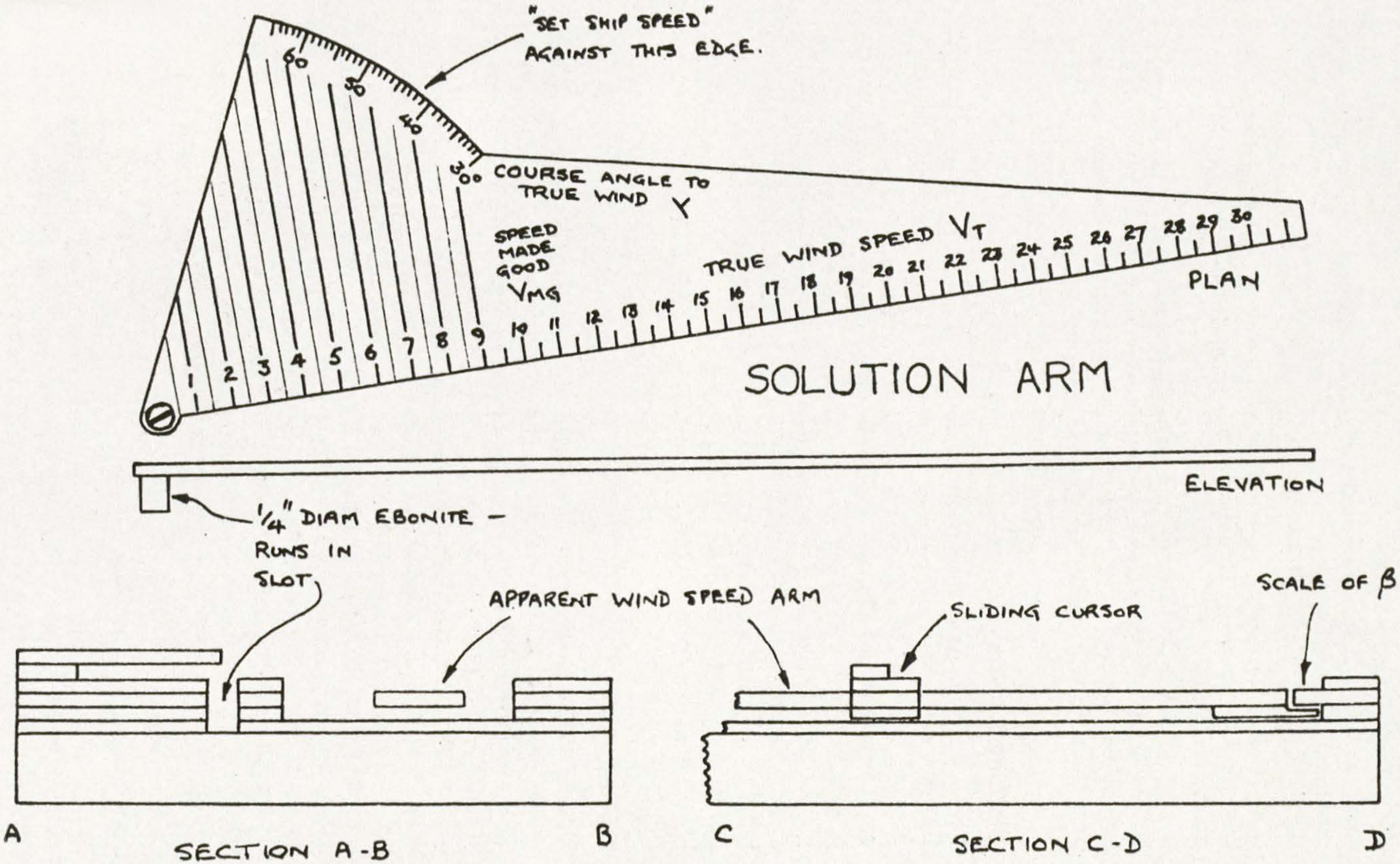
Reduction of Results

A relative velocity triangle solver is needed to produce V_T and Vmg from the readings of V_A, V_S (V_B) and $\beta - \lambda$. The diagram shows my gadget for doing this. The various quantities are reproduced in their correct relationship (though always on starboard tack) except that Vmg is read off from a position which arises from the use, in the geometry of the gadget, of a similar but reversed triangle.

In use, the "Solution Arm" (whose $\frac{1}{4}$ in pin runs in a slot) is set for ship speed V_S (V_B). The "Apparent Wind Speed Arm" is rotated for β (the leeway angle λ—5° in *DISA's* case—having been added to $\beta - \lambda$), and the sliding

V_T AND V_{MG} CALCULATOR. NOTE: SOLUTION ARM OMITTED




"SET SHIP SPEED" AGAINST THIS EDGE.
60
50
40
30
0
COURSE ANGLE TO TRUE WIND γ
SPEED MADE GOOD V_{MG}
TRUE WIND SPEED V_T
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
PLAN
SOLUTION ARM
ELEVATION
1/4" DIAM EBONITE – RUNS IN SLOT
APPARENT WIND SPEED ARM
SLIDING CURSOR
SCALE OF β
A
B
SECTION A-B
C
D
SECTION C-D

cursor on the arm is set for V_A. The Solution Arm is then *rotated* until the True Wind Speed Scale touches the sliding cursor on the V_A arm. At this point (in time and space) read off V_T. Speed made good to windward, Vmg, is achieved by a trick—the reversed or folded-over triangle. Enter the "Ship Speed Scale for reading Vmg" with V_S, and see where the particular V_S (V_B) cuts the scale of Vmg on the Solution Arm. (Note that on the latter the scales of Vmg and V_T are in fact coincident.) Finally read off γ, the course angle to the true wind.

The instrument is made of six layers of Formica, suitably cut and marked, araldited together and on to a base of ply. The range of readings on each scale was chosen to suit a dinghy and will cover most yachts, the scale used is 1 in to 4 units of speed: overall size is 10 in by 6½ in.

Plotting Results

So far I have concentrated on measurement of windward performance. My figures are therefore suitable only for a plot of V_T against Vmg, rather than a part of a polar curve. However to assist in finding the best $\beta - \lambda$, it helps to plot the points, not as dots or crosses, but as figures, eg 32, to indicate the $\beta - \lambda$, and in red or green to indicate tack. At the time of writing I have plotted some 150 readings, mostly for wind speeds between 8 and 12 knots, and with a few up to 15 knots. There is a considerable scatter, but the points indicate that it is possible to sail the boat to windward faster than was apparent in 1966 (AYRS No. 58, page 65), at any rate above $V_T = 7$ knots, though in lower wind speeds performance seems to have deteriorated!

Optimum

Plotting Vmg against $\beta - \lambda$ at different V_T's indicates the optimum $\beta - \lambda$, which for *DISA* between 8 and 12 knots of V_T is around 31°. Taking this as the optimum over the whole range, and using the line for "best performance" on the V_T/Vmg plot, I have plotted a line giving V_A against V_S (V_B) which becomes the "target performance line". For use afloat this is expressed as a table of V_S (V_B) for every half-knot of V_A. In practice, when sailing close-hauled, I sail for $\beta - \lambda = 31°$: then read V_A on the meter: then see if V_S (V_B) is actually what the target table says it should be. If my actual V_S is below the target, I'm doing something wrong: if it is above, then I should re-calibrate the boat! In practice this procedure seems to work, though the few races I have sailed in have lacked sufficient true windward legs to give full confirmation. What is interesting is that when using the instruments to monitor my performance, my other senses of how the boat is going improve.

Continued Improvement

There is of course no reason why one should not take readings while racing, and so increase one's knowledge of the boat's potential: in an ocean racer with instruments, and legs of tens of miles, the opportunities for establishing reliable figures are excellent!

Wing Sail Assessment

During the 1969 season I sailed in six races in a dinghy handicap class, in order to try and establish a Portsmouth Yardstick Number for *DISA* with her wingsail. The other competitors—usually about 10 of them—ranged from a *Merlin-Rocket* (91) through *Bosuns* (101) to *Mirrors* (122), and the helmsmen were of average club standard. By taking the average of the *other* competitors' *corrected* times, and relating it to *DISA's elapsed* time, one obtains *DISA's* Portsmouth Number. This assumes that the average of all the others is a fair average, and that *DISA's* performance was average, ie when corrected it would put her in the middle of the fleet on corrected time. The Portsmouth Numbers obtained in this manner in the six races were:—127, 123, 121, 119·5, 121 and 121. The overall mean was 121. That the true figure is around 121 was confirmed by the several neck-and-neck battles with a *Mirror* (122) sailed by a helmsman of comparable—or perhaps greater—skill. The wing sail has 103 sq ft compared with the normal RNSA's 130 sq ft, and a Portsmouth Number of 115. So a 21 per cent reduction in sail area is matched by a 6 per cent increase in elapsed time for a given distance, ie a 5·75 per cent reduction in *speed*. Perhaps one of the pundits can say how many percent more effective the wingsail is than the bermudan?

THE DEVELOPMENT OF A DINGHY

by R. R. A. Bratt

North End Works, Millers Close, Dorchester, Dorset

Although I had had a boat since the war I did not get sailing and racing regularly until I joined the Rangoon Sailing Club in 1953. This recrystallized my former interests in aeronautics, gliding and so on. Yacht sails seemed inefficient in the light of current aerodynamic knowledge, and I started giving them serious thought. It was then that I first sketched a sail with the boom removed from the bottom of the sail. I gave superficial thought to a windmill driving a propeller, and carried out quite prolonged work on a self trimming sail which was effectively a glider freely pivoted at the top of a mast. This latter was stimulated by a sketch of Hugh Barkla's though I am not aware of any precedent foı the other thoughts. In 1956 I thought that the high boom sail would be the most economical line to develop and I wrote a letter about it which was published in YACHTS and YACHTING. My ideas lay fallow though until 1963 when an eight footer was built with a high boom rig. A number of boats and variations of the rig followed.

In 1965 the IYRU held single handed dinghy trials in Weymouth. I entered *WHIPPET III*. It was rather impudent and the result was the ignominious exposure of an inappropriate hull design. It was very good for the soul, though, and I immediately started designing what should be a decent hull. I studied hull design vigorously while successively redrafting the hull shape. The thirteenth shape became *SHOOTING STAR I*. While this was being built and sailed, the process of working up the shape continued. Shape 20 was in due course built as *SHOOTING STAR II*.

It has been evident all along that our sail shape was justified. By winning a large proportion of her races in 1969 and in other ways *SHOOTING STAR II* has indicated that we have now got close to a very good hull design.

A principle point requiring attention was that I had assumed that a more efficient sail would generate more thrust with less side force, and could use a smaller than normal centre board. That may be correct up to a point but we found ourselves sailing very fast and pointing indifferently. On increasing the sail area this worsened and it was immediately clear that it would be necessary to maintain a normal sail to fin area ratio.

Meanwhile work has proceeded on *SHOOTING STAR III* and *IV* designs. *SHOOTING STAR III* was intended as a more roomy stable family sort of boat. When it became clear that *SS II* was a very satisfactory performer with good stability it was decided to merely refine it a bit and give *SS III* a miss for the time being. By further small changes in the lines and sections, the wetted area was further reduced while increasing the effective water line length. The initial stability was slightly reduced but a little more freeboard increased the extreme stability. Four years of redrafting and test have produced a shape of, one hopes and believes, some subtlety. A general description follows.

SHOOTING STAR

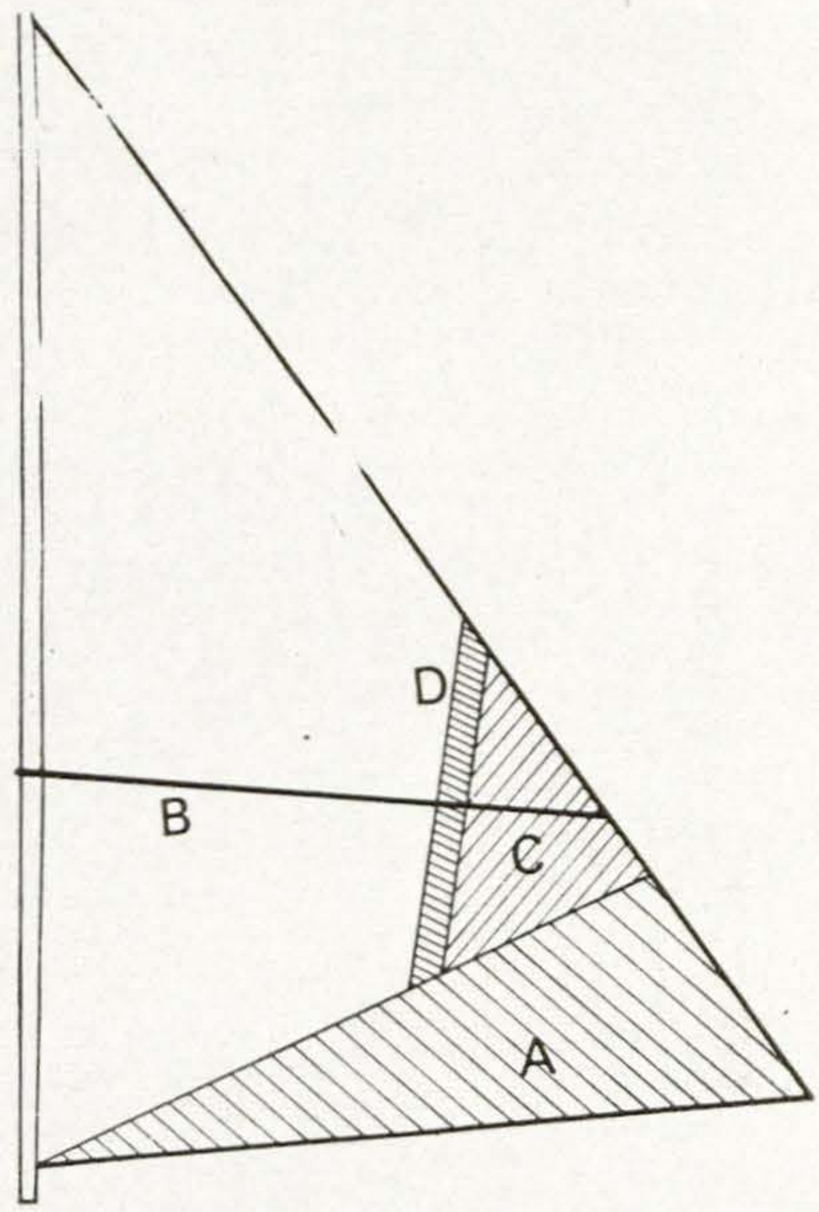
by R. R. A. Bratt

North End Works, Millers Close, Dorchester, Dorset.

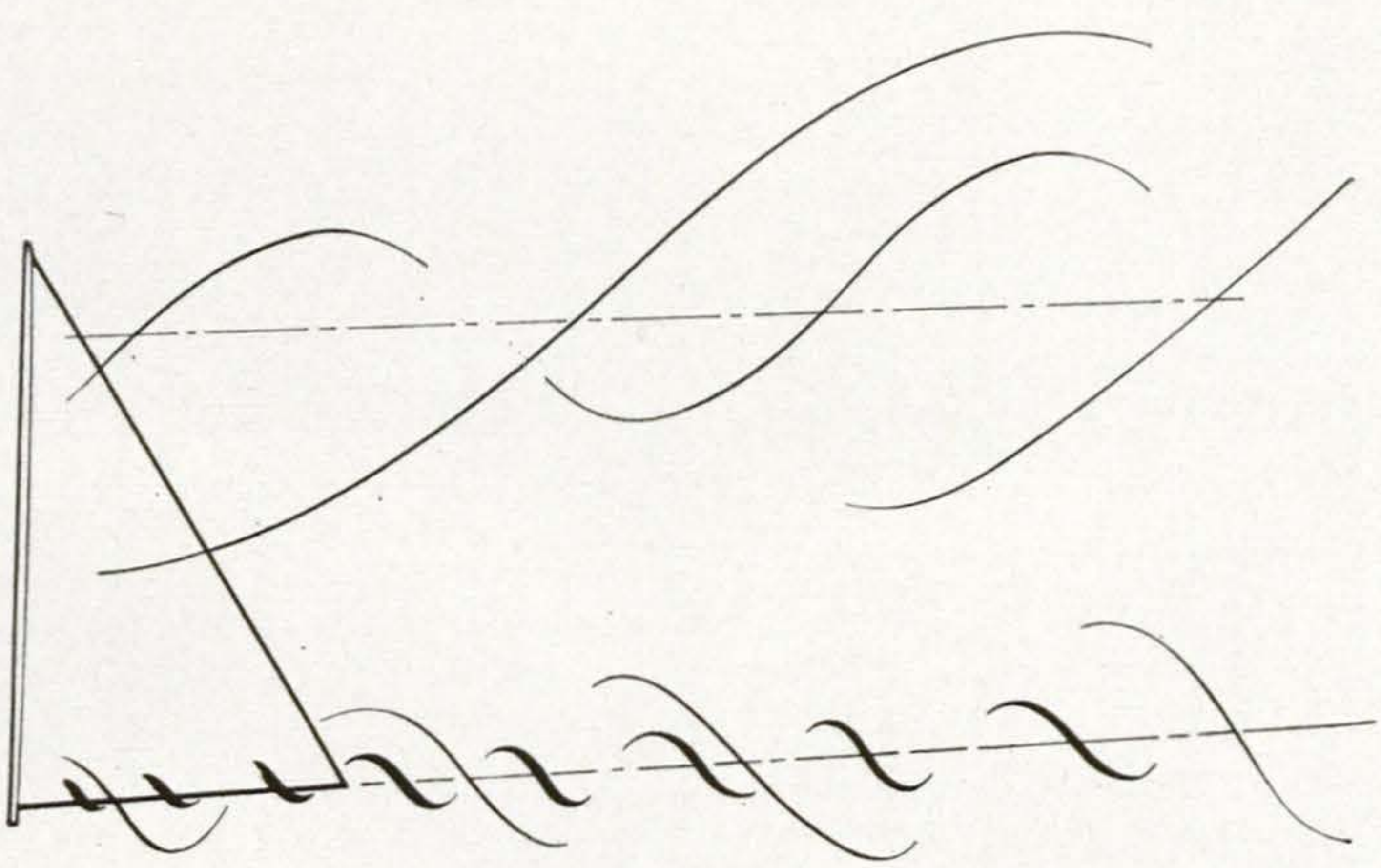
	Design II	*Design IV*
Length	16 ft	16 ft
Beam	5 ft	5 ft
Mast, elliptical trailing edge	20 ft 6 in × 10 in	23 ft × 5 in
Sail	113 sq ft	130 sq ft
Hull	Plywood	GRP
Approximate weight	230 lbs	Under 200 lbs

The high-boom rig used on this boat enables the sail to taper towards both tips. Not only does this reduce the induced drag, but a large triangle of sail in the region that would normally be the clew is omitted. This is the triangle which in the conventional boom-at-the-bottom rig lies almost fore and aft, ill disposed for driving the boat, having high aerodynamic drag of its own and increasing the drag of the centre board. In addition to its inherently better shape, our high boom sail is fitted with a balanced vertical batten which ensures that some 6 ft in the vital widest central portion of the sail can be completely free of twist. The twist of a conventional yacht sail means that when a horizontal element of the middle of sail, perhaps a third of the way up is at the right angle to the wind, (angle of incidence,) the sail above is at progressively too fine an angle while the bottom of the sail is at too coarse an angle. The boom at the bottom is the centre of an energy wasting vortex (or vortices perhaps when the angle is large), which it has been our concern to reduce.

Another feature of this extremely simple rig is that the boom is attached to the front of the mast. This enables the mast to rotate independently of the



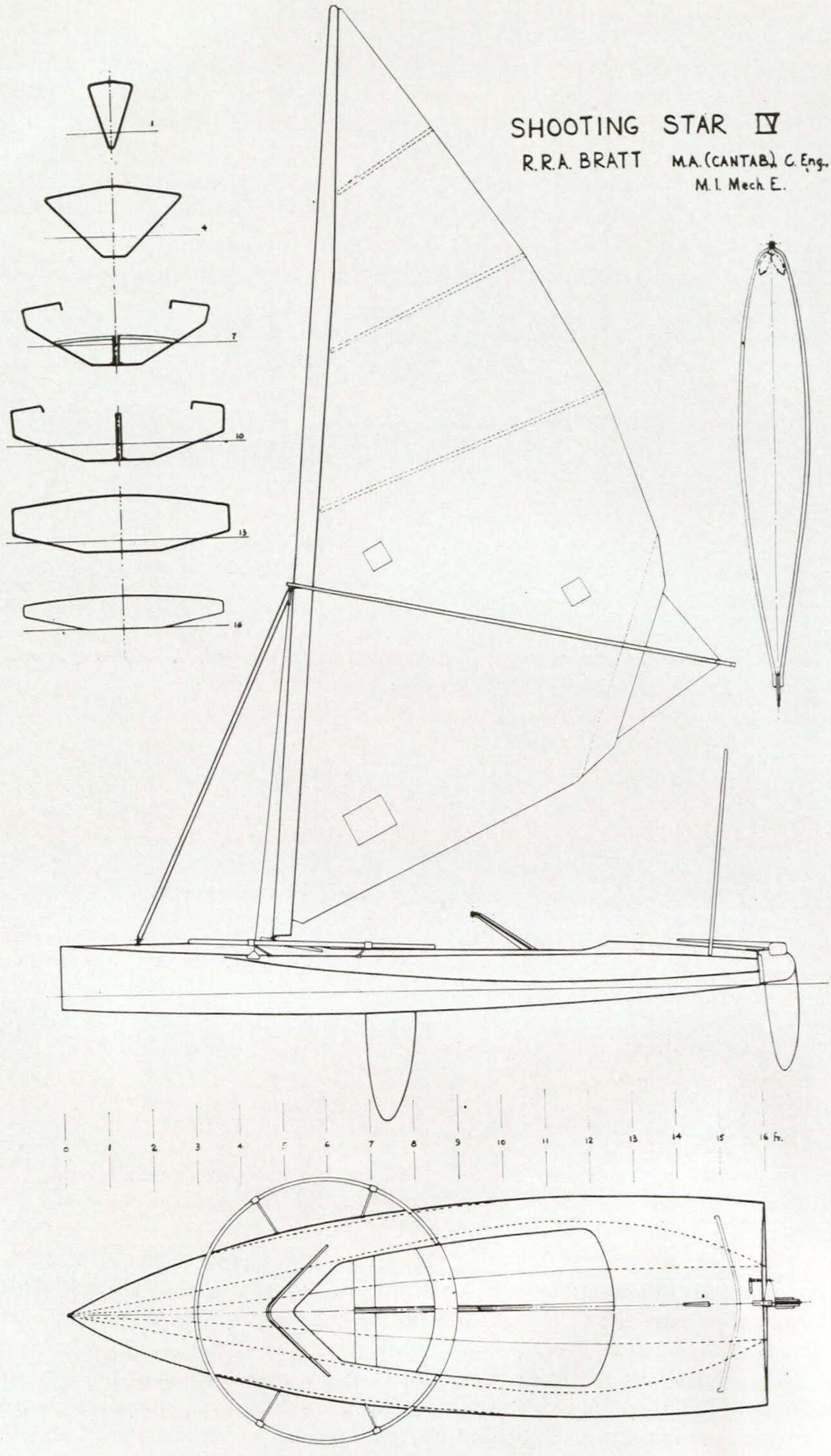
How Shooting Star Sail gets its shape. A. High drag triangle removed. B. Position of boom. C. Further triangle removed. D. Balanced battern.



Vortices developed by a triangular sail

boom and to fair with the sail on the outside, convex side, of the sail. This largely eliminates the turbulence behind the mast on the side where it is least desirable.

Original reasons for using glass fibre for the mast included difficulty in obtaining and handling alternative materials. However having taken the plunge and with the initial pitfalls behind us it has proved an ideal material. It has


SHOOTING STAR IV
R.R.A. BRATT M.A. (CANTAB.) C. Eng.
M.I. Mech E.
1
4
7
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16
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16 Ft.

strength comparable with the best aluminium alloys but only half the density. It can be moulded thinner than aluminium can be extruded. It can be continuously varied in thickness and section, and it is not necessary to use excessive material where it is not needed. The reduced weight aloft makes for greater dynamic stability, and makes the mast weight less prone to take control when large angles of heel accidentally occur.

Recovery from capsize is easy. The hull also tends to align itself better with the wind and that distressing tendency for wind and momentum to capsize again the other side is minimised.

Because the mast is strong, external bracing is not needed other than the strut and shrouds. For the same reason these can be kept short which reduces windage and interference with the sail.

SHOOTING STAR's hull is conventional in so far as it is narrow forward and flat aft. We think, and hope, that by paying meticulous respect to the principles affecting hull design we have added a mite to the development of this type of hull. So far as we know this is the first sailing dinghy to make use of a bulbous bow. It is necessary to add that we had feared that the deep running bow might make the boat slow to go about; but longtitudinal balance (round the vertical axis) and other considerations have a bigger bearing on this and it does not seem to have any adverse effects. All dinghies can adjust their underwater shape by trimming bow or stern down, but the deep bow on *SHOOTING STAR* emphasises the benefits that can follow from changing trim: maximum effective water line and low wetted area at low or medium speeds: broad short wetted area at high speeds and when maximum stability is required. In the latter circumstance the bow runs clear of the water.

Running dead before the wind *SHOOTING STAR's* sail shape loses its advantage. All sails are then just parachutes. It is in this circumstance that a prototype with a small sail demonstrated its ability to hold or overtake many bigger yachts with spinnakers. This is an interesting acquittal of the hull shape in its bow immersed trim.

To make full use of the flat stern sections when maximum stability is required the tiller has been arranged so that the helmsman can pass aft of it when gybing.

