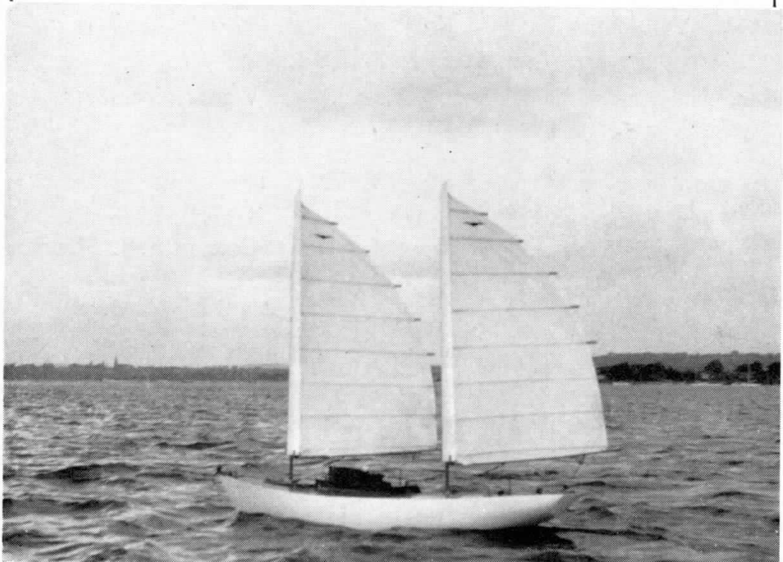
AMATEUR RESEARCH

A.Y.R.S. PUBLICATION No. 12



Col. C. E. Bowden's Radio Controlled Model

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THE AMATEUR YACHT RESEARCH SOCIETY

Objectives :

1. To encourage the design and construction of all kinds of craft whether propelled by wind, power or human agency.

2. To improve and promote the invention of any kind of yachting equipment or accessory.

3. To build up a pool of technical information on Marine subjects available to members on request.

EDITORIAL

Lord Brabazon of Tara, the British A.Y.R.S. President, is a man who has the faculty of intense application to things which interest him. He has made many flights in balloons. He has won many motor car races in the company of the British and French motor car pioneers such as the Hon. C. S. Rolls. He made and flew the first British aircraft. During the first World War, he developed the aerial camera. He played golf at a scratch handicap and won the Curzon cup with his toboggan on the Cresta run no less than three times.

In sailing, his class was the Bembridge Redwings whose 200 square feet of sail area can be put in any rig the owner fancies. Lord Brabazon tried out (1) an aerofoil sail, (2) a bipod mast rig, (3) a gaff rig with vang, (4) the Ljungstrom rig and (5) an autogyro rotor and took moving pictures of all of them sailing. He made his own wind tunnel and tested sails of many shapes in it to find which was the best.

As Col. J. T. C. Moore-Brabazon, he made his career in the House of Commons. He first worked with the Minister of Transport and finally ended up as Minister of Aircraft Production during the last war, after which he went to the House of Lords. The man of mechanical aptitudes can seldom compete in Parliament with those who worship the written or spoken word. However, Lord Brabazon's practical knowledge is combined with enough ability to express his views to have been a good influence on legislators adept at ancient or modern verbiage.

I feel that the characteristics of most of the people who are interested in yacht research are similar to those of our British President and that we could not have a man better suited to our Society.

Charles Satterthwaite has kindly taken over the job of New Zealand Secretary of the A.Y.R.S. John Mallitte, the Editor of the excellent New Zealand yachting magazine *Sea Spray* is very keen on the idea of a New Zealand A.Y.R.S. and tells me that many yachtsmen there build quite large cruising yachts. We wish them every success. Charles' new address is : M.O.W. Hydro Design, Museum Street, Wellington and not as given in publication 10.

LATEEN RIG CORRESPONDENT. C. Baty, P.O. Box 236, Zanzibar, East Africa has been appointed correspondent in this most interesting field. He lives in a district where the lateen rig is in common use and the Arab Dhows make the Monsoon voyages annually. He is willing to give anyone details of the Arab lateen in all its forms but tells me that he needs more information about the Mediterranean and Oceanic lateens.

The A.Y.R.S. needs more members to make it a really firmly established organisation. We now have just over 300 members in Britain but we must have 500 to cover all the printing and publishing costs with a subscription of 15/- a year. If every member will talk about us to his friends or at his yacht club, we could get these few extra members quite easily. A leaflet is enclosed with this copy to pass on to someone else or leave at your yacht club.

This publication is on the subject of AMATEUR RESEARCH. In it, the reader will find various ways in which he can increase his own knowledge of sails and hulls with simple apparatus which he can afford. Full accuracy will, however, need more expensive equipment and the A.Y.R.S. hopes that, in time, it will be able to provide this for the use of its members. In the meantime, if only one A.Y.R.S. member in every ten were to carry out even one of the experiments in this publication once a year, our knowledge of yachting would make tremendous strides forward.

Each piece of apparatus described here has been the subject of a great deal of thought and many of the plans have been seen by quite a number of experts to see if they can make any suggestions for improvement. All I can say is that they are the best we can now do. When they come to be made or used, however, several snags may appear and we will await the reports of the people who try them for the final suggestions and plans.

It may seem to many that we should not put out plans for research and describe apparatus which has not even been tried. It may seem that it would be better to keep to accounts of tried and proven mechanisms with just a few suggestions for future work as we have done up to now. But surely, if the A.Y.R.S. is going to be a forward-looking organisation, we must show the way to a *fundamental* study of hulls and sails with apparatus which we can afford. That is what this publication does.

It is unlikely that we have covered all the methods of yacht research suitable for the amateur here. If anyone knows of any other method, will he please send me an account of it. Naturally, an article would be preferred with drawings in Indian ink, but a letter will do.

THE AMERICAN ANNUAL GENERAL MEETING

The first A.G.M. of the American A.Y.R.S. was held on February 2nd, 1957 at the Lauraine Murphy Restaurant, Great Neck, Long Island. There were 37 people present, including the guest speaker, Mr. W. P. Carl.

The meeting opened at 8 p.m. and Bob Harris gave an account of how the Society was formed and what were the basic aims of the British group. He also read the Constitution which was adopted at the British A.G.M. to let the members present decide how much the American work should run parallel or complementary to what was being done in Britain. As both groups will be having the same publications, in which the results of all the A.Y.R.S. work will be published, members everywhere will have the benefit of any work done by either party.

A telegram then arrived at the restaurant from England, bringing the best wishes of the British A.Y.R.S. for a successful meeting.

