SAILING FIGURES

A.Y.R.S. PUBLICATION No. 56

KURREWA

CONTENTS

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THE AMATEUR YACHT RESEARCH SOCIETY

(Founded June, 1955)

EDITORIAL

July, 1966.

The following letter has just been received by Roger Gresham Cooke:

Buckingham Palace,
21st April, 1966.

From: Rear-Admiral Christopher Bonham-Carter, C.B., C.V.O.

Dear Mr. Gresham Cooke,

Thank you for your letter of 19th April. His Royal Highness will be very pleased to give his Patronage to the Amateur Yacht Research Society.

Yours sincerely,
Christopher Bonham-Carter.

R. Gresham Cooke, Esq., C.B.E., M.P.

Roger Waddington has resigned the Chairmanship of the A.Y.R.S. for health reasons but will continue to serve on the Committee.

89, Alexandra Road,
N.W.8.

10th March, 1966.
Rogor Waddington Esq.,
6, Magdalene House,
Manor Fields,
London, S.W.15.

Dear Rogor,

At the Tenth Committee Meeting of the A.Y.R.S. on Sunday, 27th February—the first since your resignation as Chairman—great regret was expressed by all those present that it had become necessary, in your opinion, to give up your Chairmanship.

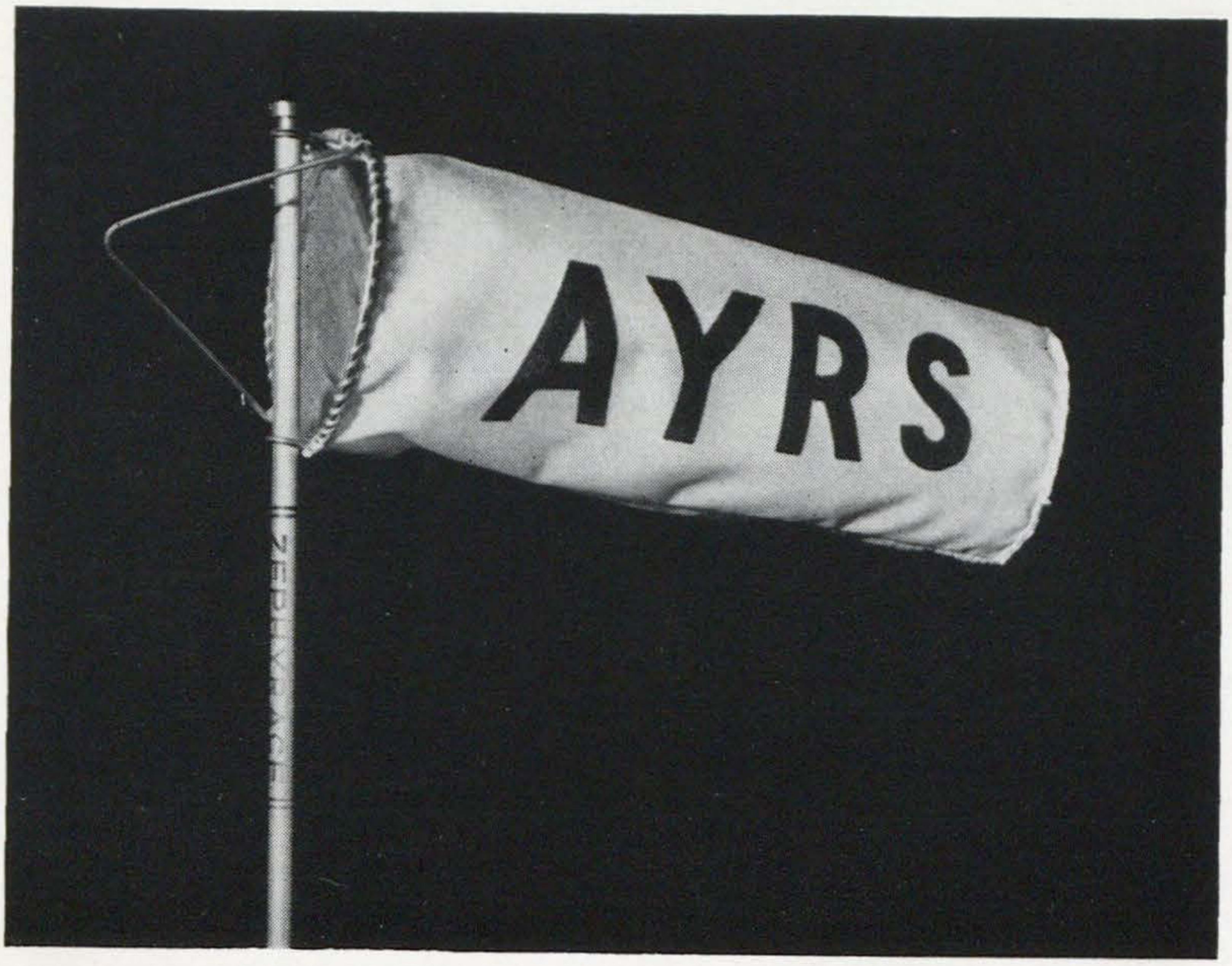
The debt of the Society to your Bulldog effort in reorganising the Constitution and with it, the general outlook and functioning of the A.Y.R.S., was recognised by us all.

There are very few people, and certainly none in the A.Y.R.S. who, had they been willing, could have undertaken this job and, having done so, could have carried it through with your determination to the present point, where the Committee is now able to leave the bulk of the routine management to a Sub-Committee and spend most of its time on the Theoretical and Experimental aspects of the Society, which are the essense of our existence.

The Committee has asked me to express to you its own and the Society's gratitude to you for what you have done and we trust that improved health will make it possible for you to continue to apply your energies to the Society for many many years to come.

It seems unnecessary to add that the Committee's feelings are also my own.

Yours sincerely,
Lloyd Lamble—Acting Chairman.



The AYRS windsock Burgee

A.Y.R.S. Burgees and Ties. Instead of the usual burgee, we have chosen a yellow windsock as being the best possible wind direction indicator. The dinghy size is 5½ inches long and costs 14/- or $2.00. The cruiser size is 16 inches long and costs 28/- or $4.00. The new design of tie with a device costs £1 1s. 0d. or $3.00.

The Weir Wood Meeting. The date for this has been arranged for 8th and 9th October, next. It has always been fun as all boats usual and unusual are welcome. No one may sleep aboard their boats, however. Will anyone intending to bring a boat please contact Dennis Banham, Highlands, Blackstone, Redhill, Surrey.

The Supreme Yacht. In *Yachting's One-of-a-Kind* races at St. Petersburg U.S.A. Meade Gougeon's 25 foot trimaran beat the A Class Scow by 50 minutes in the light airs, apparently ghosting along in no wind at all, sailing past all the other yachts as if they were stopped. Jack Knights in *Yachts and Yachting* says that it was the most vivid impression left by the whole regatta.

Joshua Slocum's "Spray". Kenneth Slack, 251, Old Windsor Road, Toongabbie, N.S.W., Australia has done a great deal of research into the "*Spray*" and is selling plans for $120 Australian.

SAILING FIGURES

This publication shows the approach of two highly astute men, Edmond Bruce and John Hogg, to the problem of measuring yacht performance. An ocean apart and working quite independently, they both produce almost identical instruments which they finally put in a box with various dials on the front.

The use of Sailing Figures. John Hogg's approach is, in the first place, aimed at improving the performance and handling of the 12 meters but the results would be of as much value for any boat at all. Edmond Bruce has also studied 12 meters but he has given us a rather more abstract picture of general yacht study in which he shows the clear superiority as a sailing machine of the multihull. Neither, of course, actually quote any figures for the 12 meters, presumably for security reasons, but I doubt if this will disturb many of us. Edmond Bruce calls them "Sailing Houseboats", as a result of his study.

The Future of Yacht Research. The result of the sophisticated instrumentation shown here is that very soon no yacht will appear commercially without its sailing performance being known and this will result in quick improvement in sailing speeds.

For all of us, this publication is as much value as the last one where we showed that the trimaran has come of age and is nearly fully developed. This publication shows that we are now ready to do scientific studies of yachts because we now have the knowledge and means. Perhaps it is very relevant that both John Hogg and Edmond Bruce are amateurs, which goes to show that the premis on which the A.Y.R.S. was founded was correct.

SAILING FIGURES FOR THE NON-TECHNICAL

This publication looks incomprehensible in many parts to me. The various writers put up complicated electronics and take figures which they put in graphs which we don't understand. Don't be disturbed by all this. It is my job as Editor to see that each article, at some point, makes various statements which YOU CAN UNDERSTAND. Or, if the idea is new, explain such points clearly. Thus, if you are not a technically minded person, you may skip the difficult passages and find the "meat" in parts, here and there. To help you in this, I will now list the results from these technical articles which will interest you.

1. The Scientific Method—this is philosophy. It is fun, if you like the stuff, but it is basically the methods of thought which we all, in fact, use to do research and development work.

2. The Ten Degree Yacht. This is a carrot for the technically minded (but also for everyone) to show what COULD be achieved by progress.

3. Edmond Bruce's article. His Figure 5 on page 47 is the pith of the matter and this diagram shows the speeds of all good boats on all courses, irrespective of size. This kind of figure will be found more and more in our publications and you should try to understand it now. In this particular figure, on a beam reach, the multihull goes twice as fast (almost) as the single hull with keel. It is always better but improves still more to windward than this and not so much on freer courses.

4. John Hogg's article. This shows (a) The variations in speed and direction of the wind. (b) The wind gradient of velocity. (c) The amount of sail twist needed to deal with this wind velocity gradient. (d) The superior value of sailing models over test tanks. (e) That the ideal heel angle for a fairly typical keel boat close hauled is 16° in a 10 knot wind. (f) That you should sail freer to the true wind in light winds than winds of 13 knots to get to windward fastest.

5. The Mehaffey Recirculation Tank is probably a better instrument for the amateur than the still water tank.

6. Howard Hart shows an instrument which can be used to improve the sail force by comparative tests.

7. Bruce Larrabee shows that it is possible to measure fairly simply the pressure on sails.

For the Technically minded. Perhaps the most important idea in this publication is given by Edmond Bruce when he says that the easiest way to take sailing figures is to instrument a motor boat with all the wonderful electronics shown. This motor boat then creeps along behind the sailing boat, taking its speed and angle of leeway, at the same time measuring the apparent wind speed and its direction, angle of heel and other things. This raises interesting prospects of 12 meter espionage and counter espionage. We can imagine the

12 meter, seeing the instrumented motor boat approaching, firing off cannon shells from the counter or putting up a smoke screen. Alternatively, in the America's Cup races, each boat would be followed by an instrumented motor boat, giving instructions by "Walkie-talkie".

However this may be, if such an instrumented motor boat proves to be useful and feasible, every A.Y.R.S. Section should possess one. Perhaps a 36 foot sailing catamaran, suitably powered, could be acquired and used. If anybody should be willing to give or lend such a boat to his section, we would be most grateful.

EXTRACTS FROM THE MINUTES OF THE A.Y.R.S.

New York Yacht Club. 20th January, 1966.

Ed. *These extracts are those which are of interest to members everywhere.*

Mr. Bruce was next to speak and started by saying he was taking the sailing fraternity to task. He feels very strongly that sailing as a science is definitely backward. If you have a theory, you should make confirmation by experiments. Theory without experimentation is no good and experimentation without theory is no good. Sailing is in this state today. He then described his experiments with the "Performance Meter" as described in the notes on the August 8th, 1965 meeting in Marblehead (A.Y.R.S. Bulletin No. 54).

Mr. Harry Morss talked about his experiences in getting measurements with the meter last year; he felt he got very few useful measurements for the time and effort involved. Taking measurements is time-consuming and painstaking he felt, but a worthwhile thing to do. He would like to devise a way of getting together with someone who is interested and accumulate more data, starting the beginning of next summer.

Jack Stoddart then called on George Patterson who described more of his wing sail experiments. This C Class size sail uses a "solid" over-counter-rotating air foil section of substantial chord with a single thickness sail running in a slot in the after end of the symmetrical solid section. George feels that, although no quantitative results are available, the concept is sound and that efficiency will prove very good as more experience is gained.

Bill Cox was then called upon and first related some of the findings of the full-scale tests in the David Taylor Model Basin. Bill was present at these tests which were run under the direction of a Committee, sponsored by S.N.A.M.E. on the full-sized 5.5 meter yacht *Antiope*.

The first series of tests consisted of towing the *Antiope* at varying heel angles, yaw angles and velocities. Other variables which were fitted into the tests were rudder angles and various turbulence stimulators along the leading edge of the keel. An interesting feature of the David Taylor Model Basin tests was that the length of the towing tank was so great that three different velocities could be tested in the same run with all values levelling off at each new speed. In fact, Bill said that the tank was so huge that to onlookers, it first appeared as if a scale model was being tested.

A second series of tests was run at a later date in the circulation tank at David Taylor. This is a rectangular flume with the model being stationary at the centre of one of the long legs. Glass viewing partitions are located in the tank walls so that spectators may actually see the action of the water on the underside of the hull. Tufts were placed all over the low pressure side of the hull, keel, rudder etc. and the conditions were observed at varying heel, yaw and rudder angles with different velocities. Bill says that the still pictures are interesting but unfortunately no movies were taken, which would have given a much more graphic picture of flow conditions.

Edmond Bruce and Bill Cox then got into a discussion of whether or not a certain amount of rudder angle was desirable from the overall efficiency standpoint, Bill voting for some rudder angle and Edmond voting against it. It finally turned out that Bill was talking about an integral rudder-keel condition while Edmond Bruce was talking about separate rudder and keel, so it was finally agreed that both were right.

Bill also mentioned a forthcoming series of tests which will be of great interest to A.Y.R.S. readers. The same boat (which is the largest-size Olympic class) will be tested from the standpoint of sail efficiency in the Langley Field wind tunnel. Tests will be run in the return duct of the tunnel, which has an available cross-section of 80 ft. by 80 ft. The normal wind tunnel test section would be a little too small for *Antiope*, but the return duct will take the full-sized boat very nicely. Air velocity will be limited only by what the test crew feel the rig can stand. This test will probably be run in March, 1966.

The David Taylor Model Basin test results and presumably the Langley Field test results will be embodied in a report being prepared by Halsey Herreshoff of M.I.T., Pete de Saix of Stevens Institute and Dick Newman of David Taylor Model Basin. This will be submitted to the S.N.A.M.E. Committee sometime in February and will then presumably be available to interested parties for a nominal fee.

AMATEUR YACHT RESEARCH SOCIETY

Woodacres, Hythe, Kent.

CRUISING YACHT DESIGN COMPETITION 1967

Prizes: First £50. Second £20. Third £10. Five prizes of £4.

The Objectives: To improve the seaworthiness, speed and ease of handling of short handed ocean cruising yachts.

The Competition: This will consist of competitive sailing trials of scale models of the yacht designs entered or, where this is not applicable, as with ease of handling, by the opinion of the judges.

The Yacht Designs. These may be of yachts of any size, shape, configuration or weight with any rig of sails desired. They may be of yachts already built or of completely new design and may be designed, built or sailed by amateur or professional.

The Entries. Entries must be in the form of scale models of the yachts, the best of which, from the interest point of view, will be displayed on the Stand of the Society during the 1967 London Boat Show. The sailing trials of all the entries will take place afterwards.

The Models. The maximum overall length is 36 inches, excluding rubber or other bumper, rudder, bowsprit or bumkin. This can represent a 36 foot yacht at a scale of 1 inch to the foot, a 24 foot yacht at $1\frac{1}{2}$ inches to the foot and so on. The actual sail area may not exceed 500 square inches and must be capable of being reefed to 350 square inches. The maximum height of any sail (but not the mast) is 36 inches above the mast mounting on the deck or cabin top. Internal ballast of 1 lb., representing the weight of crew, stores and all gear not forming part of the vessel and not rigidly fixed to it, must be carried at a representative height above the keel and must be fitted in such a way that it can be taken out and checked. Inside the model must be headroom of at least 6 inches above an area of at least 24 square inches of reasonably flat floor for which the rounded hull of a catamaran would suffice.

Internal furniture, including four full length berths, galley and head, must be representatively modelled, e.g., a flat sheet with rings on it would show a stove and enough of the deck must be transparent or be capable of being taken off to show this. Life lines and stanchions, the ground tackle and storm gear must be present in adequate amounts but are not to be weighted as part of the 1 lb. Anchors and metal parts, however, can be made of wood or any other substance. Any self steering gear, other than "Sheet to tiller" gears must be of the servo type using the water or wind flow to control the rudder (or, if a servo system is not used, the vane must be no larger than in the models using this system).

The Mounting of the Models. Models must be mounted on a firm base for which "Chipboard" is suggested. The base must be as long and as wide as the model and be painted white.

The Validity of Model Trials. Our technical members assure us that models most accurately reflect the sea behaviour of full scale yachts. Opinions to the contrary are founded on the fact that models have much less stability in the same wind speed. However, in a "Scale windspeed", the stability of models is comparable with the full size, so we will conduct our trials in a windspeed of 7 m.p.h., if we can, which represents a scale windspeed of 24 m.p.h. for a 1 inch to the foot scaling.

The Exhibition of Models. All models must be taken to 80, High Street, Brentford, Middlesex. on the 1st Sunday of December, 1966, between 10 a.m. and 5 p.m. and be given to the Boat Show Organisers. A selection will then be made of the models which will be shown at the A.Y.R.S. stand. Models not selected for exhibition may either be left or taken away.

On the last Saturday of the Boat Show at 9 p.m., all models on exhibition will be collected by their owners or deputies and, on the following day, they and models not selected for our Stand will be raced on the Round Pond in Kensington Gardens. If the trials have to be postponed, owing to the weather, they will take place at such other time as is decided by the judges.

Before the Boat Show, certain details will be asked of the entrants such as the main dimensions of the models, their weights and sizes which are needed for the exhibition cards. Lines and section drawings will not be required.

The Trials. The three main prizes will be given for the three fastest models on the two following courses: 1. Speed to windward and 2. The free reaching course. The race rules will vary according to the number of entries but a mass start seems to be satisfactory. If, by any chance, a model should win a prize at these trials but be of such a type that it would be impossible to built it at full scale or the trials unduly favour one type of yacht such as the multihulls, the prize may be divided by the judges in any proportions they think fit.

Other Prizes. Five prizes of £4 each will be given for the following:

1. Seakindliness.
2. Beheaviour under storm gear.
3. The construction and efficient working of the self steering gear.
4. The ease of handling of the sails, rig and ground tackle.
5. The elegance and general finish of the models and sails.

How to Enter. If you intend to enter for this Competition, please send notice of this to the address below as soon as possible but before December 1st so that proper organisation of the Society's Stand at the Boat Show can take place. Write to:

The A.Y.R.S. Cruising Yacht Design Competition,
Woodacres,
Hythe, Kent.
England.

No Entrance Fee. There is no entrance fee for this competition but it has to be restricted to A.Y.R.S. members. We have, however, no qualification for membership and anyone can join by sendng £1 or $5.00 to "The Membership Secretary, A.Y.R.S." at the above address. Membership will entitle one to four publications on a variety of yachting subjects including an assessment of this Competition, a course of lectures and a sailing meeting. Our year ends on September 30th and people should make it clear which year they wish to include.

Judges. These will be the A.Y.R.S. Committee. On all matters, the decision of the judges will be final. The models will remain the property of their owners. The Society will not be held responsible for any loss or damage to any model in whole or in part while in transit, on exhibition or in care of any of its members,

THE A.Y.R.S. CRUISING YACHT DESIGN COMPETITION, 1966.

This was judged by the hard test of scale hurricane force winds on Sunday, April 3rd, 1966. The entrants were as follows:

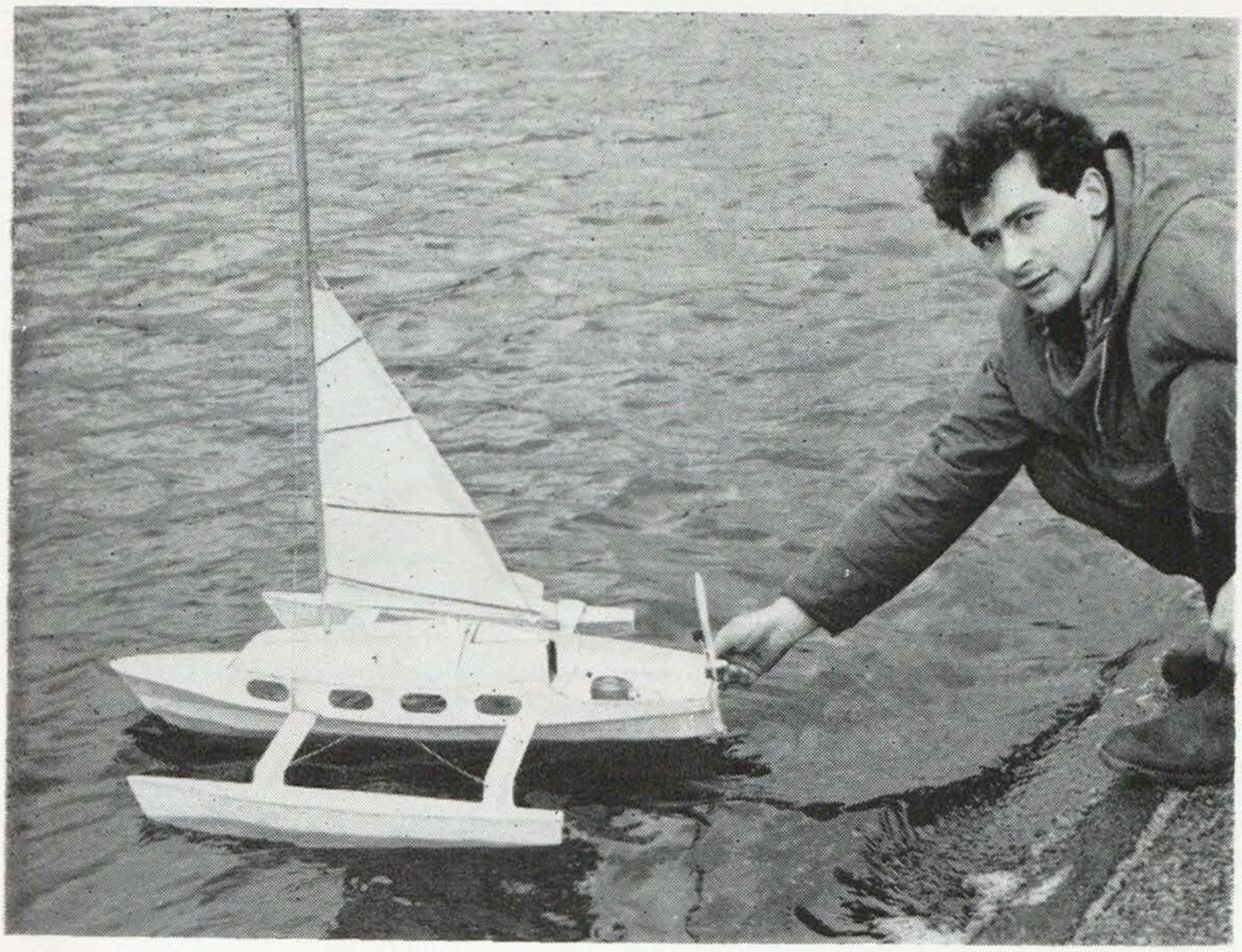
Trimarans:	Catamarans:	Monohulls:
Donald Maclachlan.	Ken Lane	Pat Darbyshire.
Trevor McMullen.	Ian Wright.	S. Miller.
G. F. H. Singleton.		Ian Mogford.
		John Morwood.

Winners: Donald Maclachlan first. Second: G. F. H. Singleton. Third: Pat Darbyshire.

Prizes: *Elegance:* Pat Darbyshire. *Sail Handling:* Ian Mogford. *Self Steering:* Ian Mogford.

It was not found possible to award prizes for Sea-Kindliness or handling under Storm gear.

The Wind. This was at first at speeds of 15 land m.p.h. gusting up to 20 m.p.h., so the races were postponed for two hours. In the meantime, competitors tried out their boats and at one time, all three trimaran entrants and one visitor—a trimaran designed by Derek Kelsall—were all capsized, showing twelve hulls upside down to the



Donald Maclochlan's trimaran—the winner

G. F. H. Singleton's hydrofoil trimaran world. The catamarans did not try to race at this stage and the monohulls were all badly pressed except for the Hillyard ketch of S. Miller which sedately sailed back and forth.

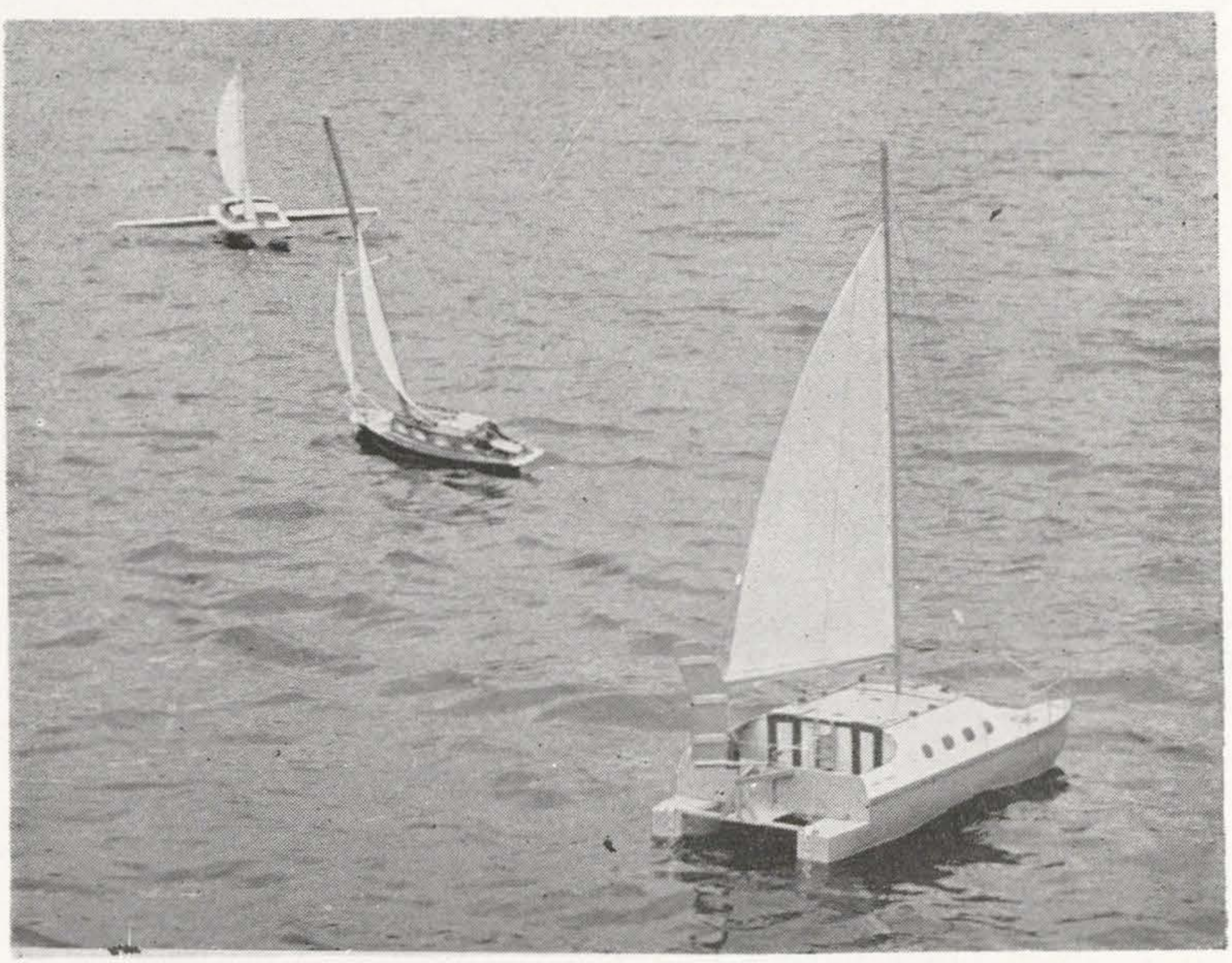
The Races. We had devised a complex set of races with each boat sailing against each other but, owing to shortness of time we tried mass starts and, in fact, this worked well.