One of *SHOOTING STAR's* innovations is the 6 ft diameter trapezing circle. Besides enabling the crew to place his weight further outboard than would otherwise be possible, he can stand where he wishes without being tipped off balance by the alignment of the gun'l relative to the mast.

The technique of sailing *SHOOTING STAR* is notably different to conventional dinghies. The fact that the sail is largely free of twist means that advantage can be taken of the greater wind loading that can be obtained at angles of incidence close to the stall. Stalling the sail is accompanied by a severe drop in performance; but the reflex to sail at a maximum angle, just below it, is quite quickly developed.

These notes were written in 1969. Various changes have been made in the design, and development is still continuing. The rudder and centreboard are now larger. Various masts have been made all with continuously curved trailing edges. The current mast is 7½ in wide.

Letter from: Wilhelm Prölss, 2 Hamburg 62, Wildermuthring 40

9th March, 1970

Dear Mr. Morwood,

A friend of mine—Dipl.-Ing. Nöldechen—has worked out a "Segelflügel" ('Sail Wing') especially for simple handling on small boats, and—as I am convinced—incorporating advanced performance characteristics. I am authorized to send you some photographs giving you a first impression.

'The 'Nöldchen squaresail', early version

The 'Nöldchen squaresail', developed version

The sail on the canoe shows the very first trials, that on the dinghy, a second and more advanced solution. Of course, the mast is turnable and pivoted. Synthetics should be used to the highest possible extent, saving weight, friction, costs and other headaches. Properly manufactured, this type of rig should provide even for small boats the advantages postulated by *DYNARIG*.

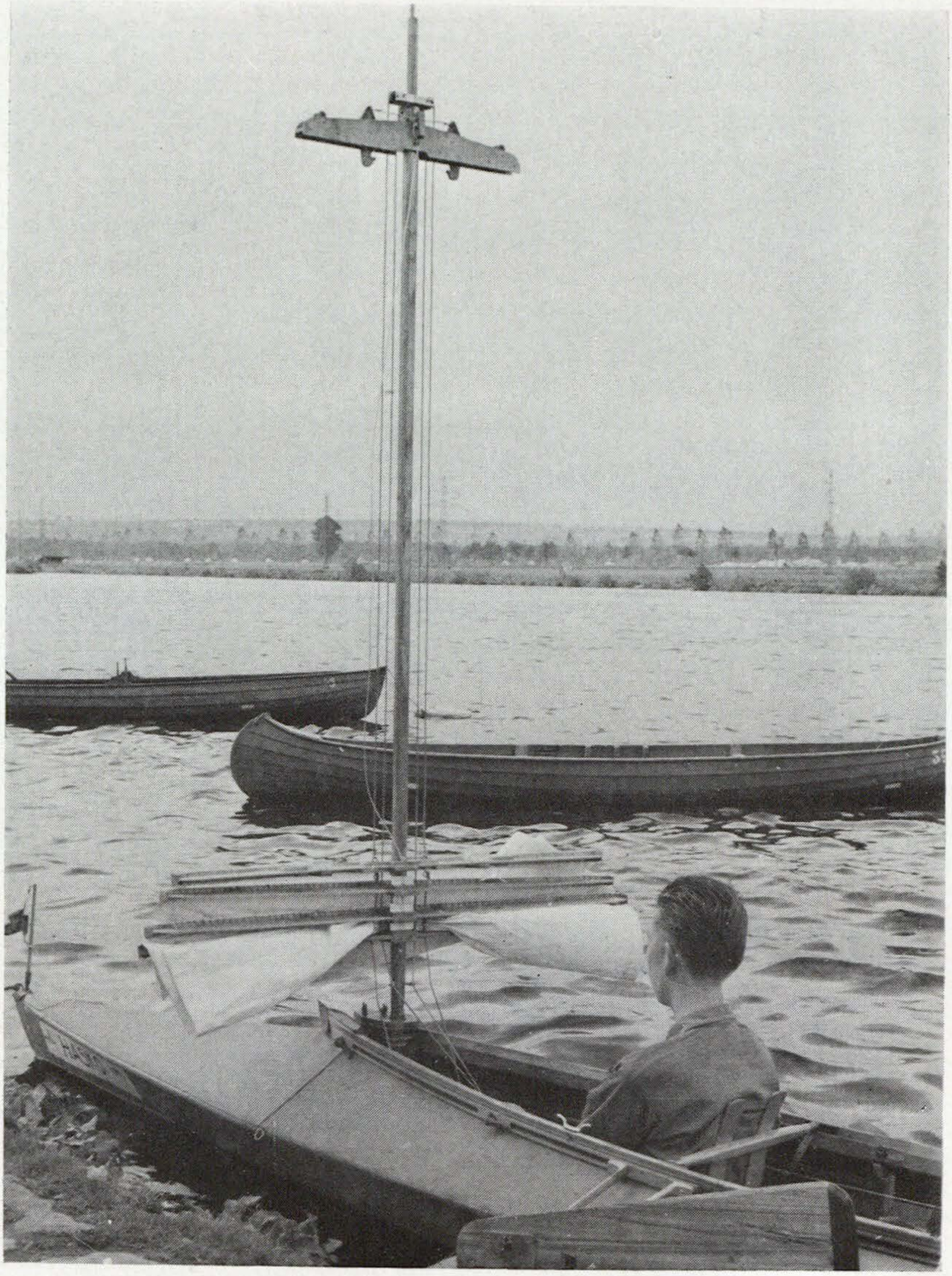
Dipl.-Ing. Nöldechen is a skilled craftsman, too, but retired already and handicapped badly by a severe leg fracture. Thus he would welcome somebody willing and able to do the next step during this season, using a boat of convenient size.

Your *Retirement Yacht*, having two "Sail Wings" (without any fore-and-aft sails) and accommodation between those masts, may well be the right answer.

Yours sincerely,

Wilhelm Prölss.

Dipl.-Ing. W. Nöldechen, 8751 Kleinwallstadt, Unterfeldstr. 5, Germany.



The 'Nöldchen squaresail', early version, lowered

Letter from: Wilhelm Prölss,

2 Hamburg 62, Wildermuthring 40
6th January, 1970

Dear Mr. Morwood,

By courtesy of Messrs. Michael Basche and Dr.-Ing. Peter Boese AYRS publication No. 70, came to my hands containing not only a translation of the extract in "Schiff und Hafen" of my paper, presented to Schiffbautechnische

Gesellschaft, but giving interesting ideas and calculations, too, in the articles beginning on pages 33, 56, 58, 59, 67 and 74, respectively.

I am glad there was only one small error in the translation: page 55 para 6 stands "Fuel and sails—costs about same" for ". . . Effektivkosten". The correct meaning of the latter is "real (effective) costs" are based on columns in diagram Fig. 13. So costs are not "about same", but related about 16 to 7 each to other.

On the other hand, I feel that there is a more serious misunderstanding of curves and figures, followed by misleading deductions, in *CUTTY SARK* and *DYNASCHIFF*. May I explain this more in detail:

Performance Figures Of CUTTY SARK and of DYNASCHIFF

". . . according to the polar curve" (vector diagram page 53) *DYNASCHIFF* will sail close-hauled not 45°, but 25° β angle. That is better than 28° with *CUTTY SARK*. And *DYNASCHIFF* doing 8 knots at 110° γ angle, and 4 knots at 55° γ angle, in a 5 knots wind, means 1·6 and 0·8 times, respectively, the speed of the true wind. Sailing close-hauled at 30° to 35° β means for *DYNASCHIFF* already the best figures Vmg against the wind (right hand side of diagram Fig. 11 page 53 AYRS, Fig. 17 page 46 special print Proelss).

CUTTY SARK doing "on many occasions 14 knots on a bow line" is, for me, an expression not enough precise. On which Beaufort force, what conditions of seaway and deadweight? How were the observations made? Are "could sail within 5 points from the wind" (ie 56°) and "sailing close-hauled" equivalent terms? For instance, *DYNASCHIFF* will do in a 20 knots (Beaufort 5) wind about 6 knots at 48° γ, 25° β; 10 knots at 56° γ, 33° β; 13 knots at 70° γ, 43° β; and 16·5 knots at 115° γ, 70° β.

The figures and diagrams for *DYNASCHIFF* were evaluated and established during 5 years wind tunnel trials. They incorporate seaway and leeway equivalent to the wind forces, and they are valid for the fully laden ship (*Mariner* type hull, 0·75 bloc coefficient δ). They are good in line, too, with the theories developed by Edmond Bruce in "Speed made good against wind".

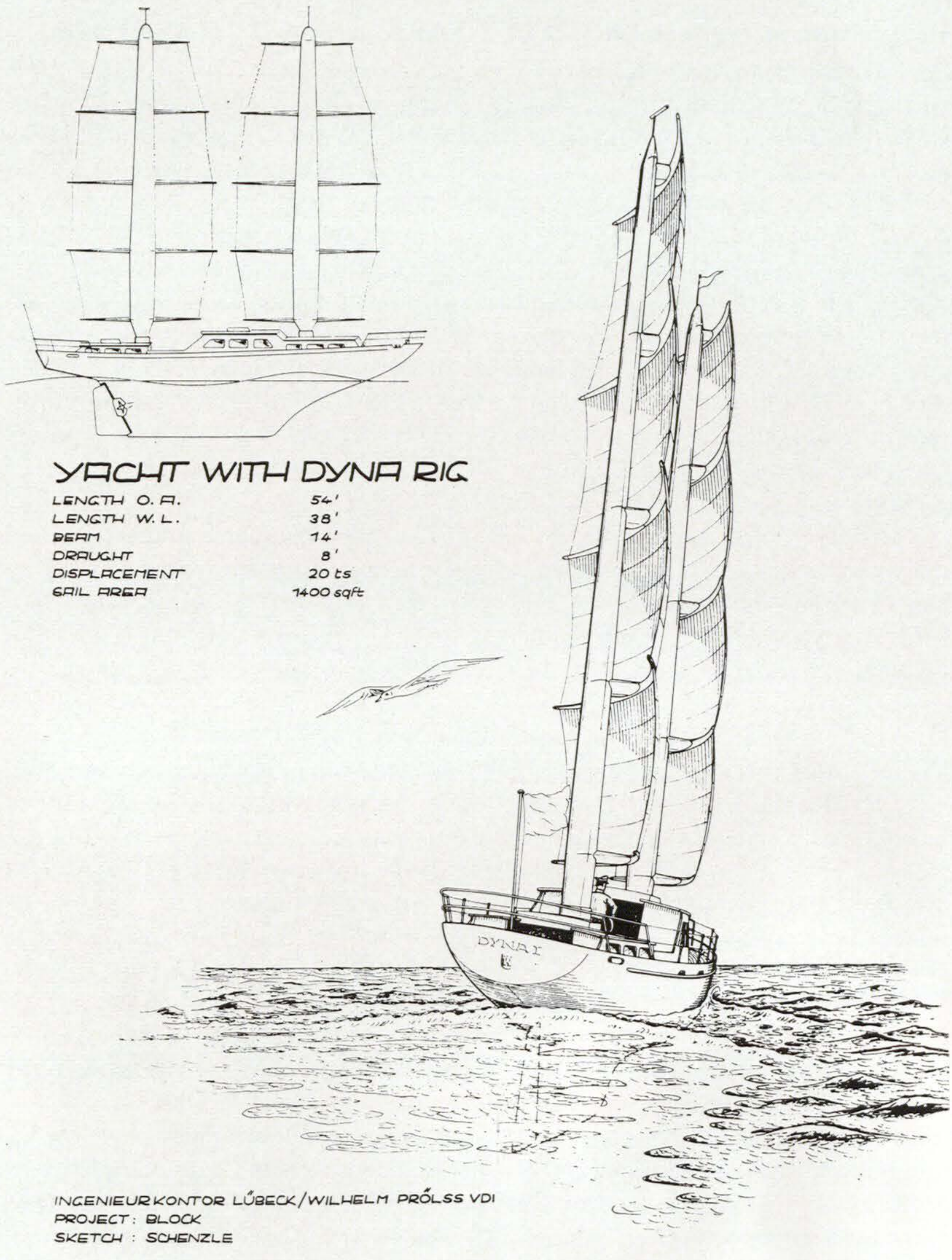
Drive Per Sail Area Unit (Specific Forces and Power)

There stands on page 58 paragraph 3 "more drive for each unit of sail area *CUTTY SARK* . . .". I'd just like to ask, on what figures that sentence is based? Such figures are derived, eg, from genuine polar curves of sails or rig. As far as I am informed, polar curves do not exist for *CUTTY SARK*, and they were evaluated and established for square riggers first time in the world by B. Wagner. Results are concentrated in his "Fahrtgeschwindigkeitsrechnung für Segelschiffe" (Report No. 132 of Hamburg Institut für Schiffbau). Enclosed you will find a special print out of Jahrbuch der Schiffbautechnischen Gesellschaft, Volume 61/1967, and—for better comparison—a special print of my paper, too. (Your readers may find the "Jahrbuch" in every adequate library, worldwide.)

Two model ships were constructed, one fourmasted barque type *PAMIR*, and one six-masted *DYNASCHIFF* (Fig. 4). The polars of those complete rigs are presented as forces per sail area unit in Fig. 5, and they are in average more than twice for *DYNASCHIFF* against the barque!

Combining those unit forces with effective sail area, hull polars and other coefficients, programming them and feeding into a computer—as Wagner did—delivers the speed curves, as given in the vector diagrammes Fig. 11. Again, they are for *DYNASCHIFF* far in excess as compared with the barque, especially with low and medium Beaufort grades, depending on the different bloc coefficients $\delta = 0{\cdot}75$ and $0{\cdot}69$, respectively.

What now about the *CUTTY SARK* figures? Their hull was finer even than *PAMIR's* hull, sail efficiency also better than with *PAMIR* (better aspect



ratio for each single sail, more light wind sails) but by far inferior to *DYNASCHIFF* on the other hand, *CUTTY SARK* had a waterline length of only about 60 m against 96 m for *PAMIR* and 150 m for *DYNASCHIFF*. So one could guess *CUTTY SARK's* speed figures laying between *PAMIR* and *DYNASCHIFF* generally biasing to *PAMIR*.

DYNASCHIFF was conceived as a sturdy bulk carrier with minimum expense for sails and rig, delivering maximum thrust, but with a small auxiliary drive for calms and very light winds.

The Arguments For The "Ship" Rig Yacht

It was just a matter of course, to check the properties and capabilities of a *Dyna* yacht against those of a sloop or yawl: the single mast performance of *Dyna* rig was near the sloop rig performance and too promising to be neglected. Details you may find in the enclosed Discussion of my paper.
Points for the *Dyna Yacht* are:

a Generally better Ccross, less Cdrag as compared with conventional square rigs, depending on the aerodynamically correct shape of pole, yards and airfoil.

b In light winds, better reach of upper wind by more widespread upper sail area.

c In a gale, hove-to even without canvas, the bare pole giving residual thrust but low drag.

d Windward excellent Ccross/Cdrag-ratio

e Running better spread of sails, no decaying of aerodynamic efficiency even when heavily rolling.

f Tacking and sail handling are one-hand job

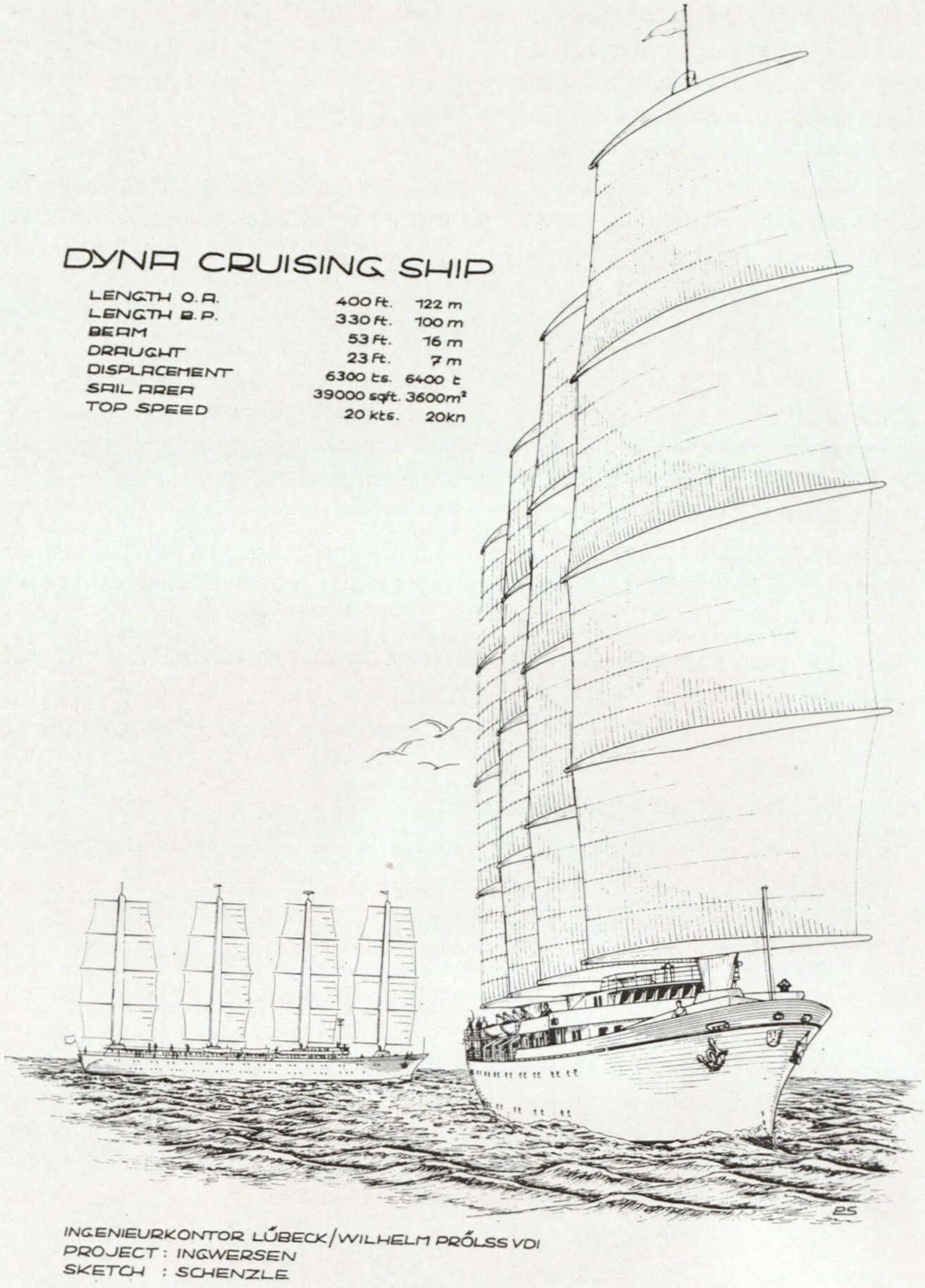
As a practical result, you will find enclosed draft sketches for a *Dyna Yacht* and a *Dyna-Catamaran*, and—derived from the *Dyna Bulk-Carrier*—for a *Dyna Cruise Ship*.

Dyna Rig will not be a cheap design—there are many precision parts especially for control and handling comfort, and there are patent rights, too. But the expense will pay, the *Dyna Rig* allowing for high average speed on ocean journeys, maintained by a very small crew even in a very big and expensive vessel, and—last not least—granting additional safety.

So far relating to *Dyna Rig*. Now allow me some words, too, with regard to your excellent proposal Polar Curves of Yacht Performance.

When beginning work with project *Dynaschiff* in 1956, I designed already this type of diagram for graphic (analogous) presentation of performance figures, and I used it from the start for the speed forecasts—sometimes not in line with the scientific customs of that time. Nowadays, this diagram seems to be already a matter of course; the German periodical YACHT is using this method, as you certainly are aware.

The only thing I'd propose to alter, is the title *Polar Curve* provisionally chosen by you and your friends: polar curves are used—as far as I'm informed



—mainly for airfoils (on aircraft), for sails, ship's hulls and other hydrofoils, presenting c_L or c_C over c_D figures. Our speed diagram, on the other hand, is presenting speeds of air, wind, ship or boat in a directional manner, and so the title should be *Vector Diagram.*

Yours sincerely,

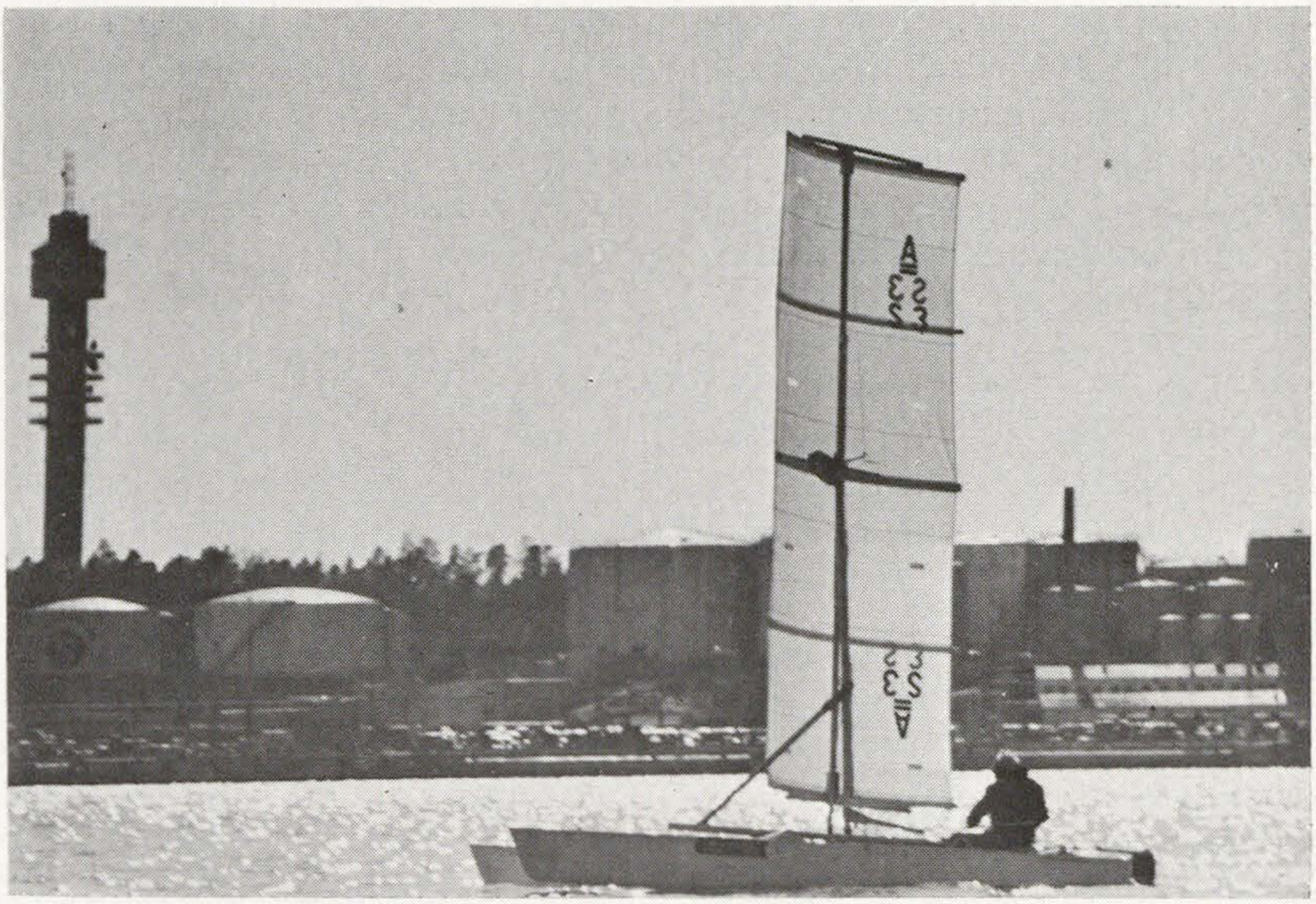
Wilhelm Prölss

Letter from: John F. Hamilton, Bergviksv. 58 S-161 38 Bromma, Sweden

Dear Mr. Morwood,

Thank you for your nice letter.

As an exchange of niceties I send you a picture of my wing-sail (see AYRS 66a, page 91) on my new A-cat *MIANDRA*.



John F. Hamilton's 'Over the top' wingsail

I am, however, not yet ready for a full report on the project, because of the optimistically undersized sheeting arrangements, which inevitably lead to capsize.

When I have again been able to collect enough spare time for further experiments I shall let you know the results.