William P. Carl, the President of Dynamic Developments, Inc., was then introduced to the meeting and gave a talk on the history and uses of hydrofoils. Afterwards, he showed most interesting motion pictures of some hydrofoil boats which had been made in the U.S.A. Among them was a film on the principle by which a hydrofoil works and it was most excellent. Following the films, Mr. Carl indicated that he would be glad to prepare a further paper on hydrofoils for the Society to be given at a later date.

A film taken by Victor Tchetchet was then shown which he had taken of the three craft *Flamingo*, *Egg Nog* and *Ocelot* at the races in Glen Cove, last Summer. The first two of these are the Trimarans and *Ocelot* is the catamaran described in *American Catamarans*. This film was quite short but it created great interest and illustrated the speed of the craft very well.

Walter Bloemhard was the next speaker. He raised a subject for research of immediate need, and suggested that a paper should be prepared by the Society on the strength of small craft ; their hulls, fittings, rigging, etc. He cited the example of several of our craft being kept from more racing due to nasty mechanical failures. Bill Mehaffey of Oak Park, Illinois, offered to assist in such a project. The first American research project will therefore be to look into several aspects of small boat strength which will help the amateur when it comes to installing a chain plate, a centreboard box, designing a mast or boom, the loads involved and how to estimate them. This will not include scantlings but it is more or less how to arrive at them. Naturally, the language will be kept right within the grasp of the amateur and the calculations will be as simple as possible. This treatise will, of course, pertain to all small boats, including catamarans and Trimarans.

Bob Harris then took up the terribly difficult question of the relationship of the professional to the Society. This was a matter which had been discussed by letter between the American and British groups without any definite conclusion being reached. It is, however, felt that the A.Y.R.S. must have ready access to knowledge which can often best be got from people who are professionally engaged in some branch of yachting. We therefore need to have such people with us. Research, too, of the kind which we are likely to undertake is unlikely to be of financial value to the professional yachtsman. As a result of these two factors, it is felt by both Bob Harris and John Morwood that people who are professionally engaged in yachting should not be debarred from membership of the A.Y.R.S. It is felt that, if a person engages in research from which he is not likely to gain anything financially, he is an amateur as far as our Society is concerned. For example, if a professional boatbuilder were to join with us as a member and help to develop some new type of craft on the same footing as other members and did not expect to have any exclusive rights in the product afterwards, surely he would be working for the good of yachting as a whole and not for his personal financial gain. He would thus be an amateur. Supposing also, that one of our members whom we are trying to make into yacht designers designs a really good boat for which someone offers him royalties and he accepts, are we to deprive ourselves of his services to the Society in all other matters ?

The Constitution and Bye-laws which had been so carefully prepared by Walter Bloemhard were then given out and all present were instructed to send in their comments on them by post and provide suggestions for their improvement.

The following officers were then elected :

President : Walter Bloemhard, 8, Hicks Lane, Great Neck, N.Y.
Vice-President : John L. Kerby, 14, Dimitri Place, Larchmont, N.Y.
Secretary-Treasurer : Robert B. Harris, 9, Floyd Place, Great Neck, N.Y.

The meeting then broke up.

THE LONDON BOAT SHOW

The photograph shows the general layout of the A.Y.R.S. Stand. In the front is a small ' Blower ' wind tunnel. An electric fan behind the honeycomb ' Air straightener ' blows wind onto the model yacht in the basin. This yacht is attached to the wooden plate resting on the side of the basin by two strings which are parallel to each other

and show the direction in which the sail force acts. For the " Triang " 16 inch model we used, this angle was 20° before the beam for a wind blowing 45° from the bow. The " Aft-dipping " lugsail of publication 9 gave an angle of $22\frac{1}{2}$° and the squaresail at the extreme left of the picture gave an angle of 25° before the beam. We reckoned, too, that the squaresail produced a greater sail force.

On top of the honeycomb are two models, most beautifully made by Mrs. Evans. The one on the left is a Polynesian type and the one on the right is an Indonesian one. Both are based on a *Shearwater III* main hull with planing floats of hard chine construction.

On the right of the picture is a model of a *Shearwater III* catamaran, lent by the Prout brothers.

Just to the left of the flash on the sail is a chine catamaran model with a furlable and reefable aerofoil sail made by Tom Lancashire. This sail has a variable shape for each tack and could be very useful.

Next come two Micronesian catamarans. The one below was made by Sandy Watson to the design shown in No. 7 publication, *Catamaran Construction.* That above it is a model of the canoe which Sandy and I made and sailed in 1955.

Next comes one of the Triang hulls with a " Mill " self steering gear made by Owen Dumpleton which demonstrated the possibilities of this type most beautifully. When blown on one side, the rudder turned one way and when blown on the other side, the rudder turned the other way.

The mechanism on the floor with the wheel is the " Owen Electric Helmsman " developed by Owen Dumpleton. It consists of the three units shown, the " Motor " unit which turns the wheel, the " Compass " unit which controls the motor unit from a magnetic compass and a " Handset " which is on the wall. On the stand, the mechanism was mounted on three wheels and would turn to any compass course set and stay there, " hunting " every now and then till a new course was set. The " Handset " could be taken from the wall and used to steer the mechanism by two push buttons, one for port and one for starboard.

Behind the " Helmsman " can just be seen the mast of the model of Bill O'Brien's catamaran *Jumpahead.* We hope to have a fuller description of this craft soon.

At the back of the stand is a model of the " Kite rig " made by Mrs. Evans. It is shown close hauled on the starboard tack. The hull can clearly be seen coming towards us. The string of the kite acts forwards of the beam but *Aft* of a right angle to the wind's direction.

Below and to the left of the kite rig is Captain Manners' " Catamanner," a chine catamaran of the " Split-boat " type with the flat sides outwards.

On the left at the back are the " Double Lugsail " and the Aft-dipping " lugsail made by David Snare. These are described in No. 9 *Sails and Aerofoils.*

At the front on the left are the semi-elliptical squaresail which had the good figures in the wind tunnel and the " Mast Aft " rig, both made by David Snare. Above them is a towing model of a hydrofoil craft with triangular-shaped sliding foils forward and a T foil aft.

Finally, there is our *piece de resistance*, a shallow, water filled tank with a very small model of the hydrofoil craft, just described. The model was towed down the tank by a string running over a pulley with a weight at the end. The model jumped clear of the water and ran most convincingly on its foils. I am holding it in my hand, ready to let it go.

Our thanks are due to Mrs. Evans, David Snare, Owen Dumpleton, the Prout brothers, Sandy Watson, Captain Manners and Roger Moore for making the models and to Reg Briggs for making the Wind Tunnel and " Test tank."