The Courses. For the close hauled course, a line was laid across the pond at right angles to the wind and the competitors were set off at the lee side of the pond, the winner being the first to cross the line, thus achieving the best Vmg or speed dead to windward.

The reaching course was approximately a beam reach across the pond. In all, two windward courses were sailed and two beam reaches.

The Race Winds. The wind had by now eased off to 10 or less m.p.h., gusting to 14 m.p.h., corresponding to 34 m.p.h. and 48 m.p.h. at full scale.

Heat I. Finishing order: Maclachlan, Darbyshire, Mogford, Singleton, Lane. Miller's boat wandered badly and did not finish. Morwood's boat without floats or hydrofoils was vastly overpowered and could not sail.



From left to right: Singleton, Darbyshire, Lane

Heat II. Finishing order: Singleton, Maclachlan, Darbyshire, Mogford. Lane capsized.

Heat III. Close hauled. Singleton, Maclachlan, Darbyshire, Mogford, Lane.

Heat IV. Reaching. Machlachlan, Singleton, Darbyshire, Miller.

As Maclachlan and Singleton had each won two first, a run off on a dead run was used to decide between the two, which was won by Maclachlan.

Comment on the Races. For gale force conditions, the races seemed to be fair enough and they were very exciting and worth while. Ian Wright's beautifully built catamaran had only been finished the night before the race and had never been in the water. The radio controlled steering was not allowed by our rules so, in view of the capsizes we had already had, he decided not to race. Trevor McMullen's trimaran was very light in weight and capsized too easily.

Lessons Learned.

1. No multihull without ballast is quite safe from capsize in hurricane force gusts of wind, the trimarans in our contest being safer than Ken Lane's catamaran.

2. Once sail is reduced enough, the trimaran becomes seaworthy and can beat to windward off a lee shore better than the single hulled boats.

3. The course keeping qualities of the multihulls was better than that of the single hulls and, in our races, the ability to finish was of the greatest value.

4. Maclachlan's self steering gear of a vane mounted on a nylon gear wheel meshing with another on the rudder of twice the diameter worked excellently.

Conclusion. To see such a variety of yachts in these scale force gales was fascinating. The behaviour of models yachts has been described as "a caricature of the full scale" and we were certainly shown some interesting yacht behaviour which I felt would have also occurred at full scale. The functioning of Singleton's hydrofoil floats showed that they gave some lift but were only doubtfully worth while when the 1 lb. of internal ballast was inside.

All the competitors enjoyed themselves and so did we all. My own model was unfortunately stolen but, as two members are making full sized versions, I am not particularly worried.

All in all, we feel that this competition was really worth while and we should run it again next year. Our thanks are due to Sir Peregrine Henniker-Heaton, Andre Kansson, Tom Herbert and Pat Morwood for helping with the organising and running of the races.

S. Miller's Hillyard Ketch, Singleton's hydrofoil behind

THE A.Y.R.S. CRUISING YACHT COMPETITION

by

G. F. H. Singleton,

7, Abbeydale Park Rise, Totley, Sheffield.

Ed. Mr. Singleton's entry for our competition was a single narrow hull (with the accommodation we required) stabilized by hydrofoils of the type shown in the photograph and at full scale in Bruce E. Clark's letter which follows this.

We would like members to know the reasoning behind our somewhat extreme entry. Whilst at first sight it may appear that we have sacrificed some of the desirable features of a cruiser purely for the sake of speed, this is not so. To begin with, we feel that the ideal keel boat type is already well known; i.e., large, light displacement ketch with a high ballast ratio such as *Pen Duick II*. To design one would not reveal any fresh information. In any case, the use of ballast means inefficiency.

We then looked at the various requirements:—

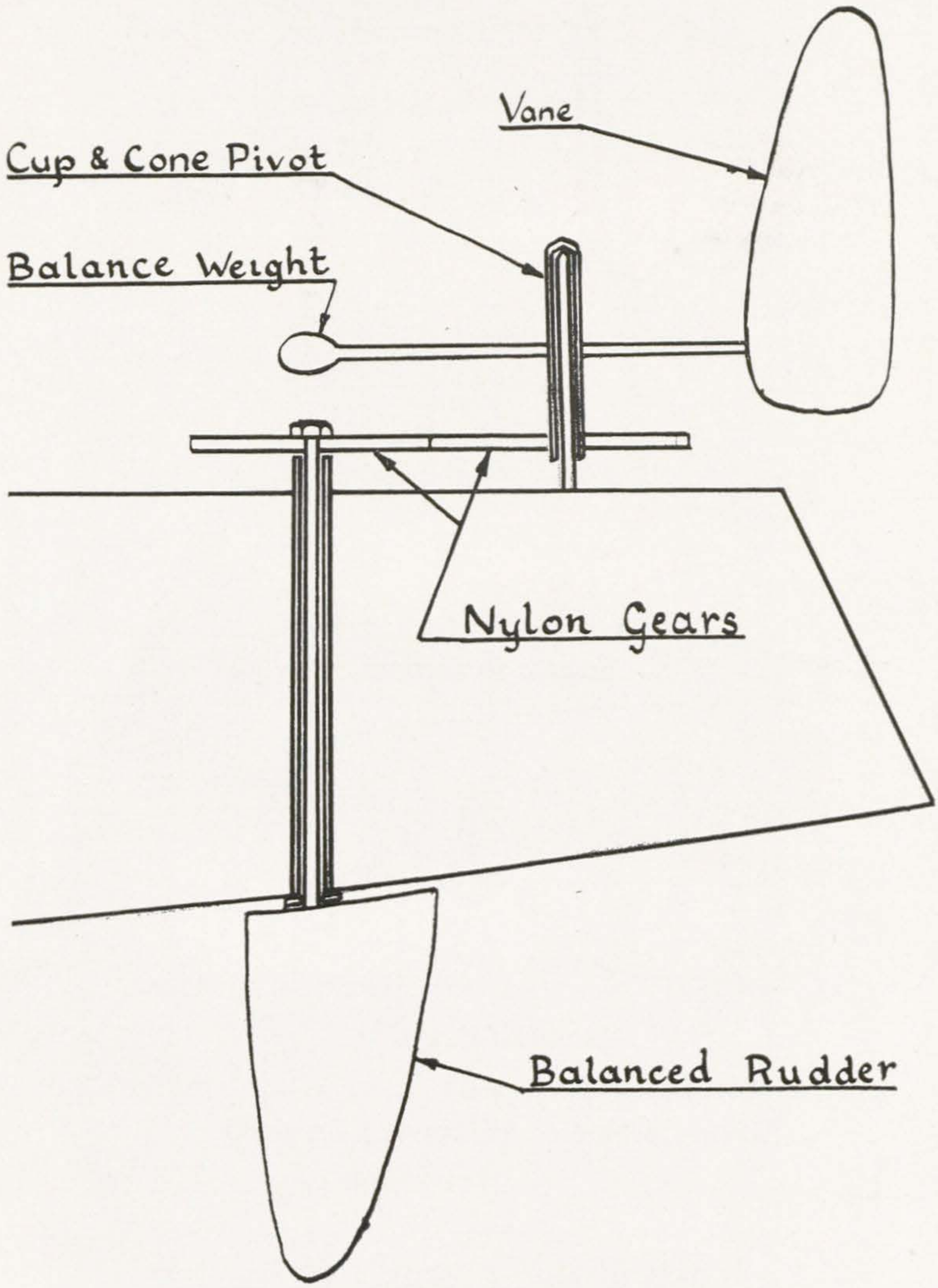
1. Smallish sail area for ease of handling.
2. High Sail area/resistance ratio. This means
   a. Light displacement.
   b. Low wetted area.
   c. Large length/beam ratio.
3. Room for four people.

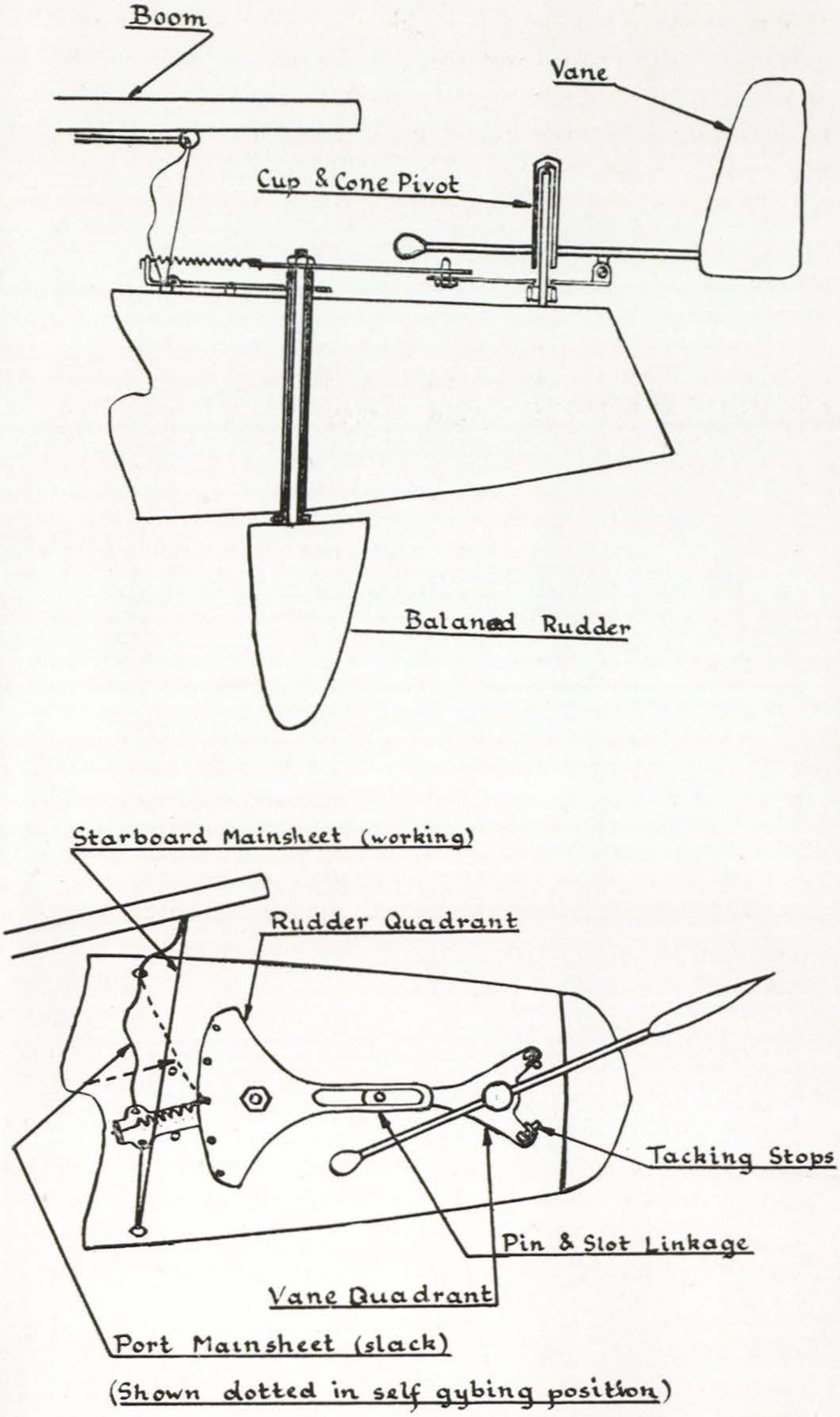
There are three ways of obtaining stability:—a. Catamaran. b. Trimaran and c. Hydrofoil. After reading Edmond Bruce's article, we chose hydrofoil because it had both maximum stability and minimum wetted area (Only one hull). With suitable design, a capsize is impossible unless the sea turns upside down. We ourselves were amazed to find that stability is still present when stopped, or going astern.

Self Steering is obviously essential for solo cruising and there are various types which work with varying success. Most of them don't work downwind because of bad rudder design and not enough vane area to cope with the weather helm and reduced apparent wind speed.

Unfortunately, the requirements for steering a model are different to full size, the main point being that a model has to tack itself. In previous model trials, we have found that a terrific amount of time is wasted when the model tacks in mid-pond and heaves-to, because the vane could not tack it back again.

Where eight or ten models are racing, the results won't mean much if half the models heave-to in the middle. We therefore designed a reasonably simple self tacking gear (which also gybes itself) which we felt would avoid wasting the organisers' time as well as our own. We tried it (and the model) the Monday before the Boat Show and to our vast relief both performed satisfactorily. If any of our fellow competitors are interested, we will be glad to explain the finer points. Details of the gear and a simpler non-tacking type are shown.





Self Tacking Vane Steering Gear

Simple Model Vane Gear. All pivots and bearings must be very free and the cog-wheels preferably of nylon. The vane should be completely balanced. The rudder shaft should be at about 20% of the rudder chord. Adjust for course by lifting vane and moving its gear wheel in relation to that of the rudder.

Self Tacking Gear. For beating, the vane pivots between the stops and provides a force to put on lee helm only, i.e., to luff. This is countered by the off centre spring putting on slight weather helm. The spring is "tacked" by the double main sheet.

For reaching, the vane is set and locked in the normal way. When running, the slack half of the main sheet is attached to the rudder quadrant so that, if a gybe occurs, large weather helm is applied to re-gybe to the original course.

Dear Sir,

Just a postscript to my letter and article about hydrofoil stabilized canoes in A.Y.R.S. No. 53. (photo page 20)

The enclosed picture is of Mr. Van Gelderen's hydrofoil stabilized canoe "Colusa" in Miami. LOA is 14 ft., beam 26 in., sail area 44 sq. ft. Van says he has more confidence in her stability with the sailing rig (and foils) than when paddling ((without foils). The cockpit is rather too small for sailing, and a beamier canoe with larger cockpit suits me better, but Van reports excellent sailing performance, and his boat is certainly dramatic proof of the value of foils on a sailing canoe. Without them he could hardly carry enough sail area to get decent sailing performance (the plans for the boat show sails of 9 sq. ft. and 13 sq. ft.).

This must be one of the lightest sailboats ever built, the hull weight is hardly 40 lb. However, I still favor a length-beam ratio of 6 : 1. This gives more hull stability, which is helpful in getting up to a speed where the foils become effective, and there is a little more time to correct mistakes in a wider boat. My present canoe is a 15 ft. 2-seater of 32 in. beam, and carries 65 sq. ft. of sail easily. The cockpit is still rather small for 2 persons sailing, however, and I am planning to build a 17 ft. or 18 ft. canoe with about 36 in. beam next, with 3 in. or 4 in. side decks and low coaming, no more deck at the ends than a *Canadian* canoe. This should have ample room for 2 or 3 people.

BRUCE E. CLARK.

Bruce E. Clark, Books
115 McGavock Pike
Nashville 14, Tenn.
Sea Books-Ocean Cruising Books a Speciality.

Bruce Clark's Hydrofoils

Dear Dr. Morwood:

In reply to your letter of 28 March 1965, regarding the proposed "Model Cruising Yacht Trials" and the accuracy of scaling both hull and sail to full size, my opinions are as follows:

I note that these models will be about 3 feet over-all. These are only slightly smaller than well established and successful model racing classes, in the U.S.A., such as Class B, Class R and Model 6-Meter. All of these classes appear to be about $3\frac{1}{2}$ to 4 feet on the water to meet their respective rating calculations.

In my article in A.Y.R.S. No. 45, I discussed two approaches to testing by means of models. One was a comparative or qualitative system. The other was the absolute or quantitative system. I consider your proposed trials to be comparative with the expectation that the better model also will be better when scaled to full size.

Difficulties would be encountered in both sail and hull if a precise, quantitative, full-size scaled comparison were attempted. These difficulties would be for the following reasons:

A hull of say 3 feet waterline length travelling at the simplified Froude Ratio of $V / \sqrt{L} = 1.00$ calculates to have a Reynolds' Number of 621,000 in fresh water at 50° Fahrenheit. In my article in A.Y.R.S. No. 30, I pointed out that frictional flow was partially laminar and partially turbulent, in unknown and unstable proportions, when the Reynolds' Numbers were between about 200,000 and 2,000,000. Towing tank workers usually avoid this region, except in the case of artificial stimulation to full turbulence which seems to be effective near the upper limits stated. Elsewhere, in this range, numerically accurate scaling to full size is doubtful. Your trials will have Reynolds' Number in this doubtful range.

The situation regarding the scaling of sails to full size is somewhat different. No sail-caused surface waves of importance are generated at the boundary of the air-water media. For this reason, the Froude ratio is usually not used in sail scaling. Nevertheless, I am of the opinion that the separate scaling, for sails, of the frictional and pressure resistance components may be possible precisely as is done for hulls.

Fluid-dynamicists contend that flow, around similar shaped objects differing in size, has the same flow pattern only when their Reynolds' Numbers are equal. This can be embarassing since a one-tenth scale sail requires ten times the velocity of flow at the same air density and viscosity. This would mean a pressure magnified 100 times per unit area on the small model sail. Magically, the dimensionless coefficients would then turn out to be the same without the need of correction. Sail testing, under such circumstances, would be ridiculous. While this manner of testing avoids correction factors, we are better off accepting the chore of applying corrections to a more convenient method of test. Here again, our present salvation is to fall back on the comparative argument for testing model sails, rather than the absolute, as we did for the 3-foot hulls. It should be a satisfactory method for either or for the sail and hull combined.

I wish that the A.Y.R.S. wind tunnel would become more active. Experiments with various sizes of the same shaped model sail could prove whether or not the pressure, and frictional components could be separated, separately scaled, then recombined as is customary for hull scaling.

Here, in the Atlantic Section of the American A.Y.R.S., we find that we have abundant model data but very little on fullsize sailing craft. Even 12-meter boats are in this same situation. Several of us are actively co-operating with Dr. Henry A. Morss, Jr. of Boston to develop instrumentation to rectify this. Portable equipment will be taken aboard any sailing craft and complete polar diagrams of performance produced without the need of towing or tethering. Our first trials will be this summer.

EDMOND BRUCE.

Lewis Cove, Hance Road,
Fair Haven, N.J., U.S.A., 07702.
April 1, 1965.

THE SCIENTIFIC METHOD

BY

CHARLES SATTERTHWAITE

This is an attempt to outline those proved fundamentals upon which all physical research study should be based, if any worthwhile conclusions are to result.

First of all, it is perhaps worth troubling to note the attributes of a scientist. A scientist is not necessarily a person of great education; neither is he synonymous with that old professor who ate his dissection specimen in lieu of his luncheon sandwiches, nor is he entirely a boffin with thick spectacles, pale emaciated features and either a superabundance or entire absence of hair. These are popular cariacatures only, fit subjects for cartoon or comic but not at all true to life.

A scientist is a human being with a certain attitude of mind, that is, the "Scientific Outlook". This does not imply a cold-blooded robot but a man (or woman) in the whole sense of the word. To be able to apply to the full the scientific method, a man must have courage, patience, self reliance, humility and persistence. The scientific method is the logical result of earnest seeking after the truths behind the works of the Greater Master. It is the obvious outcombe of the uninhibited wondering mind of youth, standing in awe before nature and asking only "Why?". It has been built up as a recognised system of enquiry, mostly over the last two centuries, by men of learning and wisdom though often with little formal education but possessing great natural talent and noble minds, intent only on exploring the natural phenomena around them.

A vast storehouse of knowledge has accumulated and over the years certain fundamentals have been proved to form the only basis on which scientific observation may proceed so that progress is achieved in the easiest and most efficient manner. These precepts constitute the scientific method.

We are an " Amateur Yacht Research Society " and therefore we should attempt to conduct our work in such a way that our findings are recorded in a manner intelligible to the majority. By following the accepted scientific method, we shall use our material to the best advantage; our results will appear in a way that is most useful and others will easily be able to carry on from where we leave off.

When carrying out any experimental work, therefore, we ought to observe the following pattern:

1. Define our objectives to ourselves and to the world at large.
2. Fully describe the apparatus we use.
3. Define a schedule of tests and procedure for each test.
4. Stick rigorously to the schedule of No. 3.
5. Record everything, no matter how trivial it may seem at the time.
6. Show a sample of all calculation methods used.
7. Summarise results clearly and concisely.
8. Write up the relevant theory and relate to it the effects of these tests and their results.
9. Draw conclusions and make recommendations for further study.
10. Supply all references.

Enlarging each of these ten points in turn:

1. It is essential to be clear in mind about the objects of the work. This in itself means a good deal of preliminary thought.

2. An adequate description of the apparatus used is most important if, in the future, the most use is to be made of the tests carried out. Line diagrams in colour best demonstrate the principles of most physical apparatus. Photographs give faithful records of actual form. The origins and serial numbers of all instruments should be noted for future identification.

3. Assemble all notes, references and pieces of apparatus. Clean all of the latter; test and if necessary repair, renovate and calibrate it. Lay out all tools ready to hand and have a recognised place for everything. Decide just how the tests are going to be done and lay out the procedure in full. Where there are alternative methods, choose the one which will lead to the most accurate results. Arrange matters so that literally everything can be recorded in a natural, logical way. Each test should cover the variation of ONE function only at a time. In this way, the absolute effects of all the possible variables may be observed.

4. Carry out the tests and *stick to the Schedule*. Record readings and observations as the tests proceed and hold periodical checks to see that things are going at the rate expected. If not, or if the schedule is no longer feasible, then *stop*. and reorganise the whole job, recording the reasons for doing so.

5. The importance of the recording function cannot be over emphasised. Nothing is more frustrating than to refer to a report and to find that one small but vital detail has been left out and cannot be checked.

6 and 7. At the conclusion of the programme of tests, examine all the apparatus and remark on any damage and excessive or unusual wear. Collate all readings and work out the derived results therefrom. In many cases, readings are best plotted in graph form. This is a valuable way of demonstrating accuracy and shows the trend of events in a better way than a table. Sensible judgement must be used to decide from a plot which readings are reliable and which are widely in error and should be neglected in the final summary, although *all* readings should be graphed. Here, the value of plotting results as the test proceeds is clear, since any random point can be the subject of an immediate check. Record in the report a detailed example of each type and method of calculation used. Show a clear and distinctive summary of results. This latter is often best presented as a separate section distinct from the bulk of the work.

8. Put the results into the picture of the background pattern of the theory of the subject so that the worth of the tests can be assessed. Has any discovery been made or have the tests merely confirmed previous work? On the other hand, what has been disproved? or are the results inconclusive? However, *never* try to twist the observed facts to fit a pet thory. This is often very tempting and in the past, many classic theories have been clung to even in the face of subsequent scientific evidence against them. A good example of this was the "Phlogiston Theory of Heat".

9. Comment on the results. Comment on the accuracy of the apparatus used, readings taken, and the effects of accuracy on the worth of the results. This is most important as the observer is usually the best judge of the accuracy of his work. Bring out all points which seem likely to bear on a future study of the subject and show any indications of the most expeditious methods of pursuing the research into new channels.

10. The origins of everything must be adequately documented so that the foundation of the work is clearly visible and others may refer to it whenever they wish.

Now, having written the final draft of the work (and duplicated it), have a clean up and destroy all irrelevant bits of paper. Paper is a useful tool but, by allowing an unnecessary accumulation, one is fairly on the way to the madhouse—or the civil service. However, be sure all your work is complete and recorded *before* you destroy the rough notes and drafts. Do not be like a very good friend of mine who often rakes through his waste paper basket for valuable information.

Obviously, the application of the scientific method demands a lot of clear thought—often the hardest work. Patience, too, and organisation are both necessary. A great deal of profound knowledge is *not* however, required.

In this article, I have postulated ideal conditions but quite often in research work it is found that, because of the nature and circumstances of the investigation, it is not possible to carry out in full the scientific method as described above. In which case, one has to do the best one can and detail the limitations of the work and the results achieved so that others who may be interested can appreciate the difficulties before them and make due allowances.

The scientific method is the basis of enlightened progress and one of the most useful of the abstract tools in our equipment. Conscientious application of its principles will provide a fine discipline for the mind and make a noble work out of any job.

THE SCIENTIFIC METHOD

BY

JOHN MORWOOD

I have never made any pretensions to being a philosopher, but an article which appears later in this publication on "The Ten Degree Yacht" has forced me to state my ideas on the philosophy of research as applied to yachts. I wrote this article as an exercise in taking just one feature of yachts (the pointing ability) beyond its optimum. There was no great thought which made me do this. I was merely copying what other people had done, for example Edmond Bruce's study of tank tests of models of all beam to length ratios. However, when I sent it to some of our technical members for their opinions, it was pointed out that my arguments took no account of the Vmg or "Velocity made good to windward" as an index of windward ability. From the yacht research point of view, however, speeds are not all important and it is conceivable that someone might cherish windward pointing rather than Vmg. Even from the Vmg point of view, it is desirable to have "over-designed" yachts so that the Vmg may be seen to be the best possible. Now, having got my ideas on the subject better formed, the article on "The Ten Degree Yacht" has been re-written and I hope that it is more understandable.