John F. Hamilton

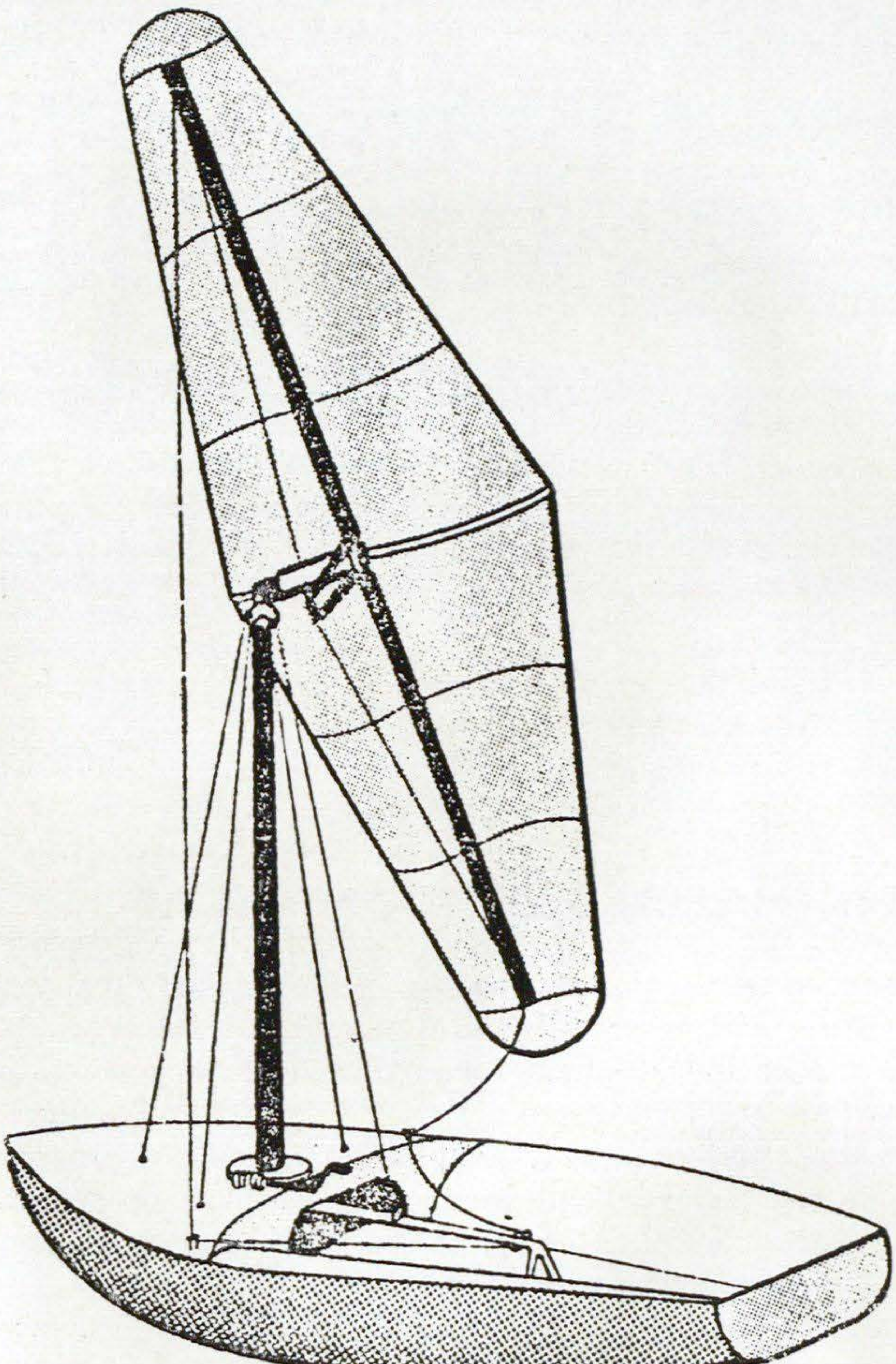
WINGED-SHAPED SAILS DON'T FLAP

A Frenchman, Albert de Galbert, has recently come up with some new proposals (British Patent No. 1 184 914) to use an airfoil as sail for a boat—or for that matter any other sail-propelled vehicle. The airfoil is rotatable with the mast about a vertical axis and is also arranged to be tilted by a sheet about a generally horizontal axis. The idea is that at each change of tack, the airfoil tilts so that each of it ends alternately forms the top end. In this way, it is in theory possible to use the high-pressure side and the low-pressure side of the airfoil respectively as such on each tack.

The airfoil itself is formed from a spar and a sail which is detachable from the spar and which forms the high and low-pressure airfoil sides. The sail is highly tensioned to give it its aerodynamic shape and limit its deformation by the wind. The inventor suggests that it can also be fitted with aerodynamic brakes and ailerons to increase lift or drag.

The inventor claims that his rigging provides various advantages. For instance, when sailing close to the wind, the lift/drag ratio of the rigging and the tilting facility of its sail reduced the angle formed by the aerodynamic force with the direction of running and thus there is better sailing into the wind with reduction of drift and the overturning couple. If difficulties arise, the mast can be released into free vertical rotation which automatically puts the airfoil into a "weathercock" position. De Galbert suggests that a number of his airfoils can be provided for the same boat and the one most suited for the prevailing conditions chosen by the crew.

Courtesy New Scientist



SOME SAIL EXPERIMENTS

by C. H. Spira

5 Forrester Road, Safety Bay, 6169, Western Australia

Publication No. 71 reached me a day or two back and the contents were particularly interesting, especially the articles on *CHEERS*, the simplest most sensible type of catamaran I have yet heard of, and the Chinese battened lugsail. This sail has fascinated me for the last eight years or so, and I have built models with it and used dinghies and a catamaran with this sail and its possible variations including a type of "semi-eliptical squaresail", so may I add my experiences to the observations in No. 71?

The Chinese Concept

The Chinese battened lugsail, whether by accidental development or intention, appears to be a superior concept of what a sail should be than the Western one of a piece of cloth extended by spars at its edges. That a sail is similar to a wing, when on a wind, is commonly accepted now; the "lift" inducing forward motion.

Now even the earliest wings on experimental flying machines were not pieces of cloth extended by spars along edges, but had a main spar and numerous "battens" over which the fabric was stretched bat wing like, giving it the designed aerodynamic shape. If that is the best way to create an aerofoil with timber and fabric then why not continue to use that construction for sails?

In the squaresails of the days of commercial sail we find something like what is needed—a main spar (mast) with crossmembers (yards) extending fabric (sails). It worked well for large ships, but no one has successfully scaled it down for small craft because it does not "fail safe" close hauled but gets aback (with dangerous possibilities even for large vessels) and the gear is too complex.

In the Chinese lugsail we again have something like what is needed—a main spar with cross members extending fabric. It works well if convenience is the main consideration and you can afford to wait for a fair wind or are ocean sailing where close-hauled work is seldom done.

The Faults

But let us face facts; as an aerofoil it is an utter failure, and do not be deceived by writers who may have knowledge of western rigs and who then darken counsel by words without knowledge of the Chinese rig.

With the mast to windward and the battens curving under the pressure of the wind you do in fact have an inefficient aerofoil of sorts—except that in light winds when you need a deep arch the sail is flat. But to try and sail to windward is nearly impossible and leeway is excessive even with daggerboards and deep rudders on an 18 ft catamaran. I know—I've tried.

With their blunt, shallow hulls I don't believe junks of most hull shapes (there are varieties) can sail closer than eight points (90°) to the wind and that would be crabwise, "looking" much higher.

But on the other tack with the mast to leeward—well! For any sort of windward work you are out of the race, and for the following good reasons.

Firstly, if your battens are pliable enough to curve for you on the other tack to make a bit of an aerofoil, they will curve for you on this tack too—the wrong way; against the mast. If your battens are rigid to avoid this wrapping around the mast when it is to leeward, then they are rigid on the other tack too and you get no aerofoil on any tack.

Secondly the mast is now to leeward and a little back from the luff, exactly where it completely disrupts any leeside flow you may have been cunning

C. H. Spira's mainsail 'reefed'

enough to induce—see W. A. Smith's informative and entertaining book "HOW SAILBOATS WIN OR LOSE RACES" page 123, diagrams D and E. And in the case of the Chinese sail with mast to leeward I have found it to be quite true.

A flat sail on a reach has about half the thrust of a properly shaped sail. Close hauled a flat sail has virtually no forward thrust. This is the best a Chinese lugsail can do on its "good" tack.

Put a "spoiler" (the mast) to leeward of a flat sail and all you have is a picturesque sail shaped wood and canvas contrivance pushing you slowly to leeward. Forward thrust is nil.

Why the interest in the Chinese lugsail then, if it is so inefficient on a wind?

For the reason that its structure is a main spar with battens (or yards perhaps, if you like) extending fabric as in a wing, and that it is simple, cheap to make, requires no expensive fittings, and most important of all it is self stowing and reefing.

The problem is—how to make this as efficient as say, a jib-headed mainsail and keep all its other virtues.

Basically there are two directions in which the sail will develop. You can make it more of a squaresail or you can make it more of a fore and aft sail.

Square Sail Trials

To do the first is to do what the AYRS Members have done in designing a "semi-elliptical square sail".

My trials with a catamaran, dinghies and a sailing model (using an inch to the foot scale model of Slocum's *SPRAY* as a "test bench"), with a similar type of sail (see diagram No. 1 and enclosed photos) were encouraging and it looked a seamanlike job. I was nearly convinced I had solved the problem.

As the drawings and photos show, a heavy diameter mast is firmly stepped into the hull. The rig allows for forestays and backstays, so it is not a completely unstayed rig—but not fully stayed either, having no shrouds. Shrouds cannot be set up to this rig, otherwise the lower trusses cannot be braced up to tack.

The good points of this rig are:—Simplicity and cheapness; there is a little standing rigging and one halliard only, as in the Chinese rig. As the halliard is eased each truss (yard), successively lowers onto the one below, self reefing the sail until it is all furled as in the Chinese rig.

As the halliard is eased the sail folds between the trusses confined by the lazy jacks (topped lifts? or buntlines? whatever you choose to call them). The braces (or sheets) are rigged in a Chinese sheet manner (there are a variety of systems actually so that as the sail is lowered one merely has to take up the slack of one sheet a side to regain control of the trusses as in the Chinese rig.

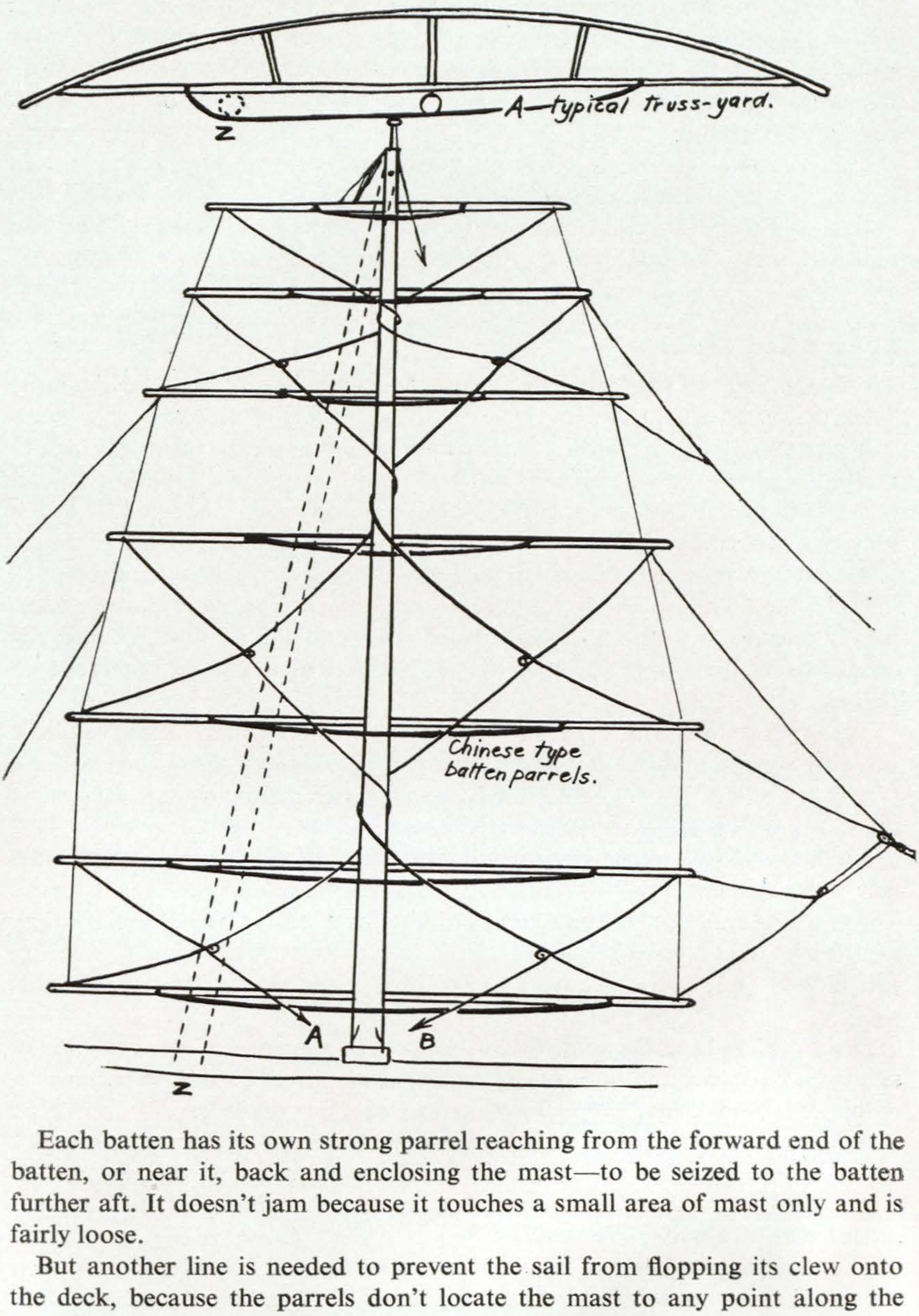
Due to the built-in curve of the truss the canvass is given its pre-determined aerodynamic curve and does not require special skill in cutting to assume an arch. (Chinese sails are simple to make too, they are made flat).

As for the manner in which the trusses are to be kept to the mast, there are two possibilities. One, the simplest way, is to parral them western fashion and the sail is unalterably a symmetrical squaresail—but having the desirable reefing and furling qualities and simplicity of the Chinese sail.

The second possibility is to keep each truss (yard? batten?) to the mast Chinese fashion, and this opens up the possibility of making the sail weathercock ("fail safe" close-hauled) to a limited extent because of the backstays.

There might be confusion about how the Chinese sail is rigged so a diagram with brief explanation follows. Diagram No. 2.

Diagram I

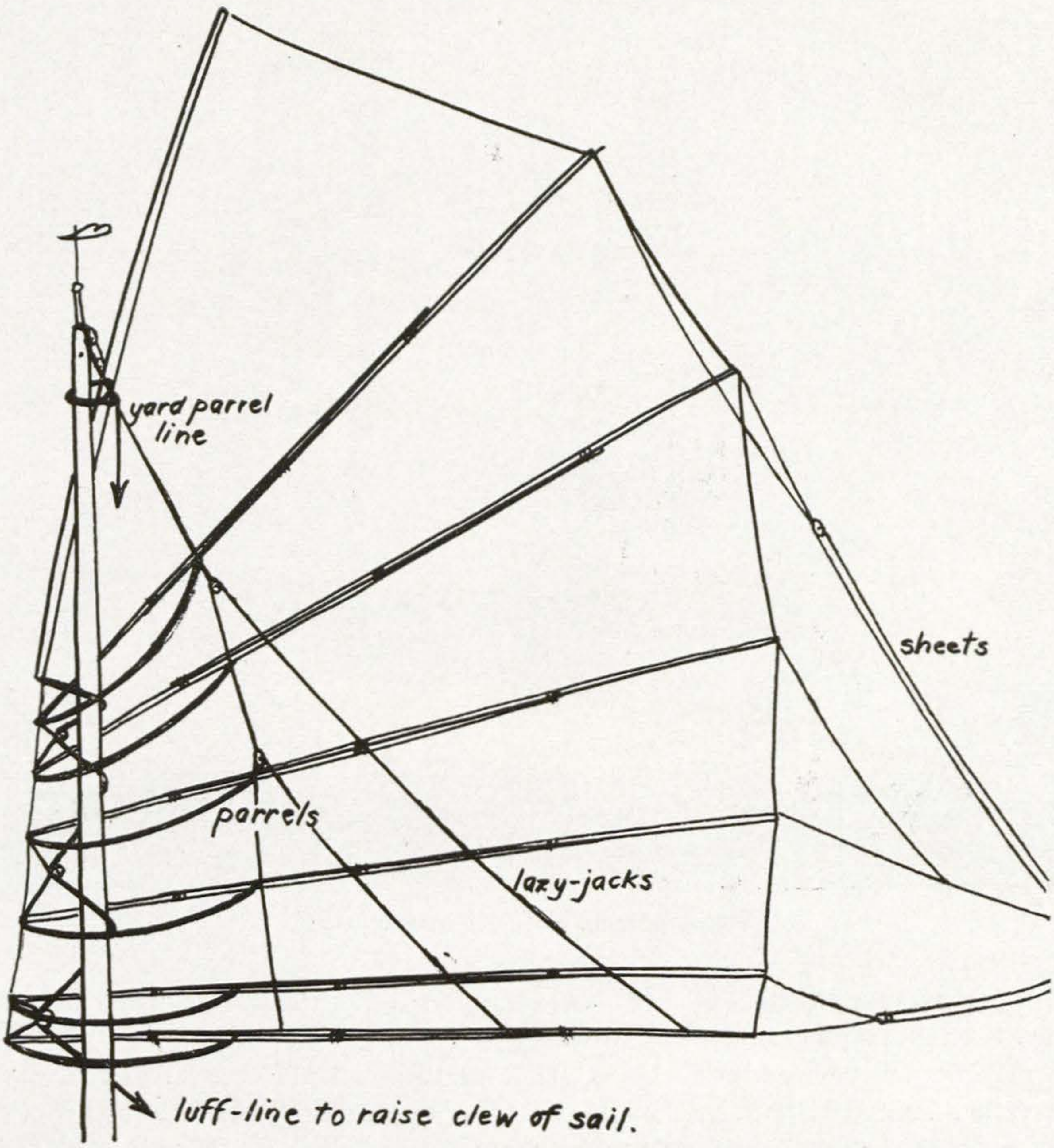


Each batten has its own strong parrel reaching from the forward end of the batten, or near it, back and enclosing the mast—to be seized to the batten further aft. It doesn't jam because it touches a small area of mast only and is fairly loose.

But another line is needed to prevent the sail from flopping its clew onto the deck, because the parrels don't locate the mast to any point along the battens.

This line leads from the heel of the yard, back to encircle the mast, forward again, to a block on a span on the next two batten ends, back round the mast

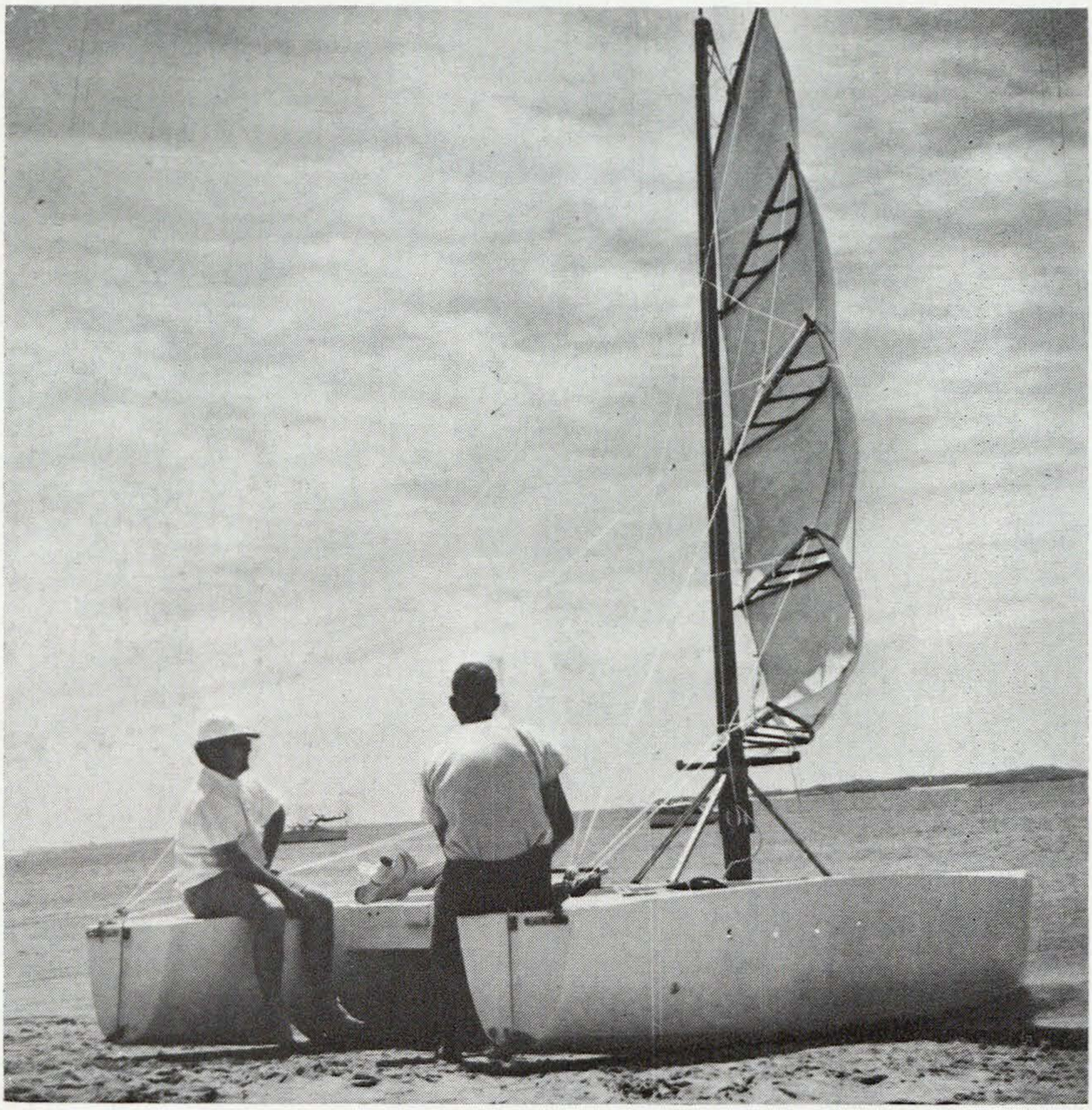
Diagram II



again, forward to the next span on the forward end of the next batten below —and so on down the mast.

A pull on this line draws the luff of the sail back to the mast, cocking up the clew of the sail. Slackening this line allows the tack to go forward and up, the clew to drop—as in the photo of a junk on page 42 of No. 71, where the fores'l "luff-line" has been eased.

Now with this "squaresail type" junk sail we've been considering, the fixed parrel could be replaced by the looser type Chinese parrel described. Again, to locate the sail relative to the mast this Chinese "luff-line" is used, but instead of rigging it to one leach of the sail, it is rigged double (see diagram No. 1) to both leaches.



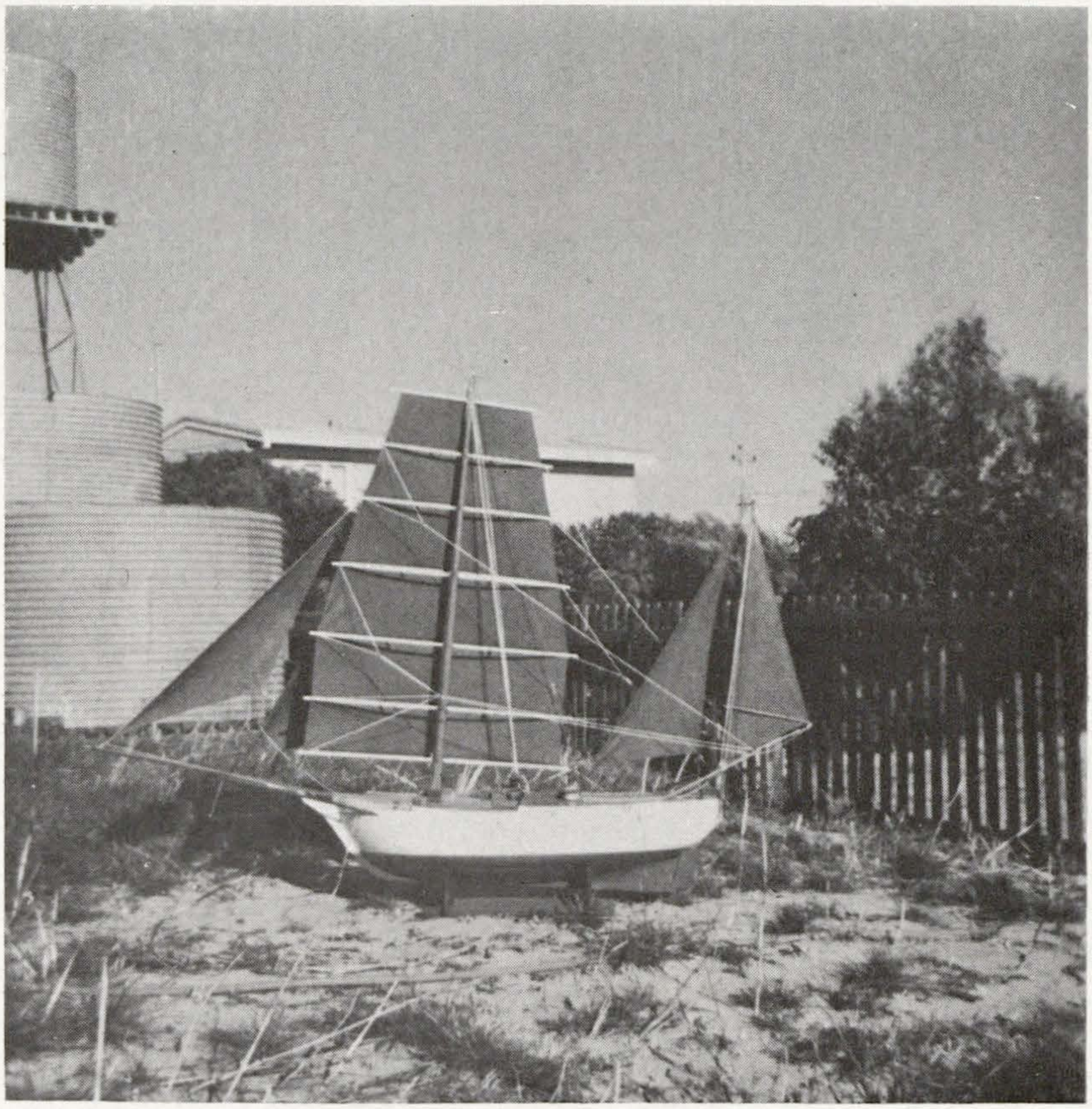
The squaresail. Note the curved yards

By hardening in one "luff-line" and easing the other the sail is shifted across the mast either one way or the other.

