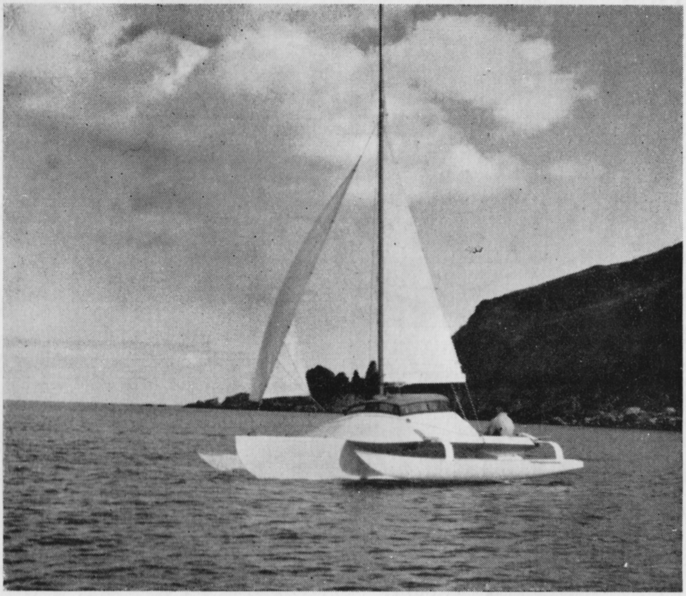
FLOATS, FOILS AND FLUID FLOWS

A.Y.R.S. PUBLICATION No. 36



David Rhys' Trimaran.

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PRICE $1.00. **PRICE 5/-.**

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(*Founded June*, 1955)

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EDITORIAL

July, 1961.

All the kind people who have sent in accounts of their craft and ideas have contributed to making this publication of outstanding merit.

The A.Y.R.S. has spread the knowledge of good catamarans all over the world and studied their design. Our members now show that they are leading the field of trimaran design. I like David Rhys craft, especially because it has a beauty not always found in the other craft and he uses an ingenious combination of foam and plywood for construction. A pretty trimaran must balance the shape of hull and floats and, if struts are used, they must be blended into the craft.

Two people (to my knowledge) sailed off the water on hydrofoils last year, William Prior and J. S. Taylor (in Australia). We have no drawings or photographs of Taylor's craft but we are pleased to have the descriptions of William Prior's two successful craft. We then show Erick Manners low aspect ratio foil craft and go on to study many ways in which foils may be used. It is hoped that members will now design and make good and efficient hydrofoil craft of all kinds.

Finally, in the years to come, the A.Y.R.S. will be concerned with wind tunnel and test tank research and we take pleasure in showing what R. J. Harrington Hudson can do with a small wind tunnel.

MEMBERS LETTERS. It would appear that, while the A.Y.R.S. publications are on the whole satisfactory, many people want more letters than have been recently given. When anyone has sent me a letter, giving some interesting idea, I usually try to get him to re-express it as an article. If this doesn't appear, interesting matter may be lost. Perhaps, therefore it would be best if people would send their letters as they want them to be published with a covering note to me personally. This would then ensure that their object in writing was clearly understood.

A TRIMARAN DAY BOAT

L.O.A.	20 ft.	Floats L.O.A.	16 ft.
Beam O.A.	11 ft. 9 ins.	Beam	11½ ins.
Hull beam	2 ft.	Weight	less than 2 cwt.

Designer, owner and builder : David Rhys, 17 Adare St., Bridgend, Glamorgan.

My first design was a trimaran which eventually settled down with a main hull about 14 ft. long and about 1 ft. 6 ins. waterline beam. The floats were about 7 ft. 6 ins. long. The overall beam was 10 ft. and the configuration was similar to Martin Ryle's *Avocet*. This boat was built in the hope of having something light enough to launch single-handed.

Performance. This was good in light winds but there was nothing like enough buoyancy in the floats and they would drive under in anything of a breeze causing solid water to hit the cross beams. These were well streamlined forward but even so, the resulting drag was enough to stop any further gain in speed.

I managed to hole the main hull at the end of the 1959 season. The floats also tended to leak so it seemed a good excuse to make a

The Rhys Trimaran

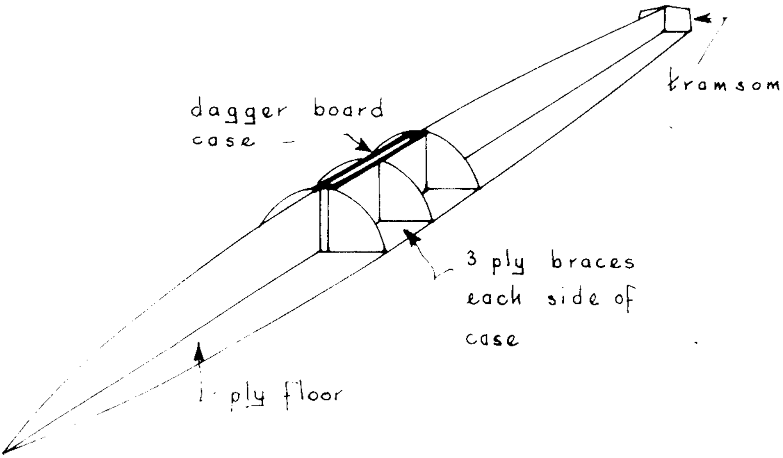
new boat. This time, I decided to build something in which I would at least have a fair chance of being able to persuade the rest of the family to come and sail. This meant that there would have to be some form of shelter from cold winds and spray.