It would appear, therefore, that I have some vague idea of a scientific method which I will (very arrogantly) set down in this article. Doubtless, many people with far greater intelligence than I have done the same and far better, but, in keeping with the A.Y.R.S., I hope that what has gone before can be ignored and we can devise our own "Scientific Method".

To my way of thinking, the steps in the scientific method are as follows:

1. Assembling all "thought to be known" facts and practices.
2. Assembling all the "thought to be known" theory.
3. Applying the facts and practices above to the "known" theory.
4. The production of new facts and practices by reasoning and experiment from the theory and applying them to the known theory.
5. The production of "new theory" and applying it to the older theory.
6. The same as 4.
7. The same as 5.

All further research to be an alternation between 4 and 5.

Let us now see how the A.Y.R.S. scores in carrying out the above procedure.

1. *Assembling the Facts.* We have certainly assembled all the available information on multihulls with as many of the handling facets of sailing them in closed and open waters as we can find. We have done the same with hydrofoils to the best of our ability but we have not covered the conventional single hulled boat (of any type) to anything like as full an extent. The reason for this is that the subject is so well covered by a host of excellent books which are available in every library and bookshop, that we expect our readers to learn these facts there.

2. *Assembling the theory.* Because there is so little published about sailing theory, we have done our best to cover this in the A.Y.R.S. in a simple kind of way. When, however, we approach the intricacies of aerodynamic and hydrodynamic theory, we immediately find ourselves in trouble because of the amount of mathematics which are involved. As your Editor, I have felt that we should rely on our contributors who understand such matters to give us the conclusions which they come to in a form which we can understand.

3. *Applying the facts to the theory.* This is usually simple such as letting out the sheet when going from a close hauled course to a reach. This causes the sail force which was pulling the boat sideways and a little forward to pull the boat more forward and less sideways.

4. *The production of new facts and practices from the theory.* The most exciting idea to come from theory is that sails should have a semi-elliptical plan form. But much can be learned by reasoning and

experiment from theory. John Hogg's article in this publication is an excellent example of finding out how a boat sails to windward by measurements. He and Edmond Bruce have both produced devices to show a helmsman when he is sailing his yacht at its best Vmg. Such exploits would not have been possible some 12 years ago when the theory of sailing was being given by Harrison Butler and the British Royal Navy as well as Manfred Curry in such an impossible way.

5. *The Production of "New" Theory.* By this I don't mean that some new aerodynamic or hydrodynamic idea will emerge from anyone's efforts. What is more likely to show up is for example the need for sails to accept a wide band of angles of attack due to the turbulence of the wind and its widely varying direction over a band of 40°.

I hope that the A.Y.R.S. is carrying out its mandate to follow the "Scientific Method" to the best of our ability. My own ideas on the subject may not be the best possible but they are the best I can do and they seem to be leading us well so far. With more men of the calibre of our best (and this can only be achieved by a great deal of very hard work) the scientific method will yield great results for yachting.

APPLYING THE SCIENTIFIC METHOD TO HULLS

BY

JOHN MORWOOD

The object of this essay is to put forward those requirements of fact and thought processes which will carry out the Scientific Method for Yacht Hulls. I divide the procedure into three:

1. The gathering of empirical facts such as Edmond Bruce, John Hogg and Col. Bowden have done so well up to date.
2. The arguing from these facts to the general concepts of yacht hulls.
3. The arguing from what I call "The Theoretical Yacht" down to the practical concept of a yacht.

Empirical Facts. These can only be gathered at their best from measurements of full sized sailing boats. Measurements of hull speeds compared to wind speeds, angle of the apparent wind from the boat's heading and leeway angle are four of the most important but a host of other measurements have been taken by people all of which stimulate ideas.

Arguing from the particular to the general. Now, taking the empirical facts which have been measured, we must look carefully into them to see if their study shows any patterns of yacht behaviour. For example, the relationship of speed with course is the most obvious one shown but leeway angle and drag angles also vary with the course and these must also be studied, and similarly we must look and find other variables and graph them.

This is the kind of argument we want relating to yachts already built because this will let us sail them to the best advantage. But, there is another method of arguing from the particular to the general which is best exemplified by Edmond Bruce's article on his tank tests with various model hulls of basic design but of various length to beam ratios. The empirical experimental facts discovered were then graphed to show how varying the hull dimensions affected the running resistance. It is this kind of work which could alter our thinking of hull design quite fundamentally. The same experiments could be repeated with hulls of box section and if the drag angles were also measured, we would feel far more sure that we were learning something about the subject.

Yet another method of arguing from the particular to the general is to use some theory to predict a yacht's performance and then "over-drive" the factors to make the performance worse than the optimum. The article on "The Ten Degree Yacht" which follows is, I think, of this kind. In this, taking as a starting point the fact that the sum of (1) the drag angle of the sails (and windage) in the air and (2) the hull drag angle equals the course made good to the apparent wind, we consider the effect and possibility of reducing both drag angles to the minimum by conjecturing hulls and sails of the appropriate shapes.

Arguing from the General to the Particular. This is the final method which I see at the moment for devising yacht hulls which will have to withstand the rigorous test bed of the sea and competitive racing. We must, I think, start from the "Theoretical Yacht" which consists of a semi-elliptical sail in the air and a semi-elliptical hydrofoil in the water, the ratio of size between them being the relative densities of air and water (about 800 : 1), if windspeed and waterspeed are the same. There is no provision for support, stability nor of necessity for working on both tacks. With the "Theoretical Yacht" in mind, we slowly add those factors which are necessary for the practical yacht such as buoyancy, stability etc. till we have argued out the shape which should be the ideal yacht. The final result may well be less than the best because we have not taken *every* factor into account but that is *our* fault, not that of the method.

ARGUING FROM THE THEORETICAL TO THE PRACTICAL YACHT

The "Theoretical Yacht" consists of a semi-elliptical sail in contact with the water surface attached to a semi-elliptical asymmatric centreboard. No means of support, stability or way of working on both tacks is present.

Support. The obvious way to conjecture support is to enlarge the proportions of the centreboard of the "Theoretical Yacht". It is immediately apparent that length and breadth must be stretched far more than depth. If we assume that our yacht is going to travel at the same speed as the wind, close hauled, the sail is about 800 times the area of the board; if half the speed, it is 200 times the area. The result of increasing the proportions of length and breadth more than depth is to produce an asymmetrical Micronesian hull. It is this argument which has always made me extol the Micronesian hull as the more efficient yacht form. In this hull, the profile shape will be a low aspect ratio ellipse while each section will also be an ellipse. The length to breadth ratio on the waterline will be 12 : 1—an interesting shape for our "Computor designers".

Stability. This can be achieved by a single outrigger, double outrigger, a second hull to leeward placed with its asymmetry the same way as the primary hull, hydrofoil or hydrofoils and ballast. There should be adequate lateral resistance from the hydrodynamic shape of the hull in theory but in practice extra lateral resistance is often needed.

Symmetry. If we do not opt for the Micronesian system, we need a hull which is symmetrical and has a bow and stern. However, it is not the best merely to make the Micronesian hull as described above symmetrical, though the Cunninghams with their *Quest* catamarans will disagree with this. It is always found that canoe sterns squat at speed so a broadening of the waterlines aft is usually found. Length to beam at the waterline then seems to decrease to 8 : 1 for fairly heavy boats (see Edmond Bruce's article in *Basic Research*). The profile, owing to the broadening of the waterlines aft now tends to become parabolic with the greatest depth forward and the buttock lines becoming nearly straight. At this stage, we can still have the semi-elliptical sections but they will be of flatter ellipses aft. This type of hull was used for the "Plank on edge" boats of the 19th Century which we know were the fastest yachts for their size and type ever built. They were, however, far too deep in order to get the ballast low and there had to be a lot of deadwood aft to allow the rig to be placed over the boat. My *Pelorus Jack* hull and Hedly Nicol's trimaran central hulls are designed along similar but, of course, much shallower lines. I use a salient ballast keel while Nicol uses a low aspect ratio fin of much the same dimensions. We both feel that our hulls have not got quite enough lateral resistance without these but this matter will be examined separately. *Pelorus Jack* has a skeg aft to steady the steering and bring the lateral resistance aft while Nicol places his keel nearer the stern than I do, and has no skeg.

Hull Sections. As stated, these are ideally semi-ellipses, of which a semi-circle is one. However, for windward work the right angled V appears to be better—the reason for this is obscure. Now, the right angled V, even with a length to beam ratio of 8 : 1, needs extra lateral resistance which can be in the form of a centreboard or a low aspect ratio fin below the keel line. Surely, therefore, it would be an economy of wetted surface to decrease the angle of the section from 90° to, say, 60° which only increases the wetted perimeter by 10% for the V while giving extra buoyancy. If this were done, one would be "building the fin into the boat".

THE RACING KEELBOAT

I am totally unqualified to make any informed criticism of the racing keelboat. My opinion of them all is that, without exception, they are aerodynamically and hydrodynamically rotten. They are the result of their rating rules but there is at last a ray of hope in the new boats being designed for the Round Britain and Solo Trans-Atlantic races. Olin Stephens, with his *Dorade* came as near to designing a hydronamically excellent yacht as anyone before or since but now spends his time most successfully fiddling with far worse yachts to make them better. If he gives the matter thought, he probably feels himself a very frustrated man.

The Hydrodynamically Efficient Yacht.

1. The keel line is parabolic, being deepest forward straightening aft.
2. The bow sections are pointed semi-ellipses, the underwater angle being 60°. The midships sections "round-off" the elliptical shape while the sections aft become rounded till they all become shallow semi-ellipses.
3. The length to breadth ratio on the waterline is 8 : 1 (not definite)

The trouble with "The hydrodynamically efficient yacht" is that it has far less stability than the conventional yacht. I do not know at what point increasing the stability ceases to be of value. Obviously, some increase of stability will not show the boat much and the extra sail allowed will give an overall increase of speed.

Increasing Stability. This is most easily done by shallowing the section again to the right angled V and having a salient keel. Of these two, the "Form" stability is the better for stability, especially where the beam is being increased but it distorts the hull from the "ideal" more. The ballasted salient keel does not provide the stability at small angles of heel so well, though it is most valuable in strong winds. It is doubtful, in my opinion, whether the added lateral surface decreases the drag angle of the hull, though it may not increase it.

The "Stabilised" Hydronamically efficient Yacht.

1. The keel line now takes on the shape of a shark's or whale's dorsal fin. It would be a semi-ellipse but for the necessity of getting the centre of lateral resistance far aft in order properly to dispose of the sail plan.
2. The bow sections are again pointed semi-ellipses but the underwater angle is increased to 90°. The midships sections develop an S bend around the same right angle, while the after sections flatten off in the normal way.
3. The length to breadth ratio on the waterline should probably still be 8 : 1 approximately because beam doesn't appear to pay except for very shallow yachts.
4. Draught: Extra sail carrying power can be obtained by increasing the draught to any amount. It is doubtful if this will improve the efficiency but it will improve the speed to windward.

The Curve of Sectional Areas. Three factors come into the fore and aft disposition of buoyancy which is shown by the curve of the sectional areas.

These are: 1. Wetted surface, which requires an elliptical distribution of profile and section. 2. Production of lateral force with leeway, which requires the greatest section forwards of amidships (cod's head and mackerel tail) and 3. Wave making capacity, which needs a "Versed sine-trochoid" disposition of sectional areas. All these requirements are different and the ideal compromise between them is likely to remain empirical unless theory and mathematics can come to our aid.

Dear Dr. Morwood:

I think your observation is correct that on a craft with a rather poor hull but with good sails, further sail improvement will provide only small results in improved pointing. The same degree of sail improvement on a good hull, however, may produce an outstanding improvement in pointing.

As a numerical example, assume that a hull's minimum drag angle is 25° and its sail drag angle has a minimum of 10°. Then a 3° sail improvement will reduce the overall pointing angle to:

$$\frac{25 + 7}{25 + 10}$$ or 91.4% of it's initial pointing angle.

However, if the hull drag angle is 10° and the sail angles are again as above, the overall pointing improvement is:

$$\frac{10 + 7}{10 + 10}$$ or 85.0% of it's initial pointing angle, a much more favourable result.

In summary, it pays best to reduce whichever drag angle is the larger. If one continuously follows this rule in an evolutionary process, the two drag angles will become equal, eventually.

I was interested to see on page 20 of *One-Design Yachtsman* for August, that the Stevens Tank personnel have abandoned the multiple restraints in testing their models. Instead, they now use floating models and tow through a single point which is equivalent to the sail's center of effort, precisely as recommended in A.Y.R.S. No. 30.

EDMOND BRUCE.

Lewis Cove, Hance Road,
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August 26, 1965.

THE TEN DEGREE YACHT

BY

JOHN MORWOOD

Introduction. One of the most difficult things about research is to define accurately and exactly the item in which we are interested. When we think of the windward performance of a yacht, we must usually think of the actual "Speed made good to windward"—the Vmg. But the yacht researcher need not think in this way. He can, for example, think only of the "Course to the true wind"—the γ. Or, he can think of the "Heading to the apparent wind"—the β-λ (λ being the leeway angle). Or, he may concentrate upon β the course to the apparent wind and this is the subject of this article.

Unless, for some reason, some yachtsman values pointing ability more than speed to windward, the value of the present concept lies in the fact that the speed to windward—the Vmg will increase as the pointing ability is improved by designing a closer winded yacht but eventually the Vmg will fall off when the yacht has been "Over-designed". This is, of course what happens to any boat but the slant of this article is to have separate yachts for each β or course to the apparent wind.

What I would like to suggest is that several yachts be designed that:

1. The drag angles of both sails and hulls are equal, and
2. These angles should be reduced by design until the Vmg can be seen to be very much worsened.

This suggestion takes its origin from "The Course Theorem' which proves that β the course to the apparent wind is the sum of the drag angles of the sails and hull, a drag angle being the angle between the line of action of an aerodynamic or hydrodynamic force and the perpendicular to the line of flow of the fluid. On top of this, there has been my exchange of letters with Edmond Bruce where he states that the hull and sail drag angles of a 12 meter are 10° and 7°, respectively, giving a β of 17°. As well as this, there is the consideration of "The Theoretical Yacht" in publication No. 44 (A.Y.R.S. *Yachts*) which consists of only a sail in contact with the water surface and a centreboard in the water, both at a drag angle of 5°. This gives a course to the apparent wind β of 10°, thus constituting one type of "Ten Degree Yacht."

Hull Drag Angles.

The Best Existing Designs. For our purposes here, I wish to consider two yachts, *Nina*, designed by Starling Burgess and *Dorade* by Olin Stephens. Both *Nina* and *Dorade* are yachts only very slightly distorted, if at all, by the rating rules including the constraint of cost. *Dorade* was specifically designed for maximum windward performance, while *Nina* was able to win last year's Bermuda race in her middle age with a lot of windward work in it. Both are similar in shape with a convex but almost straight forward keel line rounding in to the ballast keel. The underwater profile is therefore that of the dorsal fins of sharks and whales. This seems utterly right to me. The hull sections in both are right angled Vs, modified by a slight S bend which must also be right, though, of course, they both flatten the V's slightly aft.

Let us now assume that both *Nina* and *Dorade* are the best yachts that have been designed which, after all, is not far from the truth. If a 12 meter hull has a drag angle of 10°, *Nina* may well have a drag angle better than this, my guess being 9° while *Dorade*, which is deeper and narrower than *Nina*, though of the same shape, might well have a drag angle of only 7°.

Dorade has a waterline length to beam ratio of 4 : 1. If all lateral dimensions are now halved, keeping the longitudinal dimensions the same, the waterline length to beam ratio would become 8 : 1 and I believe that the hull drag angle would decrease to 5° or even less. Reducing the beam in this way would, of course, reduce the stability and this, in turn would reduce the sail area which could be carried. It is this worsening effect which has to be considered in looking for the yacht with the best Vmg.

Even should the narrow version of the *Dorade* hull produce a drag angle of 5° only (equivalent to a lift drag ratio of 11.4), still smaller angles would probably be obtained by increasing the vertical proportions to give a yacht of a higher aspect ratio in the water.

Summary of Hull Drag Angles. By taking the best hull shape known, for which I suggest *Nina* or *Dorade* and by decreasing the proportions of beam and increasing the proportions of the draught to the length, a series of yachts could be produced having lesser and lesser drag angles up to a minimum which is not likely to be less than 3° or a lift/drag ratio of 19 : 1.

Sail Drag Angles

Sail drag angles are far more difficult to consider than those of the hull. Firstly, sails are never so well defined in shape in the drawings as hulls so we are not so sure how much flow any sail will have. Secondly, without exception sails are distorted by the rules and by the necessity for reefing so the best possible shape is not easily arrived at. We have a figure for the drag angle of a 12 meter of 7°, presumably with a low cut Genoa and mainsail. However, we know that such a rig is extremely sensitive to the tightness of the forestay, the slightest sag ruining the windward performance, presumably by increasing the drag angle. This indicates that a convex luff to the Genoa would improve the drag angle quite a lot. My own solution to this is by the use of a semi-elliptical squaresail or lugsail both of which can abolish the twist of a conventional mainsail.

Wingsail masts with a sailcloth trailing edge are another solution, as used with some C Class catamarans but, in practice, their improvement over the conventional sloop rig is only marginal at the time of writing (1966), though slats or slots may well improve this.

The fact is that not enough work has been done on sails in the wind tunnel so that possible improvements are not known. In the light of this, I can only hazard my own guess that some sail or combination of sails will be found which will improve the sail drag angle while not sacrificing sail force.

Summary of Sail Drag Angles. Starting from the very good sail drag angle of 7°, I can only state that it is my opinion (or guess) that a sail or sail combination will be found with a drag angle of 5° or, by carrying the cesign to extrenes of aspect ratio, an angle of 3°, might even be possible.

Conclusion. It is my belief that, by carrying the design of both sails and hulls to the utmost extreme, the drag angles of each can be reduced to 3°. This would produce a yacht which would sail at 6° of β from the apparent wind but the sail area would be relatively small and the wetted surface of the hull relatively great. The velocity made good directly to windward—the Vmg would thus be reduced from the best.

From a research point of view, concentrating of effort on a series of hulls in the test tank to produce all degrees of hull drag angle from 10° downwards would be well worth while. At the same time, workers with wind tunnels could well be trying out various sails to see how low they can reduce the sail and windage drag angle.

When all this work has been completed and the sailing characteristics of the resultant yachts found, I think that the very close winded yachts will be slower to windward than those which sail freer. My guess as to the best yacht performance to windward is that it will occur when both hull and sail drag angles are 5°, thus making a "*Ten Degree Yacht*".

Dear Dr. Morwood:

I am returning your proposed article "The Ten Degree Yacht".

While the sum of the drag angles has the great advantage of easily showing the course-to-apparent wind angle, I find that many people want them also expressed in lift-drag ratios, as in aeronautics, for a more complete understanding.

Scientific people like to feel that anything can be improved upon. The ultimate may never be reached. With this in mind, I have suggested a slight modification.

As to my recent activities, I have much tank data but so little exists in the way of full-size measurements. I have recently confined my sailing activities to devising and testing methods for measuring the latter.

Hull speedometers tell very little about optimum adjustments since one is confused by continuous wind variations. For this reason, I have been measuring the ratio of boat speed to apparent wind speed (also apparent wind and leeway angles). The speed ratio is a much steadier criterion, especially so when the anemometer is mass loaded so that it's time of response about equals that of the hull and speedometer. An electrical balance of outputs is led to a center null indicating micro-ammeter which is provided with an adjustable amplifier, making it very sensitive.

One side of the null indicator is labelled "Better" and the other side "Worse". This becomes an indicator for optimizing sail and other adjustments. Also absolute data is obtained for comparison with that of other boats. This instrumentation has been aboard, among others, an unsuccessful America Cup defending candidate. It showed that many adjustments were not the best possible when it had been competing.

EDMOND BRUCE.

Lewis Cove, Hance Road,
Fair Haven, New Jersey, U.S.A.,
February 3, 1966.

PERFORMANCE MEASURING INSTRUMENTS FOR SAILING CRAFT

BY

EDMUND BRUCE

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Present Situation.

During his career, the writer had occasion to study closely the organizations and methods employed by research groups working in several of the "pure" and applied sciences. Most have become amazingly sophisticated and productive. However, even though sailing has had the benefits of several thousand years of experience, it is the most backward of all these sciences, in this writer's opinion, in applying a powerful research tool known as the "scientific method."

One of the basic requirements of any well-functioning scientific program is to demand a mutual confirmation between theory and experimental measurement. One without the other as a cross-check is of little value. Alone, the accuracy and worth of either are not at all convincing.

Almost all sailing craft are designed, currently, merely by hunches and guesses at the drawing board. Anything radical is seldom attempted for fear of the publicity of a failure in the hands of a purchaser. Unjustified secrecy is another great retarding factor. As a result, sailing-craft progress has been exceedingly slow. Where are the confirming measurements, *on a numerical basis*, of the performance of full size sailing craft? Even when models and towing tanks are employed, the agreement of measurements, on the final full-size boat, with the model measurements is seldom obtained.

The fact that boat A has beaten boat B in a race, possibly by luck, does not give information as to how it would fare against boat C. Numerical measurements of their important performance characteristics would provide answers suitable for most any comparison. These measurements plus enthusiastic, wide-spread cooperation are essential if rapid progress in the science of sailing is to be expected.

Within the A.Y.R.S. the writer described some of his attempts at full size measurements in publication No. 40. In these attempts, the sail and the hull were measured separately. Then these results were combined to predict the overall performance. In No. 41, Harry Hunter discussed the admirable job he did with overall measuring objectives. No. 45 showed the numerical agreement of these experiments performed on ocean apart. With the experience of these performance-measuring attempts and some others, we are now in a position to conceive and develop still more advanced measuring means. This has become the objective of several of us in the American Section of A.Y.R.S.

In this article, the writer intends to discuss some of the problems of instrumentation. Obviously, the instruments and methods must be thoroughly investigated before any elaborate program of sailing craft measurement is worth while.

Some Problems.

Owners of sailing craft have purchased hull speedometer in the belief that these would assist them in determing the optimum adjustments of sail trim, etc. I have found no one willing to state that their speedometer is an unqualified success. The truth of the matter is that, since the wind is so rapidly variable in both strength and direction, by the time one makes a readjustment, the wind has changed and creates confusion. It was incredible to read that the "secret weapon" on one 12-Meter racer was an electronic speedometer that could be read to a tiny fraction of a knot. What good is this by itself in the presence of variable and turbulent winds?

In attacking this measurement problem, it was realized that, since increased wind usually means increased boat speed, the ratio of boat speed to apparent wind speed might be a steadier criterion than knowing only the boat speed. This will prove to be valuable.

Sail force, for a fixed trim and angle of attack, is directly proportional to the square of the apparent wind velocity. Also, up to the speed of appreciable wave-making, the hull's resistance is closely as the square of the boat's velocity. Thus, in the range of boat speeds from zero to about $V/\sqrt{L} = 0.6$, a ratio of boat speed to wind speed would seem to vary hardly at all, for a fixed course to the wind and other fixed adjustments. This is true provided that one has waited until a "steady-state" or zero acceleration balance between the average wind and hull speed has been achieved.

If one can simultaneously observe an instantaneously indicating anemometer and the hull speedometer, the readings of the anemometer probably will jump around while the hull speed will change only slowly. This is because the inertia of the moving parts of the anemometer is very small whereas the hull's intertia or mass is great.

It has been found that the time-constant of response of the anemometer can be made about equal to that of the hull speedometer by adding an appropriate mass to the rotating impeller of an anemometer. A selected size of a bevel edge, thick, bronze disc was placed on contact with the top surface of a vertical-axis impeller, so as to keep the total surface area the same. This was found to provide the desired time constant without affecting the initial steady state calibration at all. Now, the wind velocity meter and the water velocity meter changed readings at about the same rate. Even if not precisely equivalent, their readings are more easily averaged because of their slow responses.

For a selected course to the apparent wind, we are now in a position to read the boat speed meter, then the wind speed meter. Their readings can be recorded and their ratio calculated. However, this procedure does not permit precisely simultaneous readings of the two meters, which is desirable for greatest accuracy. This situation can be improved with some electrical help. This can be obtained by means of a balanced null-meter and a ratio adjustment to be described later.

Instrumentation System.

Before getting into instrument details, a "systems analysis" is in order. The first objective is to devise the simplest instrumentation which will accurately measure boat speed through the water versus apparent wind speed, for sailing craft on all possible courses in respect to the direction of the apparent wind. Apparent wind speed and apparent wind direction are chosen, rather than the true wind, for simplicity. These are what an observer sees aboard a moving boat.

Beside the measurement of the two mentioned speeds, the direction of the boat's course to the apparent wind must be determined. This is the sum of the angle of the apparent wind to the boat's heading and the angle of this heading to the boat's course or, in other words, the hull's leeway angle. Thus four quantities are required to be measured by the chosen instruments. A recording of the rudder angle to the centerline is also advisable unless a center-helm sail balance is continuously maintained.

A method for the direct measurement of the single angle of the apparent wind to the course can be devised. However, an independent knowledge of the leeway angle is so important, in judging a hull's highest windward ability, that it is included as a separate item.

The best hull leeway angle for a course is one that produces the required lateral lift, to counter-act the sail side force, with the least possible drag. For high pointing, the highest possible lift-drag ratio must be achieved. A lesser leeway angle than optimum for this course means too much lateral plane. A greater one means too little, when the boat is balanced and the tiller is centered. Many designers do not seem to understand this. They incorrectly strive for a minimum leeway.

All sensor indications should appear at a common, convenient location for the observer. This almost necessitates that "transducing" to electrical voltages be used. For accuracy in reading, throughout the ranges of indication, and for simplicity of any later calculating instrumentation, the indications should be as linear as is practical.

Possibly three sets of instrumentation should be considered. One would be an assembly which could readily be moved from boat to boat. A.Y.R.S. might own these instruments and loan them out, on some systematic basis, and publish the measured results. Another form would be for private ownership and permanent installation on an owner's boat. The third would be instruments mounted on a motor-driven pursuit boat. Here again the instruments would be permanently mounted. Additional optical means would be provided to enable the accurate following of a sailing craft's course at a constant distance. Such a procedure verges on being a bit sneaky. However, it could rapidly measure many boats and would save the effort of equipment installation on these boats.