The benefit derived from this is that on either tack the line leading to the weather leach (the current luff-line) can be hardened in, giving much more area aft of the mast than forward, making it a lugsail again. This makes it a "semi-elliptical squaresail" after the AYRS manner, and I would push my wares unashamedly as to say it is superior to any I have seen so far, with no gear on it anywhere but what is already in use, and so already well tried on Chinese sails. As a "semi-elliptical weathercocking squaresail" or "square sail/lugsail" it is a shipshape job. I feel I must remark that others I have seen in the publications I would not care to go to sea with, but they would be fun to play with on lakes or rivers.

The Fault

But—and it is a big "but"—in spite of the fact that it fits all requirements; that it is simple, cheap to make, requires no expensive fittings, and is self stowing and reefing exactly as a Chinese lugsail is—and we have added great



Model *SPRAY* with squaresail set

aerodynamic efficiency, which is what we were out to do. In spite of all that it falls down in one important respect, the same as all "semi-elliptical squaresails".

And that is it must be tacked like a square rigger, with the boat swinging her head through the wind with her sail aback. (Also the mast must be both tall and strongly stepped in the hull, Chinese manner, and there can be no shrouds on which to go aloft to inspect gear).

The fact that there are few examples of sail in all its history where small craft have to put about with square rig is a strong indication that it has never been considered a safe thing to do. In fact the only type of small craft that occurs to me off hand that did this is the *HUMBER KEEL*—not a sea going craft. Squaresails on coasting smacks and revenue cutters were downwind sails hoisted to the yard with headstick and three halliards.

So unless we want to go to the expense of so rigging a boat (more permanently than the catamaran I did so rig—see the photo), and the risk of trying the rig in all weathers we will have to sadly abandon this sail (along with other "semi-elliptical squaresail" designs) as being unsafe because of not

Model *SPRAY* with squaresail furled

weathercocking fully when luffed, because of the backstays—but getting aback.

True, it is a highly efficient rig, and in the ocean where a few hundred yards make no difference you could safely and easily wear her round. But I would not like to be sailing close-hauled on a dirty night in a small craft with a rig that can be caught aback or that would not go about without a lot of hauling of lines within certain time limits.

After spending about three years thinking this one up, making models of it and trying it full size on a cat. I regretfully abandoned the idea of making the Chinese lugsail more square rigged and tried the other "tack" of making it more fore and aft, and taking the wind on alternate sides of the sail.

A more Fore and Aft Chinese Lug

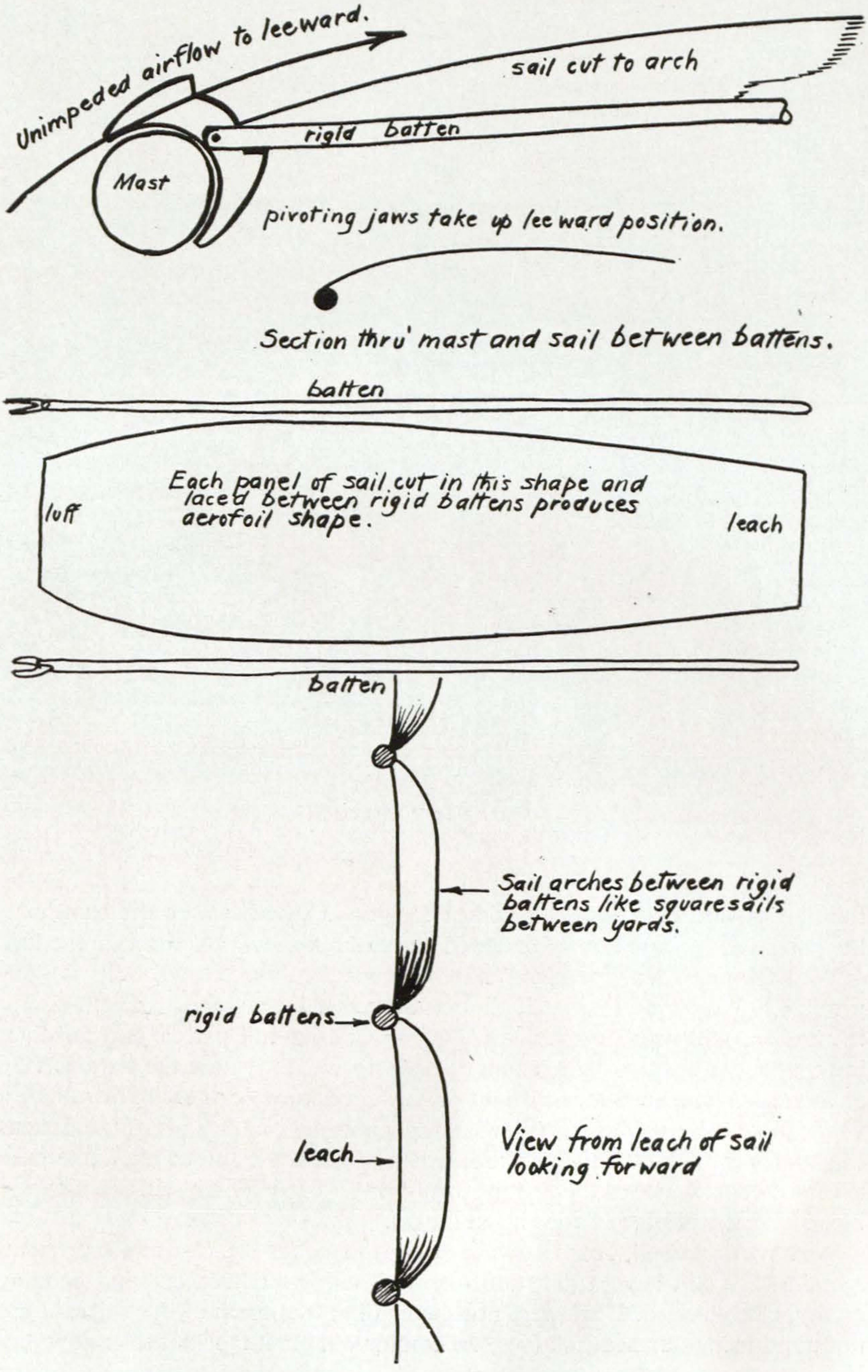
Here one is soon forced down a "funnel of inevitability". The mast must come away from one side of the sail as it makes an already poor sail useless close-hauled on one tack—so we stop the yard short at the mast (I'm talking about a highly peaked yard, as in the photo on page 42 No. 71 again. By the way, the yard must be so peaked on a stayed mast), and give it a saddle—better

Weather side of squaresail

than jaws—and that has dealt with it for good. Likewise stop the battens at the mast, producing at one a battened gunter lugsail with the mast up the luff.

We have now "Europeanised" the sail considerably. But we still have our problems. We have eliminated the grosser mast interference to airflow, but the battens still present problems. On the Chinese sail parrels and luff-lines look after the mast to batten union; how do we do it now the battens stop at the mast? The answer is by light jaws. And here we can easily introduce a very desirable refinement. The jaws can pivot easily on the ends of the battens thus putting the luff of the sail to leeward of the mast and so eliminate even the mast interference of the European gaff or jib-headed mainsail. See diagram No. 3 and the photos of the rigged model.

We have done well, but we are not out of the woods yet. One major problem remains. We still have a flat, door-like sail with no thrust, or wind bending ability, close-hauled. If we were not demanding too much of our sail and did not mind using our headsail (yes, we can have these important sails now too, if we want) to bend the airstream onto the leeside of our mainsail then, actually, Diagram III



Unimpeded airflow to leeward.
sail cut to arch
rigid batten
Mast
pivoting jaws take up leeward position.
Section thru' mast and sail between battens.
batten
Each panel of sail cut in this shape and laced between rigid battens produces aerofoil shape.
luff
leach
batten
Sail arches between rigid battens like squaresails between yards.
rigid battens
leach
View from leach of sail looking forward

our problem is solved. We have kept the Chinese sail simple and improved it by putting the mast at the luff.

Now—if we have a day-sailer, or some such craft, we can have great fun fooling around shaving battens to set our sail to an aerodynamic shape and then the whole problem is solved—we have a sail, again, which meets all our requirements we set ourselves of cheapness, simplicity in handling as a Chinese sail, plus windward efficiency.

But—again "but"—I have always visualised the sail as being used on largish craft offshore; and don't believe anyone if they tell you, you would have anything else but endless breakages and sail tearing and trouble if you had flexible battens. You would curse them like Mike Ellison and Bill King did—and theirs weren't meant to flex.

So we can either revert to our flat but improved sail of a paragraph or two back; or think again.

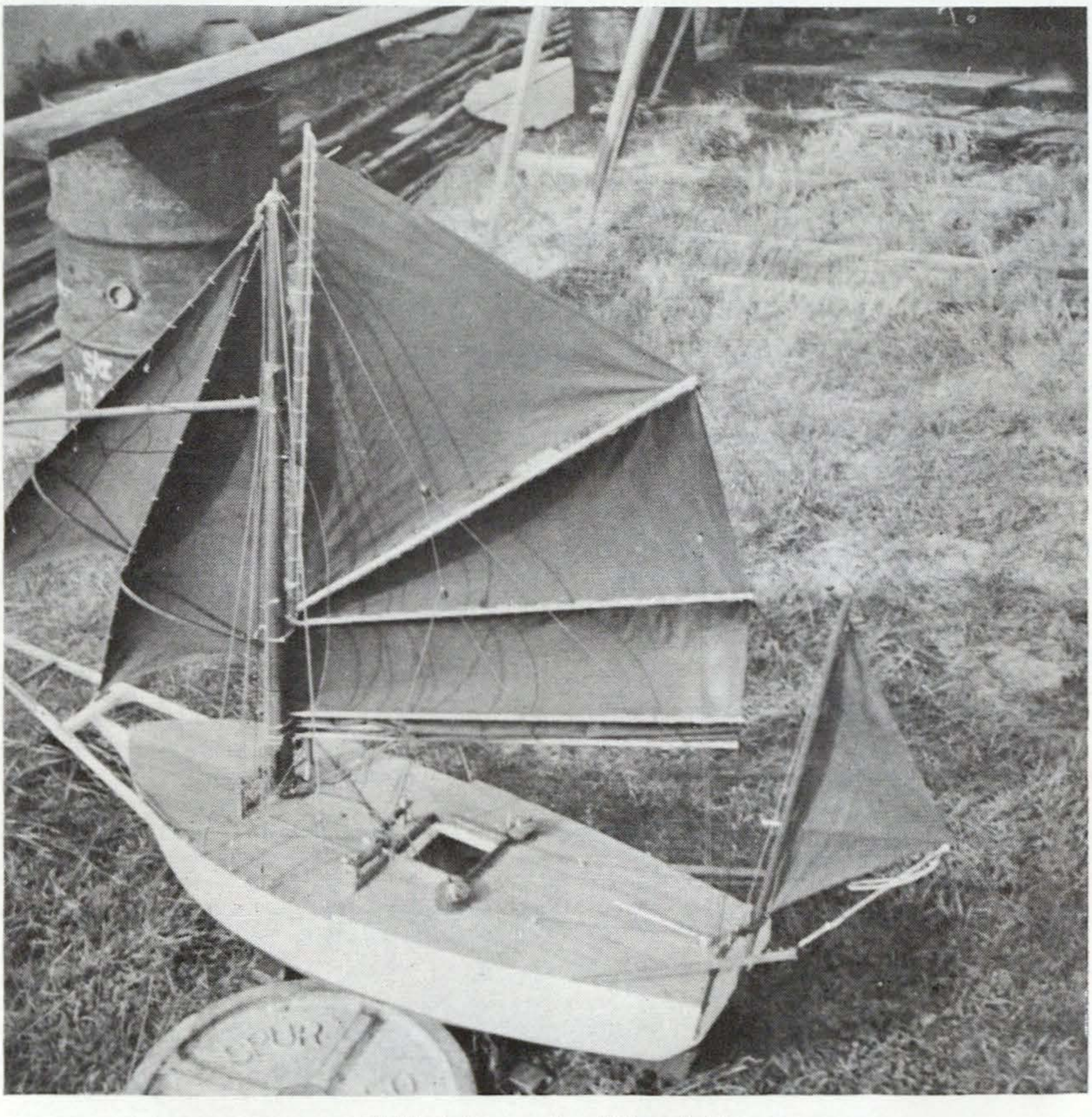
As we think again let us consider the square riggers once more. They had quite efficient sails—but their battens (yards, of course) were rigid. How was this? Because each sail blew into a curve between the straight yards.

Model *SPRAY* with C. H. Spira's mainsail, squaresail and raffees

Can't we do something similar? After all Herr Laeiz's *Flying "P"* nitrate ships made a step in the same directions we are trying to make when they put a second gaff on their jigger masts, and so put one rigid "batten" in that fore and aft sail, dividing that sail as topsails and top gallant sails had already been divided.

Why not stop becoming mentally trapped by the bending batten concept and have good, strong uncompromisingly rigid ones? Ones that will never break. In fact ones that are partway to being yards. Then cut each panel of sail separately between these battens (or yards) so that it takes a curve like a squaresail. We can lace the foot as well as the head of each panel to the battens so that no wind escapes below each section of it as it does below each squaresail. It also conveniently makes a sail of, say, 800 sq ft into manageable pieces.

Now what have we got? In effect a set of squaresails (of the modern narrow, double-tops'l type). But not set centrally across a mast but with a mast at one end (which swings nicely out of the way of the leeside air flow) and the sheet controlling the other ends, still Chinese multiple sheet rig.



C. H. Spiras mainsail "reefed"

If someone should object to the stiff batten cutting into the arch of the sail at intervals then I will object to his often square sectioned mast interfering with the leeside flow of his sail all the way up it, and remind him that square riggers suffered from the same, and worse; they had great gaps below the foot of each panel of sail beside—which I haven't got—and yet they sailed perfectly well to windward. Many times better than a junk whose sail we are trying to improve. Actually smoke and streamer tests show a normally good leeside flow over this type of sail on the model.

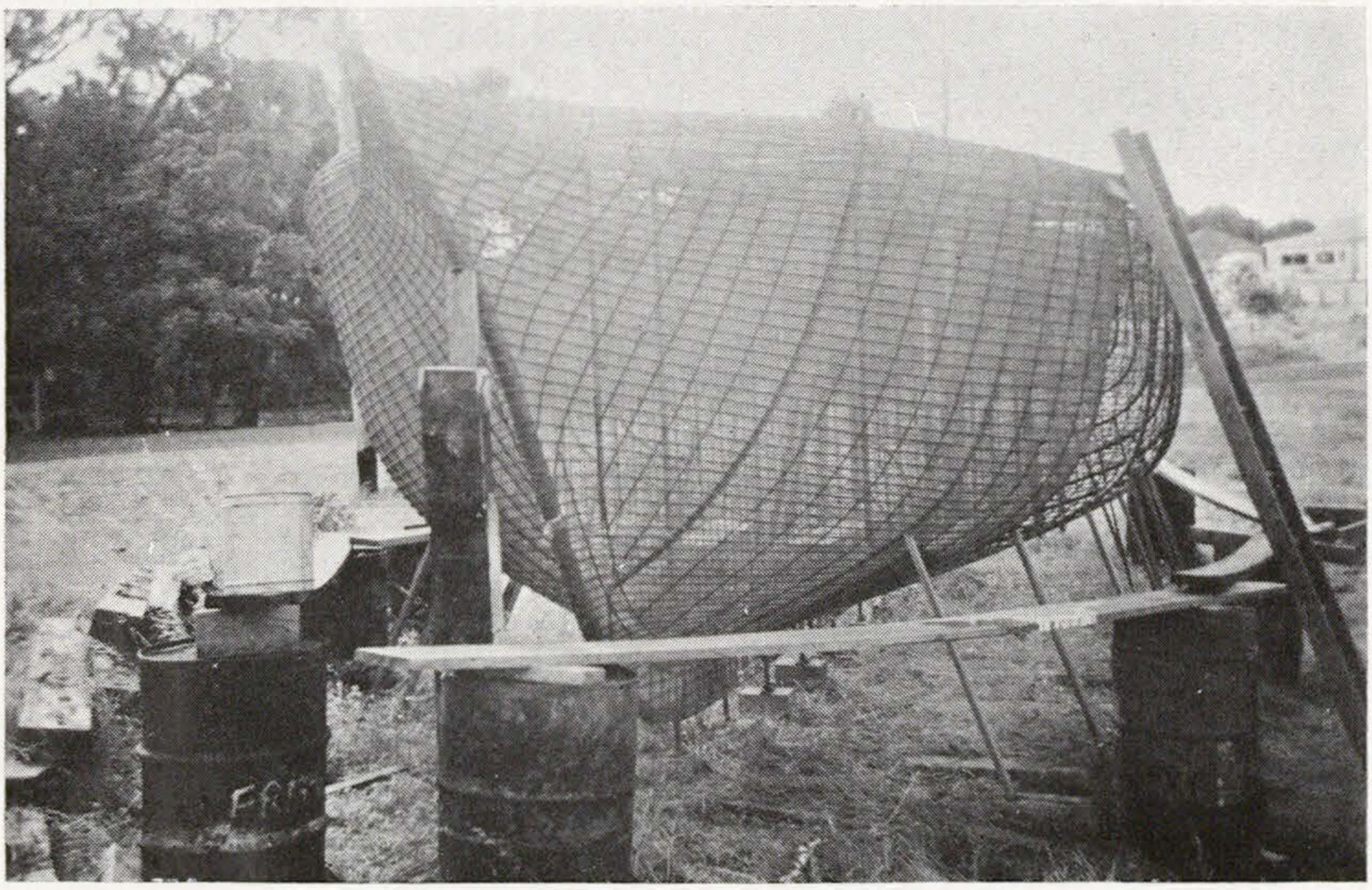
As can be seen from the photos of the model, the lower four panels can be likened to squaresails. The upper half of the luff is our old friend the topsail whose efficiency on a wind is, like Caesar's wife, beyond suspicion.

So we can look back and say perhaps we have done it.

We have kept the cheapness, the simplicity, the batwing structure, the freedom from expensive fittings (yard saddle and battens jaws are simple to make even on a model) and above all the feature which I believe makes all our inventive efforts on the junksail worthwhile—its self reefing, self furling qualities. This enables one man to ease off the halliard windlass till one or more battens drop down, adjust the yard's parrel line, and harden in the multiple sheet which will have slackened, and a sail of even great size is reefed to any depth, or completely furled.

For ease of handling the sail is supreme. We have added windward efficiency and kept the safety and simplicity—what more is wanted from a sail.

Notice that the mast is short and can be made to be stepped in a tabernacle to free one from dependence on outside facilities, because the standing rigging is conventional and can be made as strongly as needed. It can also be made thick, and so strong, because it interferes little with leeside flow as we have seen.



C. H. Spira's *SPRAY*, being made of ferro-cement

As can be seen from the photos, squaresails have been added for long stretches of downwind work, and consort well with the true fore and aft sails, making the *SPRAY* look a bit like a revenue cutter with all her sails set.

The rigging of the squaresails is quite conventional for the days when small commercial fore and afters used them. The squaresail has a bonnet to enable its area to be reduced, rather than a complex reefing gear, and is hoisted to the yard on three halliards. The centre halliard goes to a headstick to take the weight of the bunt of the sail; the head earings are hauled out by the other two halliards. The set of the twin raffees is like two jibs set flying and is self evident. An alternative raffee not dependent on the yard of the fore and aft mainsail being hoisted, is hoisted on a short yard to the masthead, set flying without braces—a common practice a hundred and fifty years ago in smallish craft.

In discussing the ways of trying to improve the Chinese battened lugsail, I am well aware that there are other ideas that do occur. But after some years of thought the two explained in this article seemed the most promising, so I dealt with them only or the account would be overlong. I hope I have laid a few misconceptions concerning the original rig, and dare I hope, shown how it may be made as efficient on a wind as western mainsails.

I hope to complete a concrete (ferro-cement) *SPRAY*, of which I enclose a photograph at an earlier stage of construction, rigging it in the manner described and seen in the photographs of the rigged model, to be used as a floating home.

POSITIVE DRIVE CUDDY CABIN

by Ralph Flood

3883, Sunbeam Drive, L.A., California 90065

PROPOSAL—to develop a positive drive, demountable, cuddy cabin for use on large racing daysailers.

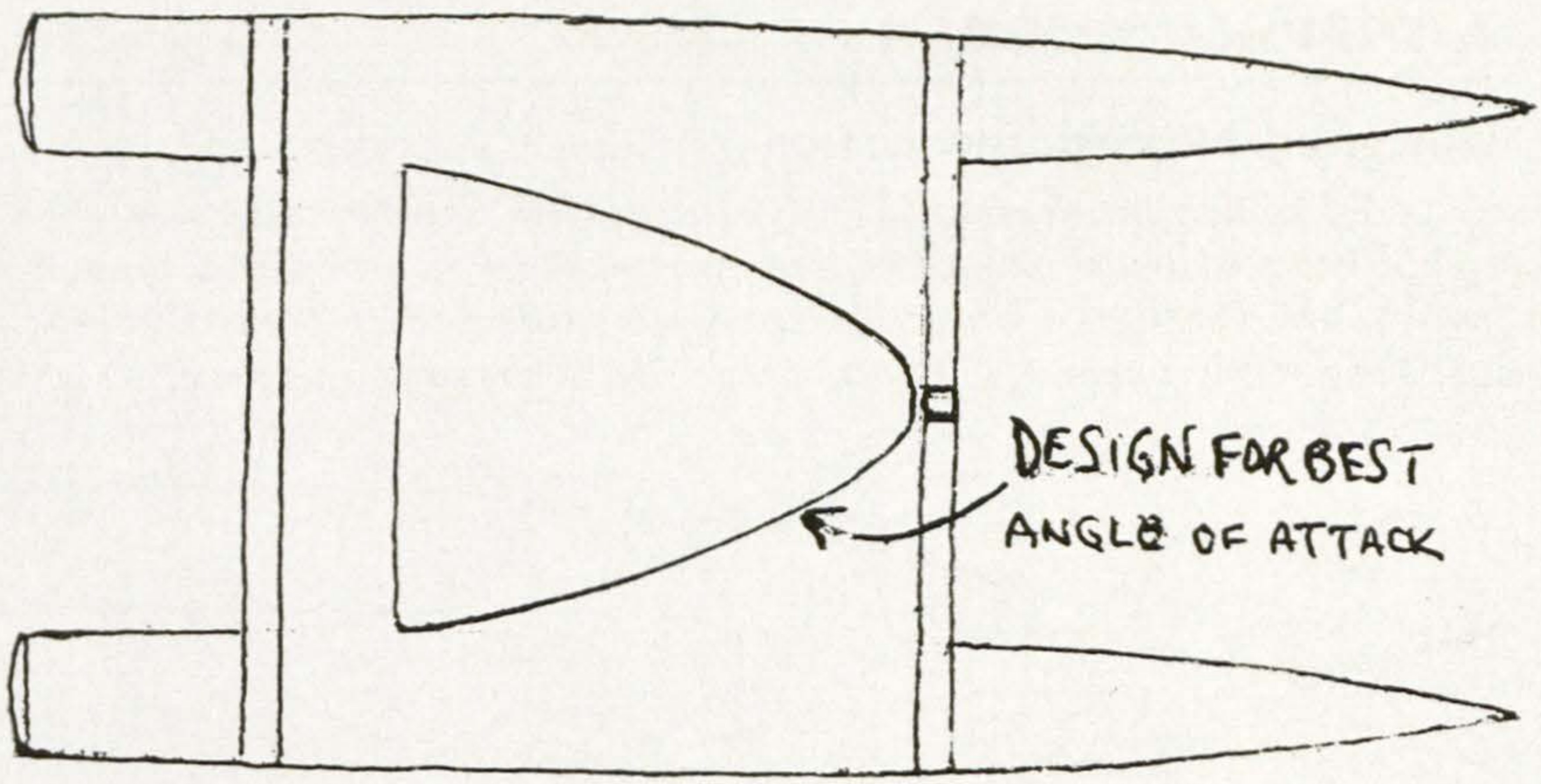
MATERIALS—aluminium tubing and 5oz. dacron sailcloth.