I had already decided to try using Polyzote (expanded polystyrene) as advocated in some A.Y.R.S. publications, bringing it to 2 inches above the L.W.L., thus giving a floor level. The minimum sitting headroom was to be 4 ft. and with this dimension, I found that the minimum length which would give a nice streamlined form was 20ft.

From the A.Y.R.S. and my own experiments, it is obvious that the floats have to be as long as possible and with very fine entries and just enough depth to give the desired buoyancy and strength.

Having decided on Polyzote, it was obviously just as easy to build a rounded shape as a chined one and this was done largely by eye, giving the maximum beam at the transom in the hope of some dynamic planing lift. The previous boat with a very narrow stern had tended to dive its bows under and I hoped that a flat transom with the weight more aft would eliminate this. The flatter transom would give more manoeuverability and be more useful as a fishing platform.

Performance. This is very good indeed. The boat puts about even without the jib and my method of reefing is to take the jib off which only produces a little weather helm. With no centreboard, the weather helm is so strong that the craft is unmanageable.



Construction. The underwater part of the boat was built upside down and the first step was to make the whole waterline plane from plywood. Above this was fixed the dagger board box and the keelson of plywood. Three plywood bulkheads were then fixed to the C.B. box to give it rigidity as it was felt that the foam would not have the stiffness needed. This state is shown by the drawing. The Polyzote was then roughly cut to shape and attached to fill all the space below the plywood sheet and between the C.B. bulkheads.

The work was then turned right side up, the topsides and frames put on and it was then turned back so that the Polyzote could be shaped and covered with glass cloth and Epoxy resin (Leicester Lovell were most helpful). The remainder was quite straightforward, 4 mm. ply being used for most parts. This bends quite easily with the help of a few saw cuts to the streamlined shelter. (Mild form of " over-development ").

This method of construction calls for very little skill but lots of patience. I found that glueing the blocks of Polyzote together and also the process of skinning with glass cloth was most tedious.

The Hull Shape. So far as " Lines " are concerned, once having decided the W.L. shape and underwater profile, the mid-ships and transom sections, the rest of the shape follows by eye. Shaping the Polyzote with Surform tools was the easiest and most enjoyable part. Professional designers may be shocked at this approach but with a boat weighing only 200 lbs. odd, a very rough calculation of C.G. and C.B. will suffice. Crew weight and distribution are all important.

Lines and full drawings of the craft could be made but I feel that A.Y.R.S. members should want to improve on craft already built and not just build a copy.

I should like to make it clear that this design was entirely A.Y.R.S. inspired and I would like to offer my sincere thanks for the pleasure and guidance which the publications have given me. If any member should want to raise any points, I will of course be glad to do anything I can to help.

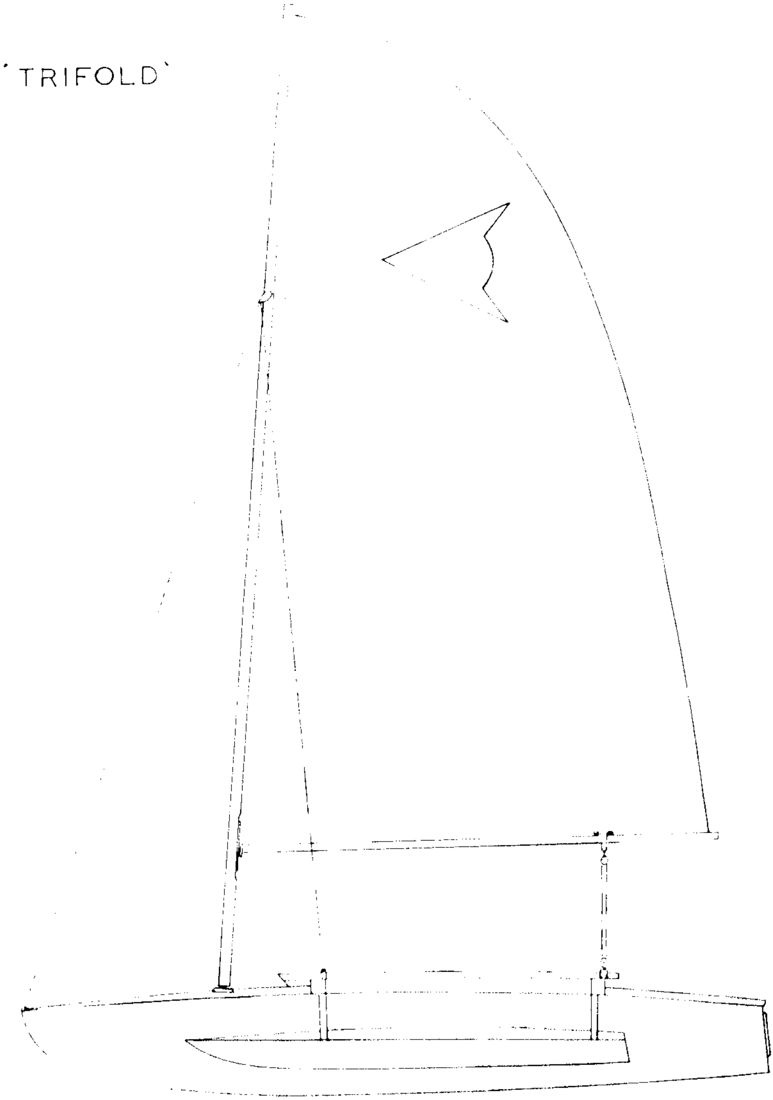
TRIFOLD

A day sailing Trimaran.