Two types of wind sensors (velocity and direction) and two corresponding water sensors are required. It is desirable to determine the best locations for these pairs of sensors.

If the wind sensors were mast-head mounted, they would encounter relatively clean air, without interference, in all directions. However, since both apparent wind speed and direction will vary with height above the water, the average conditions encountered by the sails would not be determined correctly.

To obtain average sail conditions, a better height for the wind sensors would be that of the geometric center of the combined sail areas. At this height, mounting locations, such as forward, aft or abeam, all would encounter interference by the sails on some particular course. However, on any one tack, a mounting fairly well outboard of the windward shrouds would be substantially free of blanketing or interference. Should doubt exist about the symmetry of performance on the two tacks, measurements could be made with the instruments mounted alternately in the starboard and in the port shrouds. Of course, duplicate sets of sensors can be installed if cost is not important.

The water sensors would find their best location forward of the bow, just beyond the region of the bow's pressure wave. At any other location, adjacent to the hull, an accelerated water flow would be encountered due to the hull's sectional dimensions. Behind the boat, a vortex wake followed by the turbulent wake would extend to greater distances. Taffrail logs and hull-mounted speedometers must be corrected to allow for these disturbances.

Instrument Details.

When measuring relative movement, in respect to the boat, of wind or water, one has the choice of using either dynamic pressures or velocities. Exploring the field of available instruments, velocity-

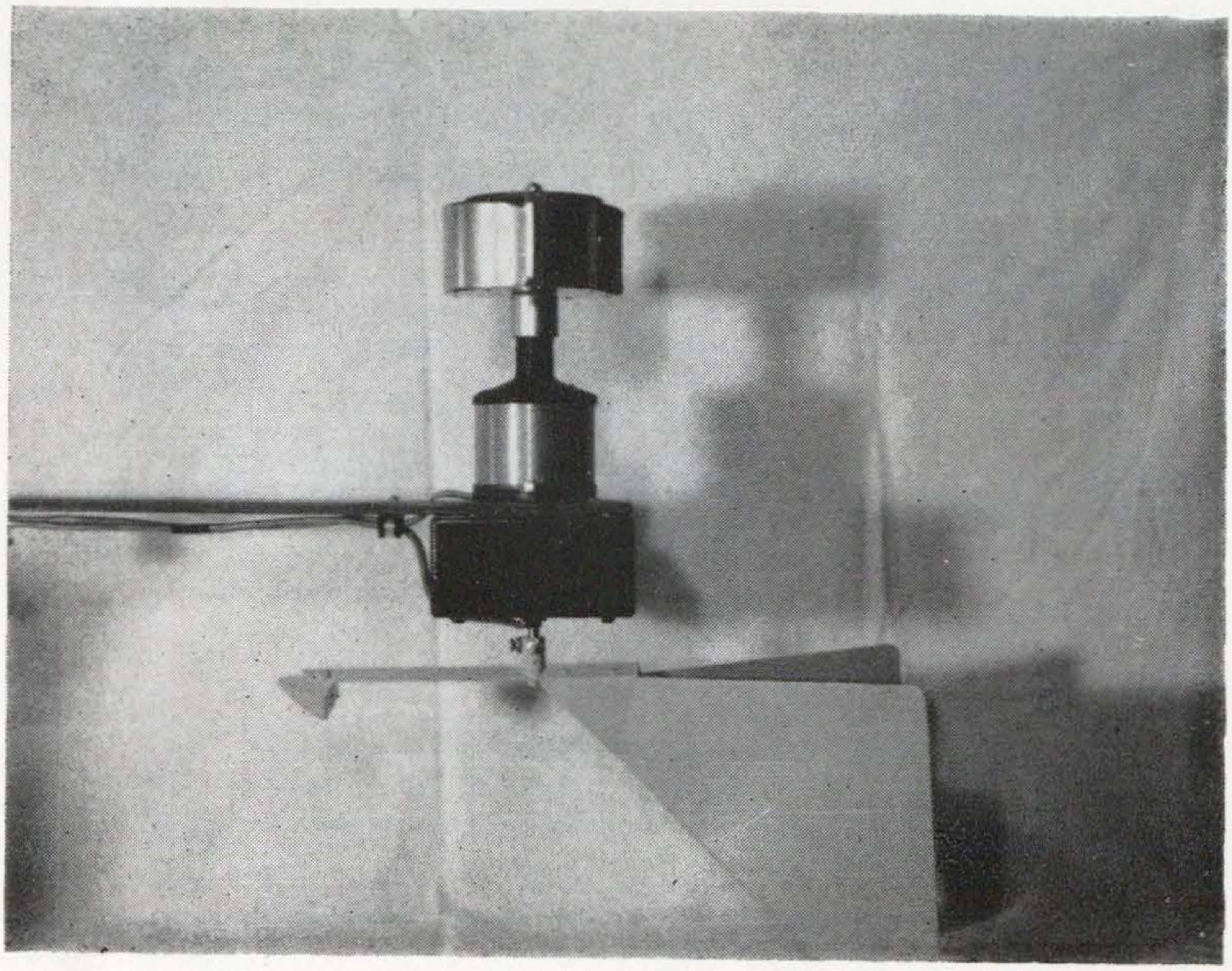

Fig. 1. *Wind speed (top) and wind direction (bottom) seisors*

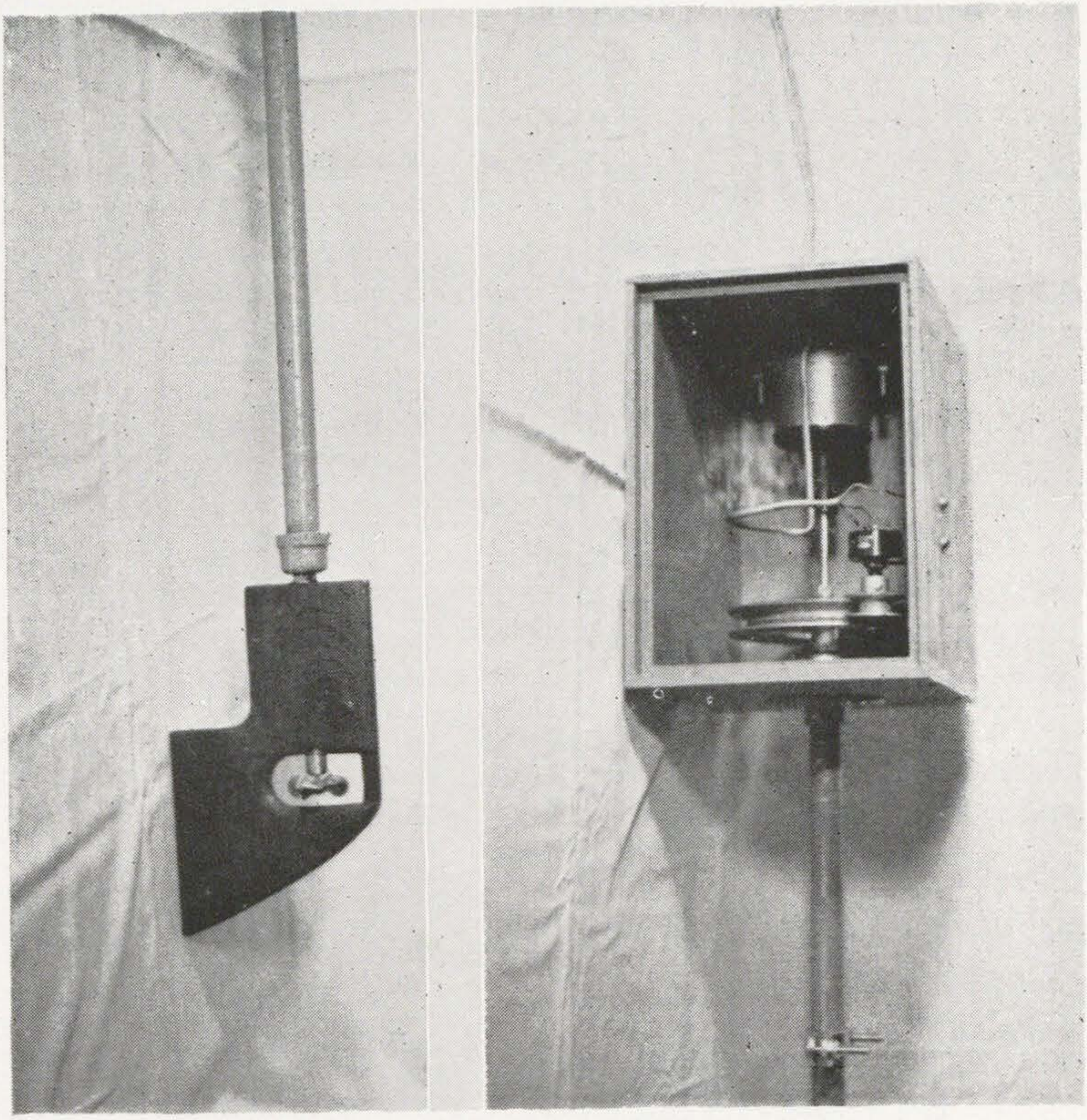

Fig 2a *Water speed and leaway angle seisars* *Fig. 2b*

to-electrical transducers appear to be more highly developed and accurate than are pressure-to-electrical transducers, although some of the newer solid-state-junction, strain guages show promise for the future. The writer plans to investigate this approach later.

In the velocity category, R. A. Simerl of Alexandria, Virginia, U.S.A. produces a fine, low-friction, weather-proof, corrosion-proof, electrical, anamometer generator that was chosen from several possibilities for the present project. It is brushless since magnets revolve in a stationary field winding. Air-core coils are used to avoid magnetic drag. Stainless-steel, instrument ball-bearings are employed. These are permanently lubricated with silicone grease. A pair of internal rectifying diodes and a center-tapped coil cause full-wave rectification of the generated A.C. to produce a pulsating D.C. The author's tests showed that electrical filtering added nothing to accuracy, but it prevented pulsing of the indicating meters at very low speeds.

Identical generators are used for both wind and water, with appropriate impellers, to permit a ballastic null-balance between them. This will be described later.

Fig. 1 is a photograph of the pair of wind sensors. The Simerl generator with its Simerl wind-impeller appears on the top. The under part shows a split-tail, weight-balanced wind-vane which operates a low friction, military type, "Spectrol" potentiometer requiring a driving torque of only 0.2 inch-ounces.

Figs. 2A joined to 2B form a complete photograph of the water speed and leeway angle sensors. A small, stainless steel, four-cone impeller is fabricated from a single sheet. It is mounted within an aperature in the water vane for protection and weed shedding. Note that both water and wind impellers are non-directional. This, of course, is not true in the case of usual propellers.

The upper, water-tight box, in Fig. 2, contains the second Simerl generator and another "Spectrol" potentiometer. These are driven, respectively, through a concentric shaft within a rotating hollow tube.

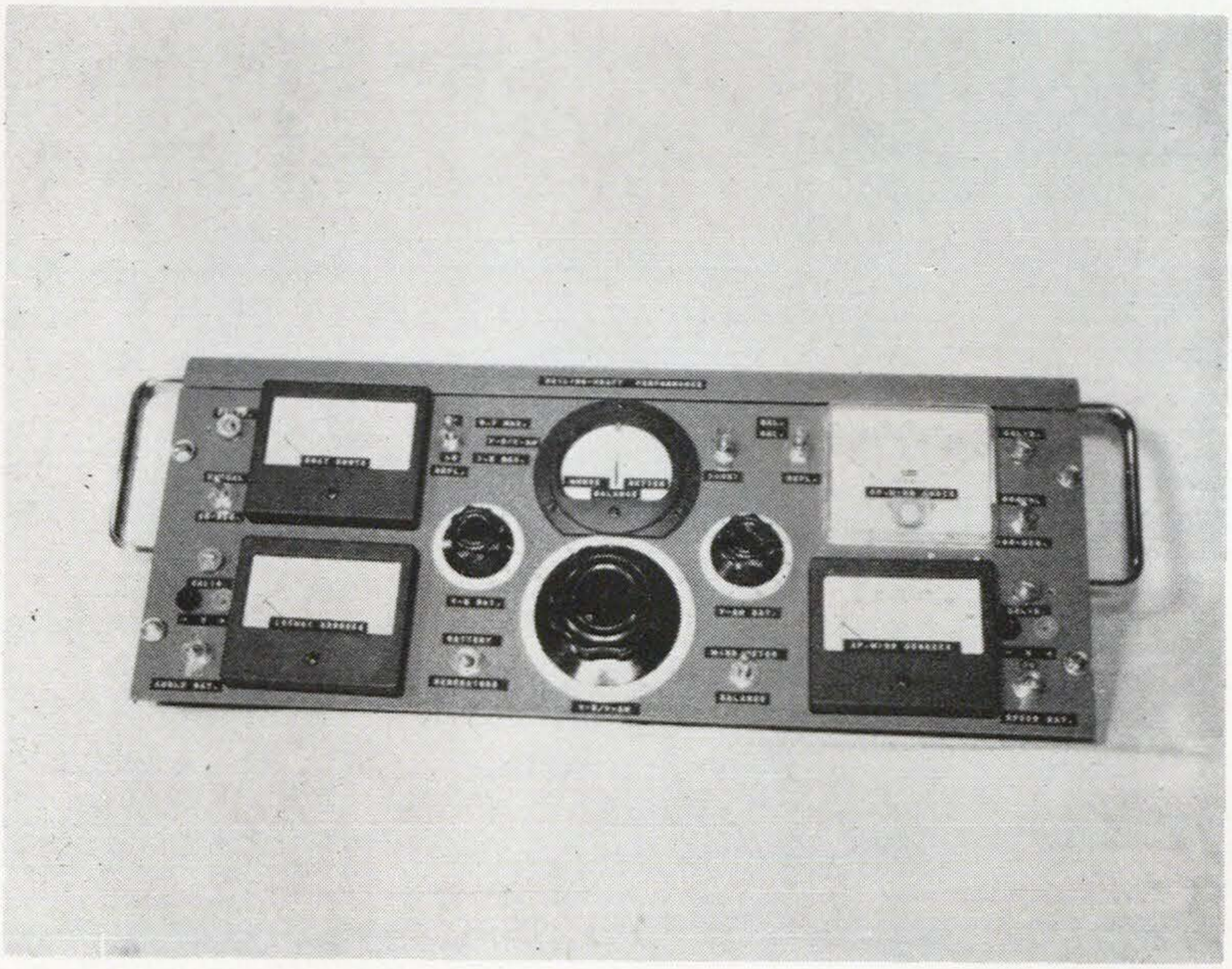

Fig. 3. Edmond Bruce's Measurement console

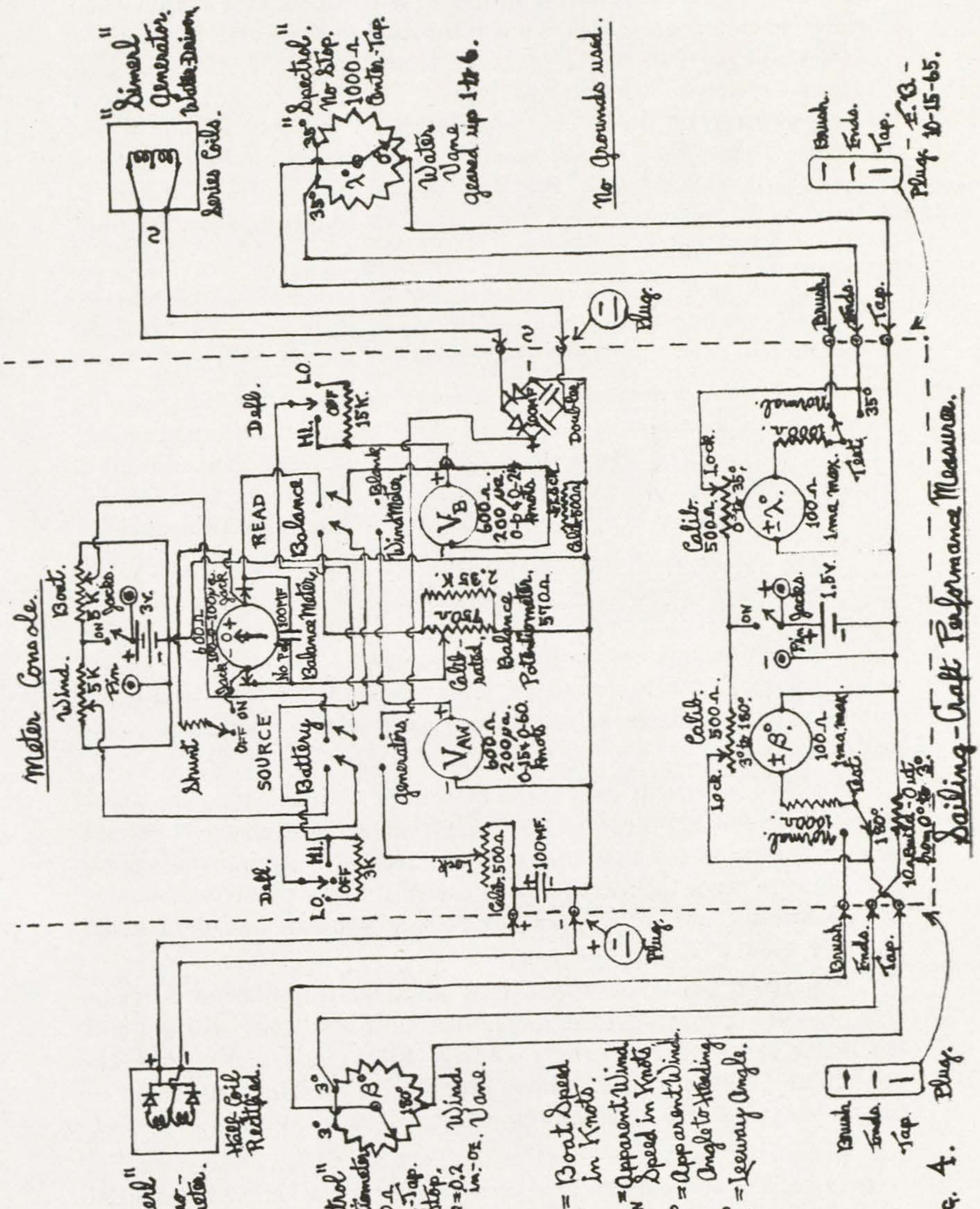
Sailing-Craft Performance Measure.
Meter Console.
No Grounds used.
Fig. 4.
SOURCE
Battery
READ
Balance
Balance Meter
Wind Meter
Plug.
Brush.
Ends.
Tap.
Wind Vane.
Water Vane
V_B = Boat Speed in Knots.
V_{AW} = Apparent Wind Speed in Knots.
$\beta°$ = Apparent Wind Angle to Heading.
$\lambda°$ = Leeway Angle.

Fig. 4.

The under-water extension of this tube is enclosed in a stream-lined form to reduce drag. This is a continuation of the water vane. The out of water portions of the mentioned tube and shaft are inside of a protective external fixed hollow pipe. The vane employs a 6 to 1 pulley step-up to drive the potentiometer through a multi-turn, anchored belt. The whole assembly is mounted on a retractable support, not shown, over the bow of the boat. This support is tailored to fit each particular boat. It contains adjustments for both depth and heel angle.

Fig. 3 is the measurement console containing five indicating meters, all controls, switches and balance-calibrating batteries. This console is mounted at a location most convenient for the observer.

Fig. 4 is the present electrical wiring diagram for the entire equipment. It is self-explanatory to those skilled in electrical construction. Many details will be found upon close study. Note that adjustable battery sources have been included to assist in balance calibrations. Fig. 4 may be passed over by those not deeply interested in details.

This assembly of instruments will be improved upon, by the writer and others, from time to time in the light of further experience under use. A recent improvement was the incorporation of double range measurements in both speed sensors. The smaller ranges produce greater sensitivity below about 6-knots for both wind and water. The manufacturer of the generator is also working on this problem.

Another important improvement was an optional, plug-in, solid-state, operational amplifier for the "better-worse" null meter. Several observers have stated that this sensitive means of optimizing sailing craft adjustments is the most valuable part of the entire instrumentation. It dramatically and easily indicates each adjustment optimum when properly used.

When the assistance of the null amplifier is called upon, great care must be exercised in the manipulation of it's "gain" control and the meter shunt so as to avoid damage to the null-meter by over-deflection. Without the amplifier plugged in, no harm can come to the null-meter but it's deflections are much smaller but still useful.

The better or worse readings are not at all dependent on the accuracy of the calibrations of speeds. They tell whether a readjustment of any kind is an improvement or not over a previous one. Calibration accuracy is required for the absolute data so that results can be compared even though by other sets of instruments on various boats.

Operating Procedure.

Before recording much data, it is wise to determine, for each course, the optimum adjustments for the sails, centerboard, balance, etc. This can be done readily with the help of the null-meter together with the adjustment of a zero balance between the boat and the wind speeds. Any change of the boat speed in respect to the wind speed, as a result of a readjustment, will cause the meter to swing in either the marked "Better" or "Worse" direction.

It has been found that, should scattering of plotted data occur, it is not usually caused by measurement inaccuracies. It is more apt to be due to sensitive departures from the best boat adjustments. This emphasizes the importance of the crew's good judgment in addition to the merit of the boat's design.

After being satisfied with the boat adjustments, data may be recorded. Actual speeds and the resulting speed ratios, between boat and wind, permit comparison with similar data from other boats. Also, one must not overlook that this can alert a racing crew to examine adjustments if the performance is less than has been recorded previously.

In addition to the angle of the helm for a straight course, one records the apparent wind velocity, the boat's speed, apparent wind angle to the boat's heading and the leeway angle. The sum of the latter two angles consolidates into the desired single angle of the course to the apparent wind. While these three inter-related values can be employed for final plotting, many may prefer the more revealing dimensionless ratios of boat speed over apparent wind speed, V_B/V_{AW}, and the speed-length ratio of the boat, $V_B/\sqrt{L}$, for plotting against the course angle. The merits of boats, even of various sizes, can then be fairly compared.

To obtain the ratio V_B/V_{AW}, one has a choice of calculating from the separate meter readings or of employing the pre-calibrated balance adjustment. The latter has the advantage of precisely simultaneous readings. An advance calibration can be accomplished with the help of the adjustable battery supplies to produce any desired meter readings. Then the balance adjustment that produces a null reading is observed. A calibration curve of this balance setting at various speeds is essential since the speed meters' calibrations are not strictly linear.

In gathering data, one has no control over the magnitudes of the wind or the resulting optimum boat speed, for a given course. However, the course can be chosen at will. To obtain the most meaningful data between three related variables, a series of measurements should be made while holding one variable constant. This constant value can be the chosen course angle. This process is then repeated at other fixed course angles.

A fixed course suggests an adjustable marker on the wind-angle meter. The helmsman carefully maintains a source that keeps the meter indicator on this mark during each series of measurements. Complete runs are taken for a family of wind headings from hard on the wind to 180°. Several selected days may be required to encounter light, medium and heavy winds on each course.

The author has to maintain a fixed course during such measurements, by careful manual steering while watching the wind angle meter. Henry Morss, of the A.Y.R.S. group working on this problem, has a similar set of instruments. He also has an electrical automatic pilot which can be changed from the customary magnetic-compass control to wind-vane control.

The most difficult course to steer by hand is hard on the wind. This is due to a great change in boat speed with small changes in course angle on this heading. My experience with Henry Morss' automatic pilot, during these types of measurements in variable winds, is that it far excels human ability to steer an accurate windward course. His pilot was described in A.Y.R.S. No. 53. Even the sailing helmsman is being threatened by automation!

Up to this point, the discussion has mentioned only the overall performance of the combined sail and hull. Some readers may be interested in a procedure that enables a separate determination of the sail force, when runnning. This sail force, of course, exactly equals the hull's resistance. Thus, both sail force versus apparent wind speed and heel resistance versus boat speed can be determined, for a running course.

After first plotting a range of boat running speeds for various speeds of the apparent wind, a drogue with a spring-scale attached to its line is dragged astern. Simultaneous readings are taken of the spring-scale force, the wind speed and the boat speed. Next, the wind speed for this same boat speed is extracted from the previously plotted curve, where the drogue was not employed.

Equal boat speeds, with and without the drogue, result from different apparent wind speeds. The spring-scale force reading is due to the *difference* in these wind speeds, acting on the sails. These measurements permit the mathematically inclined to calculate the force versus speed relationships for sail and hull, as well as their coefficients.

Data Plotting.

The reader may be curious to see plots of actual measured data which compared different boats as well as the effects of various adjustments on a given boat. It is hoped that other members of the American Section of A.Y.R.S. will report on these when sufficient data have been accumulated. It is a large and time-consuming job to get adequate data which must involve a range of weather conditions.