The International Model Aircraft Company presented us with the ten 16-inch Penguin hulls on which we showed the experimental rigs and used in the wind tunnel. The Honeycomb was given to us by Dufaylite Developments, Ltd., Boreham Wood, Herts and Messrs. Smiths kindly presented us with one of their 30-knot speedometers.

The stand was manned by Mrs. Morwood, Captain Manners, Dr. Davies, Owen Dumpleton and Tom Herbert. It was most kind of all these people to help with the good work. I have had several appreciative letters about the help which people had received.

In all, I think that we showed the yachting public the nature of catamarans, outrigged craft, hydrofoils, experimental sails and the need for yachting research. The thing I myself learned from them in return was that there is a very definite interest in twin keels for conventional keel boats, such as have been developed by the Hon. R. A. Balfour and have been used in *Buttercup*. This interest was so great that it would appear that people are even prepared to sacrifice some speed for the greater convenience of twin keels, if that is necessary. My own feeling, however, is that twin keels fitted to a suitable design of boat, may actually be faster than a single central keel, but I may be wrong.

Our stand also allowed us to meet the Editors of the Yachting magazines who have helped us so much, the yacht designers and builders and the members of the yachting trades. During the whole Boat Show, we were constantly meeting people who can help us and most of them have offered to do so wholeheartedly because they feel that we have some useful purpose to serve for the advancement of yachting. This alone has convinced all of us who were on the stand that we can, and must, do everything we can to bring the sailing boat to the utmost peak of its efficiency in all its forms and to find out all the details of handling and managing yachts so that the yachting public will get the best of healthy recreation from them.

SAIL RESEARCH

The following are the main ways of carrying out sail research :

1. A given rig can be studied to see what settings of the sails will give the greatest forward thrust on the boat on each course from the wind and in each wind speed. For example, a normal sloop rig can be sailed with a speedometer and the effect on the speed noted of altering the angle of the boom from the midline. A similar result can be got by placing dynamometers in the stays (a dynamometer is a strain gauge like a spring balance but with very little " give " when the tension increases). Other things which can be studied in this way are the leads of the fore and main sheets, the tension in the forestay, the use of the leech line, the mast rake, etc.

2. A given rig can be studied to find out how the wind flows across it. The presence of eddies behind the mast and the wind flows around the edges of the sails can be noted so that the yachtsman can have a better appreciation of the way the wind produces a force from his sails. This kind of study will increase the sailing skill of the person doing the test and help him to win races. The way the wind alters in its speed around the sails is of importance here.

3. A given rig can be studied to find out its effect on the wind at some distance away from it in all directions and how it causes the direction and speed of the wind to alter.

4. A given rig can be studied by mooring the boat on which it is set to fixed objects by spring balances. If there is no current in the water, the strains in the spring balances, combined with wind speed measurements, will allow " Co-efficients " to be calculated for all courses from the wind. (A co-efficient is the force per unit wind speed, unit sail area and unit air density). The value of using co-efficients is that similar tests can be done with other wind speeds, sail areas and air densities and the same results should ordinarily appear.

These four methods of study are very useful to study the rig of a class boat, but, when it is wished to study a new sail or sail rig, other methods can be used.

5. One Design Class Method. The new sail rig can be fitted to a boat in a One-design class and sailed with other boats of the class for a whole season. When there is a comparable standard of helmsmanship, this method will give results which are not only accurate and reliable but will also be acceptable to yachtsmen. The Bembridge Redwings of the Isle of Wight have been a development class of this type for many years. The hulls are standard and 200 square feet of sail area are allowed which may be set in any way which the owner

fancies. In this class, many different rigs have been tried since it first came out. Unfortunately, there has not as yet been any account of the types and varieties and how they performed. At present, the rig used has crystalised into a very high aspect ratio Bermudian sloop rig with a jib which does not overlap the mainsail.

6. *Model Yachts.* In most Western countries there are well established classes of model yachts racing on ponds and reservoirs. They use a " Vane " self steering gear which keeps them on a constant course to the wind and the better ones have a standard of style and finish seldom seen in their full scale sisters. Their owners claim that they are twenty years ahead of full scale yachts in development and I can well believe this, such is their keenness and workmanship. Here again, is a method of research which anyone with a new idea could use. If he can win races against the present yachts, his idea is really good, believe me. Col. Bowden, when he was developing his wingsail, made two identical model yachts which he steered by radio. He used a normal rig on one and his wingsail on the other and got comparative information from doing so. Fritz Rabe's experiment with a wingsail is described in *Sails and Aerofoils.*

7. *Wind Tunnels.* Where the difference between one sail and another is very slight, none of the previous methods will give us a certain answer because of the variations of the skill of helmsmen and the distortion in the shapes of sails with use. If we therefore want to know the final answer to such a subtle thing as where to put the position of greatest flow in a sail, whose effect cannot be measured by more than a hundred yards in a distance of several miles, we must turn to more accurate tests where every feature is under the most perfect control. This can be done by using an artificial wind whose every particle can be measured and this will usually mean that a full sized yacht cannot be tested because of the expense. Such an apparatus is called a " Wind tunnel," though there need not actually be a tunnel. Wind tunnels may be large or small, the cost varying with the size. Small ones such as we had at the Boat Show are cheap and useful. The larger wind tunnels may be very expensive and are more accurate. Details of several kinds will be given later.

These, then, are the methods which have been or could be used to do research into sails. Doubtless other methods will be worked out and, if they are, I should be very glad to have accounts of them to put in future publications.

All the free sailing tests of yachts such as sailing with speedometers or dynamometers and trying new sails either on full sized or model yachts need very little elaboration in this publication. Only people with free access to scientific equipment and with engineering experience would ordinarily try out dynamometers in their stays. The other free sailing tests would not be a matter of serious concern to undertake and would give results of self evident value. We will be very happy to publish any results anyone may get, however.

The four other kinds of tests are very suitable for A.Y.R.S. members to carry out either on their own or with interested members from their yacht clubs. Three of these tests have been grouped together as "A Programme of Sail Study for Yachtsmen and Yacht Clubs." This is designed to appeal to yachtsmen who not only want to do a scientific study but who also want to improve their sailing skills and is written in a form suitable for presentation to an A.G.M. or Committee meeting. Wind tunnels are a different matter and are dealt with separately.

A PROGRAMME OF SAIL STUDY FOR YACHTSMEN AND YACHT CLUBS

prepared by

THE AMATEUR YACHT RESEARCH SOCIETY

The object of the study which is presented here is to show the yachtsman, in the most practical way, how and why the forces on his sails develop. It is hoped that, by knowing these things, he will improve his skills and be able to sail his boat better and faster.