L.O.A.	15 ft.	Draught, ex C.B.	6 ins.
Beam O.A.	10 ft.	Sail Area	145 sq. ft.

Designer and builder : Erick J. Manners, A.M.B.I.M., 93 Ridgeway, Westcliff-on-Sea, Essex.

Most A.Y.R.S. members will know that Erick Manners has been designing and building both catamarans and outrigger boats for many years. His 18 ft. 6 ins. *Catamanner*, his 14 ft. *Sports* class and his 11 ft. *Car-Cat* are of superior design and are pretty boats as well.



We now have pleasure in showing three of his trimaran designs which are the summary of his experiments to date.

Trifold, the first of these, is what Erick (and I think most of us) consider the shortest efficient length for good performance in a trimaran when combating the short steep seas of open shoal water. Trimarans as short as 12 ft. can be made but they are so tubby to carry the weight that their performance is little better than single hulled craft of the same length.

Trifold has a nicely shaped main hull of semi-hard chine construction suitable for amateur building. The floats are of a deep V section with the stern lower than the bows. There is some " toe-in" and slope out to the float so that there is some dynamic lift — a feature which Erick has developed further in a craft shown later in this publication.

Several of these craft have been built. One owner assembles and dismantles his craft on the beach which is quickly done with the aid of wing nuts and trundles the components half a mile home on a little wheel push cart. Another young married couple, storing the craft only a short way away, similarly transport her, but in one piece. *Trifold* has been carried on an ordinary car top and also has been left on exposed moorings. Buoyancy bags under the fore and aft decks assure un-sinkability.

With all the comfort of full leg room in the deep central cockpit, she is a safe, easily handled boat and fast with her full rig. Some people, however, prefer to use a smaller rig of 100 sq. ft. for family sailing.

The complete boat can be built for less than £100, with light alloy mast and sails ready for sailing. Materials for the main hull, cross beams and floats cost about £30, including glue, fastenings, fittings and paint. A rotating mast and boom of light alloy and rigging cost about £38. Sails, using 145 sq. ft. cost about £38 (£30 for 100 sq. ft.).

Building plans of 20 sheets especially suitable for amateur construction cost £5 5s. 0d. with licence to build one boat only. Special arrangements can be made with the designer for quantity building.

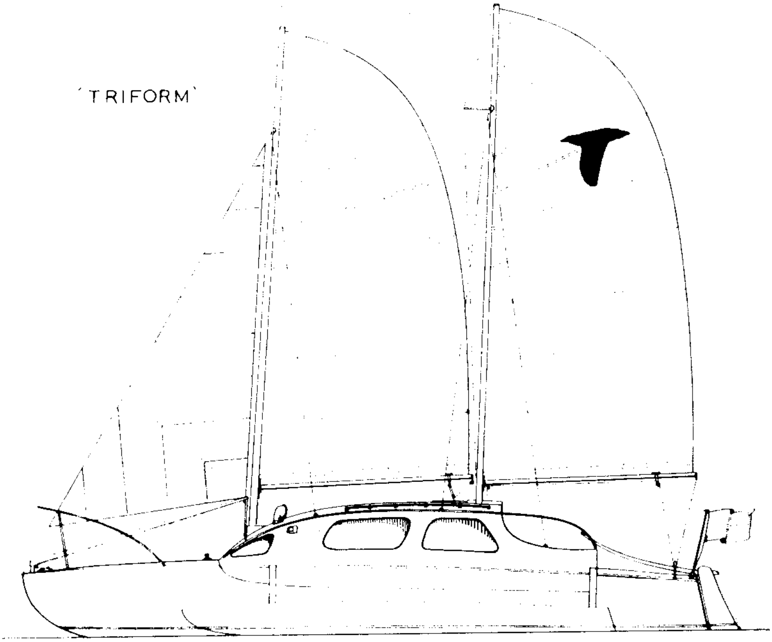
TRIFORM

A Cruising Trimaran.

L.O.A.	30 ft.	Maximum headroom	6 ft. 3 ins.
Beam O.A.	19 ft.	Draught	15 ins.
Hull beam	3 ft. 6 ins.	Sail Area (less Genoa)	330 sq. ft.
Cabin beam O.A.	11 ft. 6 ins.	Float L.O.A.	19 ft.
		Float buoyancy	2240 lbs.

Designer : Erick J. Manners, A.M.B.I.M., 93, Ridgeway, Westcliff-on-Sea, Essex.

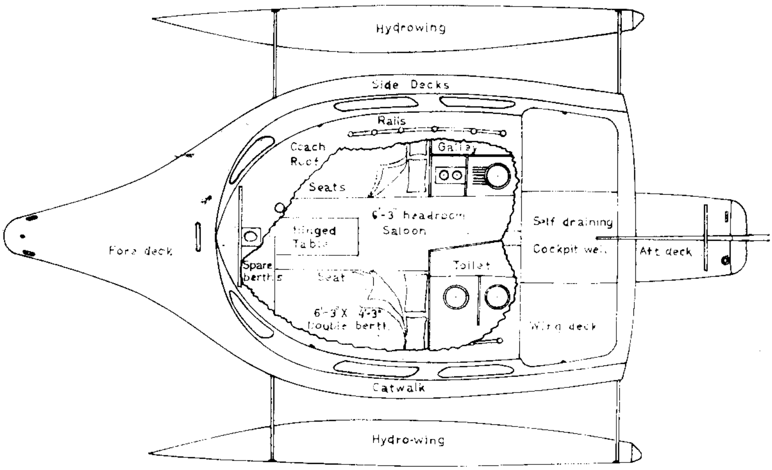
The general lines of this larger boat follow those of the smaller craft already described, except that the open cockpit is built out and decked over to form a comfortable cabin. The main hull is wide enough for two people to walk past each other and there is full headroom for a distance of 10 ft. in the cabin. The W.C. and ablutions are together in a separate compartment with full headroom and the advantage of "straight overboard" discharge, except for confined river use.