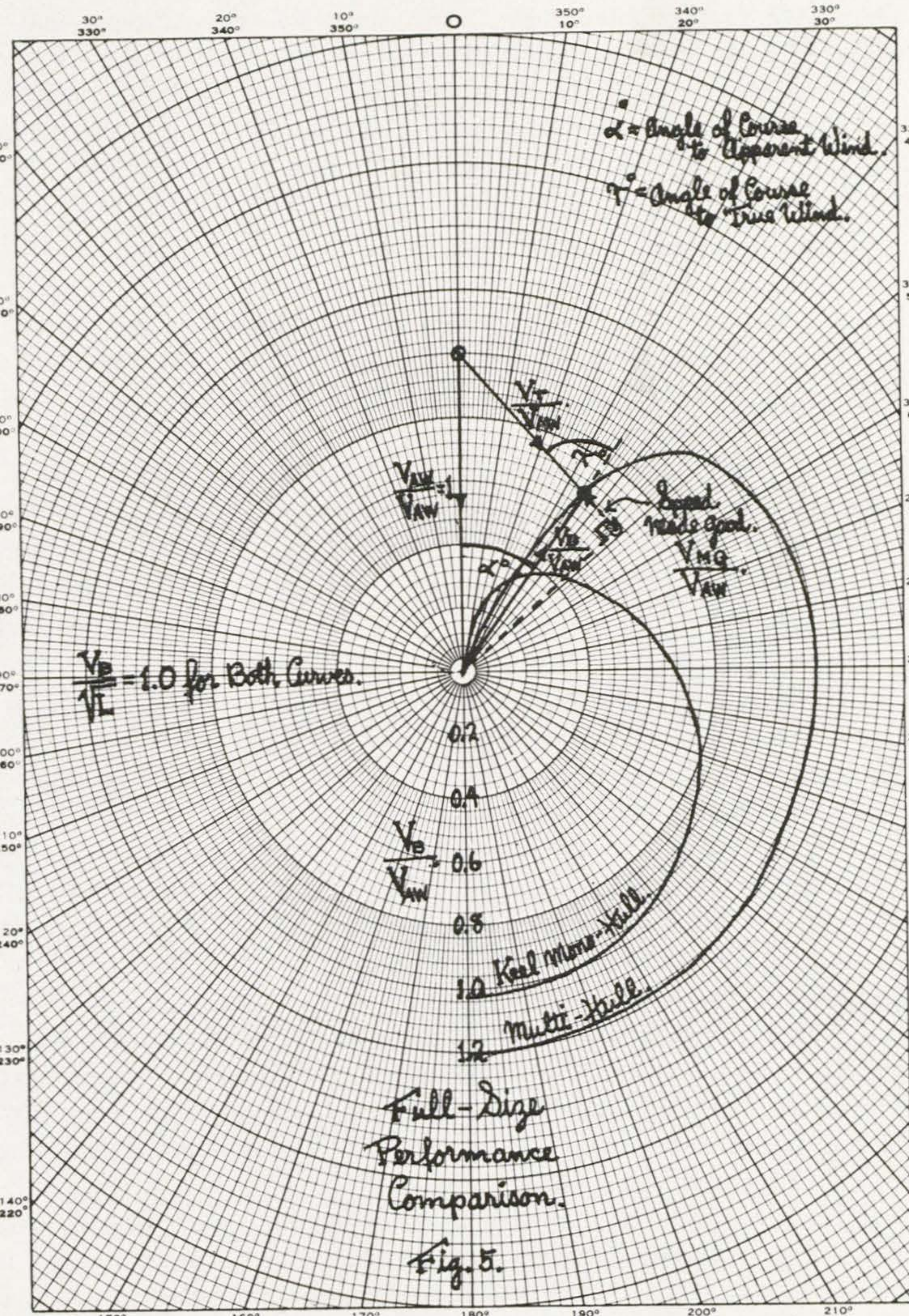

Fig. 5.

The writer has made measurements more to check out the instrumentation and its calibrations than for study of particular boats. In this process, Fig. 5 resulted. It can serve as one preliminary example of what may be expected.

There are many ways in which data can be plotted, each of which may have certain advantages. For example, two dimensional polar plots, of boat speed versus the apparent wind direction, for various fixed apparent wind strengths, permit determining the magnitude and direction of the true wind with the help of a simple construction. Another simple construction can show the "speed made good" into this true wind.

Fig. 5 employs dimensionless ratios rather than the absolute values because this permits comparison of the merit of different size boats. The mentioned advantages of the polar plot are retained and the constructions are shown in the figure. The boat speed to wind speed ratio, V_B/V_{AW}, is plotted against various angles of the apparent wind for a single fixed value of the boat's speed-length ratio, $V_B/\sqrt{L}$. This, in effect, shows how hard the apparent wind must blow for a given boat speed on any course. This curve was made possible by extracting points from a family of curves each of which represented a different but fixed course angle to the apparent wind. To obtain actual velocities, all speed ratios except $V/\sqrt{L}$ can be multiplied by the value of V_{AW} occurring for the particular point.

The velocity triangle, plotted in Fig. 5, can be in terms of the three, speed ratios to the apparent wind, as shown, or the three speeds directly. Henry Morss ingeniously uses such triangles to determine the validity of his measured data.

The measured apparent wind speed, the boat speed and their included course angle $\alpha°$ are plotted. Drawing the third side of the triangle represents the theoretical true wind speed that would satisfy these data. Also, the *theoretical* angle $\gamma°$ for the true wind to the course is thereby determined.

The *measured* angle $\gamma°$ can be obtained by observing the compass' angular change on identical but opposite tacks and dividing by two. The measured angle and the theoretical angle $\gamma°$ must agree or the data is faulty and should be thrown out. This is an elegant means for checking the data accuracy.

Fig. 5 compares a racing keel, mono-hull with a good multihull for a speed-length ratio equal to 1.0. A discussion of such results will be left for later A.Y.R.S. articles, as mentioned previously. However, it would seem that "America Cup" racing is being carried out in "house-boats."

YACHT PERFORMANCE MEASUREMENT

BY

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The following notes summarise points I made at an A.Y.R.S. talk with the addition of some recent results.

A yacht's intrinsic performance cannot be fully judged from the time taken to make a passage or the results of racing. So many factors can effect the issue—winds, tides, tactics, "form", stamina. More precise methods are needed. Improved instruments and electronic equipment help to make this possible. Much information can in fact be obtained with fairly simple instruments, but simplicity must not be at the expense of accuracy, otherwise only broad trends can be indicated.

For a number of years the writer, with Claude Bowden and Bob Curwen has made measurements with yachts of various sizes and their radio sailed model counterparts. Various methods of measurement were used, one of which, the "dynamic method" is described below and some results given.

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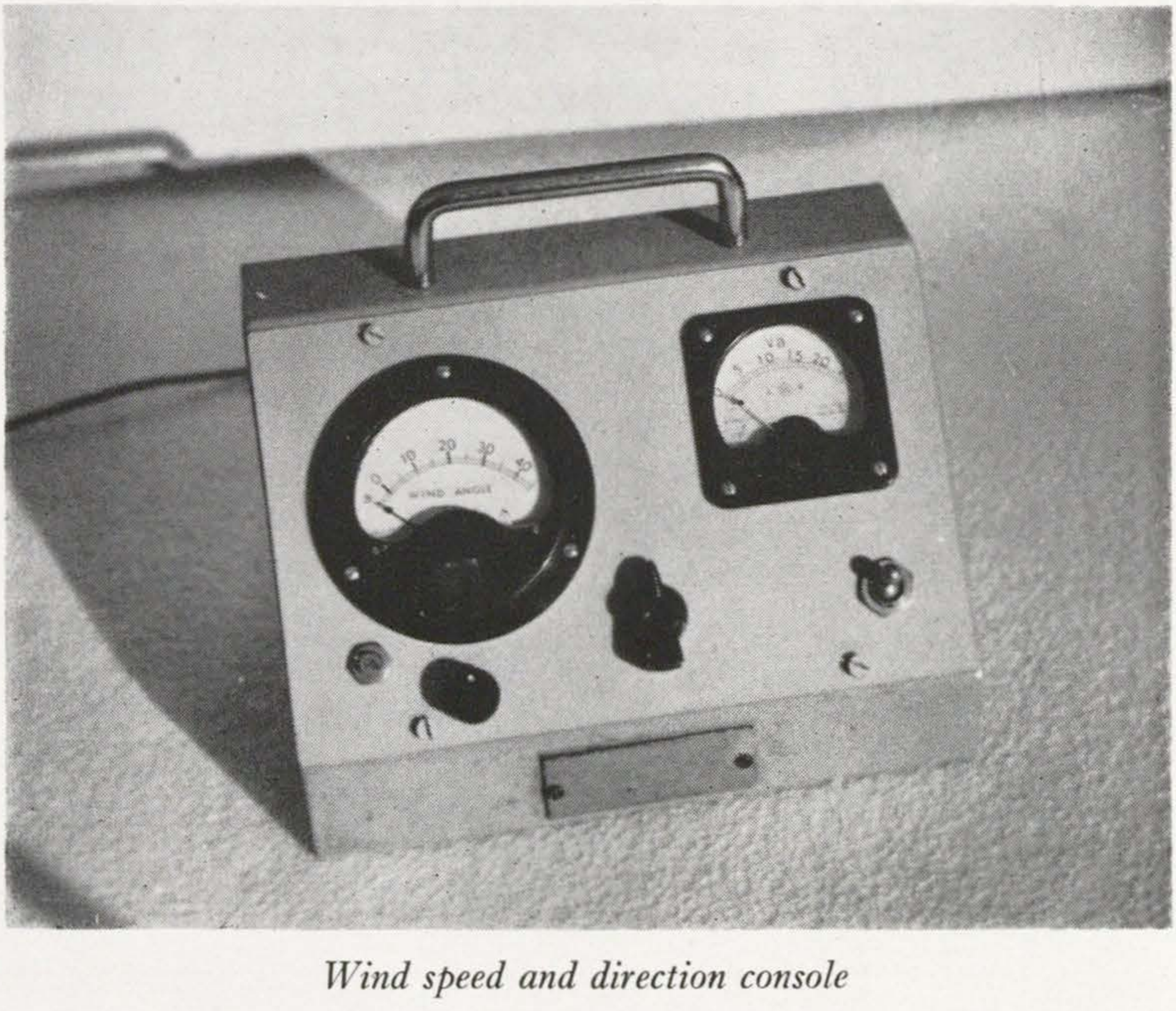

Wind speed and direction console

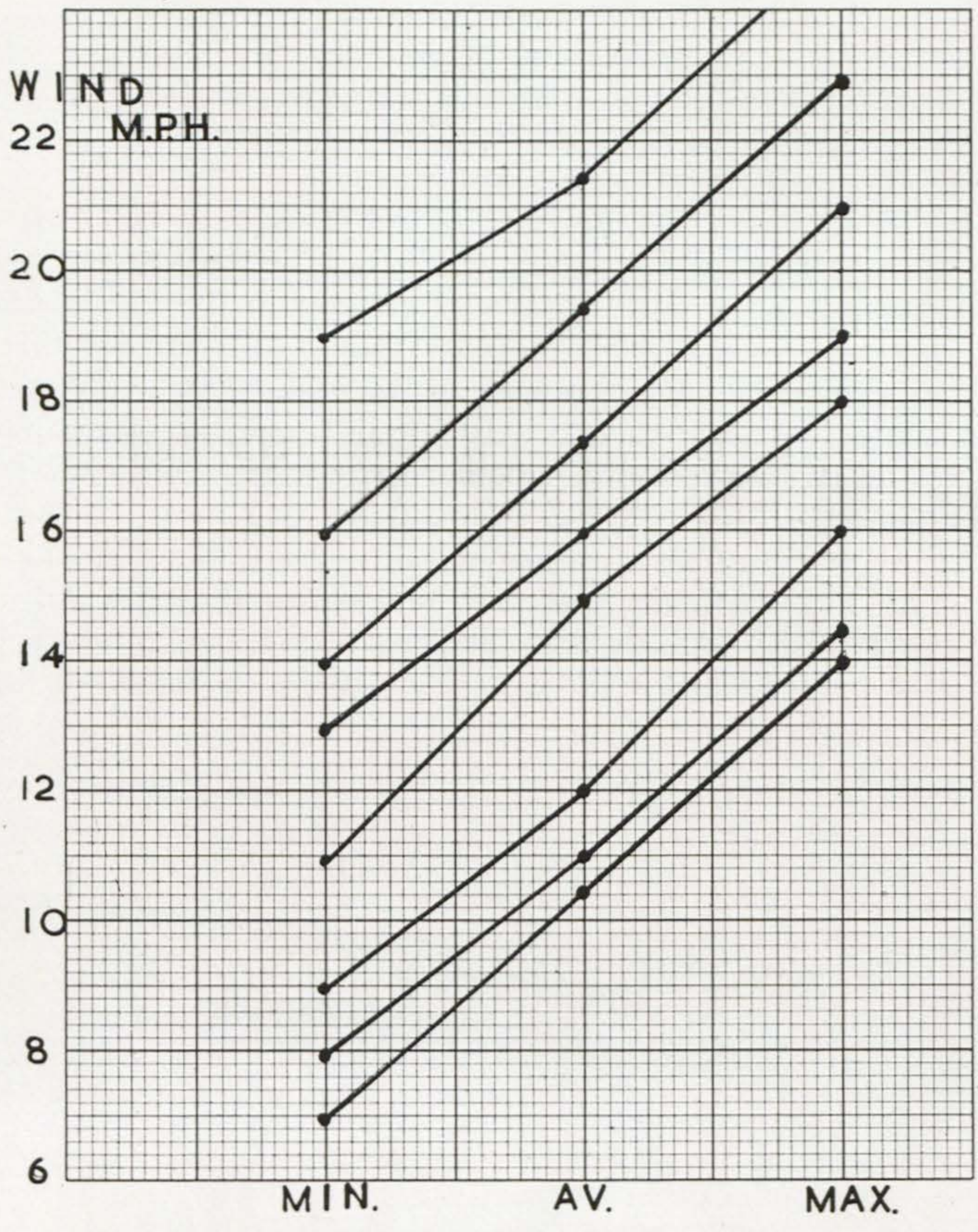

Fig 1. The natural wind violently and frequently alters its speed. From this, we can see that a wind whose average speed is 10.2 m.p.h. may suddenly drop its speed to 7 m.p.h. or as suddenly increase it to 14 m.p.h., being infinitely variable between these two limits.

It is noteworthy, that the same amount of increase and decrease occurs with all windspeeds up to 21 m.p.h. so that a wind of 20 m.p.h. may drop to 16½ m.p.h. or rise to 23½ m.p.h.

In certain atmospheric conditions, of course, the wind can be far less consistent. These are inversions, dawn, dusk, thunderstorms and calms.

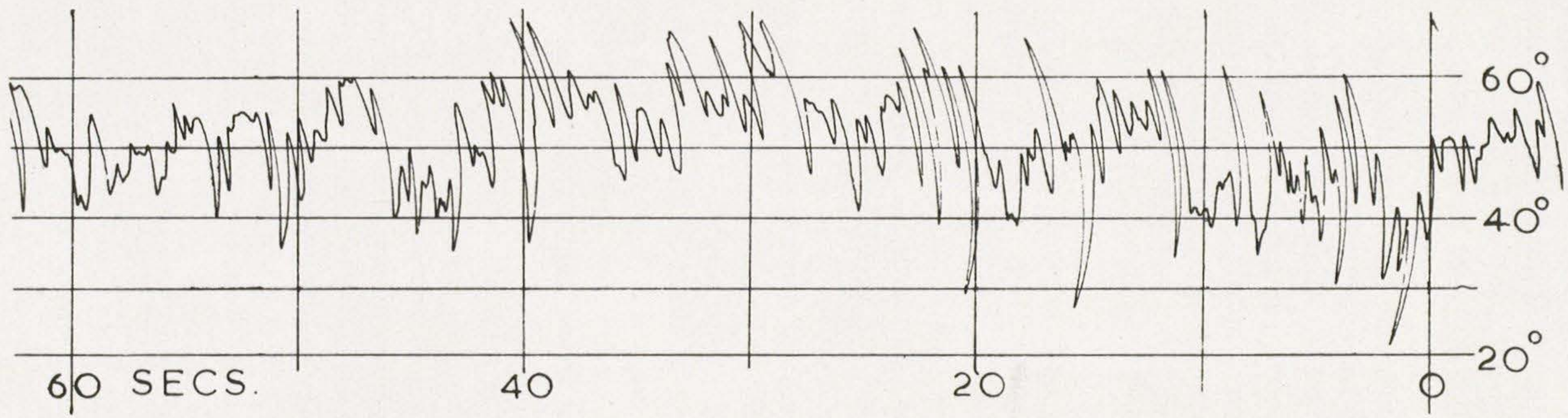

FIG. 2. The time scale on this graph reads from right to left. This graph shows the changes of direction of the wind we sail in, which joggle about through 20° on either side of the mean wind direction. Spikes of veer and backing of as much as 30° on either side of the mean may also occur.

This chart shows the rotational cause of this by spikes of veer being followed by spikes of backing and vice versa. Larger whirls are also shown by patches of veer being followed by patches of backing and vice versa.

Yacht measurement may be divided into three kinds:—

1. Those required for the study and improvement of design and for the prediction of performance from tank and tunnel tests.
2. The measurement of actual full size performance under defined conditions.
3. The measurement of comparative full size performance to improve tactics, evaluate sails and train helmsmen.

The first requires very special equipment—tanks, tunnels, etc. The second and third need relatively simple though reliable equipment, but in addition and equally important, they need sailing skill if results are to be consistent and trustworthy.

There is still a gap between 1 and 2 and the need is for information and data to be passed both ways—that is to and from the Tank/tunnel and the full size yachts.

The study of free sailing, large radio yacht models can play a mid way role in helping the correlation of the two fields, bringing together, as it were in natural, turbulent conditions, the model sail from the tunnel and the hull from the tank.

In full size measurements one leaves the controlled conditions of the tank and tunnel, and meets the variables of wind and water and these have to be taken into account:—

Wind has 1. Gustiness; the rythmic rise and fall of wind speed.
2. Directional variation; turbulence, and shifts.
3. Increase of velocity with height.

Figs. 1, 2, 3, show charts of these properties which after many measurements I believe to be typical of conditions on a normal sailing day (As it is unrewarding to carry out measurements in inversion conditions, at dawn, dusk, in freak thunderstorms or calms—these have been excluded).

Fig. 1 shows the range of wind gusts measured with an undamped sensitive flow gauge at 6 ft. Note the consistent range of the mometary maximum and minimum speeds in any given average.

Fig. 2 shows the directional variation of a vane as recorded on a fast chart recorder, in what feels to be a "clean" wind, over water.

Fig. 3 shows the wind speed gradient with height over open water. From sea level to 10 ft. the increases are variable depending on sea conditions, increasing approximately as the $\sqrt[4]{\text{height}}$. Above 10 ft. the speed increases as $\sqrt[7]{\text{height}}$ i.e.

$$\frac{V}{v} = \sqrt[7]{\frac{H}{h}}$$

when v is speed at h feet
and V is speed at H feet (the higher level).

The effect of this gradient in relation to a 12 Metre and an X One Design keelboat is shown in Fig. 4. In all except very light winds the

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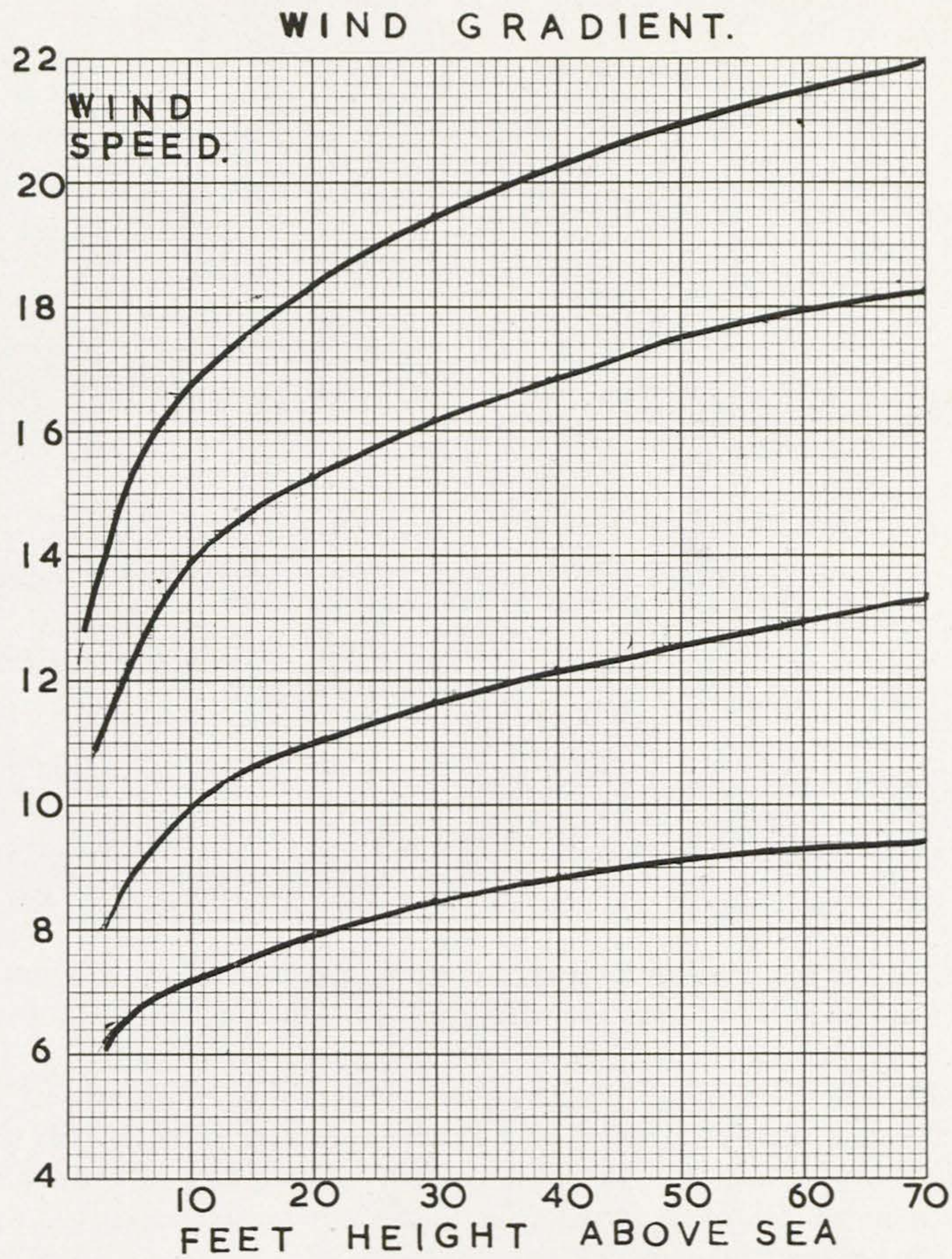


FIG. 3. The "Wind Speed Gradient" is caused by friction between the wind and the sea surface and it results in tumbling eddies in the wind which are smaller near the sea surface. With near calms, the wind layers can "shear" on each other making these ediies so small that they cannot be detected.

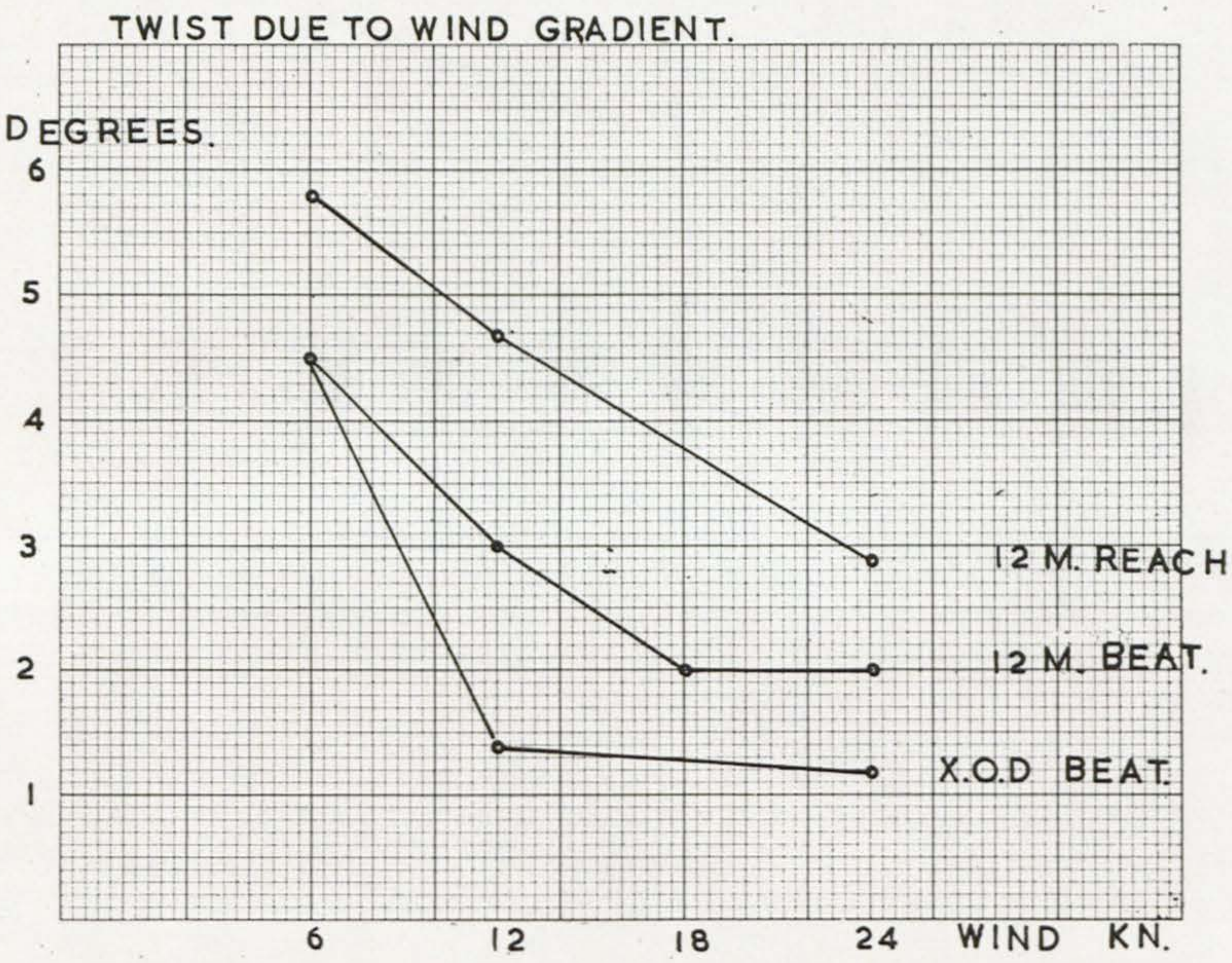
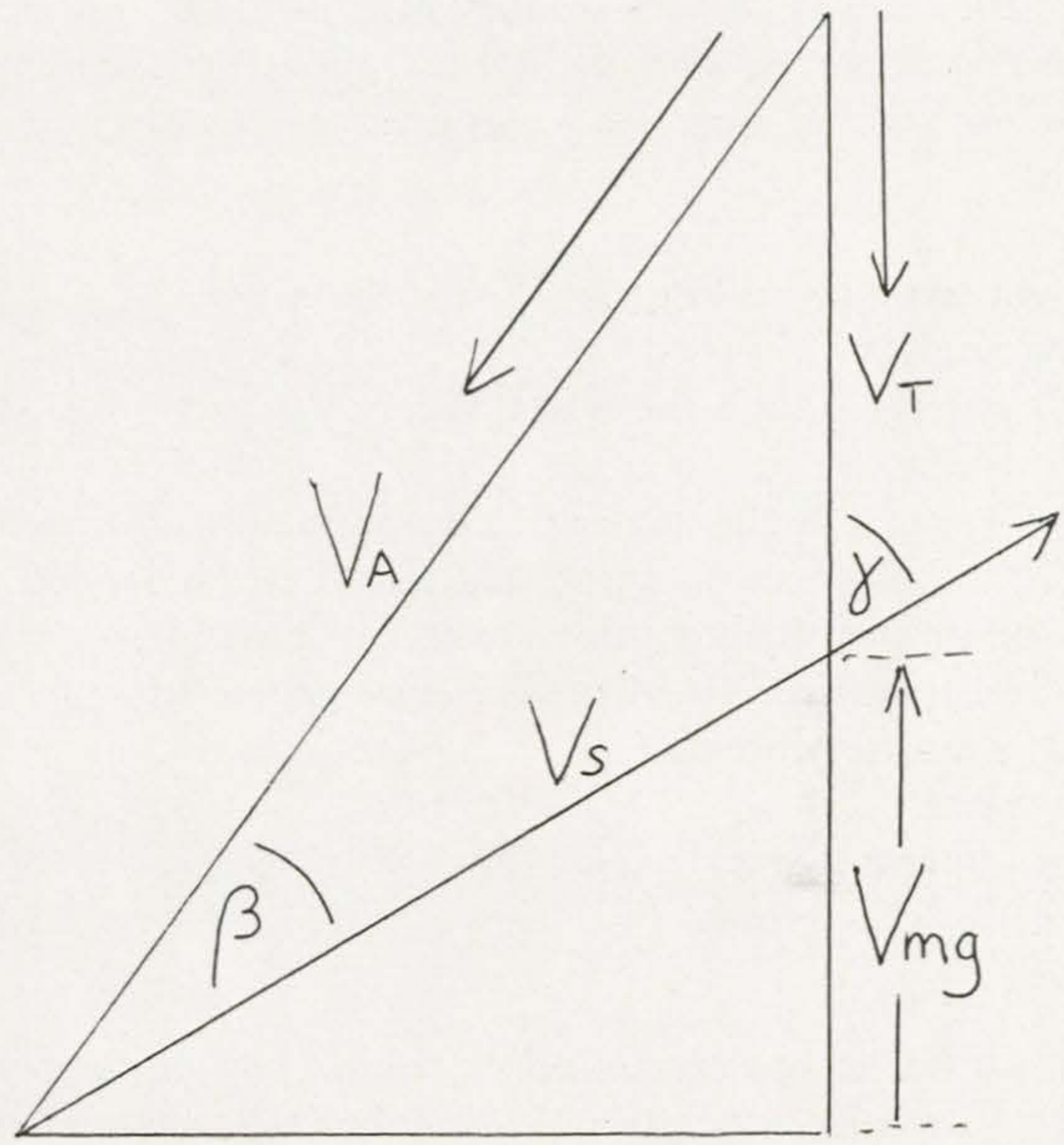


FIG. 4. A boat sailing across the wind speed gradient will have a freer apparent wind near the masthead than on the deck because the sideways component will be greater due to its greater speed. This results in a "Twist" of the direction of the apparent wind. These graphs show that a 12 meter on a reach needs a twist to its sails of 6° in light winds but only $4\frac{1}{2}$° close hauled. These figures become less in strong winds. The actual twist in a 12 or 6 meter's sails is more usually in the region of 15°.



twist of the apparent wind is only a few degrees. Sails which have greater twist than this will thus lose drive. This point is generally known but the degree of twist is often debated.