The study suggested here is divided into three parts :

1. A study of the wind flowing over the sails and hull of the boat.
2. A study of the effect of the sailing boat on the speed and direction of the wind at some distance from the boat in all directions.
3. A study of the forces produced by the sails and their reduction to "Co-efficients."

To make these three studies anything like complete, each one of them would need to be carried out for all courses of the boat from the wind and for all reasonable angles of heel. The first two tests are done with a dinghy dug into a sandy beach. For the third test, the dinghy is put into an artificial pond sunk in the sand.

The cost is negligible in these tests, even for amateurs, except for two gauges to measure the wind speed called anemometers and two or three spring balances. The second anemometer is needed to keep track of variations in the natural wind speed while wind speeds close to the sails are being measured.

SAIL STUDY — PART ONE

Equipment needed. Bamboo poles, light cloth streamers, wind vanes, two anemometers, log book. Alternatively, many smoke producing jets and cameras.

1. A dinghy is dug into the sand of a beach at a measured angle to the direction of the wind and at a measured angle of heel. Ballast or a crew will be needed to keep it in position. The sails are then trimmed to the wind as accurately as possible.

2. A cloth streamer tied to the end of a bamboo pole is then run all over the sails to mark the direction of the wind flowing in all parts. Alternatively, a row of smoke streams could be released upwind of the sails and their course could be photographed. The wind direction will be recorded in both the vertical and horizontal planes and its nature of flow noted. The flow may be steady and even in some places. In others it may be eddying, indicating that the sail is " Stalled " there. All these points will be noted carefully in the log book of the study.

3. The peak and boom eddies, if they can be identified and the smaller eddies produced by the mast and those which occur at the edges of the sails will be recorded.

4. The " Wake " of the sails will be noted.

5. The wind flow around the hull of the boat will be recorded.

6. These tests can be repeated in the eddying parts of the wind flow with a balanced vane which will record the direction of eddying flow.

7. An anemometer is then held near the sail at all parts and the wind speeds recorded. Due to the variations of the true wind speed, a second anemometer is placed outside of the influence of the sails being examined, and every time a recording of the wind speed near the sails is taken a recording of the wind speed by the outside anemometer is also taken. Variations of the real wind speed can then be allowed for in the sail wind speed.

8. The angle of heel is then altered and all the tests are repeated.

9. When all the tests for all angles of heel on one course have been done, the boat is then set to a different direction and the same procedure is repeated.

10. Throughout the whole series of readings, a close watch must be kept on the direction of the true wind as well as its speed.

11. Accurate recording of all information taken is a necessity and all readings should be taken with the utmost care so that they are as reliable as possible.

Presentation of Results. To present the results of this part of the study, profile sail plans will be used for both sides of the sails and the nature of flow and wind direction at each part will be drawn on them. To show the deviation in a horizontal plane, sectional drawings of the rig at different levels will be used and the wind flows marked on them. Streamlines will be marked where they are known.

SAIL STUDY — PART TWO

Equipment needed. Smoke producing apparatus, wind vanes, tricycles, bamboo poles and streamers, a kite or " Met " balloon, cameras, anemometers and log book.

While the study of part one is taking place, other workers can be recording the wind flows in both direction and speed at some distance away from the boat on each course and for each angle of heel. To make this simpler, it might be worth while to draw a grid of lines on the sand with, say, 10 feet spacing between those of each direction. The lines of the grid would ordinarily be in line with and across the direction of the true wind flow.

There are four ways in which the wind directions can be studied :

1. Jets of smoke can be released upwind of the boat and their course noted. When this has been done, the jets could be moved and the procedure repeated.

2. Several wind vanes can be placed at different heights up a pole on a wheeled cart. The cart is then wheeled directly down one of the lines of the grid and the directions of the various wind vanes noted at intervals of, say, 10 feet.

3. A tricycle can have its front wheel (which must have no castor action) steered by a wind vane which can be altered in height. This can then be pushed along when it will follow the streamline at the level of the wind vane.

4. Cloth streamers can be tied to the ends of many poles stuck in the sand so that all the streamers are of the same height. An aerial photograph taken either from a kite or captive " Met " balloon flying over the boat will then show the directions of the streamers.

The deviation of the streamlines due to the presence of the boat may not be very great. The effect of the sails on the wind flow around the boat may be better shown by recording the variations in the wind speed. To do this, the anemometers can be placed in a cart of some sort and wheeled down the lines of the grid and the wind speed recorded at the points where the cross lines occur. As each reading is taken, a simultaneous reading of the wind speed outside of the influence of the yacht's sails must be taken to allow for variations in the true wind speed. These readings of the wind speeds are another way of finding out the streamlines of the wind flow because the streamlines will lie at right angles to the lines drawn through places of equal wind velocity.

In this study, the course of the " Wake " of the sails should be followed to extinction. As with part one, everything studied should be repeated for all courses of the boat and for all angles of heel.

Presentation of Results. The presentation of the wind flows in this part will be done almost entirely by drawing in the streamlines at the various heights where the wind flows have been studied. The sails will, of course, be shown as a section. It is not expected that any very great vertical deviation of the wind will occur but, should this appear, another series of tests might be necessary to examine it in more detail. These further tests could use wind vanes placed with their flats facing upwards and downwards to study the vertical deviation. Alternatively, smoke trails and photographs could be used. The results of such tests could be given by drawing in the streamlines of the vertical planes.

SAIL STUDY — PART THREE

Equipment needed. Hardboard to make an artificial pond, lengths of 4-inch by 2-inch deal, pulley blocks, two spring balances, one anemometer, a clinometer and log book.

A large circular artificial pond is made from the hardboard whose diameter is about two feet greater than the length of the dinghy being studied. Its depth should be several inches greater than the draft of the dinghy with the C.B. raised. The pond is made watertight, dug into the sand with about three inches of the rim above its surface and then is filled with water.

The dinghy is put into the pond and is attached by three lines to a framework of the 4″ by 2″ deal beams so that the side force of the sails can be measured by one spring balance and the thrust force by another. The anemometer, placed at some distance away from the the dinghy will take the wind speed.