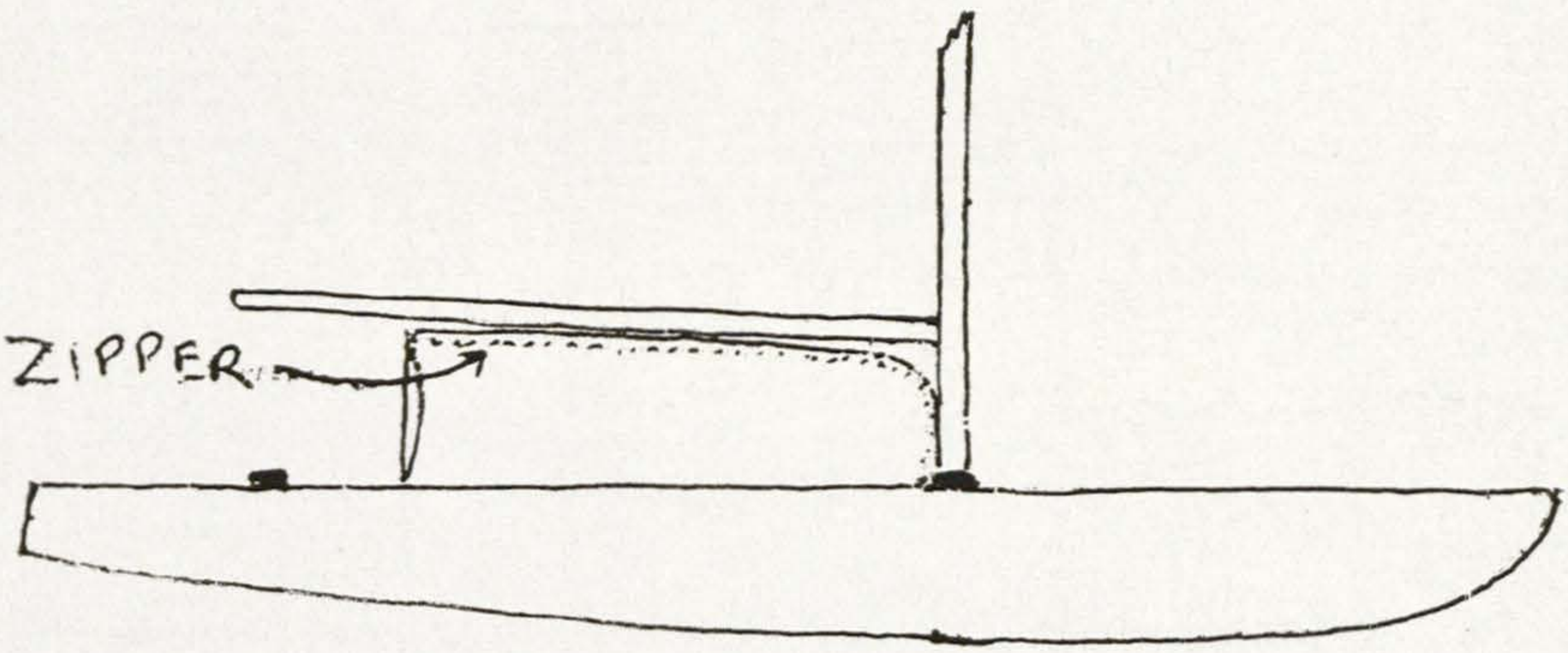
CUDDY SHAPE—this would be determined by way of a development programme.

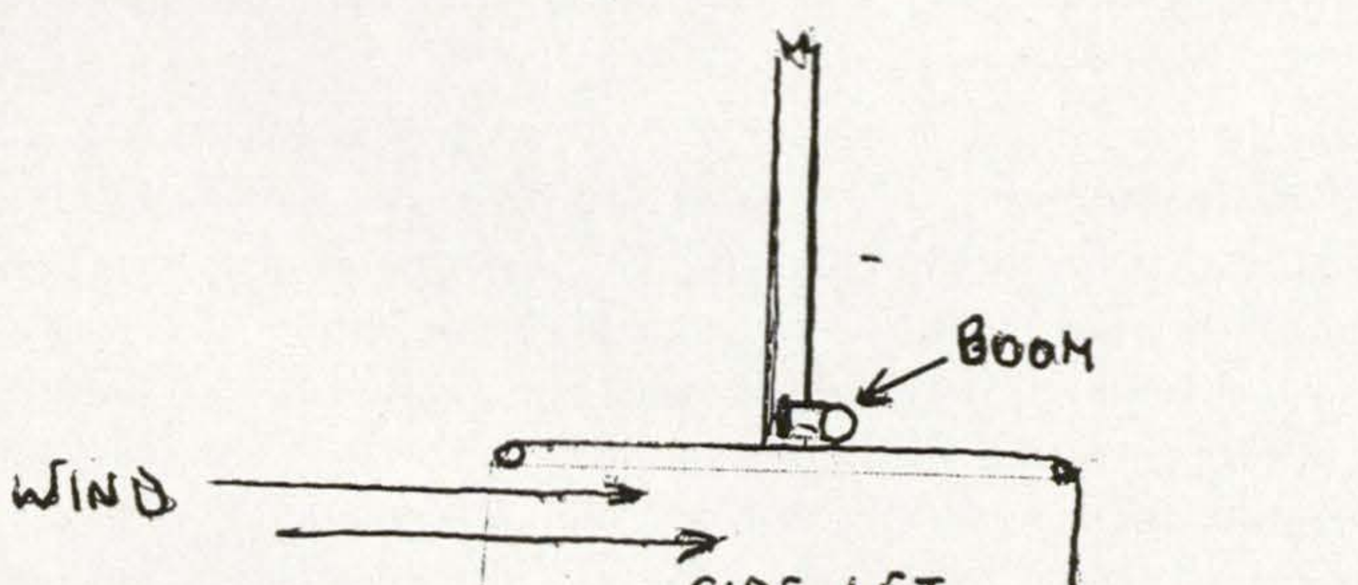
SPECIFIC BENEFITS—the cuddy could provide: a "shelf effect" for increasing mainsail efficiency. An increase of sail area when reaching. A means of shelter.

METHOD OF USAGE—the mainsail boom would be adjusted to barely clear the cuddy top in order to achieve the "shelf effect". The windward side of the cuddy would be opened by means of a zipper arrangement to allow the lee side of the cuddy to be used as a sail.

CONCLUSION—the positive drive cuddy cabin presents a design challenge which could lead to the development of a worthwhile addition to large ocean racing daysailers. And since the development cost would not be prohibitive, the proposal deserves further consideration.





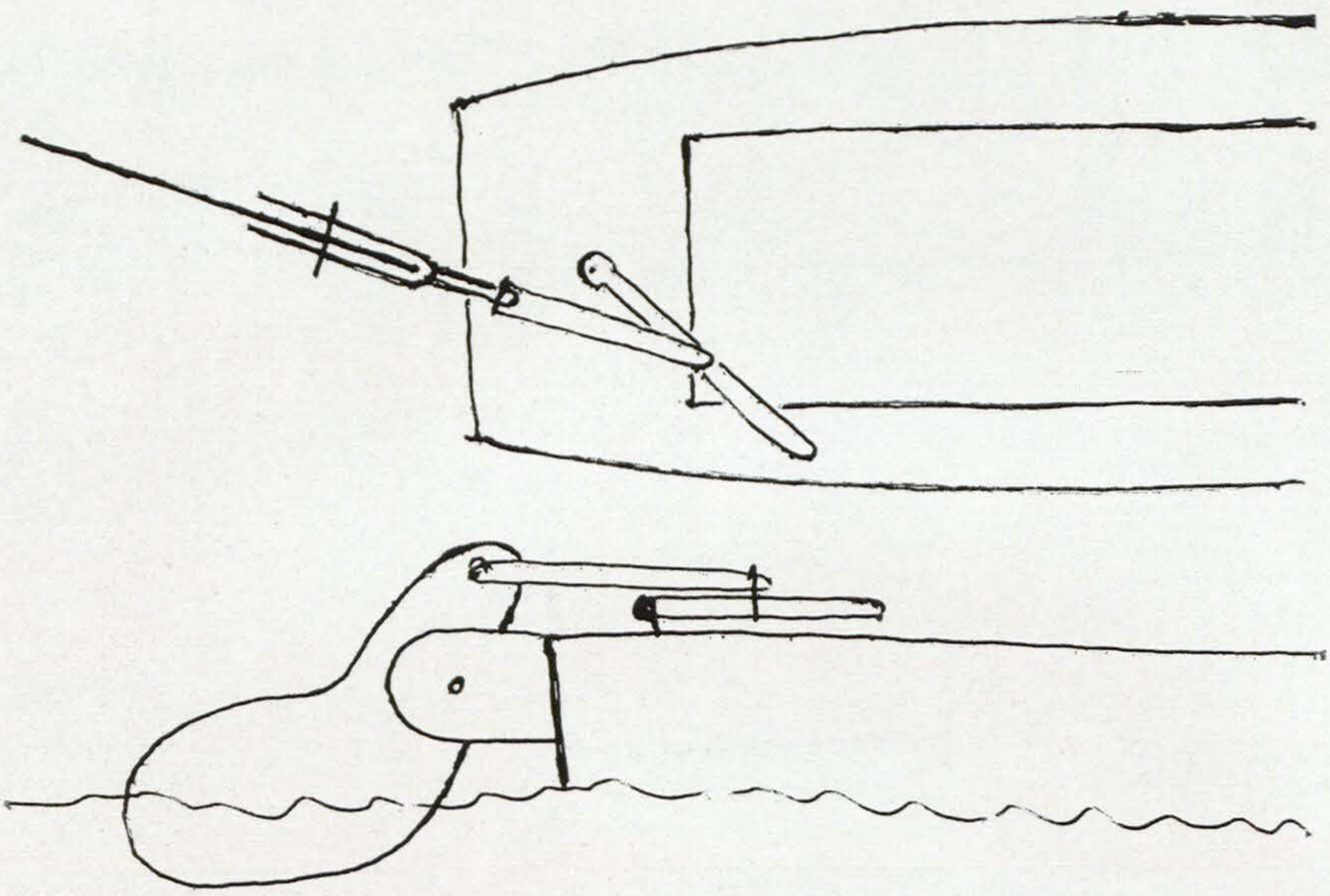


VIEW FROM AFT

A DIPPING RUDDER

Designed by Edmond Bruce

A rudder contributes quite a lot to wetted surface and hence to resistance, even if not actually being used to alter course. Many boats, especially multihulls, will run straight and do not need much steering to keep a steady heading. Their rudders produce needless drag most of the time, therefore.



Edmond Bruce sends us this idea for a rudder which is only very slightly immersed when the tiller is down but becomes fully immersed when the tiller is raised. The rudder would then only contribute to resistance when its steering qualities were needed. When not wanted for steering, the rudder's resistance would be greatly reduced.

Letter from: Ben Kocivar, Suite 2850, 420 Lexington Avenue, NY, NY10017

Enclosed is item from NY TIMES about our efforts to use kites as sail power. Possibly, membership would be interested in this effort.

I have heard from a number of engineers since this appeared and think now that one approach would be a combination kite-balloon for the lead kite of a train in order more positively to reach higher winds aloft.

Should anyone wish to provide further advice and information I would be delighted to hear from them at the above address. Photo enclosed is *not* the way we do it. Kites are normally in train, spaced about 200 ft apart and lead kite 2,000 ft or more out.

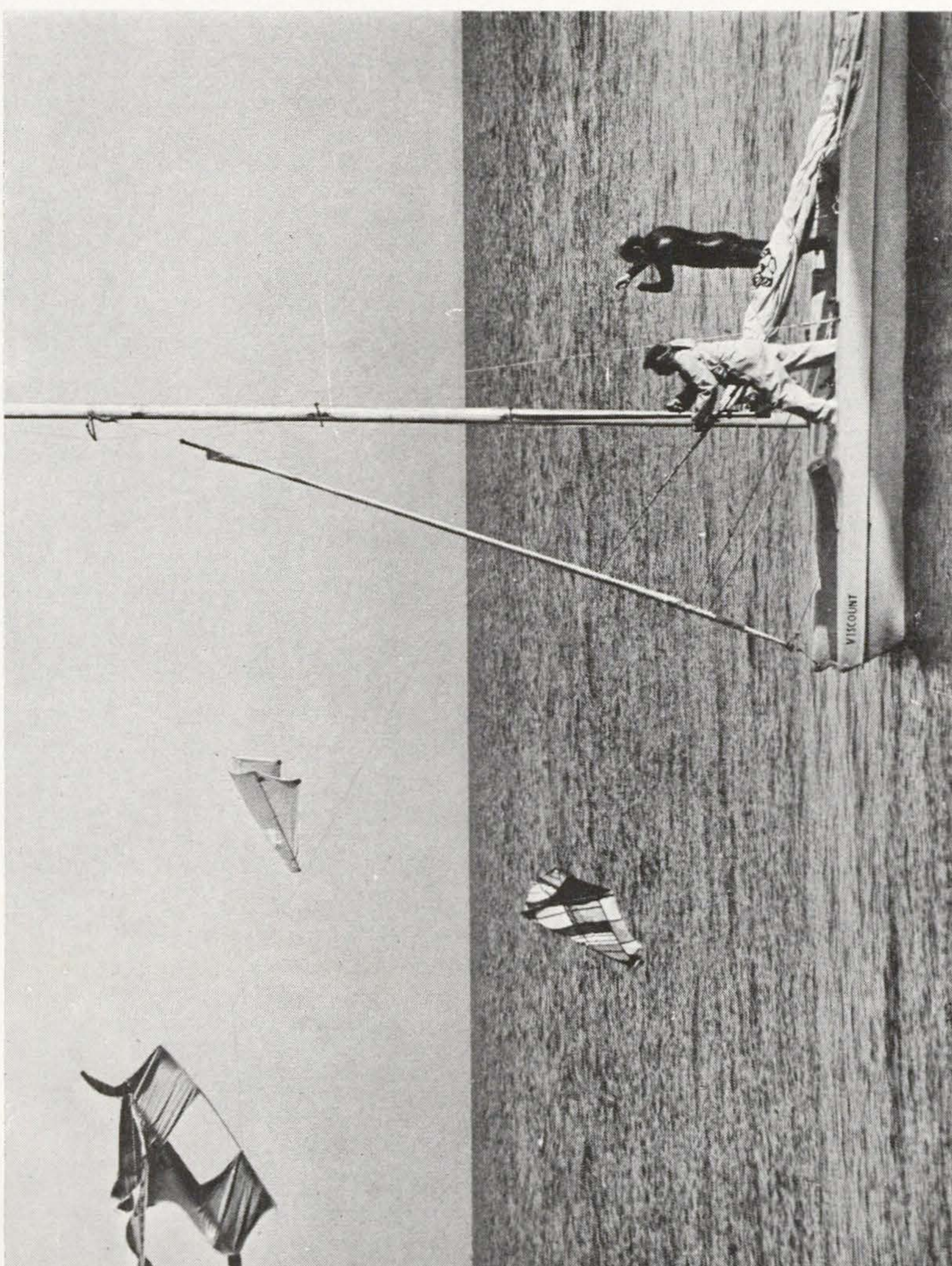
Sincerely,
Ben Kocivar

Extract from the New York Times, October 10th, 1969.

PAIR OF INNOVATORS FLY A KITE TRYING TO MAKE SAILBOAT GO

By Parton Keese

The last person who flew a kite and became famous was Benjamin Franklin. Some day, though, you may have to change that to Will Yolen and Ben Kocivar, who have been doing strange things with kites off the Roton Point Yacht Club in Connecticut.



Flying kites from a catamaran

Aboard their *TIGER CAT*, a 17½ ft *Pearson* catamaran, Yolen and Kocivar have been experimenting with kite power as a means of propelling a sailboat. They're hoping the idea is workable because they are aware of how silly they look standing on a boat in the Sound, holding a large fishing rod with the line going up instead of down.

"We do attract a crowd," Kocivar said, "which makes it doubly difficult, since we have to keep our kite line from tangling with other masts. But it must look odd to sailors who can't see our kites in the clouds."

Yolen, who calls himself the world's kite-flying champion, and Kocivar, a freelance aviation writer, make a good team. Yolen, who is 61 years old, once challenged a maharajah to a kite-fighting duel and won. He says he can make anything go up, while Kocivar, 53, is an expert on glider parachutes and making things go forward.

"But the concept is not original with us," Kocivar admitted. "A century or more ago, Portuguese fishermen returning home in a calm used to launch kites in search of winds, high above."

The idea of using kites to pull sailboats first began to jell in Kocivar's mind following last year's Hallmark kite exhibit here. He also took a trip on the Staten Island ferry with Dave Barrish, an ex-pilot who was testing a new glider wing, with the ferry acting as the "world's largest wind tunnel."

Why couldn't a kite be adapted for a sail, Kocivar thought. He even began to envision a controlling kite that could be converted into a windward spinnaker, which would really turn Ratsey and Lapthorn upside down.

For the moment, however, Yolen and Kocivar are content to experiment with known designs. On their last attempt, which fizzled when the wind died, they first sent up a bird kite—"You want the lead kite to be a type that can get up as high as possible"—and then attached a French military box kite to the line, followed by an ordinary dime-store kite.

"We've had as many as six kites on one line," Kocivar said, "and you'd be amazed at the drive power they develop. There is even another asset. Since the lift is also upward, there is less tendency for a boat to tip since it's kept upright."

Yolen and Kocivar—look that up in your encyclopedia (some day).

Letter from: Pat Patterson, Foss Quay, Millbrook, Plymouth

29th November, 1969

Dear John,

Re: the Retirement Yacht

My family and I have just spent 18 months living aboard *ICONOCLAST*. At last the house is near enough finished to live in so it was with some relief we moved out of the boat before another winter set in. It is wonderful living aboard, particularly up a quiet creek, in Spring, Summer and Autumn.

The major winter bugbear is condensation, caused by the moisture from sleeping bodies. *ICONOCLAST* is sandwich construction. What is needed is heating and ventilation in sleeping cabins and wardrobes and the inside skin lined with thin sheets of polyether or similar foam (the stuff they make seat cushions of). This has worked well inside my Bedford Van, and has the admight provide a useful part or two; he had loaned it out years ago but was sure that it was available if I could find who had it, as it had not been on the ice for a long time. I took up the trail and the boat was found under the porch of a house some miles down the line. Rummaging around, we found all the bits and pieces, and as we dragged it out into the daylight and looked at it—I blinked my eyes. The label on the very ancient cotton sail confirmed it.

It was the design of the very first bow-steering boat ever made, as done by Beauvais in Wisconsin and made by the Joys boys. And class "E". What a crate! She looks like one of those brutal big old auto roadsters of the '20's—a high angular hood or bonnet ending in a vertical dashboard and then a shallow tray in which the driver rides out in the blast, with a large wheel to try to get leverage to control her. Obviously one should sail her in goggles and a cloth hat on backwards, with a dead cigar butt clamped in one's teeth. She was a mess and her nose block was smashed, but I have restored her and must put her name on the freshly red side. It is the original name—and perhaps inevitable for the first boat to turn up in this area back about 1930, fitted to steer at the opposite end from the usual one—"*ASCEND II*".

With this craft, we can have photos and specifications of the earliest to the latest example in the development of the "E" front steerer—limited only by 75 sq ft of sail measured. The old *ASCEND II* is hardly bigger than a "DN" although rather more massive in section; hardly half the size of a modern "E"!

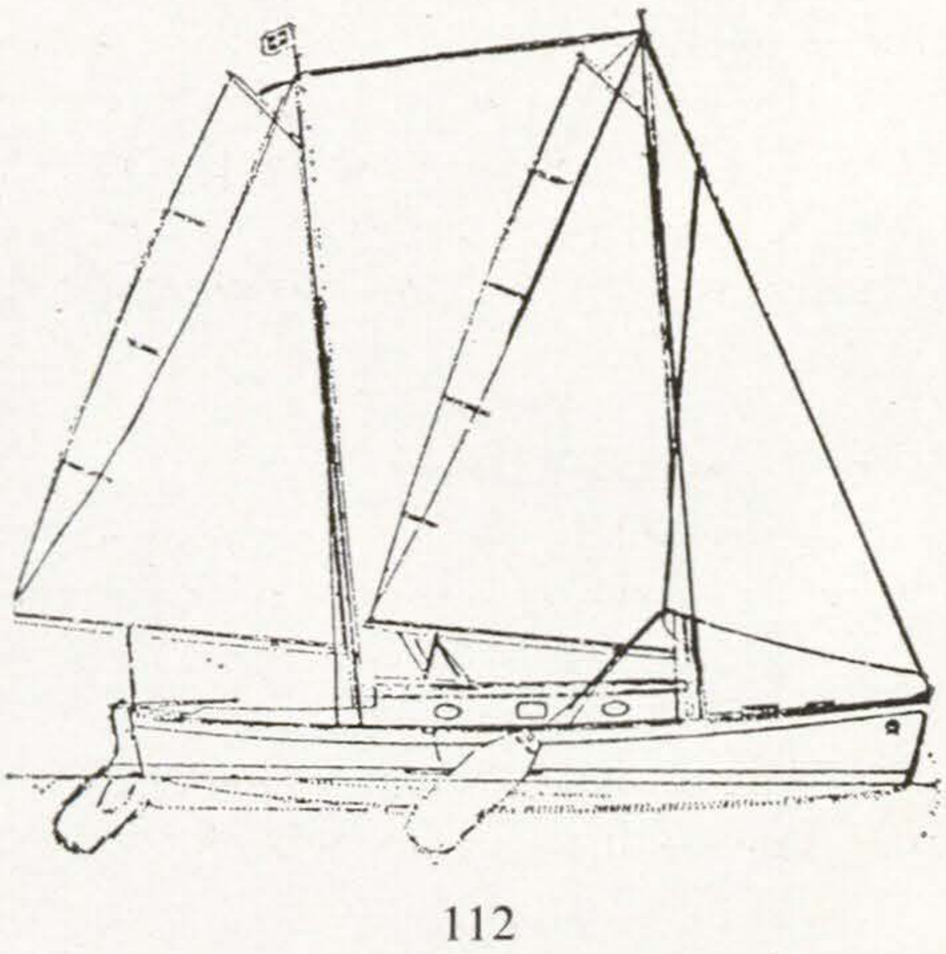
Dick Andrews

Sent in by: Dr JOHN FAIRLEY, British Columbia.

MEADOW LARK
MODERN CRUISING SHARPIE

Length overall 33ft, beam 8ft. 2in, draft 15in.

This remarkable small yacht was designed by L. Francis Herreshoff for shoal water cruising sailors. The design has many unusual features. To keep

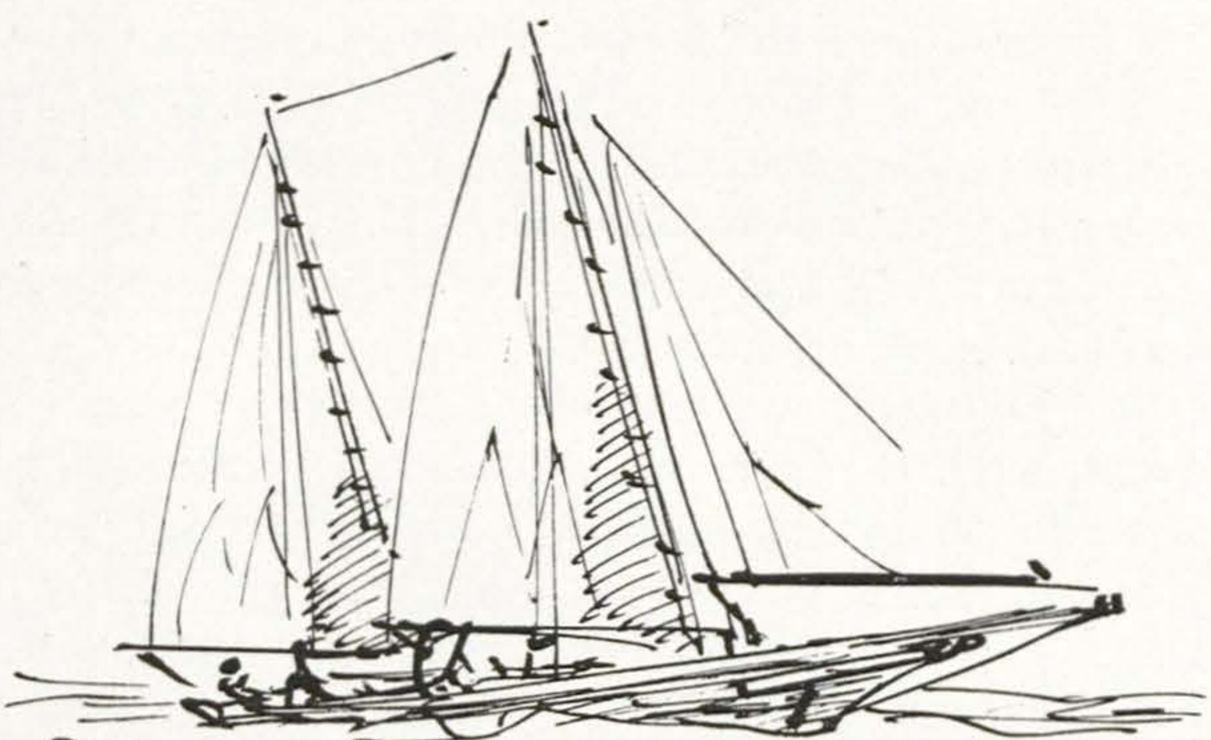


The description of your Irish cruise in *KINNEGOE* is delightful. Why not pick up a boat and take it by land or however, to where you want to sail it? The American Indians were always portaging canoes from water to water, as did the Vikings.

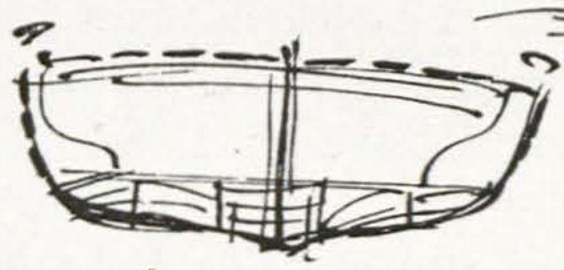
. . . Upset multihull dept:—Come warm weather, I shall haul out the old *SERENDIP*—my original 18 ft trimaran—and see what I can do to make her sit back up on her own. It should figure to work with one flooded float and a weight on the board, which in effect would make the boat a narrow fin keeler. The water resistance of sails *and* the flats of a side deck and flat float deck would be a problem, but I remain opposed to side decks in a trimaran in any case, and wide float decks may not be so great either.

. . . At a party last year, a fellow gave me an old ice boat which he said

section of above



"bugeye" —



section of "bugeye"

Actually, the New Haven "sharpie" was a two-masted "sharp" rigged craft, not excluding rotating sticks—and a round race at the deck should be possible so that a non-stayed plank mast rig would be possible if desired. However lowering would not be so simple.

. . . I have talked with George Patterson about his work with a catamaran hull (single) and Bruce foil, and he comments that the foil must stay loaded to work—and so a wider shoaler hull would probably be better as not competing with the foil in providing lateral stability on a reach. He thinks that the foil would be then fine with a dinghy section hull.

or the water level dropping out of sight. We had it all, of course, but not any more.