The Floats. These are asymmetrical buoyant floats which should develop considerable lateral resistance. Asymmetry in trimaran floats must be entirely satisfactory and better than symmetrical floats, though recent trimarans do not seem to have used it. The floats look small but the sail area is small and with the schooner rig, the centre of effort will be lower than with a sloop. Their buoyancy is greater than with *Gem* (A.Y.R.S. No. 34).

The Rig. A schooner rig is shown and this should be satisfactory and result in easier handling. It is usually simpler to lower the middle sail than to roll in a reef in a larger sail and the sail balance still is good. Erick Manners points out that a sloop rig would be more

'TRIFORM'



expensive and the mast would have to be stepped in the middle of the cabin. Actually stepping and unstepping the twin masts would only be a one man job, as compared to the need for several men with the single larger mast.

Accommodation. There is room for four adults. This compares with the 5 or 6 berths of Erick's *Black Cat* (described in A.Y.R.S. No. 35) which is more expensive to build. Building licence and plans for this cruising trimaran are supplied for £10 10s. 0d., as for the *Black Cat.*

CORMORANT

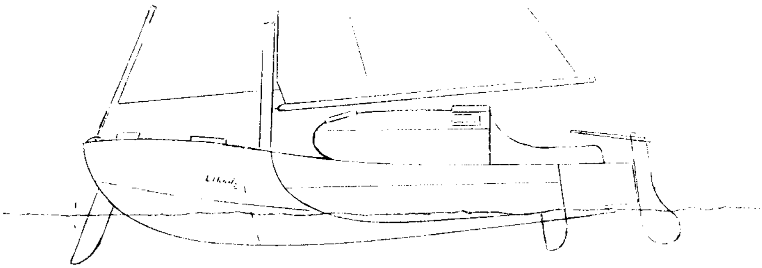
AN OCEAN TRIMARAN

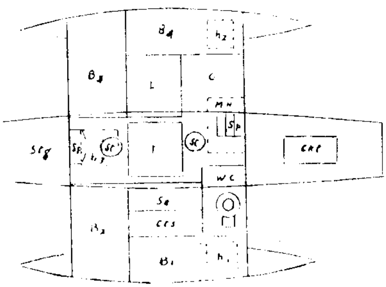
By T. C. Burnham, 4035, Malaga Avenue, Coconut Grove, Miami 33 Flo., U.S.A.

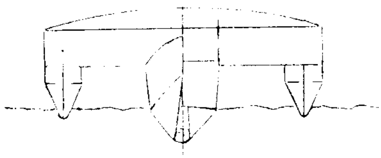
Length main hull	30 ft.	Length floats	16 ft.
Beam main hull	4 ft.	Beam, floats	2 ft.
Draught	18 in.	Displa. immersed	2100 lbs.
Beam overall	15 ft.	Sail	350 sq. ft.
Displacement	3200 lbs.		

Foreword. The urge to build a multi-hull must first have occurred when one of our distant ancestors discovered the disadvantages of crossing a river astride a single log, and started adding logs. Came the raft, then the two log canoe and finally the three log canoe. The sticks which held the logs together and apart kept increasing in size until now we have the modern catamaran with single " log " holding two " logs " apart, and the trimaran with two " logs " holding three " logs " apart. *Cormorant* is a trimaran with one log holding three logs apart, a system which owes something to the catamaran. The basic configuration can be pictured, thus :

By varying the relative lengths, their widths, shapes and displacements, a variation can be found in the response to wind and seas and loading to suit the kind of craft desired, be it racing, day-sailing, cruising or houseboating. It is not practicable to include everything in one design. For reasons of economy and utility, *Cormorant* is a 30 ft. design of moderate proportions, wherein some speed is sacrificed to seaworthiness and comfort.







If you sail for fun, and most of us do, you will find the open sea to be not much of a pleasure unless you have incorporated in your vessel a good measure of the comforts you are used to demanding ashore. This means that your craft must carry something of a load. But why not ? What is a vessel but a carrier ? For the speed merchant we visualise hulls moulded of featherweight cellular plastic resin carryings two desiccated midgets with shaved heads and wearing only jockey shorts made of 4 oz. nylon. For the seagoing vessel extremes should be avoided, and careful overall planning should prevail. *Cormorant* is designed for a crew of two or three of medium stature who wish to take a cruise of two or three weeks and return to plan further cruises.