When the dinghy and the framework to which it is attached have been put so that the boat is set to a measured angle from the wind, the thrust force, the side force and the wind speed are recorded

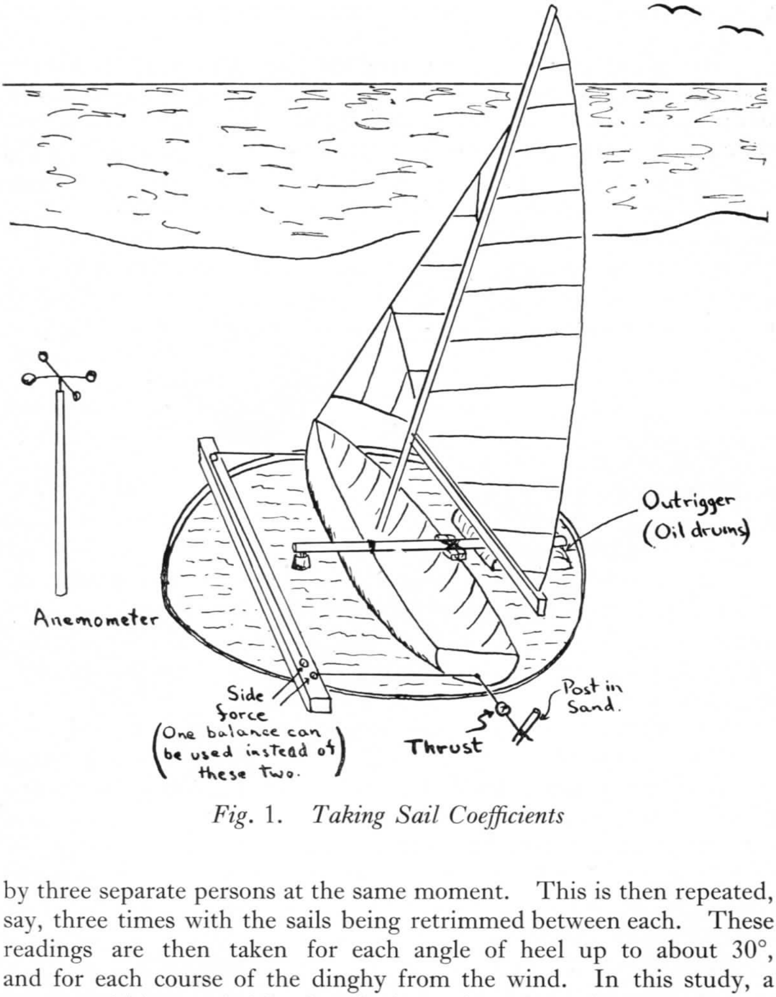

Fig. 1. *Taking Sail Coefficients*

by three separate persons at the same moment. This is then repeated, say, three times with the sails being retrimmed between each. These readings are then taken for each angle of heel up to about 30°, and for each course of the dinghy from the wind. In this study, a crew would be needed in the dinghy to keep it at the desired angle of heel which would be recorded by a clinometer which they could watch in a mirror.

Presentation of Results. To present the results of this series of tests, each value of the thrust and side force would be reduced to a " Co-efficient " by dividing it by $\frac{1}{2} A \rho v^2$. These coefficients would then be tabulated and graphed as a series of curves to the course of the boat from the wind. These curves would include the effect of the angle of heel on the coefficients.

A METHOD OF STUDYING PEAK AND BOOM EDDIES

One of our members has suggested the following method of studying peak and boom eddies. A tubular scaffold is erected like football posts, with two vertical poles at the sides and a pole across the top. A network of wires is then put in the figure to form a lot of small squares. At every point where the wires meet, lengths of white cotton thread are then tied on with a blob of cotton wool at the free end. Alternatively white knitting wool can be used. If this structure is then placed down wind of a boat with sails erected, a photograph of it from down wind will show the peak and boom eddies because the threads will corkscrew, whereas they will come straight at the camera elsewhere. Our member suggests taking about 12 photographs with the boat on different courses.

When this Programme of Sail Study was first written, it was sent to some of our members, who commented on it as follows :

Sir Geoffrey Taylor : The main difficulty is that the wind is never sufficiently steady in one speed or direction to make it possible to get a steady reading even at sea. You will have to examine your readings carefully after they have been made to ensure that the conditions were as steady as possible, i.e., the change of readings of each observer during the chosen interval must be small.

You might measure the shape of the sail by drawing horizontal black lines on the sail and then photographing the sail by a wide angle camera placed as low as possible in the boat and pointing up parallel to the heeled mast.

Incidentally, you would, I imagine, have two balances to measure the side force at each end rather than combining them in one, for the position of the " centre of effort " is as important as any other thing in the mechanics of sailing.

Professor H. B. Squire : 1. The natural wind fluctuates and it will be necessary to take readings during steady intervals of about 5 seconds. This is one of the main difficulties.

2. The hull probably upsets the air flow badly. Tests in Part I should also be made without the hull by carrying the mast in a hollow tube driven into the sand.

3. A few measurements of the variation of wind velocity with height should be made.

4. In Part III, the required angle of heel should be obtained by ballast and/or outriggers.

Dr. C. N. Davies : Simultaneous wind speed recording will only help as regards fluctuations in speed. Swing in direction will be a nuisance. Obstruction by the body of the observer on the cloth streamer on the end of the bamboo will change its direction somewhat.

Only under the meteorological state of inversion is turbulence negligible and the wind is usually light on such occasions.

I dislike the engineering basis of a hardboard bathtub to be sunk in the sand and made watertight. I prefer concrete.

Dr. Davies also suggested that it be made quite clear that what all these static tests were studying was the variations of the " Apparent wind," or the wind the boat actually sails in. Its speed and direction are different from the " Real wind " due to the forward speed of the boat.

Summary. From these comments and those of many other people, the main difficulty will be with wind fluctuations. If this is going to be troublesome, it seems a little ambitious to try to take the position of the centre of effort at the *first* trial by using two balances for the side force. Surging might cause trouble. Professor Squire's suggestion about outriggers to maintain the angle of heel seems to be well worth while and would be far better than using a living crew.

WIND TUNNELS

A " Wind Tunnel " consists of a motor driving a fan, thus producing a current of air which flows around the sails being tested. The fan may blow the air onto the sails as in our little model at the London Boat Show or it may be put on the other side of the sails and suck the air away after it has passed them. Apparently, it doesn't matter too much which method is used but the " suction " method gives a slightly smoother air flow, though this does not so fully represent the wind. In both types, there must be a honeycomb placed upwind of the sails to straighten the air flow. This straightening only removes oblique wind flows such as are made by the swirling blades of the fan. Large eddies such as one finds in the natural wind and which also occur as the result of the air coming off corners of furniture in the laboratory may pass through a honeycomb because they can be converted into variations in wind speed. They will not ordinarily cause much in the way of noticeable effects.

There are three main types of wind tunnel :

1. *The " Blower " type.* This is the kind we used at the Boat Show. It is shown diagrammatically in Fig. 2. All one needs is a fan, an electric motor and a honeycomb air straightener. Though

not elaborate, it can be very useful and its very simplicity makes it the most valuable for the amateur. Even in the smallest size, it can be made to give us some useful information. The tests we have done on our little wind tunnel, for example, gave results which are in accord with what Lord Brabazon found and are to be expected from a theoretical appreciation of the sails concerned.