We don't like "pop" safety valves—the GWR knew a thing or two—just a gentle sizzler which reseats itself without too much pressure-drop; there's the rub . . .

The Ship's "Doctor," or cook, presiding over the galley coal-stove is the other vitally important member of the Ship's Company; the remainder provide dinghymen, deckhands, boat's crew for the 16 footer, trainee greasers and firemen, engine-drivers and quartermasters learning the snags and hazards of the Tideway, the signals, the manoeuvres, and all that is done by those who go down to the sea in ships.

George Warder,
SL "*SPRAY*" London

Letter from: Dick Andrews, 25 Audubon Drive, Ossining, NY 10562
30th December, 1969

Dear John,

Your discussion of retirement yachts brought to my mind the wonderful old "bugeye" *AFJEN*, upwards of 60 ft o.a., whose elderly owner single-handed her up and down the coast each summer, about forty years or so ago. The *AFJEN* was a big old thing and she was pure "bugeye"—a genuine old Chesapeake Bay workboat. She didn't even have a kicker in her, but used a little motor launch which she carried in davits to starboard except when it was wanted in a calm and would be dropped in alongside for a push. (To port, she carried a ravishing little pulling boat with a heart-shaped transom.)

The "bugeye" was of course nothing else than a giant log canoe with a "sharp" rig. It was made of squared logs pinned together in a platform as adzed to the underbody shape of a double-ended, beamy but fine lined canoe. Knees were fixed to this platform and the side planks fastened to them. There was a long centreboard. They were pretty boats, with a clipper bow and the platform built at deck level aft gave them the room on deck of a transom sterned craft. The rig was distinctive; two sticks of more or less equal height with a *drastic* rake aft, and the "sharp" or jib-headed sails, boomed and fitted with lazyjacks (as was the jib); this made it very simple to tack ship or drop sails, etc. A few bugeyes were "square-rigged" (gaff headed sails) but made much more work. The bugeye was fast and able, but few ever were made into yachts due to their size and yet quite shallow hulls.

The vacation or retirement home on water in the USA is here in the form of the outboard powered houseboat. Now the problem is sailing, and the windage of a shallow form with full headroom. One answer to this is suggested by your *KINNEGOE* itself—or by the many road trailers for camping used here, which are a box inverted over a box—to cut windage as towed by a car on the road—and readily expand to full height at stops.

I enclose a sketch of a "bugeye" rigged super-*KINNEGOE* which uses the halliards of the plank masts, conveniently raking, to lift the tops of the two cabins. There is, incidentally, much to be said for the two cabin arrangement. Admiral Byrd laid out his camps at the South Pole with at least two chambers separated by a passage, so that there was always another place to go.

controls with imminent lifting of the safety valve to skip for'd and tend fenders and warps.

A really good tuned-chord whistle? Yes—you can't have one in a motor boat, even air blown, which *sounds* right.

Manoeuvrability? Its just as easy as sculling over the stern—a turn ahead and a turn astern if you want them.

Alan Kitson, the owner, and I had a lot of fun with *OSBORNE*, a steam "barge" ex "Victoria & Albert," making the film "*Those Magnificent Men . . .*" at Pinewood Studios, in 1964.

Handling was tricky, as the "pond" got a swirl around it.

The engines ticked over silently, and Allan deliberately released steam and blew the whistle or nothing would have been seen or heard.

External combustion of paraffin was faultless during shooting, though after our return to the Thames (overland) the oil burner flashed and burned Alan's eyebrows off . . .

Paraffin has too low a flashpoint, and it is not recommended: use central heating kerosene if oil is preferred. We were converted to coal, which is no trouble at all. (Contribution to research).

We took endless trouble to get the details right, but you, the audiences, do not see anything in the glimpse you get of us.

What a life! 7 carpenters and 5 plumbers all the weekend; muster in the small hours for steam and shooting at 0800; wind blowing at us from aero-motors; drilling the "German Aviator" in the water as to avoid danger from the propeller; extra-men dressed as sailors, including us!

We were the only ones genuinely attired.

Steamboats small enough to avoid having a "Black Gang" continually below, firing, trimming and clinkering can be delightful.

We watch the engines, so called because there are always two, high and low pressure and sometimes three "Triple Expansion" on one (or each) shaft for self-starting, turning over silently and slowly enough to count the turns while we steam alongside a roaring Diesel.

We have an Engineer, or "Chief" who doubles fireman occasionally with no more than a scoop of coal, and he can take the air sitting in the engine-room companionway most of the time.

We talk to each other naturally and quietly; transmit engine-room orders by gong from the wheel house though it is only speaking distance; we solemnly chalk up the revs. passing each landmark, and we are always fascinated watching the oil drip upwards through the water-filled sightglass at one drop a minute or less, if we can manage it.

Skipper does "nothing", overseeing the wheelhouse and engine-room from the after well deck. His eye is on the traffic and the necessary haulings round and navigation signals on the whistle, and also on the water gauge in full view through the companion unless the "Chief" is a former Chief ERA, RN, or an ex GWR "Top Link" Driver.

Thats just about all there is to it. No "panic stations". No urgently roaring oil burners, blowing off of safety valves, pumping of cold water to quell same, over filling with the resulting priming, or water coming through to the engines,

Letter from: Colonel N. M. Barnardiston, East Cranhams, 44 Somerford Road,
Cirencester, Gloucestershire
15th April, 1970

Dear John,

I enclose my sketch for a steam turbine outboard which might be rather fun. The sketch is almost diagramatic because I don't know enough about turbines to put in the details; I have however dimensioned it to show that a turbine and gearing could be fitted into a reasonable sized pod. I would hope for about 4 bhp at about 10,000 rpm so with a 50:1 reduction differential gear the screw would only be doing 200 rpm. I suggest that the walls of the pod would act as a condenser and the water be returned to the boiler by a pump. I have shown the boiler as a separate unit inside the hull but it might be possible to have a flash boiler mounted on top of the unit and turned by the tiller, this would obviate the use of flexible piping.

Turbine blades are very costly if made as in full scale engines; it might be possible without too much degradation to use sheet steel pressings.

There is of course an enormous amount of work to be done if an idea like this is to be developed; this is in the nature of a stone chucked into a pond!

N. M. Barnardiston

... TO SING THE SONG O' STEAM ...

by George Warder CEng, MIMechE

19 Vaughan Avenue, Stamford Brook, London, W6

Those unfamiliar with steamboats sheer off usually. Steam gives silent power, cosiness, characteristic smell due to oil compounded with rapeseed, and an air of contentment and absence of urgency.

You may have all this with a Merryweather fire-engine boiler and a little set of compound reciprocating machinery called launch engines.

There need be no more than ten minutes preparation after flashing up—a nice blaze of driftwood and bits of Welsh (if you can get it!) Fire engines steamed in four minutes, but they cheated with a gas jet in the floor of the fire station.

You *could* use Calor, but the "pop" would be fearsome if you ignited a furnaceful of gas . . .

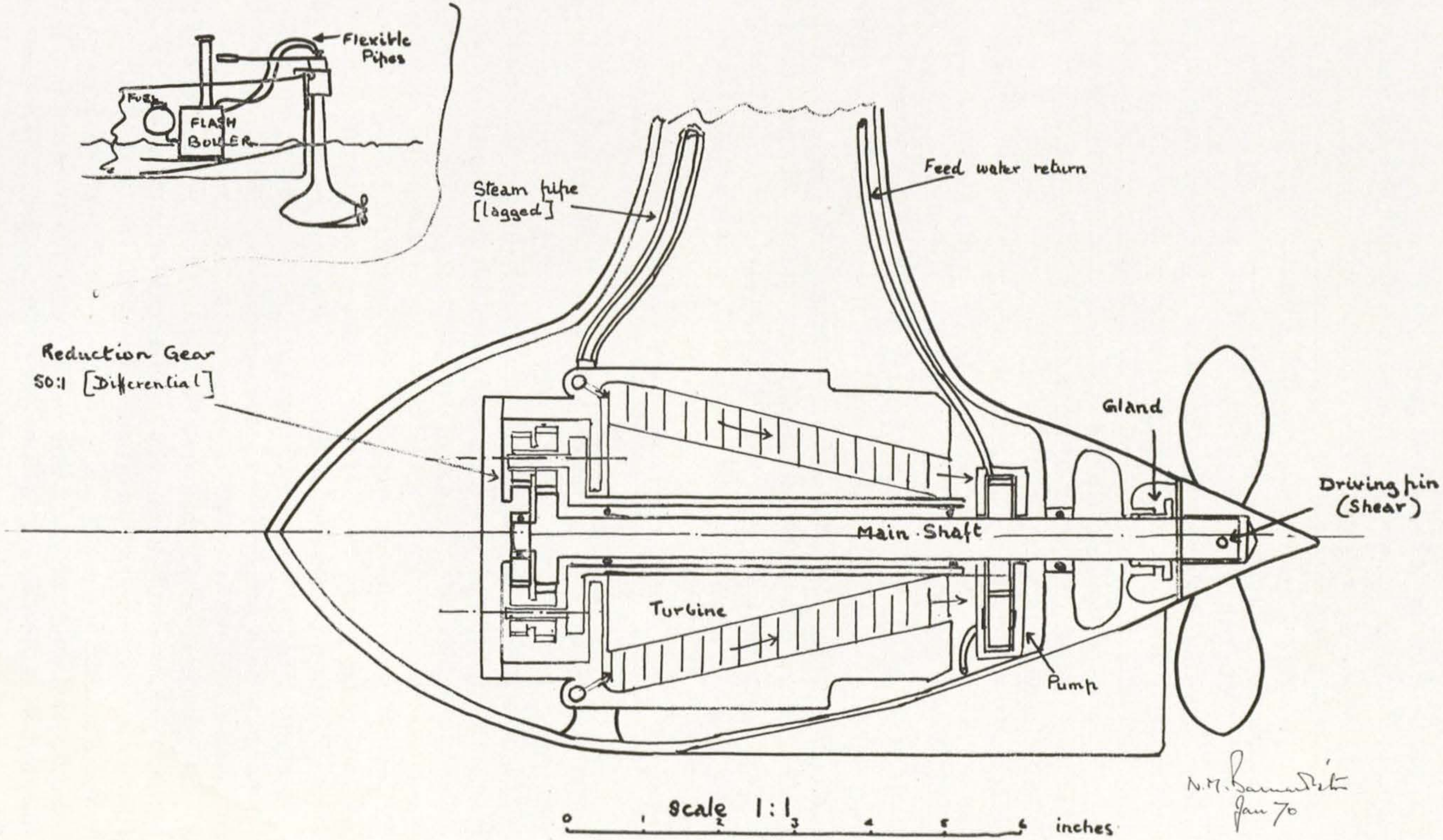
Oil, perhaps—domestic heating sort—the burner is 100 times more trouble than all the rest. Use electric blower, pump, and ignition if you can accept it, but all oil-burners roar.

Seawater trips?—Condense by keel tube and hard chrome all the rods and pump plungers to control the steam and water leaks—it *all* depends on this.

Crew? I believe in a proper crew who all know their duties, or better still all the duties, so that no panic stations are billed.

Single-handed control? It *can* be done. We like to see the engines turn over, the right way, when we receive orders—the crankshaft and propeller actually stop at "Stop Engines", and they don't *always* turn if operated "blind". Reversing *can* be made more certain by "no lap no lead" methods, but water of condensation may beat you even then. I have no interest in leaving the

SUGESTION for STEAM TURBINE OUTBOARD.



posium on auxiliary engine possibilities. Organ himself could quite easily occupy a whole evening, but possibly a better alternative would be to try and find a suitable person to talk about steam as well, in order to stimulate argument. In fact, I do not think it would be difficult to find a suitable person to do this if you were interested. Over the last twelve months I have, in fact, been collecting details of all the small steamboats in this country, so I am reasonably in touch with that world. But it must be said that most of these people are more orientated towards the preservation of the past than thinking in terms of future development.

My impression from studying the subject a little and operating my own steam launch, makes me think that to achieve an acceptable degree of automatic operation of a plant tends to involve an unacceptable degree of complication and expense. Also, there is usually a weight and space penalty; whereas the modern Stirling machines are comparable with diesels as regards weight, size and fuel consumption.

Incidentally, I read into your article the implication that the Stanley steamer had a coil ('Flash') boiler, whereas, in fact, it was a vertical fire-tube affair wound with piano wire.

Yours sincerely,

Strathcona

Ed.-Allan Organ gave a lecture on the Stirling Cycle Engine to the AYRS *in London in November,* 1970. *It appears that Messer Phillips, of Eindhoven, Holland have been working on this engine for many years and, by the use of high pressure hydrogen and a heat exchanger, have pushed up the efficiency to be comparable with the diesel and, of course, it is perfectly silent. It has many other advantages over conventional engines and a few disadvantages.*

Letter from: A. D. Ost, The Rectory, East Hanningfield, Chelmsford, Essex

Dear John,

Your remarks re: auxiliary power for your retirement yacht suggested a flash steam plant, heated by alcohol. I remember reading some years ago in an American Mechanics magazine an account of a propulsion unit for a US Naval torpedo. Basically, it is an alcohol-water torch which generates steam for the motor. Apparently, the alcohol, or blowlamp, is ignited and water is then injected (I think coaxially) into the flame. The result is a blast of steam and hot combustion gases fed to the motor. Possibly, an enquiry on the other side of the Atlantic, via AYRS publications, would attract an American 'Torps' to investigate possibilities. I am certain that the information must be unclassified as I read it in a non-naval magazine.

Such a steam generator might even be the answer to your electric generator, especially as there is no noise of the power cycle as in petrol or diesel motors. I gather that the initial power to start the alcohol torch and water injector is by a compressed air tank.

I can see a power unit like the above both light and powerful and inherently safe from fire risk. The one curse to this scheme in Britain is the crushing tax on Methanol but it might not affect craft afloat, in some circumstances.

A. D. Ost

a delight of simplicity. A friend of mine built a high performance steam racing car some years ago and he made several trips to America to consult with authorities there. The machine had tremendous performance with corresponding problems which were never resolved. His business house failed but whether or not this was due to the steam venture I wouldn't care to say.

Thank you again for your always thought provoking ideas. Enclosed sketch.

Ken Sully

Letter from: W. O. Meek, Rockstone, St. Martin, Jersey, CI

Dear John,

About using a steam engine—the petrol engine, with its high voltage ignition and tiny, easily choked jets in the carburettor is, when you think about it, about the worst type of engine for the conditions in a small boat.

I have long been interested in small steam engines, but there is almost the same auxiliary equipment with a 10 hp engine (about the minimum useful size) as with a 500 hp one. Also, they are not automatic, and when running, the gauges etc have to be watched constantly. So I reluctantly gave up the idea of using steam.

There is, however, another approach—the hot air engine. The original engines, designed by a parson, Stirling by name, about 150 years ago, ran well and were built up to hundreds of horse power. They failed because the materials they then had would not stand up to heating and cooling for any length of time. They are now completely obsolete.

The heat cycle of a hot air engine is not very different from a jet engine—they are both variations of a constant pressure cycle. In its basic form, it is very simple. There are no valves, just a source of heat and another of cold.

Today, with heat resisting alloys, the main drawback of the early 19th Century could be overcome, and because this would enable higher temperatures and pressures to be used, efficiency could go up to probably equal a petrol engine.

It should be possible to design a hot air engine and, using high pressures and an inert gas as the working fluid (the hot air used to oxidise the metal surfaces of the engine), it would be compact and saleable. Once started, it should continue to run without attention and without noise.

W. O. Meek

Letter from: Lord Strathcona, 20 Lansdown Crescent, Bath BA1 5EX, Somerset
5th December, 1969

Dear John Morwood,

Immediately on reading your thoughts on the retirement yacht in Bulletin No. 70, I wrote off to Allan Organ in Birmingham University who has been working on a modern version of an invention dating back to 1816. I believe that the Stirling cycle engine offers a better possibility of a silent and non polluting yacht engine than steam. I enclose a paper which outlines what this is about.

My thought was that you might at some stage like to have a lecture/sym-

5 *Lights* and additional Gas Heaters as desired.

All the above gas equipment is available, or members can convert ex-'mains-gas' equipment, available cheaply, by changing the jets.

6 *Hot Air from Engine Cooling Fan* ducted for cabin heating, clothes drying etc. Already carried out in a number of boats.

Additionally a refined electrical supply could augment or replace some of the above items.

1 *AC (suggested) Generator* direct driven from engine giving high output at low speed.

2 *Solid State Rectifier* incorporated in dynamo using fully tried public service vehicle equipment for battery charging.

3 *Lighting* (fluorescent if desired, again well tried equipment is readily available), *Radio, Radio-Telephone* etc.

Alternatively a 110 volt or 220 volt equipment of proven reliability could be used.

Unlike solar cells, hot-air engines and the like which even the might of Philips Electrical and General Motors seem to be having difficulty in making commercial, all the above equipment has been used and proven. The Newton Abbot man who uses compressed methane obtained from sewage and compost publishes full details of his project—there are limitations on its use for road transport that would not apply in this context—a colleague of mine has these particulars and I can find the address if any members desired.

Regarding the risk of using the gas, there are plenty of reliable gas detectors available.

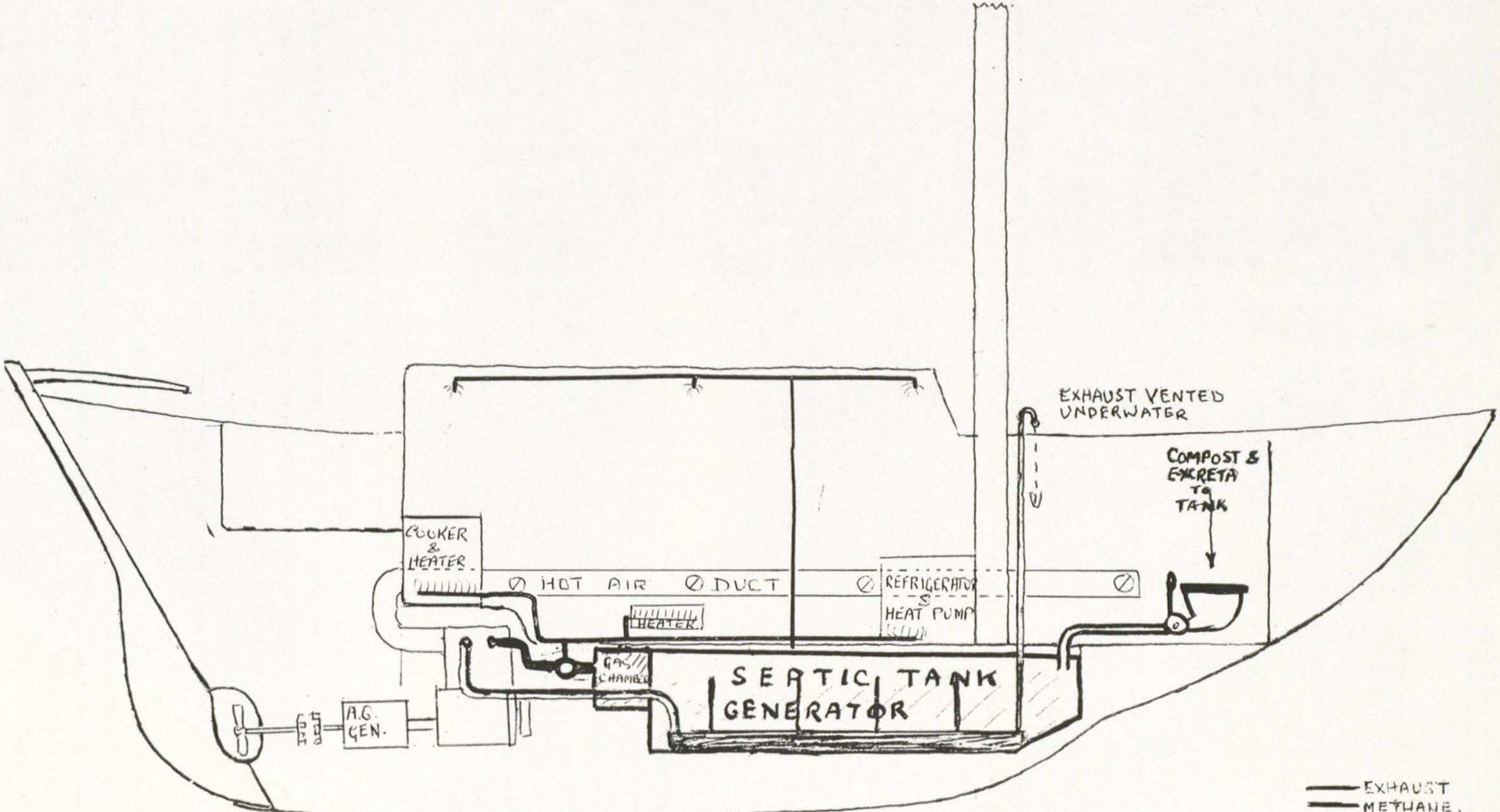
Ferro-Cement Hull

I do not think a f-c structure terminating at the waterline would be reliable from the joint leakage standpoint. As complete f-c hulls, with cabin-top, bulkheads etc inbuilt, are quite satisfactory, there would be no point in incurring this risk for the slight weight reduction in not bringing the hull up to the top-sides in f-c. There is also difficulty in obtaining a shell structure—which the f-c hull should be, if it were of composite construction. The hull section would have a wide bilge section to allow low accommodation of the engine—again nothing new in f-c design, and of course incorporate the tank.

Steam Engines

Although one would probably carry some liquid fuel as an alternative for the above gas-driven unit; I feel steam propulsion is not practical—the size of the installation; boiler and condenser together with necessary fuel would occupy an excessive space. The complications of using sea water preclude its use even for cooling an IC engine, hence my option for air cooling with the advantage of simple hot air heating.

Thermal Efficiency, from memory—I think the best Cornish Engines were about 1 per cent, good express locomotives about 8 per cent, twin-cylinder compound about 15 per cent, turbine with condenser in power station about 28 per cent, compared with say 25 to 35 per cent for petrol and IC units. It is nice to enthuse about steam but its practical application makes the IC engine


EXHAUST VENTED
UNDERWATER
COMPOST & EXCRETA TO TANK
COOKER & HEATER
HOT AIR DUCT
REFRIGERATOR & HEAT PUMP
HEATER
GAS CHAMBER
SEPTIC TANK
GENERATOR
A.G. GEN.
EXHAUST
METHANE.

Without becoming technical—in cold weather chill the intake air before reheating in order to achieve the desired humidity and in hot weather chill the air to a lower temperature than desired and reheat to the desired temperature (the lowest temperature will determine the humidity of the reheated air).

I hope that some of you medical men will come up with a decent method of disposing of human waste. Discharging sewerage and any waste is now forbidden here and the Coast Guard are enforcing this with no nonsense tolerated. I looked at the Boeing 747 aircraft the other day (550 passengers). The chemical toilets looked very good. A few days ago, I saw an electric WC but at a consumption of 3 kw per man per evacuation, I considered it a rather expensive domestic engine.

I, myself, am planning a 45 ft 0 in L.O.A., 11 ft 6 in Beam. 4 ft 0 in Draft lugsail schooner with main and foresails of the Chinese junk pattern. Accommodation from forward; peak, forecastle, dressing room extending across the hull fitted with shower as well as WC etc, main cabin, galley, hold and auxiliary engine room, after cabin, berths for three or four maximum, plenty of hanging lockers. Electric cooking, air conditioning and ventilation. There will be no fixed propeller. As I will have a 3 Phase 50 cycles per second electrical system I will use a power pod not unlike a torpedo, which I will rig outboard when required. The power pod will store in the hold when at sea. You see my philosophy is to sail where possible but I refuse to cook over a smelly stove. My galley will consist of power outlets and my ovens will be high frequency kettles. The saucepans will have their own built-in heating elements.

Bill Jones

Letter from: Ken Sully, c/o The Cottage, Withiel, Nr. Bodmin, Cornwall
30th November, 1969

Dear John,

Thank you for the No. 70. I am delighted that you had such a pleasant time with your boat in Ireland and I'm sure your account of the expedition will bring pleasure to many members.