Design. The main hull shape is mostly A.Y.R.S. (see Pub. No. 28) : fine forward for slicing through the waves, high in the bow to provide reserve buoyancy, rather beamy to promote livability, with a rather flat run to reduce squatting when downwinding. Overhang is moderate (see *Gemini* A.Y.R.S. No. 15, p. 34). Float design can also be found in A.Y.R.S., with modification. See A.Y.R.S. No. 18, fig. 11, p. 30, A.Y.R.S. No. 34, *Tilloo* and *Nimble.* The modifications are a high chine and the proposed 60° vee. Slap and transverse oscillation are thereby reduced (it is taboo to speak of roll in a multi-hull). Overall beam at 15 ft. the writer considers to be the maximum for a 30 ft. utilitarian vessel, since time spent on land or in harbour where great beam is a menace is better than 90 per cent. of its life.

The cross " log " holding the three hull " logs " in position becomes the cabin. Thus the area over the floats is available for berths and storage accessible from inside, while at the same time beam windage is reduced as compared to a hull with fore and aft cabin of equal volume. The reserve buoyancy in the beam ends of this athwartship cabin is a definite safety factor. The leading edge is fared upward to provide lift in the event a float should be driven under at speed. Good seamanship is the best insurance against capsize in any vessel, nevertheless the additional safeguard of extra buoyancy far out should reduce the risk of accident.

Construction. For the amateur builder of a vessel of this size, marine plywood with overall covering of fibreglass is still the preferred method : $\frac{3}{8}$ in. for the centre hull and $\frac{1}{4}$ in for the remainder, with double thickness of glass-resin below the waterline. Keel and chine could follow the pattern shown in A.Y.R.S. No. 18, p. 29 and 30 (Morwood). This pattern was used successfully on the floats of *Tilloo,* A.Y.R.S. No. 34, p. 36. (Other refs. : A.Y.R.S. No. 10, p. 5 and p. 21). Careful " beef-up " should be done at all places where higher stresses would be encountered, notably at hull to hull intersections and at skin junctions where there is a change in direction.

Accommodation. Overall length of cabin is 9 ft. 6 in. and overall beam 15 ft. There is full headroom in the centre hull and 3 ft. sitting headroom elsewhere. Cabin sole is 2 ft. 6 in. wide. The dining table, which stows in the locker, can accommodate four persons.

Wet clothes hang in the W.C. Additional access to berths 1 and 4 is by hatches 1 and 2 in deck above. Access forward is through hatch 3.

Sail Rig. A conventional Bermuda plan is preferred, with roller reefing jib and main. Steering is by tiller, with optional additional steering inside by pulley and cable from tiller to a wheel situated under forward hatch 3 and off centre. Halyards and roller reef can be reached from this hatch. Three boards are shown, all external, going into slots in bow of main hull and stern of floats. Balancing should be easy with this arrangement, and the extra lateral plane provided should improve the windward qualities. Furthermore, with the aft boards up and forward board down, the vessel would come head to wind and fall off only slightly as sails are lowered. When hove-to in heavy weather, rudder would be unshipped and light but strong sea anchor streamed with heavy dacron rope and link chain bow pennant for anti-chafe. The response of a multihull to this arrangement would be far better than is found in a conventional single hull vessel with keel. Boards should be made of high tensile light alloy.

Dismantling. Floats and main hull are attached to the cabin by removable bolts so that the craft may be taken apart for transportation overland to out-of-season storage. The largest component is the cabin hull ; large but not unmanageable. The first 8 ft. of the bow section unbolts at the bulkhead line (bulkhead to each section). Attachment would be made by means of bulkhead thru-bolts.