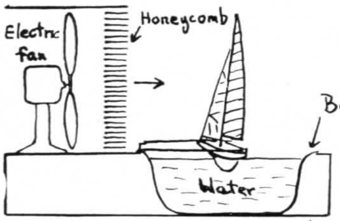

Fig. 2. A " Blower " tunnel

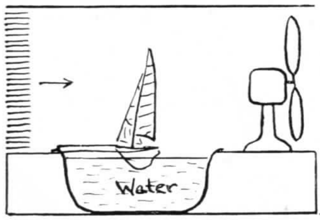

Fig. 3. A " Sucker " tunnel

2. *The " Sucker " type.* This type is shown in Fig. 3 and produces a smoother airflow than the " Blower " type. Again, a fan, an electric motor and an air straightener are used but a " Tunnel " is also needed to direct the air to the sails and fan. With this system, therefore, there is greater cost and space occupied. The size of model which can be put in a tunnel of this kind is only about three quarters of the height of the tunnel, whereas models of almost the full height of the air stream can be used in the " Blower " type. Though this tunnel system has these disadvantages, the smoother airflow which it produces may make it worth while, but against this smooth airflow is the fact that the rougher flow of the " Blower " type is more like the natural wind flow with its eddies and it is also likely to reduce the " Scale effect " and make the model behave as if it were a little bigger.

3. *The " Closed " type.* This is shown in Fig. 4. It uses the same air all the time by running it around in a circuit and is therefore more economical for high speed wind tunnels. However, because energy is constantly being added to the air, it would become hot if some cooling system were not to be included and this and the friction of the walls make it wasteful of energy and unsuitable for the low speeds we want for sail tests.

Construction. This would present few difficulties, especially if the " Blower " type were to be used. The sails to be tested could be mounted in a small dinghy in a concrete bath and hitched to three

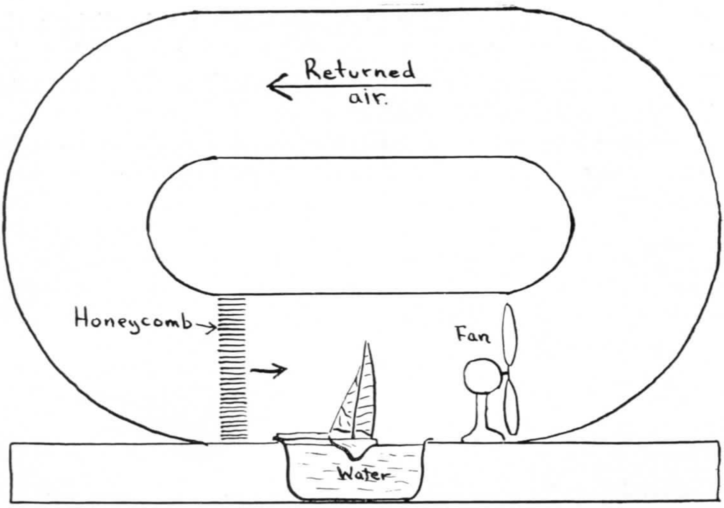

Fig. 4. A " Closed " wind tunnel

spring balances as in Fig. 5, or to one spring balance as in Fig. 6 The motor would have to have a range of speeds so that the " Scale effect " would be capable of being found from the results themselves. By increasing the wind speed, we could find out the effect of increasing the " Scale."

Cost. The cost of a wind tunnel depends largely on the strength and size of the wind flow required. The one we had at the Boat Show only cost a couple of pounds. For an A.Y.R.S. wind tunnel, we would really need a tunnel about 10 feet square and an 8 h.p.

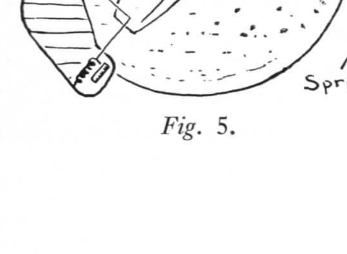

Fig. 5.

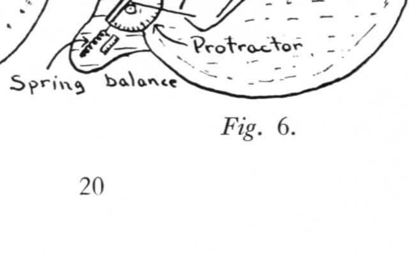

Fig. 6.

electric motor. Lord Brabazon's motor was $\frac{1}{2}$ h.p. and his models had masts in the region of 2 feet high. Sir Richard Fairy's tunnel was 17 feet high and he used a 10 h.p. motor. Both these tunnels were of the " Blower " type.

Instruments needed. To get the best out of a wind tunnel, certain things would be needed, though a very great deal of very useful knowledge could be got with the simplest equipment. For the ultimate in frills, Owen Dumpleton suggests the use of the following : Smoke puff dispensers, stroboscopic lights, really good photographic equipment, electric strain gauges, adequate pitot and static pressure probes with sensitive pressure gauges and, of course, a group of devoted and enthusiastic workers.

HULL RESEARCH

Hull research by methods which we could still apply has been used from the earliest times. Without question, the ancient Egyptians used some method of finding out which of two hulls had the lesser resistance and some method of doing this was almost certainly applied by every race which aspired to faster ships and used the common balance in the course of its everyday trade.

In our modern age, the custom of " weighing " two hulls in a current of water has gone out of fashion and the reason for this is hard to find. Perhaps it gives extra prestige to the Ancient Mariner to look at a hull and say, " Now there's a nice little hull but it won't be as fast as the hulls we had when I was a boy." Perhaps it is the result of Froude's finding that the resistance of hulls at low speeds is mostly due to wetted surface and designers can merely measure the wetted surface and predict the light wind performance with fair accuracy. Or, perhaps, it was the discovery that tank tests of a sailing yacht made with the model upright and making no leeway did not give the same result as the full sized yacht sailing close hauled. Suffice it to say that Nat Herreshoff, who probably designed more successful yachts than anyone else, did not hesitate to tow models of his yachts against each other in a pond and the more successful modern American yacht designers use tank tests freely. One might say that the impartiality of a test stimulates a designer to his best work.

Even in a one design class, some simple test can be of value. Think of the long hours of polishing which are put in to keep a dinghy at the peak of condition. Are they really necessary ? A ten minute towing test before and after the polish would give the answer. Similarly, it would be a simple matter to find out the best fore and aft trim for various speeds.