Water Conditions.

Tidal flow can seriously affect some performance measurements but the Dynamic method—that of taking measurements on board the yacht while sailing, is independent of tidal flow since the whole measurement "framework" travels with the vessel. Waves and choppy or rough water, on the other hand are a condition of the test and will influence the results accordingly, as they are desired to do. The comparison of results obtained in smooth water with those of similar wind strength, but in choppy water provide interesting guides to the effect of pitching and rolling, to keel disturbance, increased resistance and loss of drive. It is here that the predictions from the tanks tests show the greatest divergence from the actual measured results.

Tests.

Although tests on all points of sailing are made, those showing windward performance have been selected.

Tests of sailing performance have been described in the A.Y.R.S.

bulletins particularly E. Bruce's interesting articles. The following Dynamic method (as opposed to Static Course method, which I hope to describe on another occasion,) requires the measurement of five main values:—

1. Apparent wind speed Va.
2. Apparent wind angle to centre line of boat β-λ.
3. Heeling angle θ.
4. Yacht's speed through the water Vs.
5. Leeway angle λ.

Other data such as the angles of jib and main to the yacht's C.L.; position of the mainsheet on track, sail shape etc. is logged to give as complete a picture of the conditions of test as possible.

These are then used to solve the usual vector triangle to give:—

Speed made good to windward	Vmg knots.
True wind speed	Vt knots.
Course angle to app. wing	$\beta°$
Course angle to True wind	$\gamma°$

Wind Speed Va.

This must be accurately found if results are to be comparable. A change of $\frac{1}{2}$ knot in wind speed can make 20% change in Vmg. at some parts of the curve. The cup anemometer works well for this purpose. I use $2\frac{1}{4}$ in. cups on $2\frac{3}{4}$ in. radius arms, with a fast electrical counter which is operated from a light contact breaker on the spindle of the cups. This gives an integrated total over short periods of fifteen to thirty seconds which are the usual periods for taking test samples, the other readings being taken over the same period.

For instantaneous readings the cups can be mounted on the spindle of a miniature electric motor which then generates d.c. current proportional to the wind speed. The motor must be very free running. A 0-5 Milliampmeter is suitable for measuring the current. I prefer the counting method as it gives very consistent results.

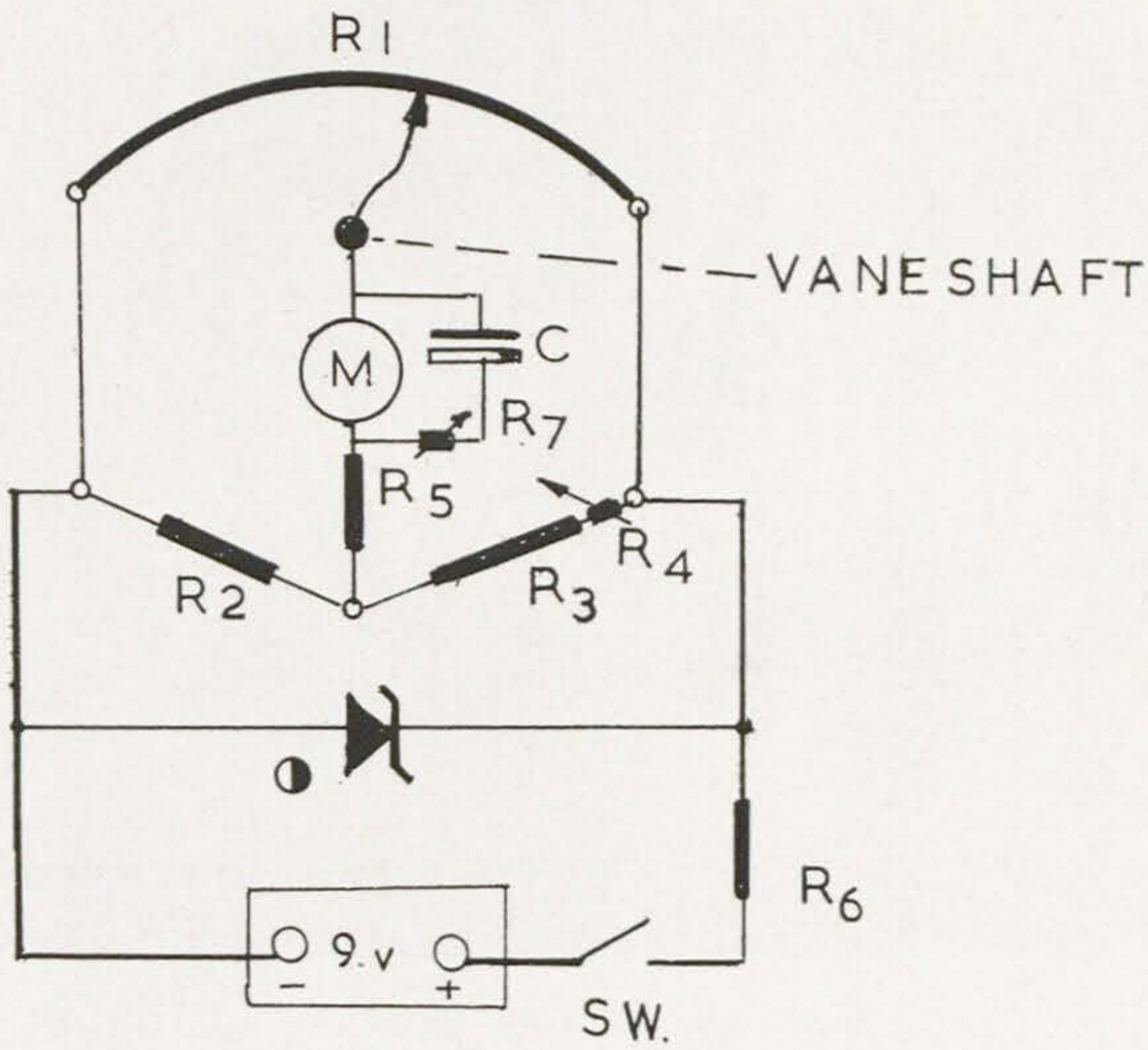
Apparent wind angle(β-λ).

This is measured with a Vane unit. There are now commercial units available. A unit may be made by mounting a light vane 6 in. x 6 in. on to the shaft of a "Desyn" type of repeater transmitter and via a 5-core cable to the indicating meter at deck level or in the cockpit. This method suffers from 1. Stiffness—makes the vane sluggish in lighter winds. 2. Limited accuracy. 3. Difficulty of damping. A better method is to use a low friction linear potentiometer which forms part of a bridge circuit (fig. 5). Normal radio "pots" are too stiff for this purpose, but the low friction pot can be driven by a small vane

Continued on page 58

WIND ANGLE INDICATOR

CIRCUIT

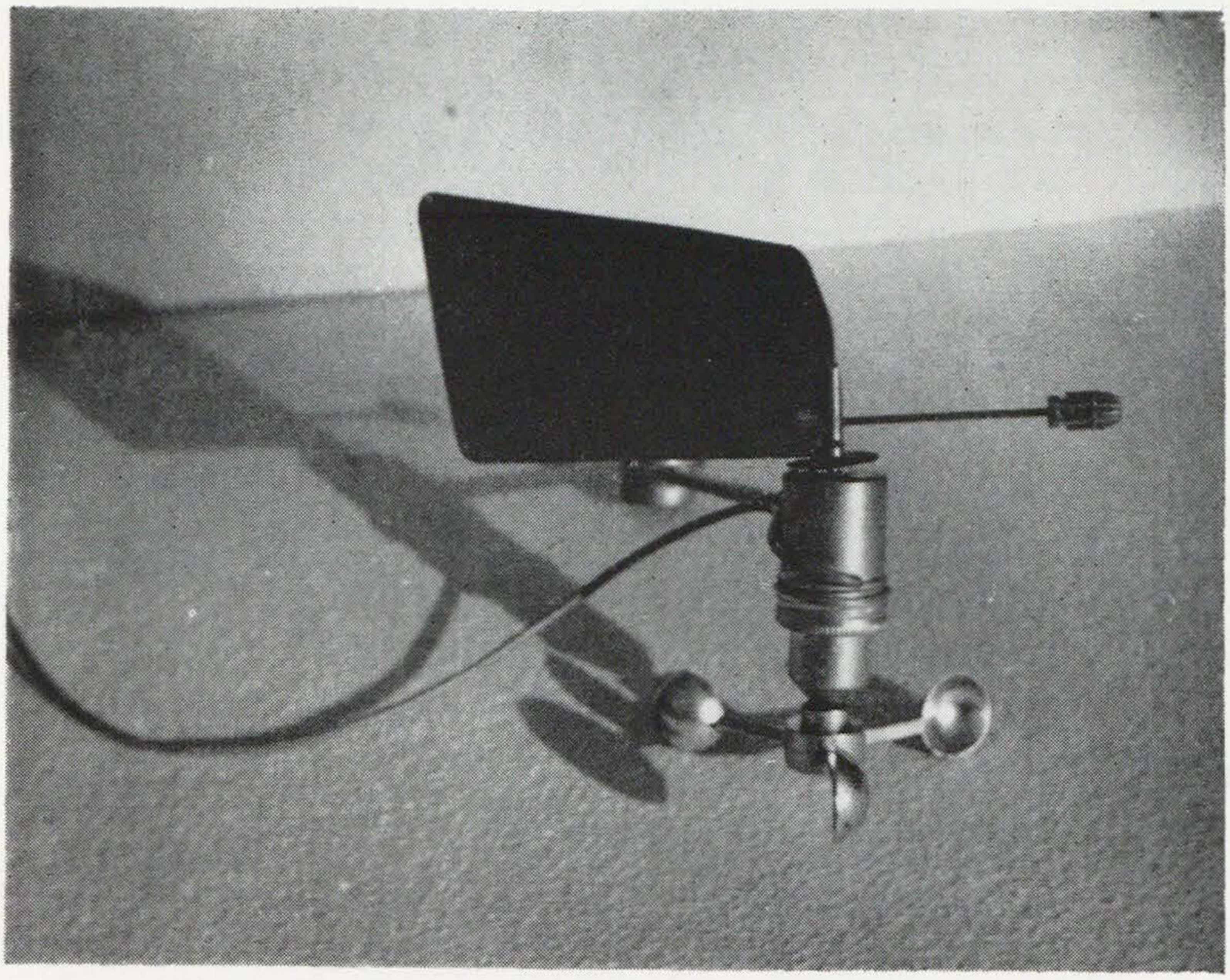


R_1 3 K OHMS LINEAR POT.
2,3 3·9 K
4,7 100 PRESET
5. 6 K
6. 47.
M. 0 - 200 μA
◑ DIODE OAZ 210
C. 500 μF. DAMPING.

FIG 5

J.C.H.

Wind Vane indicator diagram. The circuit is a conventional resistance bridge with the wind vane directly attached to the very free moving potentiometer. A movement of the vane results in a change in the meter current. The battery voltage is stabilised by means of the Zener diode OAZ 210. The variable resistance R_4 enables the system to be adjusted to zero the vane. The resistance R_7 produces variable damping in conjunction with the condenser, which is necessary to reduce excessive swinging.



Vane and cups for wind angle & speed

5 in. x $2\frac{1}{2}$ in. and will give an open scale reading to at least 1°. They are particularly suitable for electrical damping, to reduce the effect of wind variations.

In the case of the results given below, the cup—vane unit was mounted either at mast head or on an inclined staff out to windward (12°) which comes near vertical when heeling, and is near the centre of effort height.

Heeling Angle. θ

The heeling angle is constantly varying by as much as 15°. It can be measured with a simple pendulum type of indicator, and damping is not usually necessary as the frequency of swing is relatively slow (55 per min. for an X boat and 35 for a five tonner—slower still for larger boats).

The heeling angle plays a vital part in conjunction with the yacht's speed in controlling the amount of leeway made. Unnecessarily high angles of heel can obviously destroy high pointing characteristics of a yacht. Overcanvassing is an example of this but the less obvious effects only become apparent when measurements are taken. There is one heeling angle only to give optimum results with a given yacht and rig for each wind speed.

Leeway Angles. λ

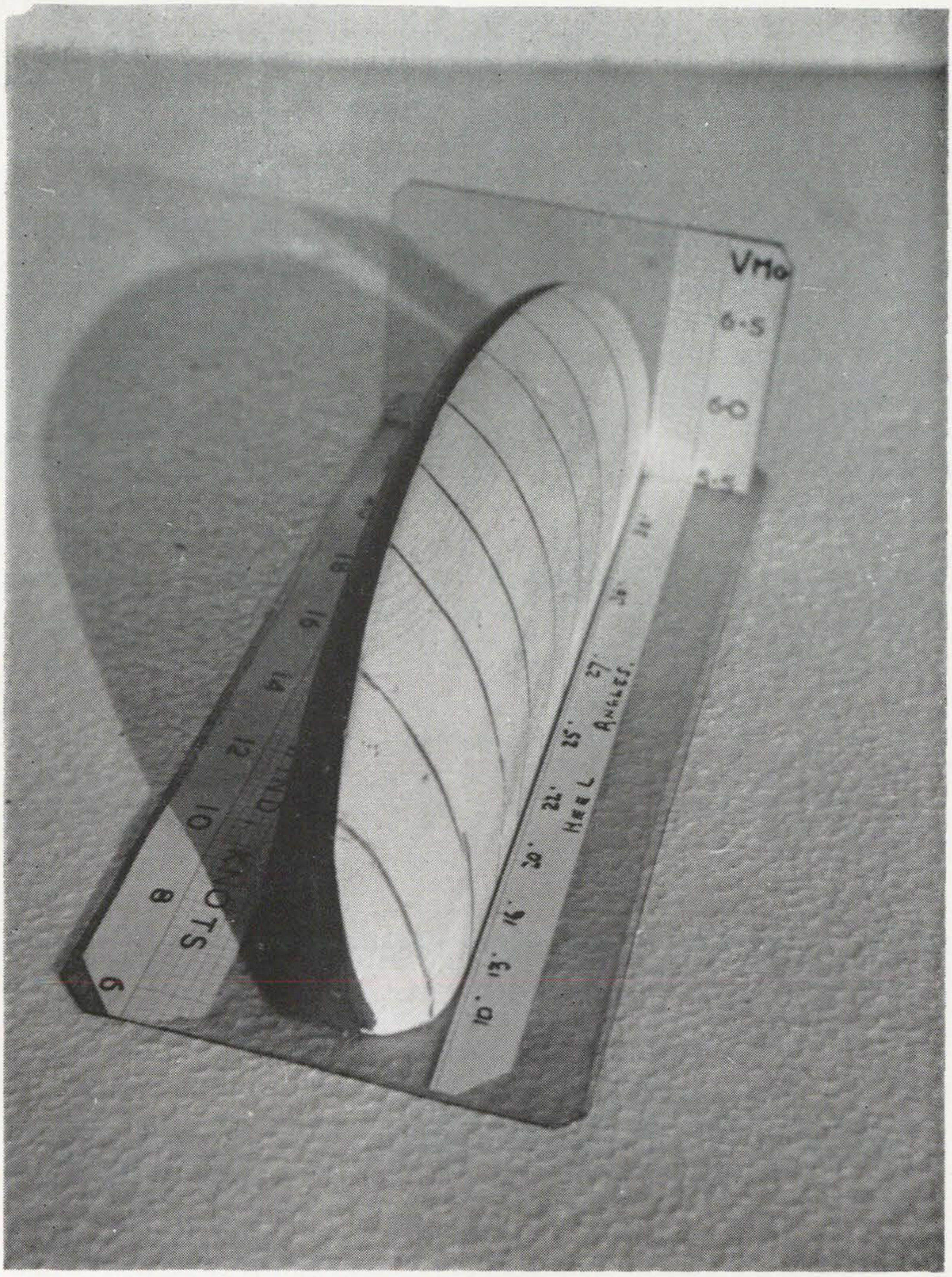
These are not easily measured. Various methods have been used—vanes over the bow or between keels, sighting devices, pitot static devices and trailing gear. A method of reeling out a drogue/float as the boat travels along a steady course is satisfactory, the angle between the line and the CL of the boat being measured and the heeling angle taken at the same time. Whichever method is used it is convenient to construct a chart showing leeway plotted against speed, for various angles of heel. This is then used to apply to results of subsequent performance tests on the same hull and rig. The reason for this is that it allows the helmsman and measurer to concentrate entirely on the test run sailing, without the added complication of obtaining leeway angles at the same time. We are experimenting with a method of taking direct readings, which if satisfactory would alter this technique.

Yacht's Speed (Vs)

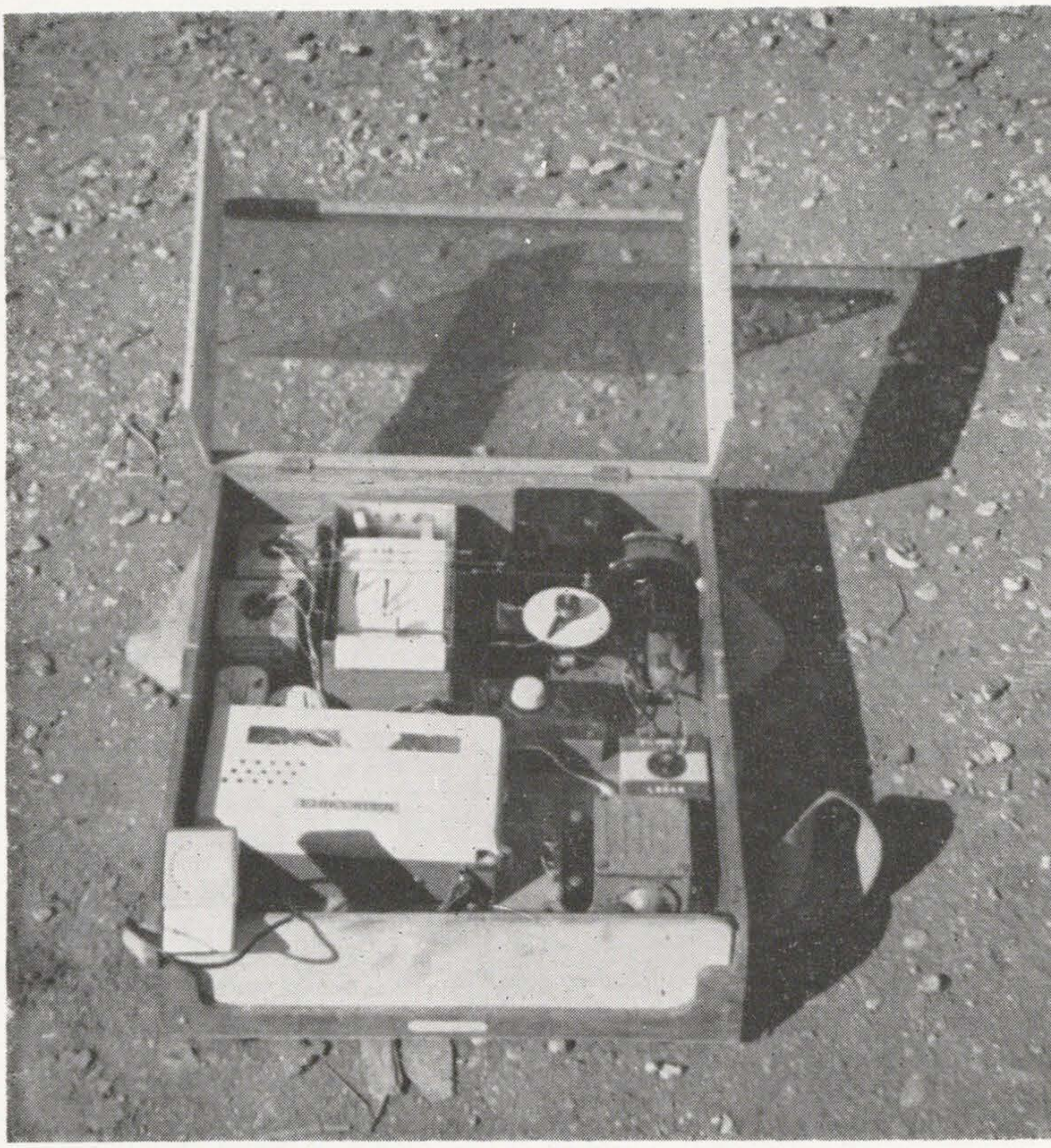
A number of speedometers have appeared on the market recently. Since the tests are taken purposely over periods of short duration the speedometer should have a sensitive response. The speed figures shown in the following results were taken with Brooks and Gatehouse's Hermies and Harriers. A Walker Log fitted with a simple contact breaker and electrically counted has also been used on occasions.

Recorder

Although it is possible to get good results from spot readings on the various instruments, the readings do, even when damped, vary continuously. For this reason mainly, a multipen chart recorder was made and the various signals — wind speed, water speed, wind and heeling angles, pitching, were fed to the pens on the chart. Incorporated in this equipment is a small tape recorder on to which can be read other important data such as sheeting angles, sail shape and sea conditions. This equipment gives more satisfactory results and the charts provide a great deal of additional information such as heeling and pitching ranges and frequencies, damping, etc., all important to the study of a yacht's behaviour in rougher water, about which we need to know much more. The chart recorder is of advantage also in sail evaluation and helmsman training, because the results can be examined and discussed after the testing is over.



This photograph shows a model of how a helmsman must steer for best Vmg. Low windspeeds Vt are at the upper end and high windspeeds Vt are at the lower end. For best Vmg., the helmsman must steer and sheet his boat so that he stays just on the apex of the spur all through the wind range. If he sails too close or heels too little due to sheeting, he falls off one side. If he sails too free or is too closely sheeted, he falls off the other side.



Top left: Multipen chart recorder. Bottom left: Microphone and tape recorder. Top right: Pitching and heeling mechanism. Bottom right: Wind speed integrator.

Results.

To obtain the values for the desired optimum sailing conditions, test runs were made to "straddle the optimum target" by sailing a carefully planned pattern of angles to the apparent wind, over as wide a range of wind speeds as possible. On various test days the major part of the wind range can be covered. This produces a meaningful scatter of results from which the optimum can clearly be found, beginning with the optimum Vmg and then referring to the component values which make up the Vmg figures. In this way the optimum results are actually those producing the best speed made good.