The Retirement Yacht

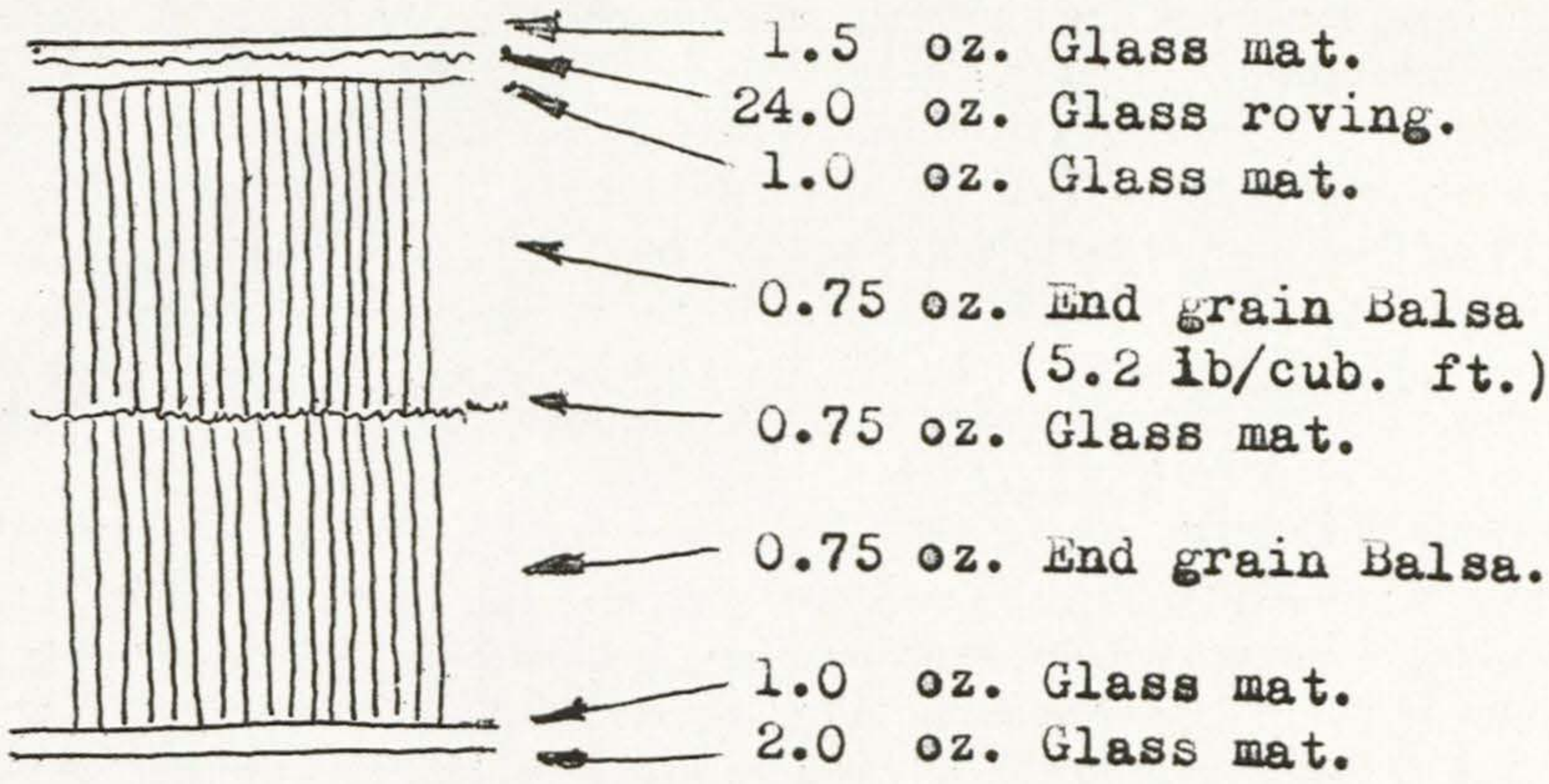
Noting that marsh or sewage gas has a high calorific value, evidenced by its use to supply the motive power for several sewage works and by a Newton Abbot man to run his car, I suggest a modification to your scheme.

1 *A 'septic tank' cum gas producer*. The Newton man finds that chicken excreta is a valuable adjunct, so perhaps non-vegetarian skippers (no use to me) could implement their diet as well as improving gas production by carrying a source of fresh eggs and meat with them. Remember the producer-gas bus of war years—steady moderate power is all we need.

2 *Slow speed Petter or Lister type Air cooled Engine* converted to run on the above gas. Calor Gas people sell suitable valves but they are so simple AYRS members would make their own.

3 *Refrigerator* (plus Heat Pump modification as you suggest if desired) heated by gas feed from tank.

4 *Cooker*. Fuel supply as above.



Resin in Polyester to Spec. Mil-R-7575-C.

trains its men to perhaps the highest standards of small boat handling, nevertheless the usage is much more severe than a yacht will get. As the Balsa is completely immersed in resin, no decay occurs. Even if a boat hull is ripped on a spike so that the Balsa is exposed, the absorption of water is at a very low rate. Repairs are easily accomplished.

Composite construction such as you suggest will result in failure. The trouble with glass foam panels is the extremely low shear characteristics of all foams. If you want feather light hulls for a race go ahead with foam but avoid it if longevity of the hull is required. Remember, I do not say that foam panels are never suitable but in this context, for the service intended, they are.

I will leave the aerodynamic and hydrodynamic considerations to you and Edmond Bruce.

I fear your steam engine will prove to be a "will o' the wisp" in the final analysis. With the current phobia here about air pollution a terrific amount of research for a replacement for the automobile engine is under way, and it would appear that an organic vapour turbine/electric system or a gas turbine/electric system may well be the outcome. At present we have low emission gas turbines here and the hold up has been development of very high speed alternators which will eradicate reduction gearing from the gas turbine system. The gas turbine is also silent (believe it or not) when used outside of aircraft applications.

For the present the diesel is, to my mind, the most practical approach. Rather than attempting to recover waste heat from a refrigerator, recover it from the diesel, circulate the cooling water through the living spaces after boosting the temperature by an exhaust gas heat exchanger. Run your auxiliary engine and use AC for air conditioning, refrigeration. Why not cook by electricity when under way as well as when in a marina? Get a good heavy duty auxiliary and run it.

I am glad to see your remarks on ventilation, but I will add a thought on air conditioning as, if I read you correctly, you are a little off base regarding hot weather.

vantage of nicely bending into compound curves and recovering its shape after being touched.

The anthracite stove in the saloon was excellent. For lighting we used electricity sparingly as it is such a bore having the charger banging away—even one as quiet as a Honda. The main light in the saloon is an Aladdin circular wick type with mantle above. This is a real winner. It drops into a fixing on the saloon table so cannot tip, gives a good light, and useful heat. It is essential to have ventilators in the cabin roof.

Auxiliary Power

I have been puzzling over this ever since I finished *ICONOCLAST* sufficiently to sail her. A retractable prop aft on a long hull cavitates in the slightest lop. So for a boat to be used at sea or in Estuaries this is unsatisfactory.

A 3 hp diesel surely could not produce sufficient Shaft hp to overcome the windage of your boat. It blows like hell right up and down the canals as I discovered when crossing England by canoe. Of course the wind is always from ahead.

Ideally I suspect that some form of propeller jet unit is the answer but I plan to fit on my boat a 12 hp Seafarer inboard petrol engine driving a Watermota V.P. propeller (one unit in each hull). I will let you know at the end of next season if it is as successful as I hope it will be.

Pat Patterson

Letter from: Bill Jones,

Dear John,

I would like to make a few technical comments on your ideas for a "Retirement Yacht" in AYRS No. 70. I must caution you that in my opinion the composite construction of Ferro-cement and pvc sandwich will fail in service. Experience here by the US Coast Guard has proven beyond doubt that, for durability, fibreglass-foam sandwich construction is unsatisfactory. It has been found that glass-foam combination crush under impact and the skins separate from the foam. Let me suggest a more durable and equally light construction to which it is easier to attach fasteners as well. I refer to what is known here as "End-grain Balsa Sandwich Construction". A typical construction would be as in the sketch and I chose this because I have seen records of actual testing of such a structure.

This section weighs exactly 3·0 lb/ft^2. Testing of a panel 6 in wide, loaded at two quarter span points on a span of 18 in to a max load of 1000 lbs gave the following results—Deflections measured at mid point of span.

Deflection at 1,000 lb = 0·0900

Ultimate load = 3,090 lbs.

Load was applied dynamically at the rate of 0·08 in per minute so that the maximum load occurred between 3 and 6 minutes.

Sound absorption and thermal properties are excellent; indeed at some frequencies better than foams. This construction has given an excellent account of itself under service conditions and, although the Coast Guard the space below free and to simplify construction leeboards instead of a centreboard are provided. A centreboard trunk is apt to be a source of trouble, weakens the hull, as it cuts right through it. A hinged rudder allows her to be beached under normal conditions. Total sail area is 456 square feet and is kept low by providing short gaffs. Power is supplied by two single cylinder 5hp. motors. *MEADOW LARK* provides comfortable cruising accommodations for four people, should be inexpensive to build, and with reasonable care should last a long time.

Eight blueprints price $20·00.

SOME THOUGHTS ON GALLEYS

by Anthony McLean

The first requirement is obviously an efficient means of cooking. There are numerous designs and types of cookers to suit all tastes and sizes of boat so I'll just deal with the merits of the three most common fuels used.

Paraffin or Kerosene

If well maintained, virtually smell free, burners of the Primus type being preferable to the wick type, giving a hotter flame.

Alcohol

Slightly more expensive to run, but no smell and little maintenance required.

Butane or Propane Gas

Provided that the system is well installed and used with intelligence, it is safe. The bottle should be stowed in an enclosed locker which has a watertight bottom so that in the event of a leak at the regulator (the most likely place) gas cannot get into the bilges, gas being heavier than air. The installation of a gas detector is desirable but not essential. A good practice is to check for leaks, after changing bottles, with a solution of soap and water around the connection. In the event of a concentration of gas in the bilge, ventilate thoroughly and pump out the bilge, gas can thus be pumped overboard. Beware of switching on lights and smoking until the gas has been completely dispersed.

Advantages of Each Type

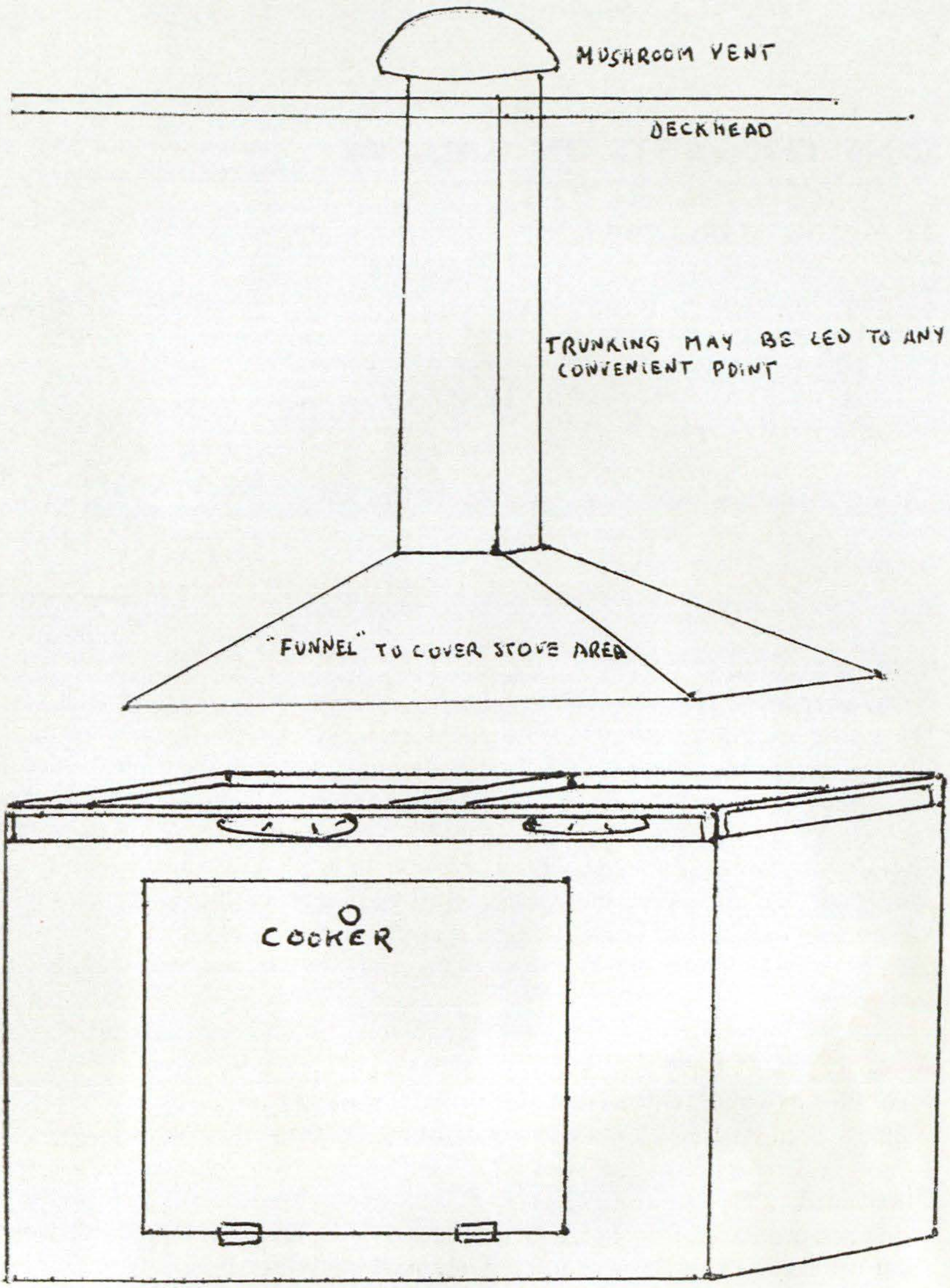
Paraffin, Alcohol, is available anywhere. Cheap and safe.
Butane/Propane, flame more easily adjusted, convenient to use. Clean.

Disadvantages

With pressure Paraffin cookers, the fuel must be first class, clean and free from water contamination. Burners and nipples must be cleaned regularly to prevent poor performance and smell. On wick types, the wick must be kept trimmed or it will smoke and greasy black smuts will get everywhere.

Butane/Propane, can be dangerous if sufficient care is not taken. If cruising abroad it may be necessary to use various brands of gas, involving different shaped containers and regulators—each company charging a deposit for both items.

Whatever type of stove is used, adequate "fiddling" must be fitted to prevent pots and pans from becoming mobile.



Ventilation

Adequate ventilation is essential in a galley but draughts in the vicinity of the stove are undesirable. A good idea is to have an inverted "funnel" over the top of the cooker (see drawing) with trunking to a ventilator. The heat from the stove is sufficient to create an updraught to draw out unwanted steam, smells, etc.

Working Surfaces

There is nothing worse than having nowhere to put that hot saucepan or the plates when dishing up, and of course the surface must be within easy reach of the cook so that he/she doesn't have to move too far. You cannot have too much working surface in the galley, ask any housewife.

Stowage space

Adequate lockers and racks must be provided, I like to have the cups hung on deep cup-hooks and plates in sectioned trays or plate racks. A place for everything and everything in its place.

Washing up facilities

A sink with drainage overboard (with seacock at outboard end) can be fitted to all but the smallest craft. There are many different shapes and sizes on the market but an inexpensive one can be made from a plastic bowl with a plug fitting fixed through the bottom. A deep bowl is better than a shallow one. A lid can be fitted over the top to provide more working surface but it is ten to one you want to get to the sink just when the top is covered with crockery or pans.

A fresh water tank with a pump at the sink is a desirable feature even if its only a jerrycan with suction pipe put through the top. The average small boat doesn't carry sufficient water to use for washing up so the use of salt water with "Teepol" or other liquid soap can be used. A salt water pump at the sink is a luxury to be indulged in if possible but be careful to have it marked—salt tea tastes awful.

Position of Galley

The best place for the galley is aft of amidships, the pitching moment is less and it is closer to the helmsman. The disadvantages of this are :

1 That, as the natural draught of any boat is from aft forward, the smells from cooking tend to permeate through the boat, and;
2 That everyone has to disturb the cook when passing back and forth.

Security for the Cook

Anyone who has had the doubtful pleasure of cooking in a wildly gyrating galley will appreciate the necessity of being able to wedge oneself in, leaving the top half of the body free to stay in the upright position. Boats with a large galley should have a locker (more working surface) or a bar arrangement about waist high that the cook can lean his/her back against leaving both hands free to work with.

This arrangement, if properly made and fitted takes up very little space and can make the galley look quite attractive.

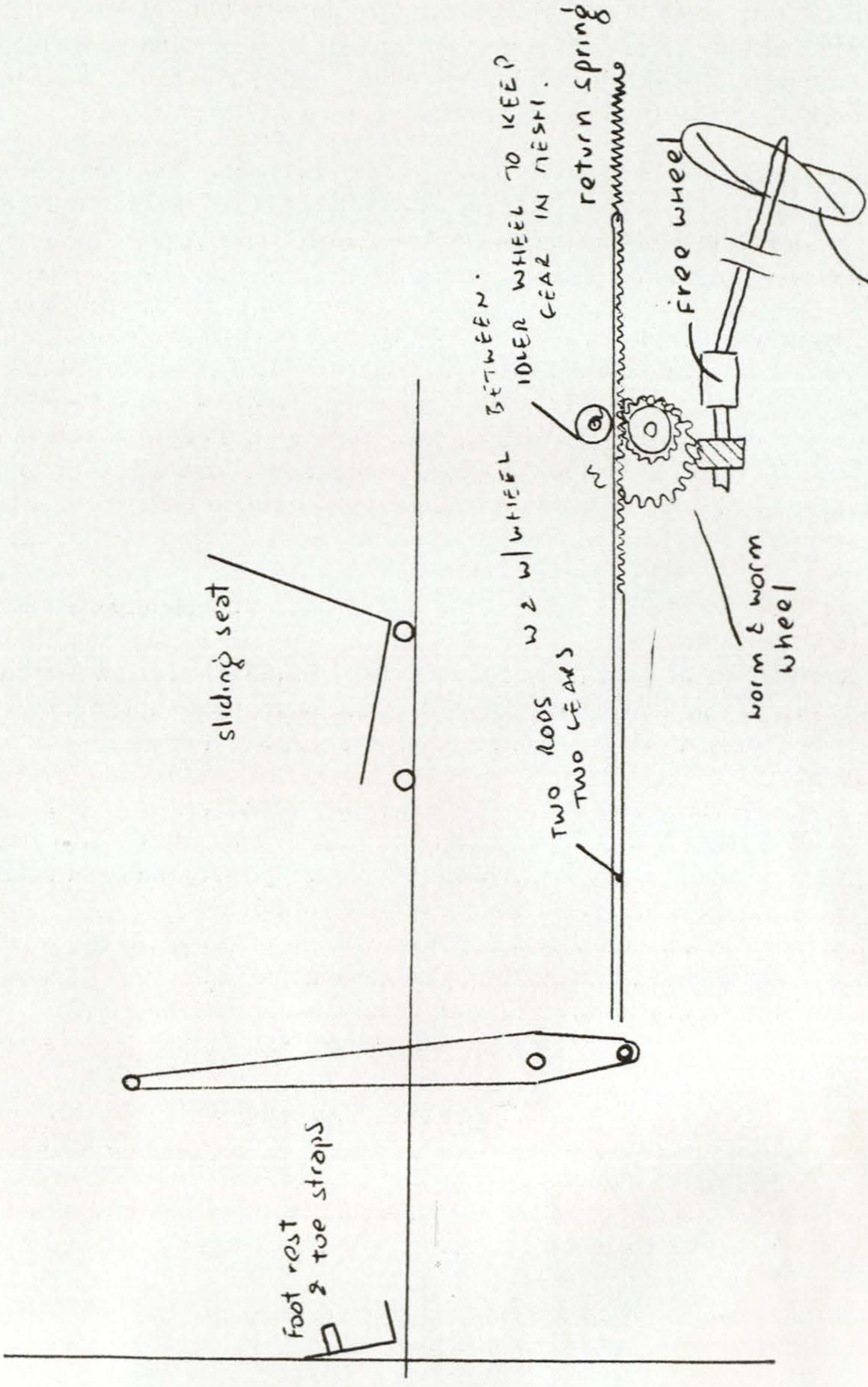
Letter from: P. A. Townsend,

Highburgh House, Packhorse Road,
Gerrards Cross, Bucks.
20th October, 1969

Dear John,

I thank you for your letter of the 16th October. I enclose a carbon copy of a sketch I did for Birmingham university, showing the sort of thing I had in mind for manual screw operation. Pedals alone would be inefficient, in my opinion. With my system the whole body would be used. You would get many turns of the screw for one long slow pull.

P. A. Townsend



Letter from: Ed Doran, Jolo, Sulu, Philippines
17th March, 1970

Dear John,

Your very complimentary letter of 13th February, caught up with me yesterday. Your comments are most appreciated (ie re: Totrola Boat).

I'll be happy to send the Polar Curve graph, but it will have to wait until my return to the US in August.

I'm working on boats here, later on refits in Taiwan, still later on single outriggers in the Carolines. This is a most interesting and profitable sabbatical leave that my wife, younger son Tom, and I are enjoying.

Thus far, I have taken lines off five different types of native boats and canoes, and gotten performance data from two. My Bruce-type electronic gear still has bugs so am using an apparent wind vane, hand anemometer, boat speed "wand", and protractor for estimating leeway from the wake angle.

A few interesting bits:—Floats on all the double-outriggers are toed *out* a few inches at the forward end—contra trimaran practice. Reason thus far unknown. The *MORO VISTA* is a wonderful sailor on a very broad reach and down wind, but it performs miserably on the wind. Makes 10° of leeway or more; Gamma is about 80°! In tacking, the lower yard of the lug sail is rolled up with the sail, vang is slacked, sail stood vertically, "capsized" inside out, passed around forestay and mast to the new lee side, then unrolled, vang tautened to get a stiff luff, and sheet retrieved and hauled in—a very cumbersome procedure!

Ed Doran

Letter from: Michael Posnett, Hirdre Faig, Llangefni, Anglesey

Dear John,

The recent Lifeboat disaster prompts a little thinking, and perhaps by thinking in public through AYRS we can improve on the existing self righting principles. I would like to put forward three new lines of thought to be shot down.

1 A large float like a catamaran masthead float or small flying saucer mounted on two substantial gantries. This should make the centre of buoyancy well below the centre of gravity when floating upside down and thus unstable in this position. The sea would be rough and selfrighting would take place. It could be tried on an existing boat and others could be converted.

2 An hydraulic propeller unit(s) mounted in the air above the quadrail. This would be operated by a compressed air hydraulic reservoir and automatically set in motion by a pendulum switch. This system can also be tried on existing boats.

3 The top of the boat can be a half cylinder. This structure is very unstable upside down. It poses some problems which could be overcome such as:

a Where do the crew see out.

b How do the rescued get aboard.

c The design of buoyant self closing hatches.

These might be needed for all three designs.

Perhaps something might come out of these.

Michael Posnett

ESTIMATING DISPLACEMENT

by John F. Darby

6a Henderson Avenue, Malvern 3144, Australia

Introduction

An approximate estimate of displacement, either of a new design at an early stage when only the main dimensions and the general form are known, or of an existing craft for which full drawings are not available, may be required. Such an estimate was provided by the old Thames rule, which suited hulls of the general shape common when it was devised, but could give misleading results when applied to the slender forms that followed. This paper presents a similar rule for multihulls and other boats with canoe bodies and perhaps fin keels.

The rule is found by an exact calculation for a certain assumed form, with corrections estimated for other shapes. It will fit many modern designs because

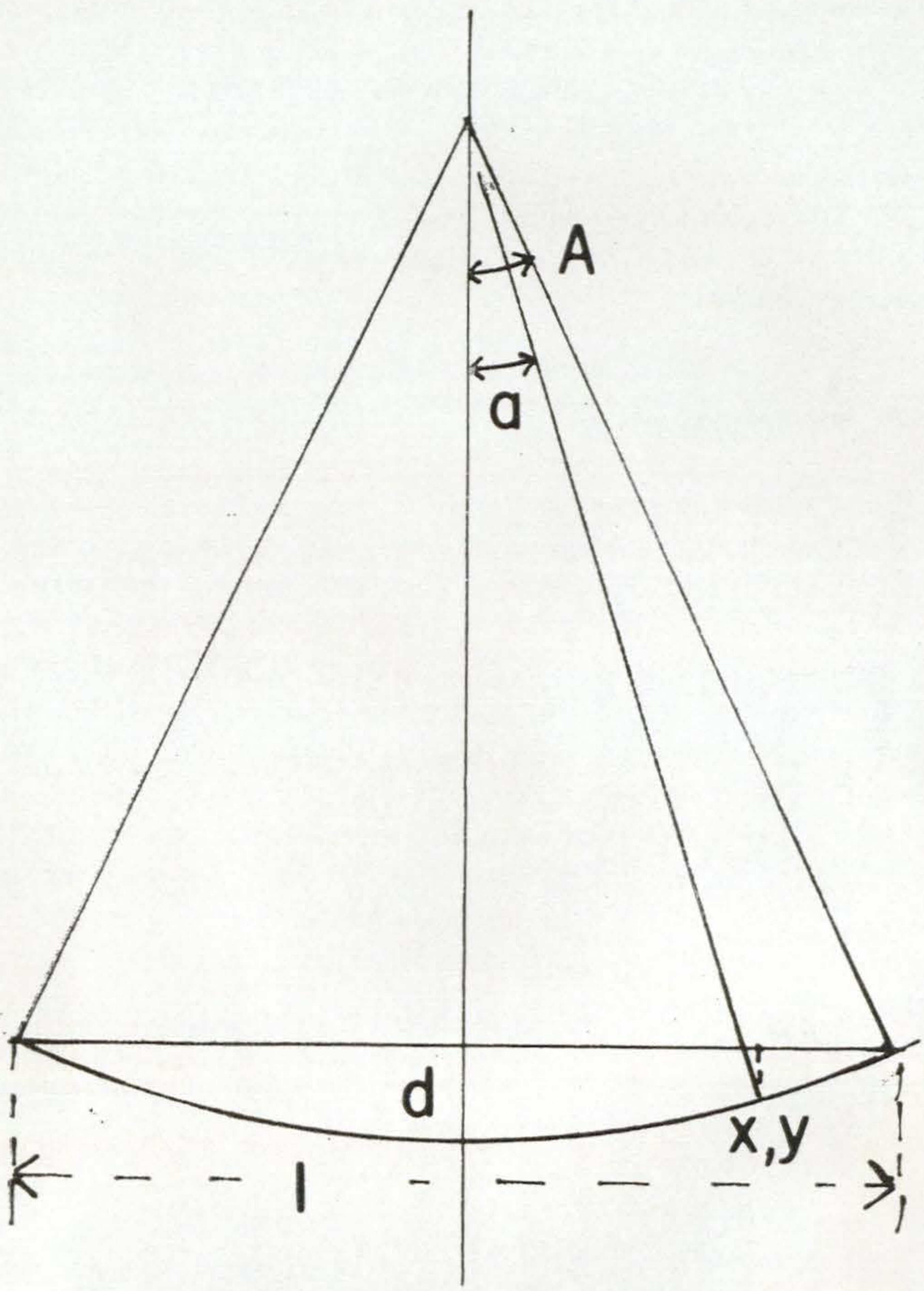


Fig. 1. Assumed form, showing symbols and co-ordinates

building economies have almost eliminated reverse curves in waterlines, making most craft everywhere convex outward. Thus the simple shape assumed is often a good approximation to the actual form of a multihull, especially when corrected as described below.