In the case of the Ocean Racers, however, I should think that a simple resistance test would be of the greatest interest. As most people know, races are won largely by the skill of the helmsman and crew in getting the utmost from the yacht. A fast hull in the hands of a person who is keener on enjoying the race than winning it, will not shine, whereas a slower hull with a perfectly tuned rig and a crew who will drive her, will often beat her. A resistance test would make the point quite clear as to where success should lie.

Perhaps it is merely human *not* to want to know that you have a faster hull than your more successful competitor, but I cannot help feeling that the rate of yacht development would increase greatly if every yacht were to be compared with the other yachts in its class. A case in point here is the twin keels such as have been developed by the Hon. R. A. Balfour or those used on *Buttercup*. We would all like to know if these are more or less efficient than a single keel. About an hour's towing with suitable apparatus would give us the answer.

Method of Hull Research. There are three main ways of hull research, all suitable either for full scale yachts or models.

1. A simple balance test.
2. A test with two lines, one taking head and the other taking the lateral resistance.
3. A test with two parallel lines.

The Balance Test. This test is the ancient one. Tow ropes from two boats placed in a tideway or river current are tied to the ends of a pole and the point of balance is found where the pole will remain at right angles to the current. The lengths of the two sides of the pole from the point of balance will give the relative resistances of the two boats. A more modern version of this, described by Bob Harris and others, is to use a motor boat and place a pole across its bows so that each of the boats under test is well clear of its wash. This system can only give the resistance of the two boats when they are not making leeway. Heel can, of course, be given to the boats under test but this is rather unrealistic in the absence of leeway because heel implies side force and side force implies leeway.

The Head and Lateral Resistance Test. It is necessary to test two yachts at one time with this method. Otherwise, the lateral force of one yacht would cause leeway in the motor boat. In this case, a pole is firmly fixed across the bows of the motor boat and there is a block at either end through which lines pass to take the head resistances of the yachts under test by spring balances on the motor boat.

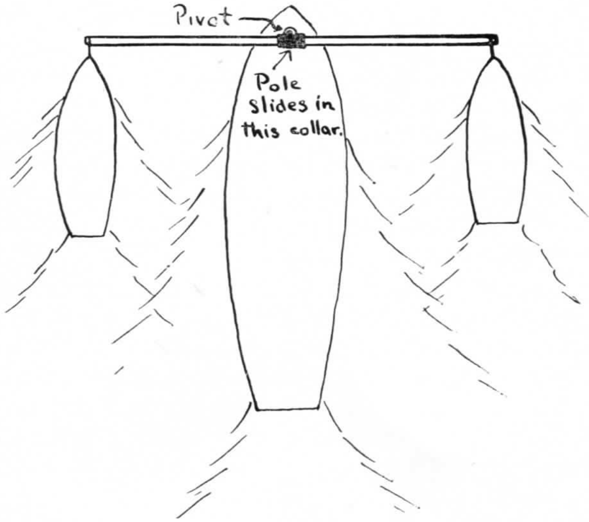

Fig. 7. "Weighing" two hulls' resistances

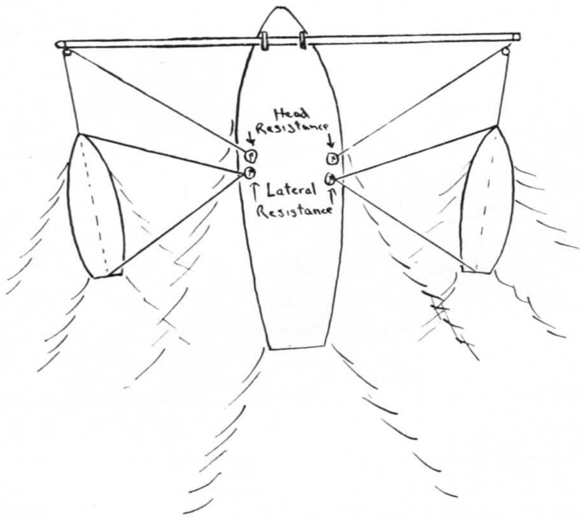

Fig. 8. Head and lateral resistance "Weighing"

To measure the lateral resistance of each yacht under test, lines of equal length are fastened to the bow and stern and are brought together to a spring balance on the motor boat. By adjustment of the three lines, the head and side resistances can be taken. The forward line must, of course, be accurately aligned with the fore and aft axis of the yacht. An angle of heel can be given to the yachts under test by ballast on the side deck.

With a model yacht, a similar system can be used but the angle of heel can be given by a third line from the mast head to the spring balance taking the side resistance. With a model, the forces on the hull can also be taken in a mill stream, a tidal flow or even between the bows of a catamaran.

The Parallel Line Test. At full scale, a motor boat would again tow two yachts, one on either side. Each yacht would be attached to it by two lines which are parallel to each other. On the motor boat, the lines would pass around blocks on beams placed at an angle to the fore and aft line and go aft to one or two spring balances on each side. These balances would give the head and lateral resistances

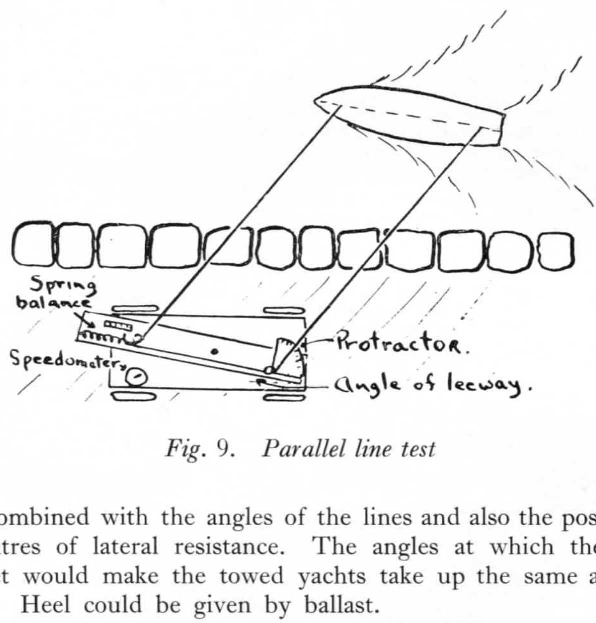

Fig. 9. *Parallel line test*

when combined with the angles of the lines and also the positions of the centres of lateral resistance. The angles at which the beams were set would make the towed yachts take up the same angles of leeway. Heel could be given by ballast.

For a model, the system shown in the drawing has much to recommend it. Here a trolley runs along the side of a pond and a bar on it is connected at either end to the bow and stern of the model. Heel can be given by having two lines at both the bow and stern connected to the top and bottom of short masts. Leeway is defined by the angle of the bar.

Harold P. Wiggins has sent me the following account of two test tanks which may be of value. I quote his letter.