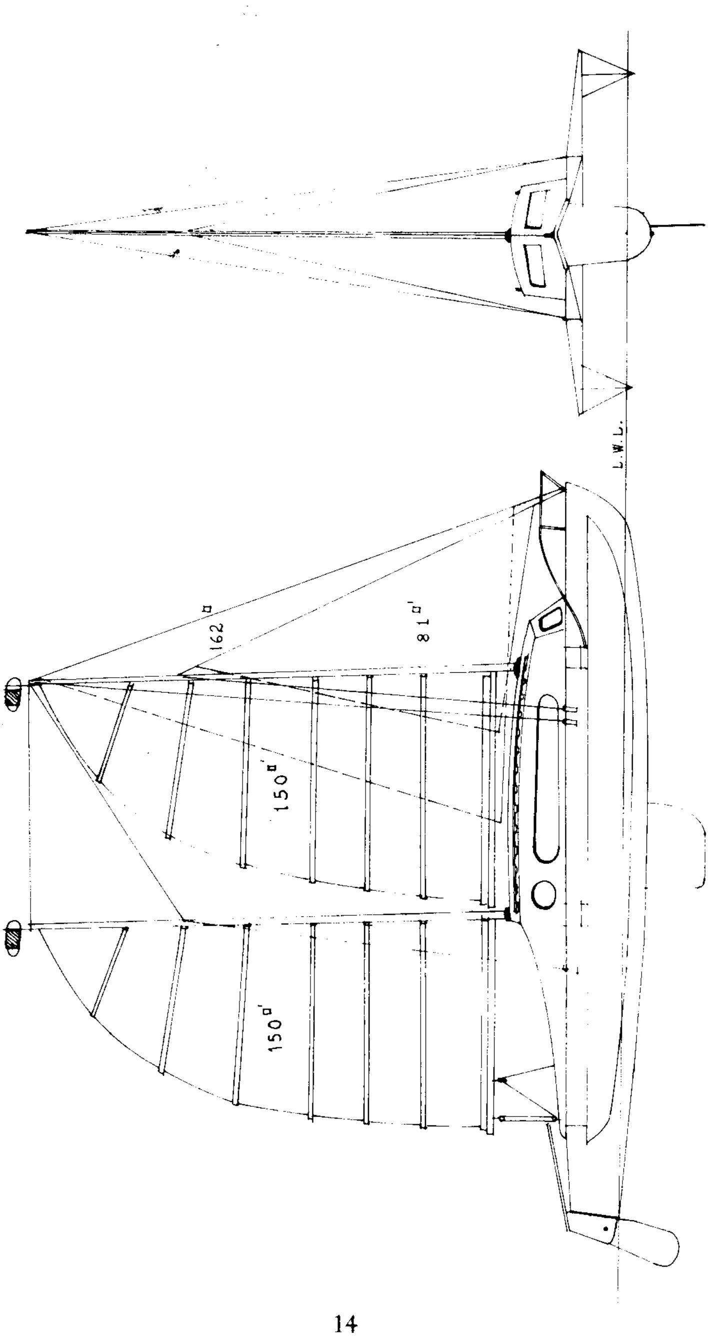
A CRUISING TRIMARAN DESIGN

L.O.A.	36 ft. 0 ins.	Float L.O.A.	30 ft. 0 ins.
Beam	18 ft. 0 ins.	,, beam	2 ft. 3 ins.
Main hull beam at gunwale	2 ft. 9 ins.	,, displ. approx.	2700 lbs.
Cabin beam	6 ft. 0 ins.	Weight	3000 lbs.
Cabin length	16 ft. 0 ins.	Sail area	381 sq. ft.
Headroom	6 ft. 0 ins.	Sail area with Genoa	611 sq. ft.

Designers : Prout Bros., The Point, Canvey Island, Essex.

This trimaran design by the Prout Brothers embodies all the lessons we have all learnt so painfully over the years and must be considered a good example of modern practice.

The main hull is a stock 36 ft. Prout hull and the floats have the deep V which experience has shown to be most useful, if not as fast in theory as the right angled V. In other respects, the craft is similar


L.W.L.
162
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150

to Dan Campau's *Gem*, which is described in *Ocean Trimarans*. One feels that the points of the floats forward are a little too fine for practicability when coming alongside a quay wall and these would have to be strongly reinforced or brought up more like the sterns.

Summary. A trimaran design is shown which should be cheaper and faster than a catamaran of comparable length. I feel that it will be a prettier boat than Dan Campau's *Gem*. It is to be hoped that many of these boats will be built.

TRIMARAN CONVERSION UNIT

By D. P. Welman,

Pierce Close, Prestbury, Cheshire.

In recent years I have been too far from the sea to make it worthwhile to keep a sea-going boat and I have had to make the best of what chances I could get with a 14 ft. dinghy. This has driven home the fact that even if you only want occasionally to race you must still sail a recognised class boat and this limits you to a design of comparatively low stability.

Single handed sailing at sea for 4 or 5 hours at a stretch can be too much like hard labour in a fresh breeze, and I have, this last winter, studied this problem with the object of combining, in one boat, Class racing requirements and stable conditions for day in day out holiday sailing almost irrespective of weather (short of a gale !). This brought me to design a Trimaran " Conversion " Unit for my G.P. 14 which I thought might be of interest to Members of the A.Y.R.S. Obviously, if speed is the main objective one would not start with a G.P. hull but since for other reasons the G.P. hull is a primary requirement, the problem is a little unusual.

The design requirement was to produce a completely detachable outrigger unit which would

(1) Permit single handed sailing with a standard dinghy rig under sea conditions in winds up to force 4 without " sitting out."

(2) Provide that the additional gear would (a) occupy no useful space in the boat, (b) not interfere in any way with the normal handling of the boat as used without such gear, (c) retain normal balance and tiller feel without alteration of any kind to standard mast, sails or other gear (intelligent use of centre plate excluded).

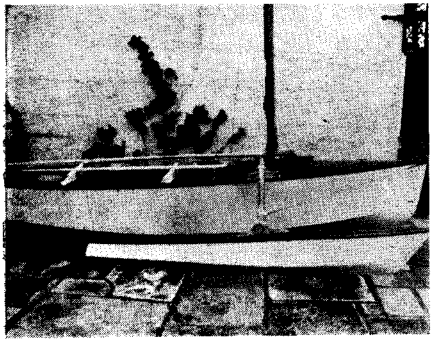
(3) Allow the outrigger gear to be readily and completely demountable in 10 minutes or less.

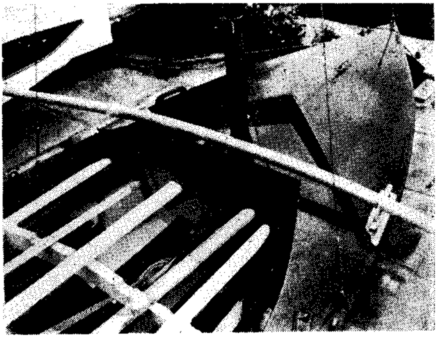
(4) Let all extra gear be carried readily in or on the main hull when trailing.

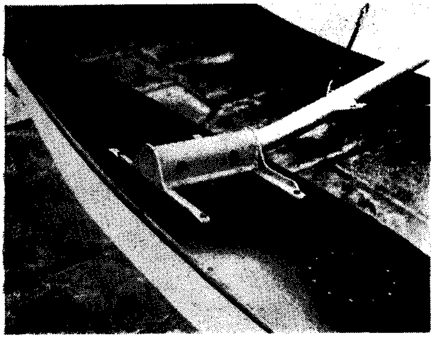
The first requirement ruled out any form of single outrigger and it was clear that the Trimaran was the only suitable form. The overall beam should preferably be no greater than the dinghy length and the floats must be of a width to fit each side of the centre plate casing for trailing and short enough to allow the standard boat cover to be used over all.