Continued on page **63**

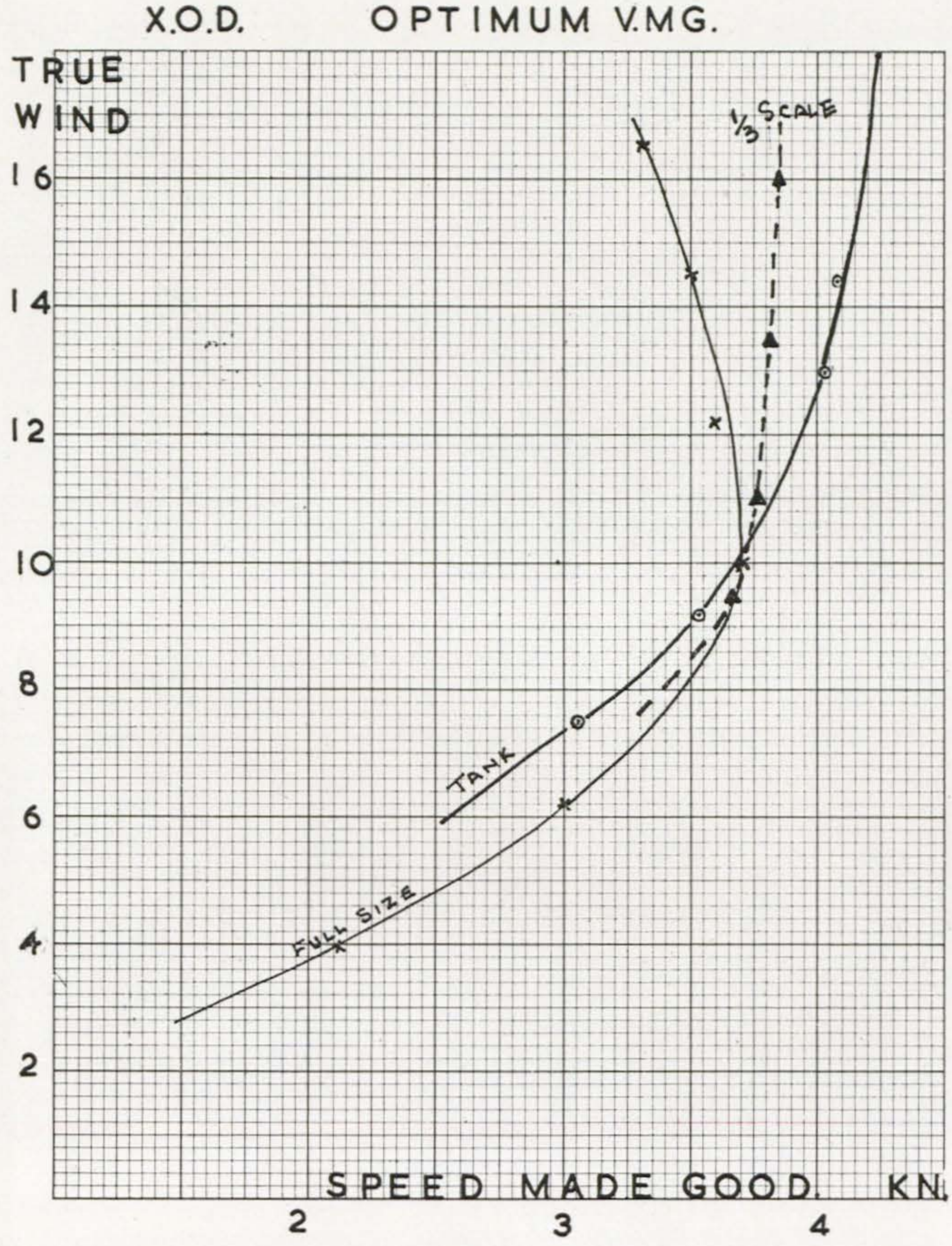


FIG. 6. These graphs show the best possible speeds to windward (expressed as Vmg) of an X One Design keel boat in various wind speeds. As the wind speed increases from a calm, the Vmg increases to a maximum of 3.7 knots when the windspeed is 10 m.p.h. At higher windspeeds, the Vmg falls off, due to the rough water, sail distortion and pitching.

The dotted line shows the performance of a one third scale radio controlled model of the same boat. In lighter winds, this coincides with the curve for the full sized boat but is better in strong winds. The third graph shows the performance predicted by the test tank. This is pessimistic at low wind speeds and optimistic at the higher range, due to the rough water.

The presentation of an overall picture of measured performance requires several graphs which are closely interrelated. Some of these are shown below with brief notes. From the main graphs a solid model of optimum performance can be built which shows clearly the slippery slope which a helmsman must follow in order to hit the optimum as often as possible in the constantly varying conditions. (Photo).

Graph 6. *Vmg against True wind speed.*

These three curves refer to a well tuned and sailed X One Design keel boat (see *A.Y.R.S. Bulletin No.* 41).

Curve "Full Size" is the measured near-optimum speed made good to windward of the full size boat. Note the curving back of the line in higher wind speeds due to the increased resistance in rougher water, sail distortion and reduced drive.

Curve "1/3 *Scale*" Shows the scaled up optimum results as measured with Col. Bowden's the 1/3 scale X*OD* radio sailed model. This coincides with the full scale at medium wind speeds and is better at the higher range. It is probable that the full scale can with further tuning be driven to approach more nearly this curve. (This was achieved when tuning up the 12 metres in calm water.). In slightly higher scale winds the model's performance curves back as does the full scale boat.

Curve "Tank" shows the tank test prediction of an X.OD. The comparison shows that the tank predictions are pessimistic at low winds speeds and optimistic at the higher range due to the rougher water conditions which the tank does not take into account. This is bourne out in exactly the same way in the 12 Metre full size and model test results.

Graph 7. *Vmg against the Course angles* (δ).

This shows the effect of decreasing the course angles at a given wind speed, obtained by sailing successively closer to the true wind. The Vmg rises to the optimum for that wind speed and falls again as the boat is pointed closer. Note the decreasing heel angle (θ) which is measured at the same time, and the particular heel angle which coincides with the optimum performance.

Graph 8. *Sailing angles over the wind range.*

The optimum angles to the wind for best Vmg at various wind speeds are shown in three curves. In light winds it is usual to find yachts sailing at much higher angles than these and it is only by very

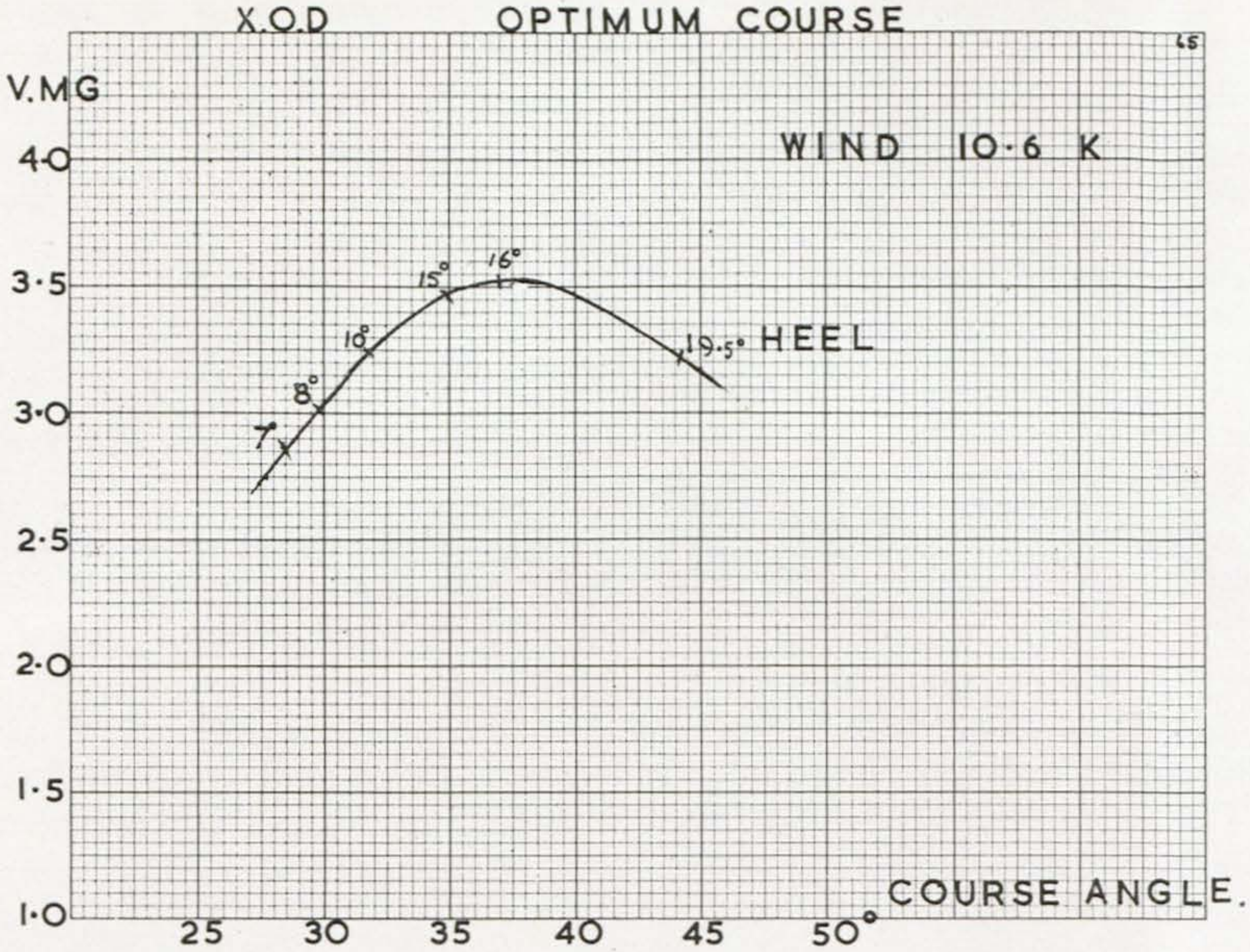


Fig. 7.

careful sailing that they are held down to the values shown, which results in races being won.

At the higher speed the angles again increase as greater resistance is encountered.

It is clear from these curves that the yacht's heading must constantly follow—or anticipate—the wind gusts (see Fig. 1) to maintain optimum results. In this lies the secret of working the gusts practised by skilled helmsmen, quite apart from the shifts of the apparent wind direction during gusts, and the changes in the angle of incidence, when heeling.

The middle curve shows the optimum course angles to the apparent wind.

The bottom line shows the optimum heading angles to the apparent winds, which is what the helmsman senses on board, with the aid of burgees ribbons, vanes etc. The difference between these latter two curves is of course the leeway angle.

Graph 9.

The scatter deliberately produced by sailing at wind angles between "very close" and "full and by" show the large range of heeling angles which can be covered in any given wind. The optimum

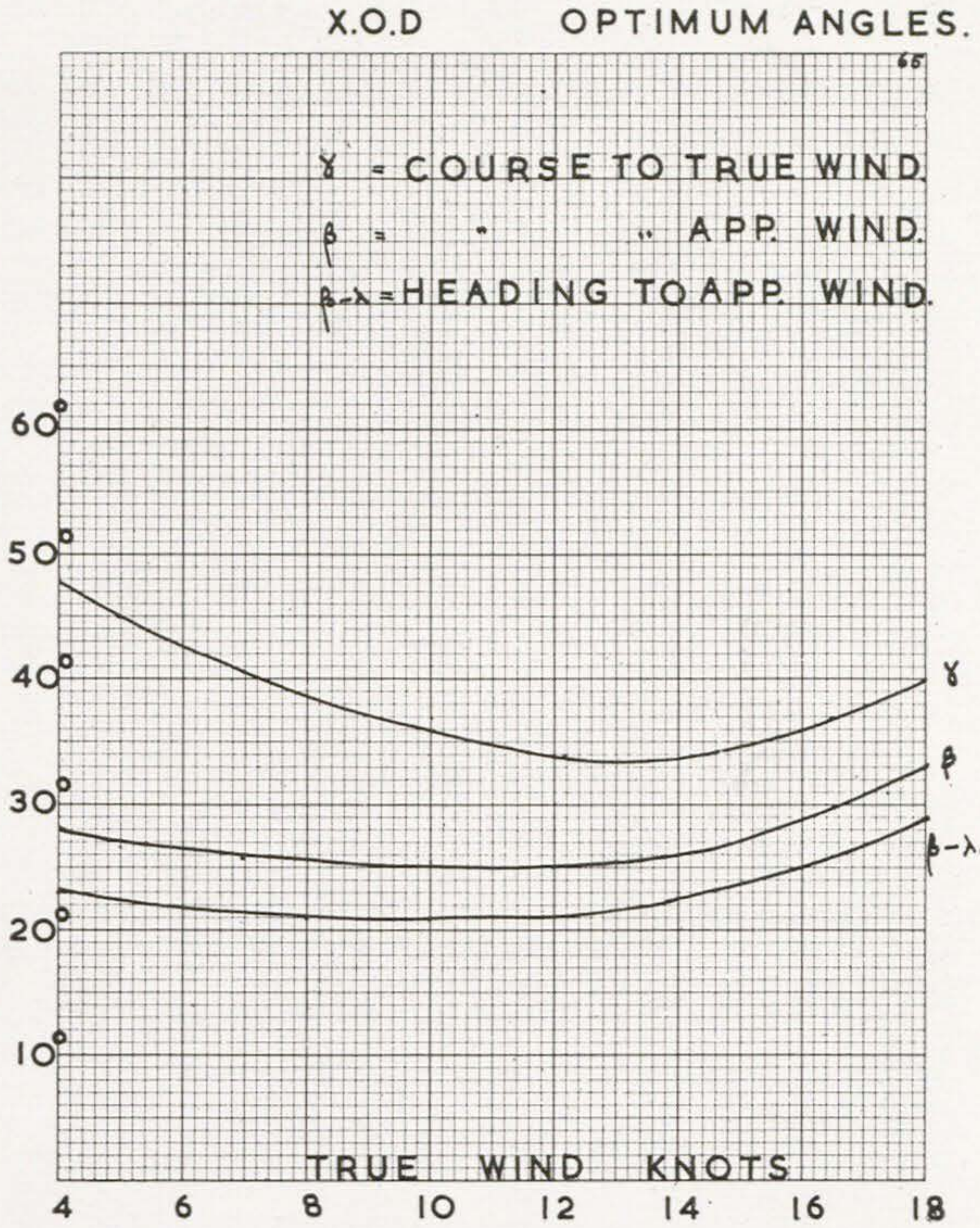


Fig. 8.

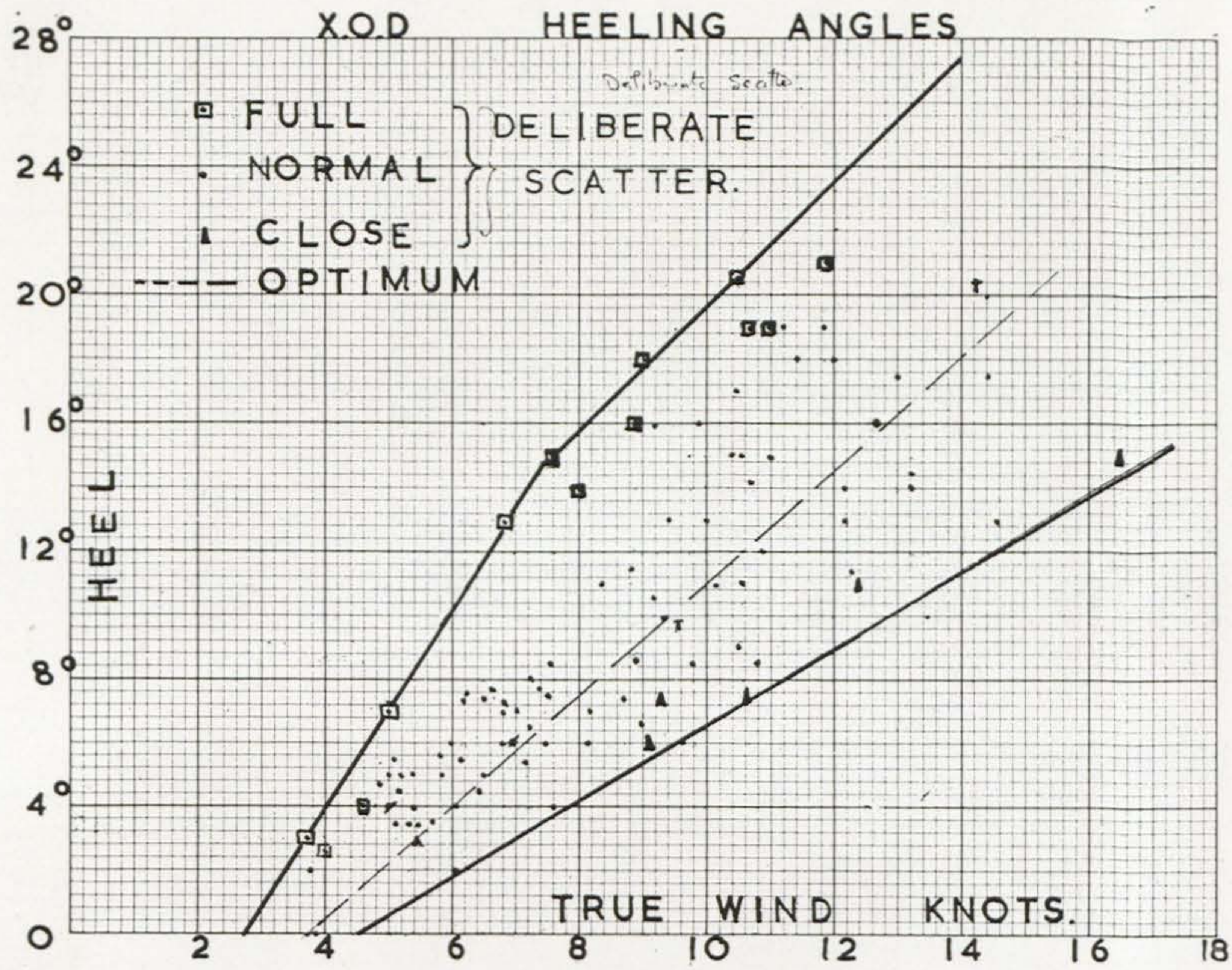
line shown represents the only correct heeling angle for optimum results with those sails at each wind speed. The *actual* results obtained when testing give a clear insight into the helmsman's skill and his sheeting habits. It is not always appreciated that he can be heeling wrongly due to wrong pointing and/or to wrong sheeting. Or he may point correctly but by wrong sheeting fail to reach his optimum drive, and this will be shown in the heeling angle.

Working Curves.

The remaining graphs are working curves showing the relationship of various values as obtained from measured results.

Graph 10. The relationship of beta and gamma is consistent and a useful curve when studying the result of changes in one or more variables.

Graph 11. The speed made good over the true wind speed, against the range of wind speeds. This and the next curve are of



Above: Fig. 9 *Below: Fig.* 10

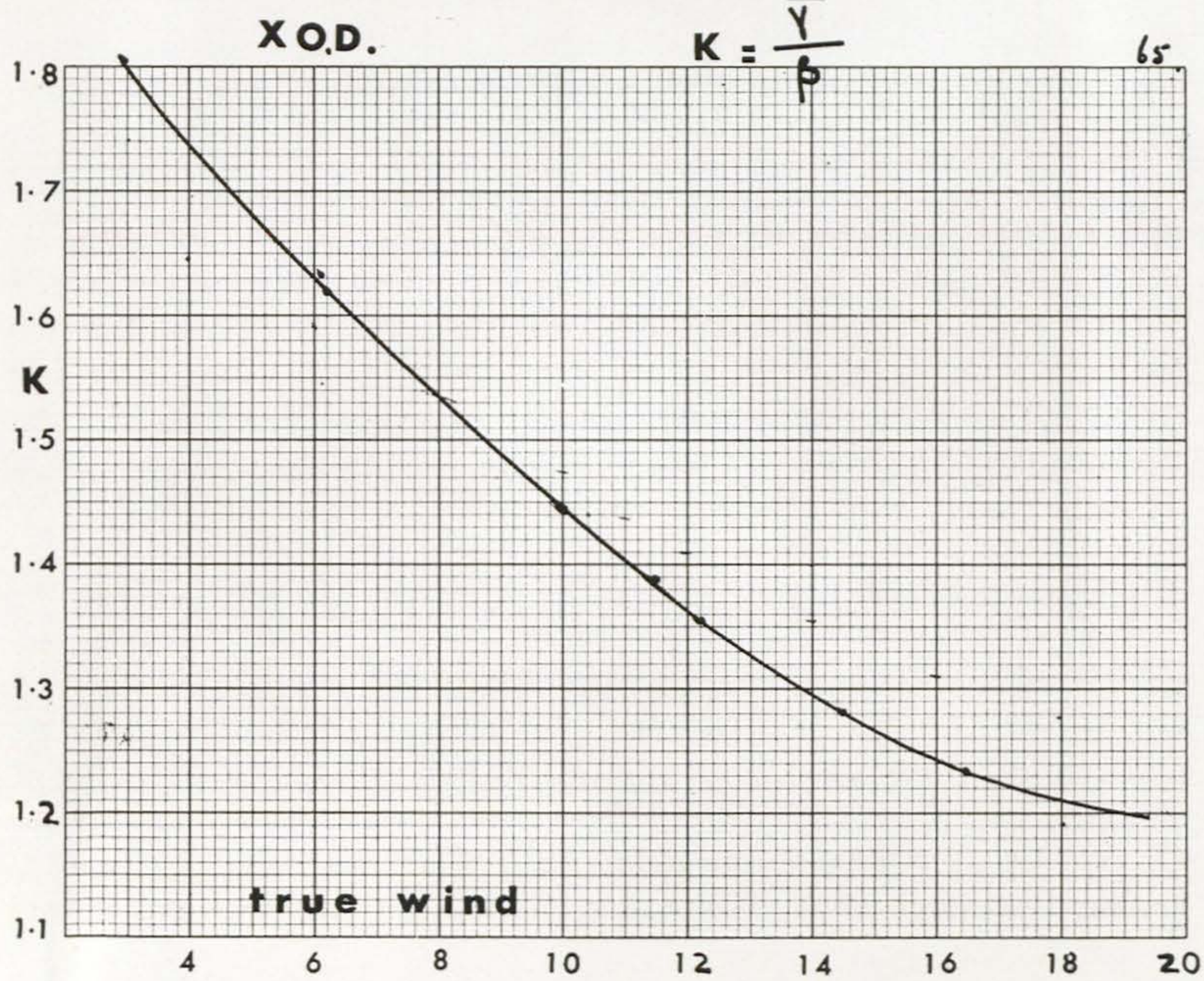


Fig. 11

use in connection with the design of rather more sophisticated instruments which can form a rapid indicator for the helmsman to judge his performance. Various degrees of computing are entailed.

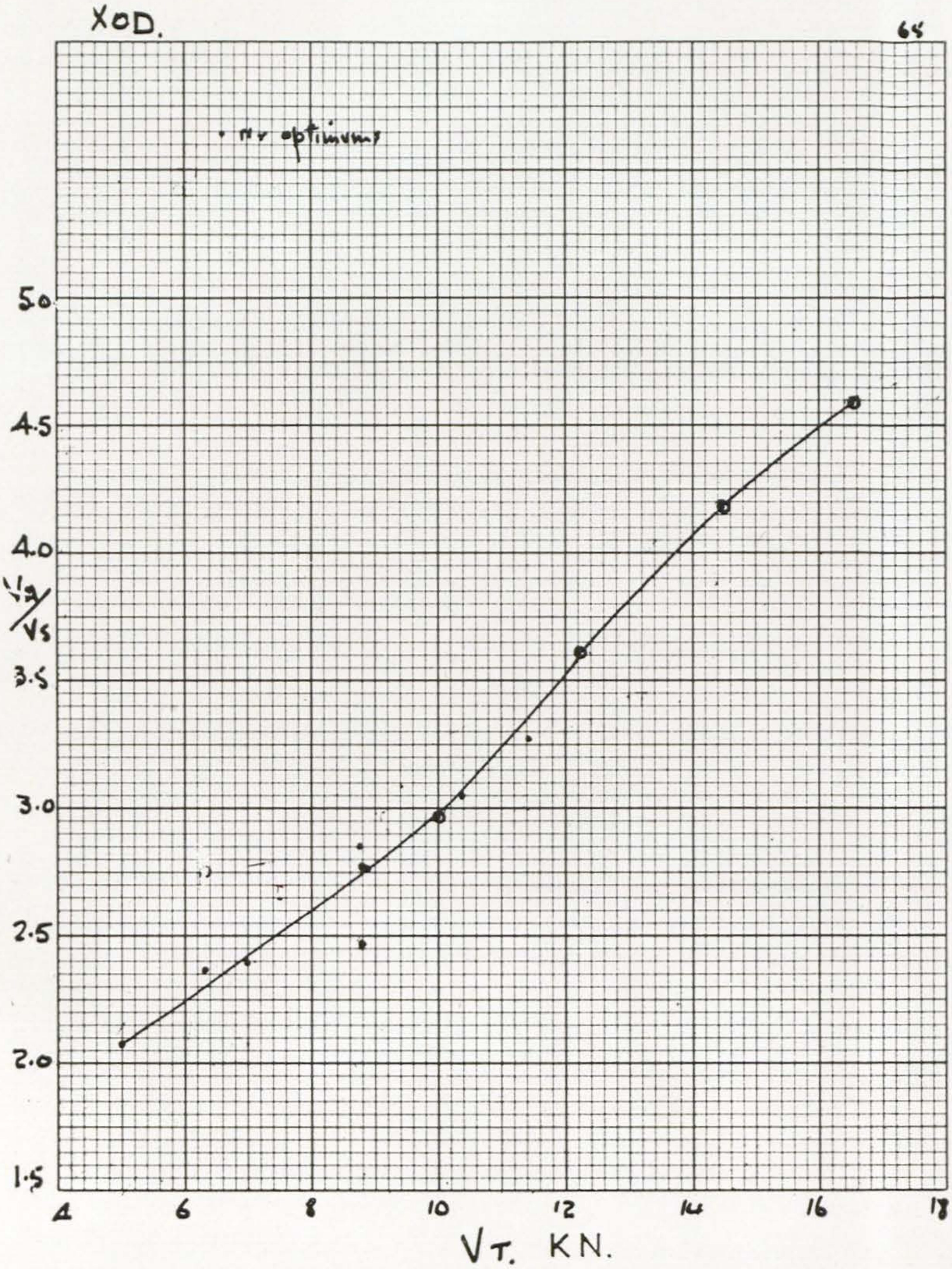
Graph 12. The same applies as with Graph 10. This shows the relationship of apparent wind speed to yachts speed over the wind range.

Graph 13. This shows a typical curve of Yachts speed against various values of β. In this case in a wind of 6 knots.

Conclusion.

As techniques and instruments improve it should be possible to obtain increasingly useful information on actual performance.

It is hoped to describe a test method using simpler instrumentation which is particularly suitable for tideless waters such as Weir Wood, on which a preliminary trial was made recently and found to be very suitable, from the point of view of clean winds and sufficient space.


XOD.
65
• ηv optimums
5.0
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4.0
3.5
3.0
2.5
2.0
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Vg/Vs
4
6
8
10
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14
16
18
VT. KN.