" Some years ago, I knew a fellow who was keen on dinghy racing and used to like to build his own dinghys, and he certainly built several very successful ones.

" He made for himself a testing tank which looked like a glorified horse trough. It was made of wood, something like the attached sketch. At one end it had a sort of gallows from which was suspended a triple tackle made from some very nice pulleys, such as are used for the weights of old grandfather clocks, which he had picked up cheap in a junk shop. This, with various weights hung on it, gave him a very steady and easily adjustable motive power for towing his

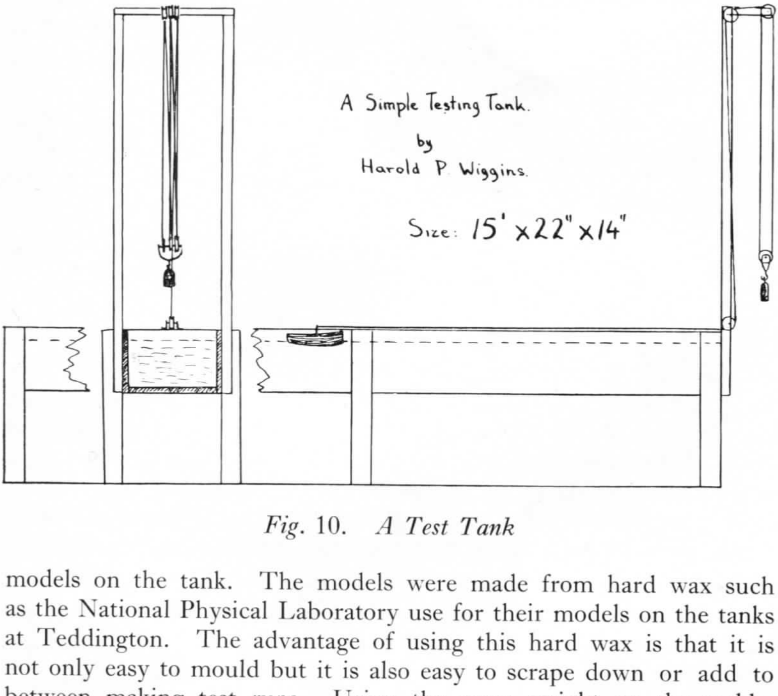

Fig. 10. *A Test Tank*

models on the tank. The models were made from hard wax such as the National Physical Laboratory use for their models on the tanks at Teddington. The advantage of using this hard wax is that it is not only easy to mould but it is also easy to scrape down or add to between making test runs. Using the same weight on the tackle, it is very easy to time with a stop watch consecutive runs of the model after slight alterations of the hull shape. When he had completed these tests to his satisfaction, he then took off the lines of the model, which was usually on the scale of 1 inch to 1 foot, to make a drawing for the actual dinghy he proposed building. The test must have been of value because his dinghys were certainly very good and fast.

" A perhaps rather more scientific elaboration of this idea was used by Alexander Hall & Co. of Aberdeen in 1839 when they were designing the first real clipper ship ever built, viz. the *Scottish Maid.* She was of ' markedly unusual and experimental type,' the result of prolonged tank tests that Halls carried out. (This is the earliest example I know of models being tank tested, although I think it probable that the French had done something similar in the eighteenth century because their warships in those days were so markedly superior in speed to any other country's, including Great Britain's).

" Halls evidently used a tank similar to my friend's but, I think, better in conception. The description of their tank is so interesting that I transcribe it here from the ' Mariner's Mirror ' Vol. XXIX, Page 74.

" ' The new model (of the *Scottish Maid*) was the result of painstaking study and exhausting experiments with models in a *glass* tank and of methods that were not only highly original for those days, but were extremely ingenious and effective. William (Hall) was anxious to observe closely the direction of water diverted by the bows and hull of the ship cleaving it and found means of attaining this by building a glass sided tank 10 feet long by 16 inches deep and 12 inches wide, and by filling this with water to a depth of about 10 inches and to a further depth of 1½ inches of transparent red-coloured spirits of turpentine.

" ' When the model was placed in the tank, the view seen through the sides of the tank was a red band of the lighter spirit extending 1½ inches down the hull of the model from the water line, and the clear water below it. A line attached to the mast of the model was carried forward to a drum on the edge of the tank and over it, a weight was attached. The same weight and drop being used with various models and shapes of hull allowed comparison of the results seen in the speed of the model and in the water movements, as well as the burying or lifting of the bows.

" ' Some of the most striking and valuable of the observations made were due to the clever device of covering the surface of the water with red spirits of turpentine. This showed clearly how, with certain lines of bow and hull, the fluid displaced at the stem was forced downwards under the forward pressure, although the spirit being lighter would naturally tend to remain on, or quickly return to the surface. With certain models, at least one-third of the red fluid was observed to escape the pressure by passing downwards and along the bilges, and then rise towards the quarters, spreading out at the same time in the wake.'

" From these experiments of Halls' " continued Mr. Wiggins, " one of the characteristics of the famous clipper ships was evolved, viz. the hollow water lines forward. These hollow water lines can be very clearly seen in the famous *Cutty Sark* now that she lies in dry dock at Greenwich."

It is quite obvious that these test tanks, described by Mr. Wiggins, were both very useful. However, it would seem that the modern dinghy or yacht designer would be better served by a test tank which

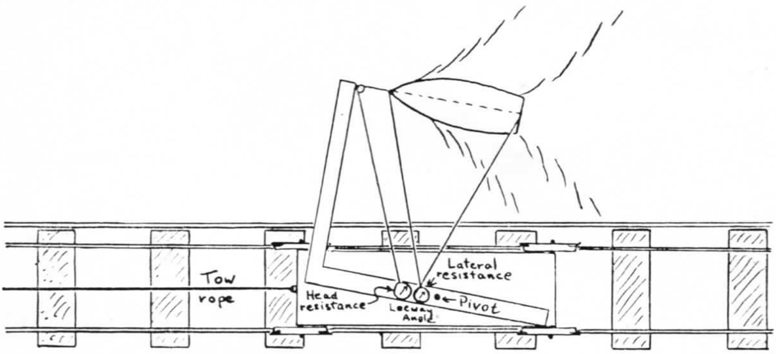

Fig. 11. *Taking head and lateral resistance in a Test Tank*

gave him some indication of the lateral resistance developed by a hull at various angles of heel and leeway. The modification to these tanks which could achieve this would be to have a trolley running along the side of the tank which was towed by the falling weight. The yacht hull could be attached to the trolley by one of the connections already described. Ideally, the tank should be four times as deep as the draught of the yacht and four times the width of its beam.

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