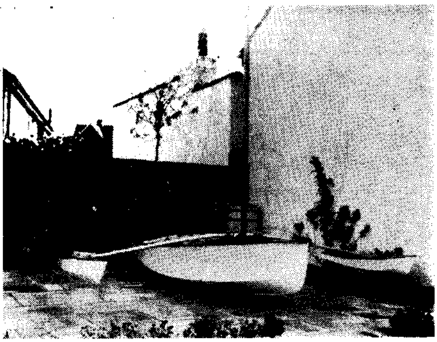
Floats — To meet these requirements the maximum beam could not exceed 14 ft. and the length (depending to some extent on the shape of the float) should not exceed 7 ft. 6 in., while the maximum draught would be limited to 10½ in. Here, of course, arose the only serious difficulty, since using these limits and correct proportion and underwater form gave too low a figure for buoyancy which was required to be 200 lbs. per float. Thus, the design shown in the photograph resulted which gives a buoyancy figure of 168 lbs. per float.

Beam — To comply with requirements 2 (a) and (b), only a single beam could be used. This was constructed from a Dural tube 2 in. in outside diameter with a ⅛ in. wall thickness, bent to a









natural curve and mounted on brackets placed immediately over the main frame of the dinghy which is just abaft the mast. The method of mounting is shown in the photograph. The ends of the beam were set up 5° to the horizontal for the usual reason and so positioned as to give the floats 5½ in. clearance from the surface of still water with the boat on an even keel.

Float Brackets - These are not of final design by any means but were run up to enable a test to be made with the floats in choppy sea conditions, the floats being allowed to pivot on the beam 7° bow up and 15° stern up.

Stays One stay (as shown) from each end of the beam to the hounds and one stay to the bow (a stay back to the midships gunwale has since been added so as to obtain full triangulation and added safety but tests did not show it to be necessary).

The whole rig is very simple and although designed for added sailing comfort and not for speed, I have been very surprised by its performance. The balance of the boat is very little affected as the whole rig only weighs just over 50 lbs. while her handling is completely unaffected. She goes about perfectly, and, even with the lee float intentionally driven under, shows no tendency to weather helm or to pull on the wind.

Over a week of sailing in very mixed weather I had no inclination or need to even sit up on the gunwale. I tried her in really unpleasant conditions with a short deep chop which is always uncomfortable in a hard chine dinghy and she behaved perfectly. The floats took quite a bit of punishment but " followed " the sea well as a result of their freedom to pivot in the vertical plane.

Close hauled and reaching she is a sheer joy to sail ; while running before a stiff breeze with both floats clear, I failed to get her to roll with the wind on either quarter. She is also quite noticeably faster close hauled and you can see no material wake from the lee float. It is clear therefore that increased drag is well outweighed by increased steadiness resulting from the firmer handling of the main sheet and better average heeling angle.

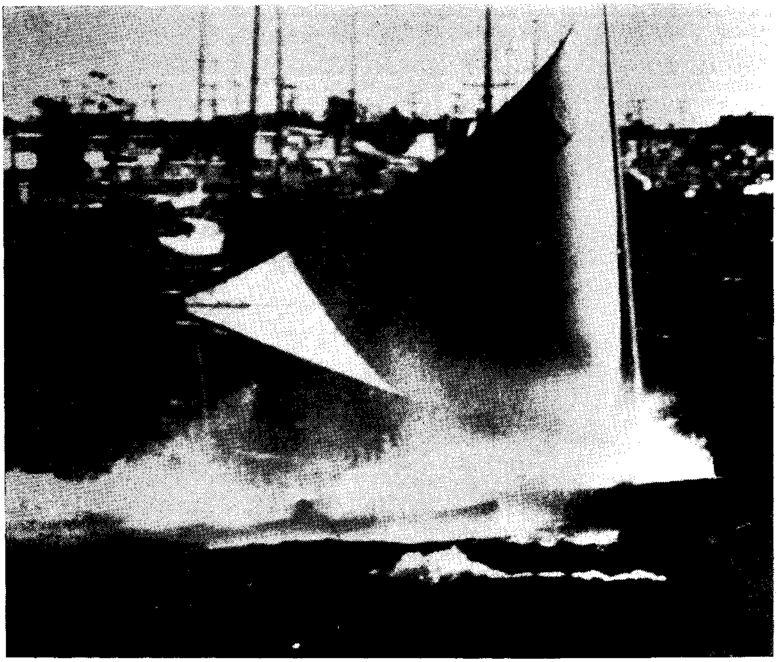
No difficulty arises in launching or beaching and she only differs from the straight dinghy when coming alongside a jetty but this only calls for the sort of care that should be normally exercised (though often is not).

I am delighted with the results and I find that I am by no means alone in the desire for one boat which can serve the double purpose of racing or really comfortable general day sailing — particularly when single handed.

OROFENA — A POLYNESIAN OUTRIGGER

L.O.A. 18 ft. 6 ins. Designer and builder (in 1955) : Carter Pyle.

The photograph shown here was taken at Newport Beach while *Orofena* was sailing at 24 m.p.h. as registered by a pitot speedometer. It is most interesting to see the spray climbing up the forward half of the boat, indicating surely that she is not planing, even at this speed. The outrigger float, which one takes it is the dark shape in the foreground, on the other hand is not making much spray and may be planing. Photographs of this kind are rare and hard to get.