Fig. 12

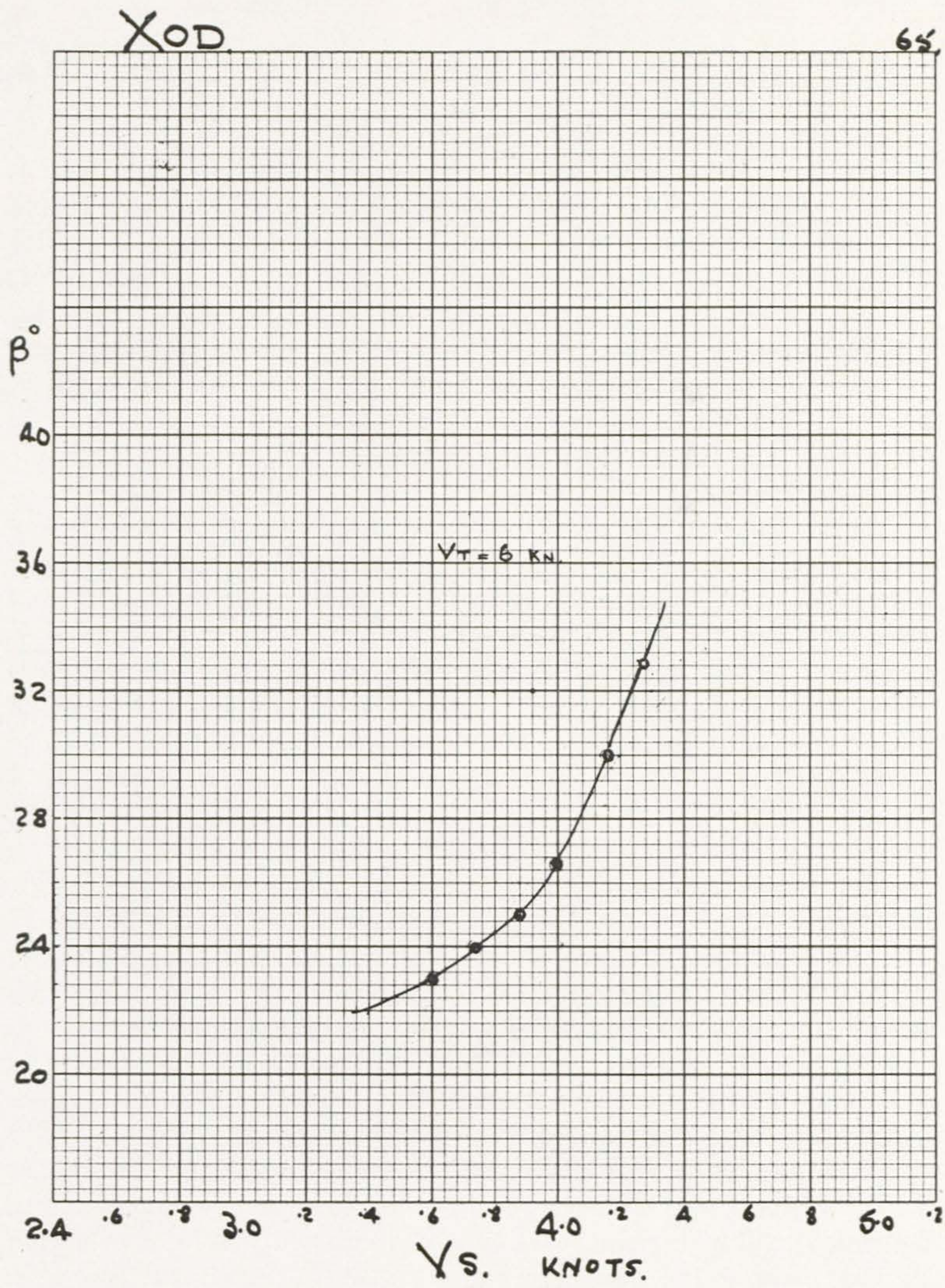


Fig. 13

THE RECIRCULATION TANK

BY

BILL MEHAFFEY

1174 S. Scoville Ave., Oak Park, Illinois, U.S.A.

Prior to World War II, the Navy had Professor Hamilton then at the Iowa Institute of Hydraulic Research try a moving water tank by diverting a flume from the Missouri River and allowing the water to flow over a dam. This is a wild river and the results were poor, but interesting. A "Recirculation Tank" was then made at Taylor Model Basin. I first saw this in 1941 while under construction and my interest was considerable. The tank has a cross section of 22 ft. by 11 ft. and has two variable pitch propellers with a total of 2,000 H.P. The maximum water velocity is 10 ft. per second with some wave conditions.

After the war, I maintained my interest and Allan Murray encouraged me by stating in a letter that he believed it could be done if someone would work hard enough. I made my present tank as a scale model of the tank I intended to build in order to study flow problems. These appeared at 5 feet per second water velocity when waves became serious. It has taken ten years to tame this problem plus changing to the laminar flow technique Bruce developed. The lower speed required helped in avoiding critical depth waves but I still had trouble with a hydraulic jump at the entrance to the measuring channel. I finally eliminated this by a floating styrofoam damper, faced with a hardware cloth turbulence generator. This small scale turbulence dissipated the energy and stopped the jump. It rapidly dies out before reaching the model position. The turning vanes are of the type used in wind tunnels and are designed for optimum spacing. It took three sets to finally obtain the optimum for this tank.

The drive consists of two 7.5 in. x 10 in. propellors driven by D.C. motors from a variable voltage power supply. The total horsepower is about $\frac{1}{2}$ h.p. for 3.5 ft. per second velocity.

The two propellors turn in the same direction and we had at first a whirlpool at the discharge end of the channel. This resulted in too much hydraulic slope. We finally eliminated this by providing a settling basin at the discharge end with several cubic feet of water. There was evidence of rotation effects. In the measuring section. we then placed an orifice plate with 8 holes across the lower channel. This was followed by hardward cloth screens and honeycomb and one additional screen.

This small tank has been used on sailing yacht tests of my design and several other designers. It takes two people to operate, one to set and maintain speed and one to read the dynamometers.

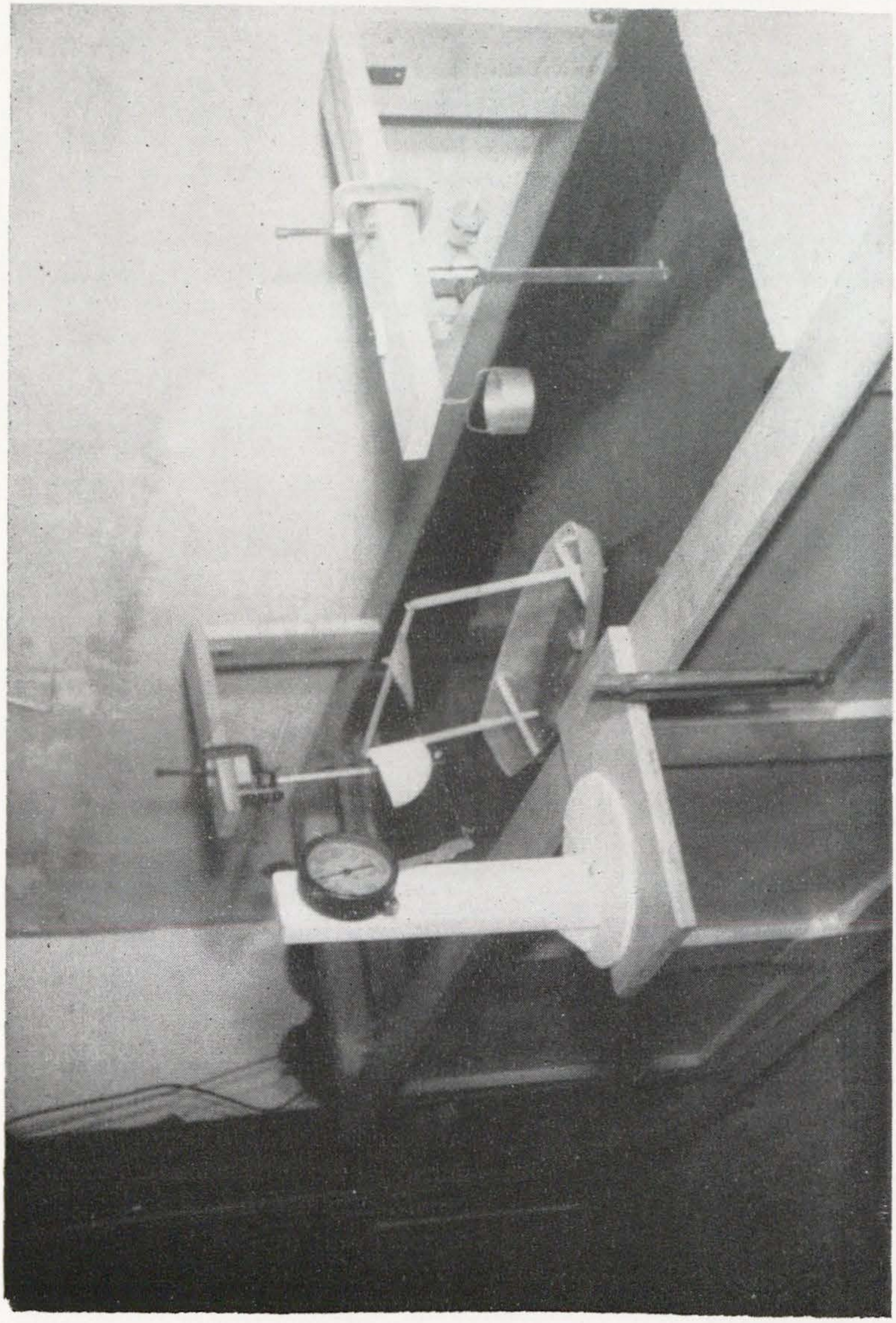
A larger tank has now been made and is in my backyard. We have not set it up yet but expect to do so in the near future. It will require two 3 H.P. motors and I hope we can achieve as good a flow pattern in it as with the smaller tank.

The new tank will be equipped to maintain speed automatically by a servo system from measured water velocity. This will save a lot of time. The tank water will be kept at one standard temperature by heating elements and a refrigeration system. The water will be continuously filtered to minimize the algae problem. At present, we can only use the tank in fall and winter and early spring because we want about 60° maximum water temperature.

Results. We have tested a large number of models, working in the laminar boundary range, the models being small. We have a full scale correlation of the *Lightning* which gives close agreement between our tests, Bruce's tests and full scale. Although we have several other full scale and model correlations, my tank testing colleagues refuse to accept the laminar flow method of testing because the capillary waves present should modify the waves around the model. However, since I do considerable commercial tank testing, I am in the process of building a normal still water tank similar to the Stevens Institute of Technology Tank at my family boat plant at Tiskilwa, Ill. This should eventually settle the argument.

The Recirculation Tank is very convenient for windward testing of sailing yachts with heel and leeway. We use a cord and wind force dynamometer as shown in the attached picture, taking care that the model C.G. position is correct.

Problems in Testing. In regard to laminar flow testing, both Bruce and I have had much better correlation than one would expect. It is well known that in the range of velocities from 9 in. to 24 in. per second, the model-generated waves are not exactly the same type as encountered on large models at correspondingly higher speeds. Barnaby gave a 1% error in wavemaking resistance for a velocity of 1.32 ft. per second. This phenomenon of composite gravity and capillary waves is covered in great detail in Lamb's "Hydronamics" and Dr. Hunter Rouse's "Fluid Mechanics for Hydraulic Engineers". To investigate this, I made a 9.5 inch model *Lightning* and ran the upright resistance and expanded to full scale. The results also correlate with the full scale tow even though capillary waves were clearly present. I should engrave a 4.25 inch model and see how well it correlates for a



The Mehaffey Recirculation Tank.

more positive check. My tank testing colleagues feel that the total wave-making drag is probably equal but that I might be in error on heavy displacement forms. Bruce feels that the model is inside the Mach angle of the capillary waves and, therefore, is not affected. Even if this is correct, the model must supply all the energy in a still water tank and the tow force would be affected. His argument could hold for my recirculation tank where the moving water can supply the energy for the capillary wave system.

I have found it best to avoid this problem by using one model size for all tests, selected to have less than $V = 0.7 \sqrt{L}$ at a velocity of 1.32 ft. per second. I also hold the tank water at a temperature which will keep the hull speed below the transition zone.

Bruce's plastic skin is difficult to use at the higher velocities as it swamps. Both Bruce and I have always found the laminar flow resistance coefficients higher than Blasius gives. Two of my hydrodynamicist friends point out that if we used one half the velocity in calculating Reynolds number on the skin, we would agree quite well with Blasius. This is similar to calculating bearing friction on viscous greased bearings. In the turbulent range, this is not necessary because 50% of the velocity change occurs in the thin laminar sub-layer under the turbulent boundary layer. I have done a lot of work on this problem and intend ultimately to use tabular values. If this is done, the water must be kept circulating through a filtration system to keep algae at a minimum.

There is another problem in all tank testing; what area to consider. Naval tanks go to great pains to calculate wetted surface by Taylor's mean secant method which is ridiculous because there is always some loss of wetted area due to flow separation in the afterbody and a small area in which laminar flow exists in the forebody. The friction data is from plank tests in which there is little chance of flow separation. It is also probable that only the components of area in the line of action of the tow force contribute to the measured resistance.

Bruce likes to work with weight in model scaling. This is satisfactory if boat and model are both in fresh water. If the boat will sail in salt water, it is best to keep volumes in proper scale or the wetted surface will be incorrect.

Dear Dr. Morwood,

Regarding Mr. Mahaffey's recirculation tank, several years ago we were exchanging data to compare results, particularly on identical surace-floating skins.

Both tanks showed an exponent of 1.5 with speed when skin data was plotted on a log-log scale. This proved that both tanks were in the laminar state. However, the recirculation tank consistently had higher coefficients than my still water tank.

I suddenly realised that a re-circulation tank always drags its model or skin *up-hill.* On the high-pressure side of the impeller, the water level is raised. It is lowered on the low-pressure side. Thus, this difference in level appears as a level gradient throughout the rest of the tank.

EDMOND BRUCE.

RE-CIRCULATION AND STILL WATER TANKS

BY

JOHN MORWOOD

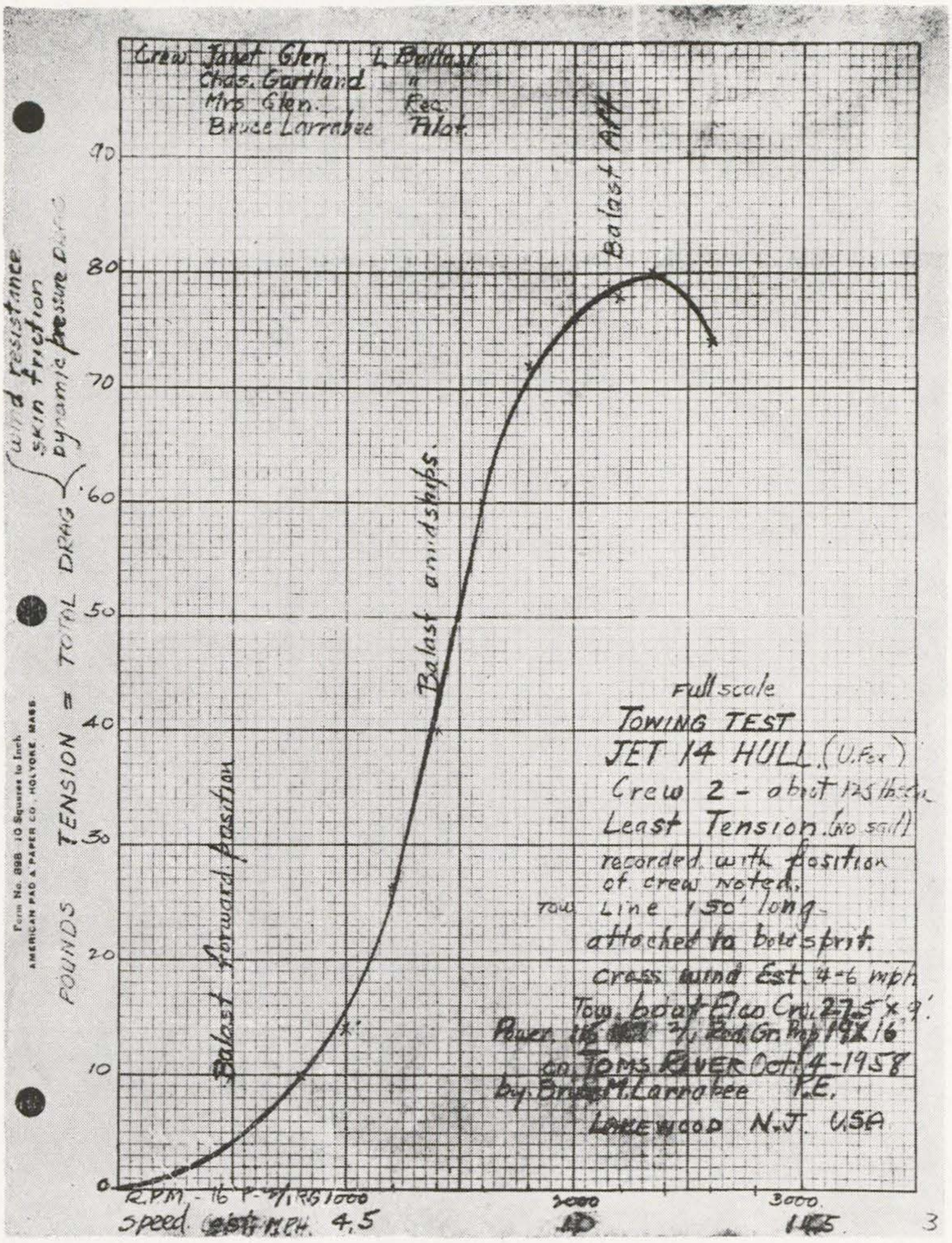
Some two years ago, we made a Bruce Tank and proved that good readings could be taken from it for running courses. But we rather boggled at the space necessary for close hauled tests and none of us at the time had the energy to set up these tests. Now, that tank has been put in the hands of one of our members and we will be interested to see what results he can get.

Some five years ago, too, Owen Dumpleton made a small re-circulation tank from a galvanised four foot long bathtub by putting a sheet of plywood down the middle and driving the water around with a propellor driven by a small electric motor. Honeycomb at either end of the test section smoothed the flow while guide vanes led the water around the curved ends of the tank. This tank was relatively crude and the walls were rough but it showed the principle nicely. We used it for a demonstration at a Boat Show.

These two tanks and gazing in awe at the long stretches of water and complicated instruments at various laboratories have been my only experiences of test tanks. On this very limited experience, I feel that the re-circulation tank could well be the instrument of choice for the A.Y.R.S. member who wants to test models within the laminar flow area. Its main value is the compactness of the instrument when testing close hauled performance and drag angles of hulls. The construction and instrumentation of such a tank would make an excellent thesis for a more advanced student. Perhaps an A.Y.R.S. member would volunteer to make one for us for which I feel sure the Society would be pleased to meet his expenses.

Dear Sir,

Having learned that a towing test at a commercial tank would cost a minimum of $1,000, after the models were made, I picked



up a used 200 lb. spring balance with which to run some full scale towing tests on my *Jet* dingy. The chart shows that the resistance increased from 10 lbs. at about 4 m.p.h. to 82 lbs. at 10 m.p.h. and reduced to 72 lbs. at 12 m.p.h., when the boat began to plane.

The crew of two had three positions to assume for pitch control and, during the test, they were shifted to find the position of least drag. The most favourable position of the crew reduced the tension as much as 20 lbs. at the higher speeds. Until this test, I had no idea of the resistance of these hulls or the effect of pitch control at the different speeds.

More of this type of testing should be done to determine the effect of skin friction. I intend to tow another *Jet* with a smooth polished bottom which was not true of the boat used in the tests above. A comparison with a *Flying Dutchman* hull would also be interesting.

The Sail Pressures Developed. The *Jet* has 100 sq. ft. of sail area. We can therefore from the above figure estimate roughly the pressures developed on each square foot of sail area, which I have never found in any book.

Boat's Speed.	Forward pressure per sq. ft. of sail.
4 m.p.h.	1/10th lb.
10 m.p.h.	8/10th lb.
12 m.p.h.	7/10th lb.

These full scale towing tests were subject to some variables which alter the results:

1. The wake of the towing craft 150 feet astern will create an unnatural horizontal force on the hull, plus or minus.
2. The point of attachment of the towing line will not simulate the normal point of the resultant drive from the aerodynamic forces of the sail.
3. The effect of heeling on hydrodynamic drag was not investigated.
4. The hydrodynamic drag should be related to the velocity of the boat and not the R.P.M. of a propellor towing the test unit.
5. An investigation of propellor slip on the towing craft indicated a variation of from 35% to 50% slip when the cruiser was under free way with no tow. A 115 h.p. engine with 2 : 1 reduction gear was turning a 19 inch diameter by 16 inch pitch propellor. Top speed at 3200 R.P.M. motor speed gave 17 miles per hour. The least slip occurred at 1500 R.P.M. when 7.75 M.P.H. was obtained. The tow would, of course, increase the propellor slip.

Regardless of the obvious imperfections of such a slip towing test, it appears that much can be learned from the results

Bruce M. Larrabee.
144 Adelaide Place, Lakewood, New Jersey, U.S.A.

Dear Sir,

Here are two more photographs of my comparative sail test stand. We use it flat calm conditions and the boat speed gives us the wind speed on the sail and we measure the resultant sail force in strength and direction.

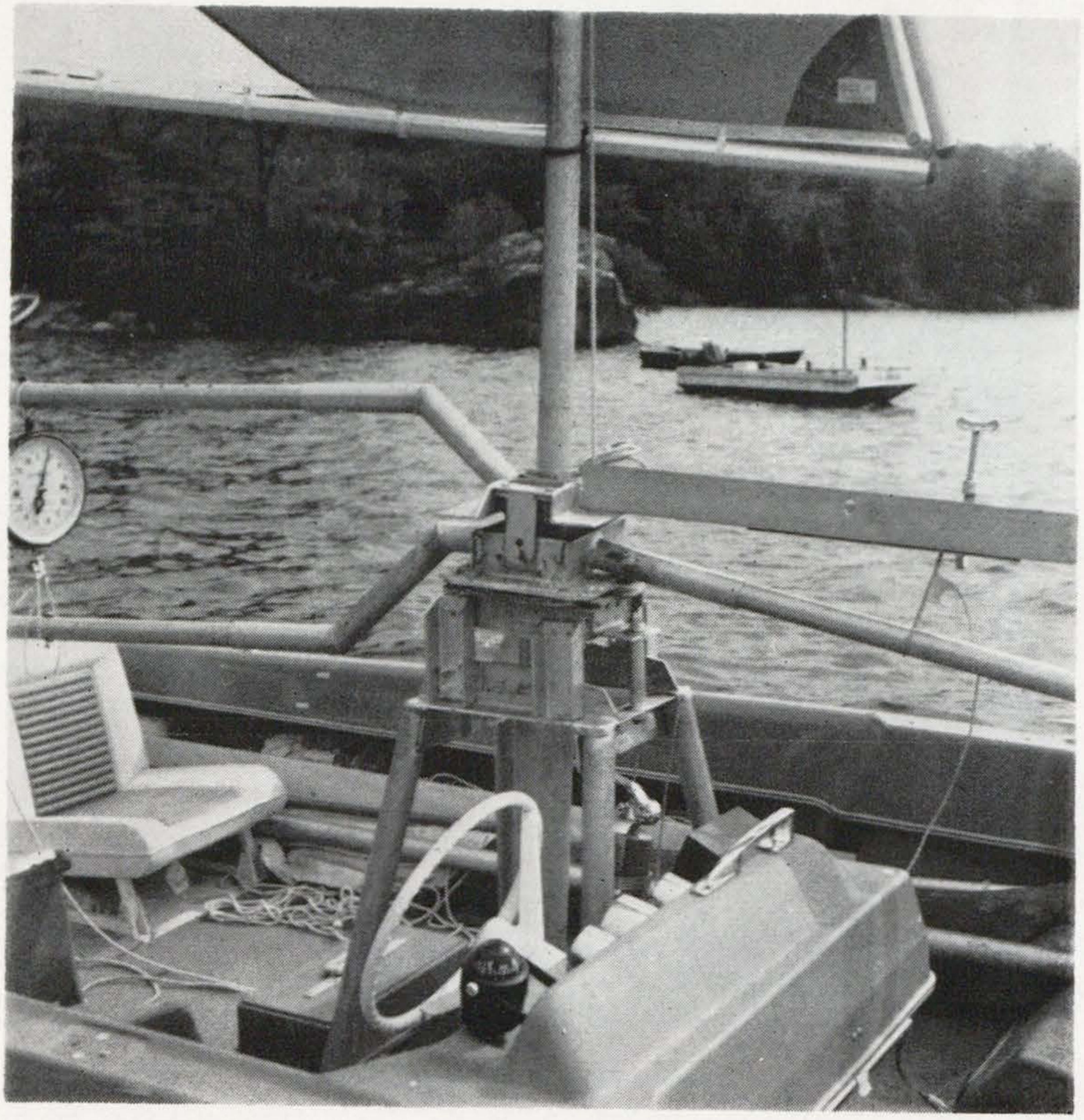
The calm conditions which are necessary for satisfactory testing

only exist, except rarely, from six to eight o'clock in the morning. I like to have sailors test their own sails; so far only a few have been able to get to the Lake which is nine miles from my home at such early hours.

We are only making comparative tests of *Sunfish* sails. The sails vary to some extent though they are all made by Ratsey. We can show that higher readings of the spring scale are obtained with loose outhauls, and with the halyard attached to the yard at $7\frac{1}{2}$ feet from the tack, making a better aspect ratio.

I find it difficult to balance the mast and sail about the pivot point, so each time the testings have different readings on the spring scale than tests of another day. Consquently, it is foolish to quote any figures. One day, we think we have found some fact; then the next day it is disproven.

I attended the A.Y.R.S. meeting at Marblehead and found it



very worth-while. Edmond Bruce is a treat to see and hear. His combination of wind speed and boat speed seems like a constructive invention. Mr. Bruce says that he found it necessary to weight his anemometer because it registered too fast. In my tests, the sail has seemed to respond ahead of the anemometer. Of course, I don't have the mass of boat to content with, and am only measuring air speed.

Since the meeting, I have been reading the Publications and, on Pages 4 to 6 of No. 41 you deal with the writing of articles so that we can understand them. At Marblehead, I was talked down when I said that some articles in the publications used too much maths. For instance, when reading Mr. Bruce's article on Optimum Area of Centreboards, it was difficult for me to understand the Optimum from the figure on Page 14, useful in determining the sq. ft. both other sized hulls. These scientists unfortunately write for other scientists and not for the less fortunate ones.

HOWARD P. HART.

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