Assumed Form:

This shape is in profile an arc of a large circle and in transverse section a semi-circle, giving the waterline the same shape as the profile. The surface is generated by revolving the profile arc about the centreline of the water plane. This is the form used by Bruce for the model trials described in AYRS No. 45 and is shown in Fig. 1, where R is the radius of the profile arc, B is

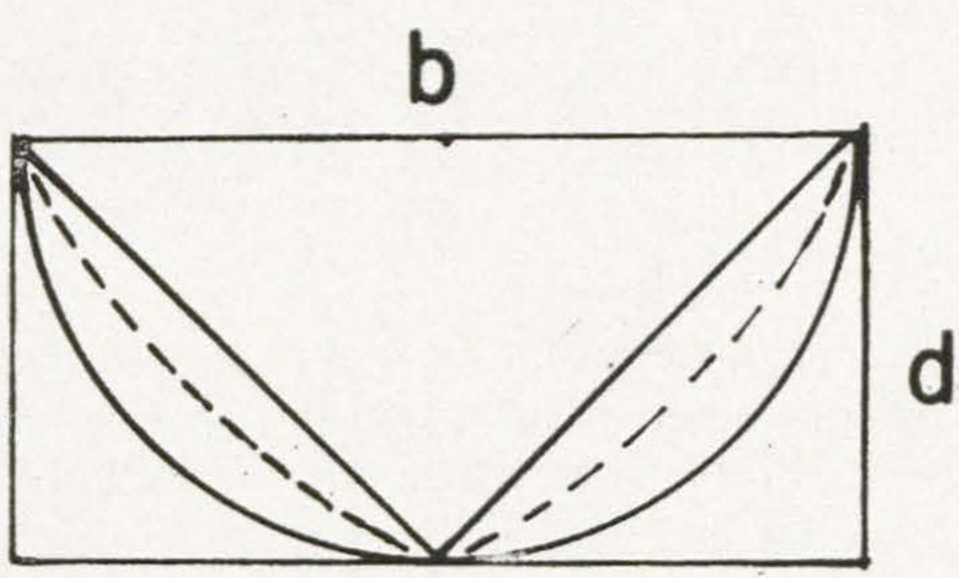


Fig. 2. Full lines—semicircular and triangular sections; dotted line—arbitrary section

the beam at the waterline, d (=B/2) is maximum draft and l = nB is the waterline length. Co-ordinates x and y are measured ahead and downward from an origin amidships at the waterline, and A is the maximum value of the angle a between the radii from the centre of curvature of the profile to points on the profile amidships and at the point x, y.

Derivation of Rule: In Fig. 1

$$y = R\,(\mathrm{Cos}\ a - \mathrm{Cos}\ A),\ x = R\ \mathrm{Sin}\ a$$
$$d = B/2 = l/2n = R\,(1 - \mathrm{Cos}\ A).$$

From the large circle

$$l^2/4 = d\,(2R - d)$$

hence $n^2 = l^2/4d^2 = 2R/d - 1$

and $d/R = 2/(n^2 + 1)$.

$\mathrm{Cos}\ A = 1 - d/R = (n^2 - 1)/(n^2 + 1)$

$\mathrm{Sin}\ A = l/2R = 2n/(n^2 + 1)$

Now, volume displaced $= 2 \int_0^{l/2} \pi y^2 dx = \pi R^3 \int_0^A (\mathrm{Cos}\ a - \mathrm{Cos}\ A)^2\ \mathrm{Cos}\ a\ da$

$$= \pi R^3 \int_0^A (\mathrm{Cos}^3 a - 2\mathrm{Cos}^2 a\ \mathrm{Cos}\ A + \mathrm{Cos}^2 A\ \mathrm{Cos}\ a)\ da$$

$$= \pi R^3 \int_0^A (3/4\ \mathrm{Cos}\ a + 1/4\ \mathrm{Cos}\ 3a - \mathrm{Cos}\ A\,(1 + \mathrm{Cos}\ 2a) + \mathrm{Cos}^2 A\ \mathrm{Cos}\ a)\ da$$

$$= \pi R^3 \Big[\tfrac{3}{4} \text{ Sin a} + 1/12 \text{ Sin 3a} - \text{a Cos A} - 1/2 \text{ Sin 2a Cos A} + \text{Cos}^2 \text{ A Sina} \Big]_0^A$$

$= \pi R^3$ (3/4 Sin A + 1/12 Sin 3A − A Cos A)
$= \pi R^3$ (Sin A − 1/3 Sin^3 A − A Cos A)
Putting R = 1/21 Cosec A
Volume $\pi 1^3$ (Cosec^2 A − 1/3 − A Cos A Cosec^3A)/8

$$= \pi 1^3 \left(\left(\frac{n^2 + 1^2}{2n}\right) - 1/3 - A \frac{(n^2 - 1)(n^2 + 1)^2}{8n^3} \right)/8$$

If 1 is measured in feet and we take the density of sea water to be 64 lbs per cu ft this becomes

$$\text{Displacement} = \pi 1^3 \left\{ 2\left(\frac{n^2 + 1}{n}\right)^2 - \frac{8}{3} - A \frac{(n^4 - 1)(n^2 + 1)}{n^3} \right\} \text{lbs}$$
$$= \pi 1^3 C \text{ lbs, say}$$

If the section is a rectangle instead of a semicircle the constant π is replaced by 4. If it is a (right-angled) triangle the constant is 2. If it is of some other shape which occupies a fraction f of the rectangle then the factor becomes 4f. These possibilities are illustrated in Fig. 2.

Value of C: (Illustration on page 121) (If not open together)
The parameter C depends on the form factor n; it is shown plotted as a function of n in Fig. 3 (curve A) for the range of n from n = 2 to n = 20, a much longer range than is likely to be needed. The curve is seen to be nearly a straight line on a logarithmic scale, with the approximate equation C = 4·5 n^{-2} by inspection and C = 4·413$n^{-2.104}$ from n = 4 to n = 12 by least squares. Over this range n^2C varies by less than 1 per cent from the mean value 4·31 and displacement is given accurately enough for our present purposes by 4·31π $1^3/n^2$ lbs or 271Bd lbs, when length 1, beam B = 1/n, and draft d = 1/2n are all measured in feet. This becomes 34·5 f1Bd for the section that fills the fraction "f" of the circumscribing rectangle Bxd. If the draft is not equal to half the beam a more general expression is required which will be discussed in a later paper.

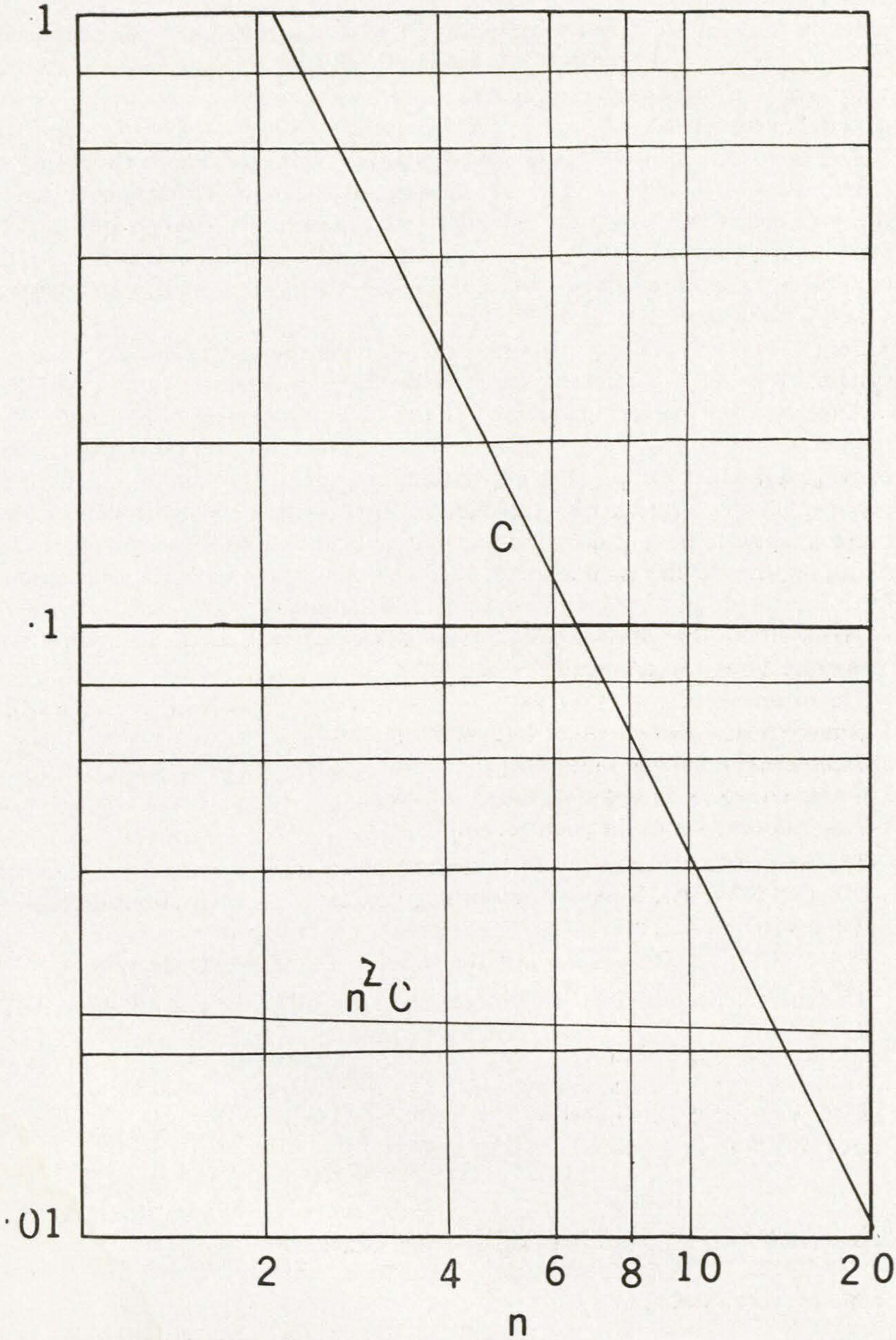
If the maximum draft does not occur at the centre of the water line then the shape can be divided at the maximum point and displacement found as the mean of the values for two fictitious craft, one twice as long as the fore-body and the other twice as long as the afterbody.

A NEW NAVIGATION SYSTEM

by W. D. Antrim

287 Nahant Road, Nahant, Mass., USA

I have devised a new navigation system which may be useful for self amusement or in survival conditions. The system enables one to find positions to rough accuracy with very little equipment, in fact with nothing but what a fisherman



3. C and n^2C as functions of n, logarithmic scale. For n^2C multiply ordinates by 100 would probably have with him in a rowboat. All one needs is a wrist watch and a tide calendar, such as are given out gratis at Boat Hardware stores and Gasolene stations.

Before the details, a few reservations. I have not tested the system adrift in a lifeboat, but business does cause me to fly around, landing here and there, where trials of the system have worked quite well enough to encourage me to issue this write up.

The basic idea is that at sunrise, and at sunset, one can observe the angular relationship of the sun to the horizon without a sextant. The angle at these times is, of course, zero. Tide calendars usually also give sunrise and sunset for the area for which they are issued. One needs to know the latitude and longitude of the tide calendar's issue. In my case, that is Boston, Massachusetts, which is about 70° 55 W and 42° 15 N.

Sunrise and set is usually rounded off in minutes, but this is not a precision system. However, it does work much better than other means, such as RDF.

Another contributing inaccuracy is that the sunlight is never more refracted that at sunrise and at sunset, but many observations and timings have convinced me that the refraction is reasonably consistent at about one minute of time. That is, sunrise, which is defined as when the upper limb breaks the horizon, appears to have occurred one minute before it has actually happened. At sunset, the sun has set one minute before it appears to have set. Correction for this error should be factored into the calculations.

The system also assumes a Mercator world, so that departures from the temperate zone would magnify errors.

The information required is:

1 Observed sunrise in minutes (plus a minute).
2 Tide calendar sunrise in minutes.
3 Observed sunset in minutes (minus a minute).
4 Tide calender sunset in minutes.

The simple formulae to put this information in are:

$$\text{O S R} - \text{T S R} = -\ 3{\cdot}6 \text{ latitude degrees} + 4 \text{ longitude degrees}$$

and

$$\text{O S S} - \text{T S S} = 3{\cdot}6 \text{ latitude degrees} + 4 \text{ longitude degrees.}$$

The latitude degrees require a correction factor other than at mid-Summer, which is:

$$\frac{\text{days from June 21-23}}{9{\cdot}250}$$

Instead of 3·6 latitude degrees, the equation would then be:

$$\text{O S R} - \text{T S R} = -\ \frac{\left[18 - \dfrac{(\text{days from June 21-23})}{9{\cdot}250}\right]}{5 \text{ longitude degrees}} + 4 \text{ longitude}^\circ$$

$$\text{O S S} - \text{T S S} = \frac{18 - \dfrac{(\text{days from June 21-23})}{9{\cdot}250}}{5 \text{ latitude degrees}} + 4 \text{ longitude}^\circ$$

For a trial of the system, it will be easier to follow if information is used from 21st June, 1967 on which day the tide calendar gives 4.07 for sunrise in Boston and 7.24 for sunset. (1968 calendar gives the same times). In Philadelphia observed sunrise was 4.31 (add a minute) and observed sunset was 7.34 (subtract a minute).

The equations can now be filled out:

$$4.32 - 4.07 = -3{\cdot}6 \text{ lat,}^\circ + 4 \text{ long}^\circ$$
$$7.33 - 7.24 = 3{\cdot}6 \text{ lat,}^\circ + 4 \text{ long}^\circ$$

Adding the two equations:

$$34 = 8 \text{ long}^\circ$$
$$\text{long}^\circ = +4{\cdot}25^\circ = 4^\circ 15'$$

Adding to longitude of Boston:

$$\begin{array}{rl} & 70^\circ\ 55'\ \text{W} \\ + & \ \ 4^\circ\ 15' \\ \hline & 75^\circ\ 10'\ \text{W for Philadelphia.} \end{array}$$

Subtracting the two equations:

$$16 = 7{\cdot}2 \text{ lat}^\circ$$
$$\text{lat}^\circ = 2{\cdot}22^\circ = -2^\circ\ 13'$$

Subtracting from Boston:

$$\begin{array}{rl} & 42^\circ\ 15'\ \text{N} \\ - & \ \ 2^\circ\ 13' \\ \hline & 40^\circ\ 2'\ \text{N for Philadelphia} \end{array}$$

and sure enough that's where Philadelphia is.

Another example:

On 21st June, 1968 Boston sunrise is listed as 4.07 and sunset 7.24. Observed sunrise in New York was 4.23 (add a minute) and sunset 7.32 (subtract a minute). Now we can write the equations:

$$4.24 - 4.07 = -3{\cdot}6 \text{ lat}^\circ + 4 \text{ long}^\circ$$
$$7.31 - 7.24 = 3{\cdot}6 \text{ lat}^\circ + 4 \text{ long}^\circ$$

This time we will solve for miles (statute) from reference. If one degree of longitude is about 50 miles and 1° of latitude is about 70 miles, then solve as follows:

$$24 - 7 = 17 = -3{\cdot}6 \text{ N} + 4 \text{ W}$$
$$31 - 24 = 7 = 3{\cdot}6 \text{ N} + 4 \text{ W}$$

Adding the equations:

$$24 = 8 \text{ W}$$

Applying factor for longitude miles:

$$24 - 50 = 8 \text{ W}$$
$$\text{W} = +150 \text{ miles (from Boston)}$$

Subtracting the equations:

$$10 = -7{\cdot}2 \text{ N}$$

Applying the latitude miles factor:

$$10 + 70 = -7{\cdot}2 \text{ N}$$
$$\text{N} = -97{\cdot}5 \text{ miles (from Boston).}$$

This says we went to South 97·5 miles and West 150 miles, which puts us in the New York ballpark.

Chances are that if one is actually putting the systems into practice, position at sunset would be different than at sunrise. One would drift, sail, or row in a direction. A dead reckoning estimate would be used to advance the observed sunrise to the sunset position.

Suppose we estimate drift is about 180 miles at 237° (so that it fits above example), then:

$$\text{Sine } 33^\circ\ (270 - 237)\ 180 = 97{\cdot}5 \text{ miles}$$
$$\text{Cosine } 33^\circ + 180 = 150 \text{ miles}$$

Now we can write the equations:

$$4.24 - 4.07 = -\ 3{\cdot}6 \text{ lat}^\circ + 4 \text{ long}^\circ$$
$$7.31 - 7.24 = 3{\cdot}6 \text{ lat}^\circ + 4 \text{ long}^\circ$$

This time we will solve for miles (statute) from reference. If 1° of longitude is about 50 miles and 1° of latitude is about 70 miles, then solve as follows:

$$24 - 7 = 17 = -\ 3{\cdot}6 \text{ N} + 4 \text{ W}$$
$$31 - 24 = 7 = 3{\cdot}6 \text{ N} + 4 \text{ W}$$

adding the equations:

$$24 = 8 \text{ W}$$

applying factor for longitude miles:

$$24 + 50 = 8 \text{ W}$$
$$\text{W} = +\ 150 \text{ miles (from Boston)}$$

subtracting the equations:

$$10 = 7{\cdot}2 \text{ N}$$

applying latitude miles factor.

Working backwards:

$$\frac{?\ +\ 70}{-\ 7{\cdot}2} = -\ 97{\cdot}5$$
$$? = 10$$

and

$$\frac{?\ ?\ +\ 50}{8} = 150$$
$$?\ ? = 24$$

then:

$$\text{O S S} - 4.07 = \text{X}$$
$$7.31 - 7.24 = \text{Y}$$
$$\text{X} + \text{Y} = 24$$
$$\text{X} - \text{Y} = 10$$
$$\overline{2\text{ X} = 34}$$
$$\text{X} = 17$$
$$\text{Y} = 7$$

And thus a new observed sunrise can be substituted.

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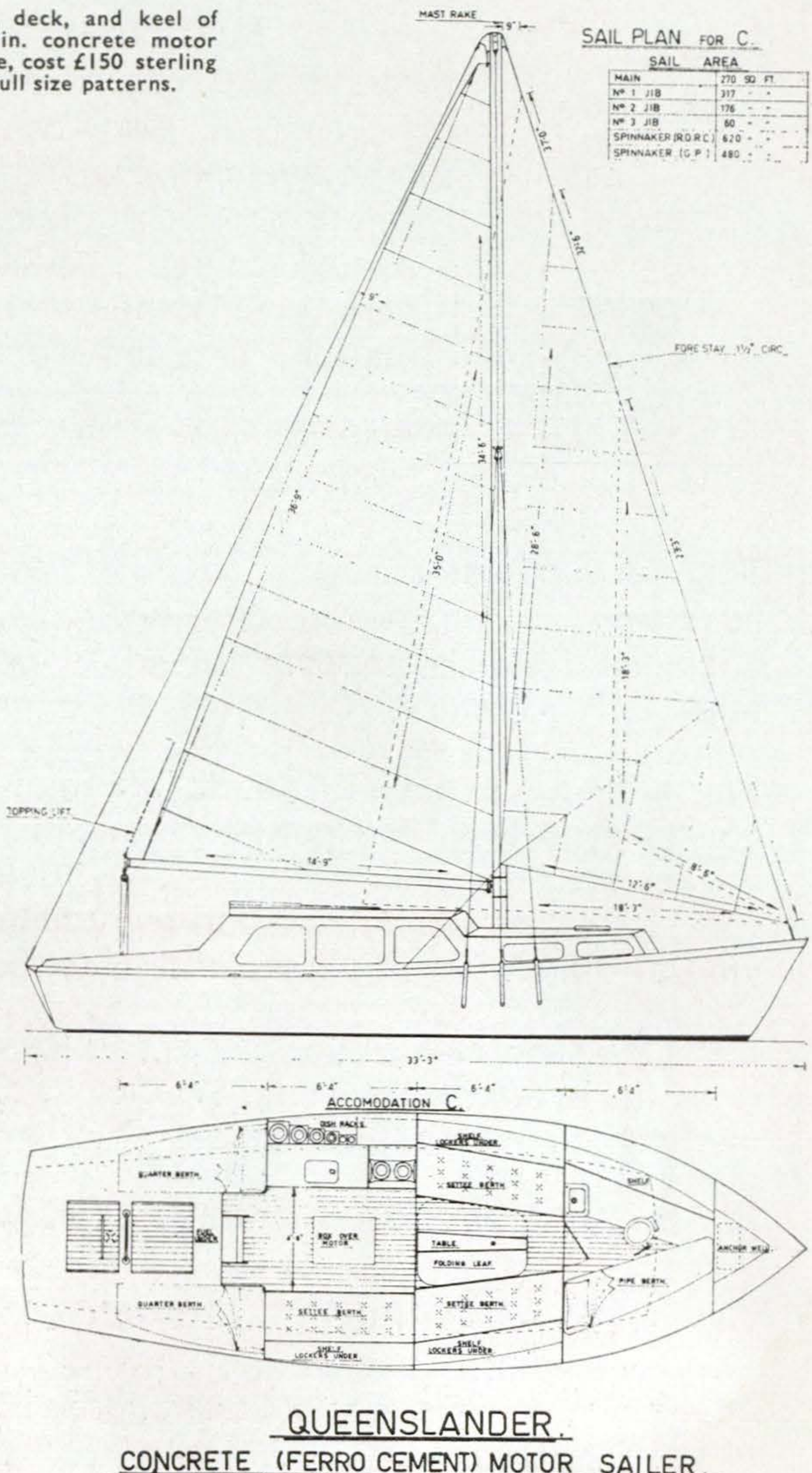

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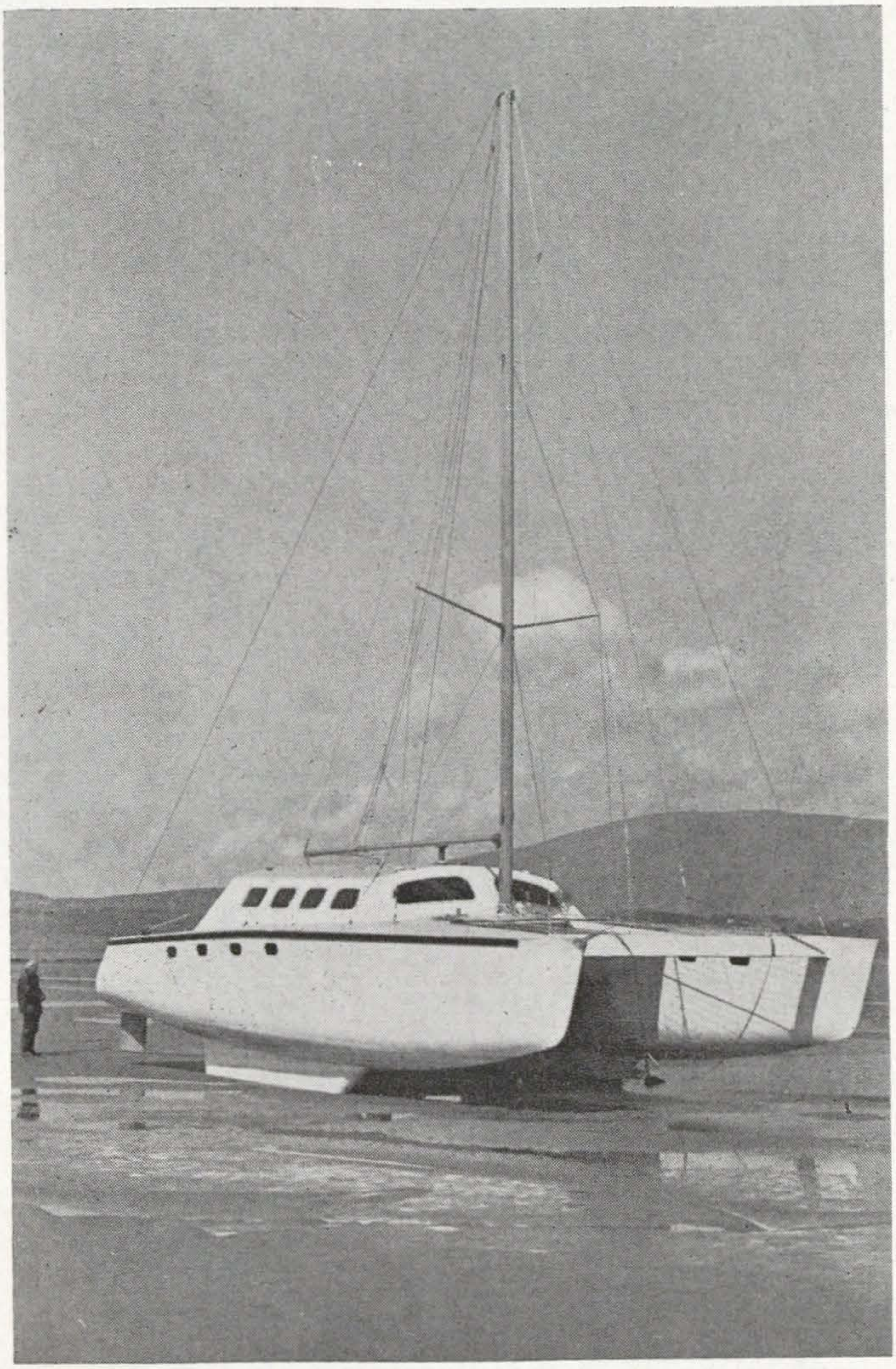

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