Orofena.

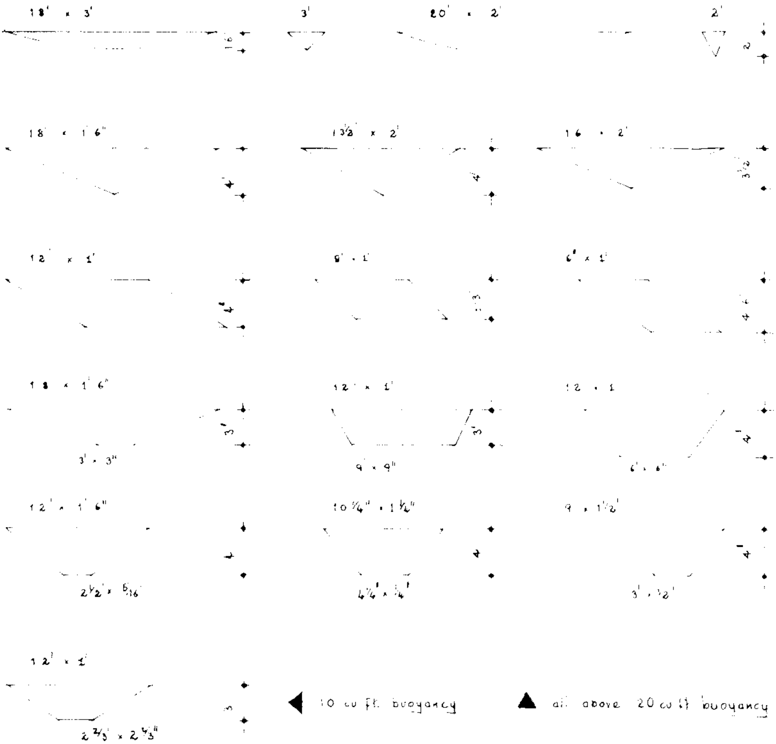
TRENDS IN TRIMARAN DESIGN

By John Morwood

It must be self evident that all the principles of catamaran hull design apply equally well to the main hulls of trimarans. For small day sailors, therefore, the hull shape of *Freedom* and the other good designs we have shown are perfectly suitable and correct. On the other hand, for open ocean work, it seems reasonable to make some concessions to the comfort of the crew and use slightly slower hulls of deeper section such as *Ocelot* by Bob Harris (A.Y.R.S. No. 10 – *American Catamarans*). I think that the account of Arthur Piver's *Nimble* in the Atlantic shows that the motion can be pretty lively at times and, though the keen people of the junior ocean racing groups seem to be able to tolerate this, one doubts if the facility is universal.

One may therefore say that there is a good case for using deeper hull sections for ocean-going cruising boats than for day sailing trimarans. Asymmetry, of course, has no place for trimaran main hulls.

Trimaran Floats. Again, we now know the fastest possible shape for floats. It is either the traditional Micronesian or Indonesian shape or, if one wants to use sheet plywood, floats of the right angle V triangle section. But again, deeper V's than 90° are being used to ease the sea motion which can be of value even in a day sailer. These increase the speed when the sail force is not exerting much heeling moment but are less efficient close hauled in a hard blow.



Now, if we allow that floats of a section with a V less than 90° can be efficiently used, we immediately find ourselves having to study all such floats and foils to see where we are. The previous page shows 15 different types of floats and buoyant foils, each of the same displacement when immersed (20 cubic feet), except for the bottom one, which has 10 cubic feet.

The Shallow V Section. Both the floats shown have very little wetted surface relative to some of the floats below and we know that they go well.

The Triangular Plan Form Floats. The three floats shown of three different thickness to chord ratios have relatively little wetted surface. This type of float will allow the craft to heel in strong winds, and have an easier sea motion than most other floats. In light winds only the tips of the floats will be in the water so their drag will be very small indeed. If angled-in with dihedral, they will produce a certain amount of dynamic lift in strong winds and, as shown by Erick Manners, air entrainment does not occur. Some float cr foil along these lines might be the ideal solution of the trimaran configuration.

Parallelogram Floats. The main difficulty about the triangular plan form float is the absence of buoyancy at the lower end with its attendant loss of initial stability. Parallelogram floats overcome this but, apart from ease of construction, they don't appear at first glance as the best solution.

Truncated Triangle Floats. Six different types of this plan form ror floats are shown of different thickness ratios. This form seems fo me to combine the easy stability of the triangular plan form with teasonable initial stability. Also the point of the triangle which must be vulnerable is removed.

Summary. The final shape for trimaran floats has yet to be devised but a study is made of the different varieties which could be useful. The bottom float on the page has 10 cubic feet of buoyancy (640 lbs.) which would be suitable for a day sailing trimaran.

CATAMARANS AND TRIMARANS

By M. F. Gunning, M.R.I.N.A.

Little Hawsted, Steep, Petersfield, Hants, England.

The Catamaran (" Cat ") has now established its position as an extremely fast sailing vessel. In recent years the Trimaran (" Trim ") is claiming attention. It may be of interest to compare the two types from the point of view of resistance.

Any such comparisons must be based on more or less arbitrary assumptions. Here are compared a " Cat " and a " Trim," each with a length of hull of 30 ft., while the floats of the " Trim " are 25 ft. long. It may be argued that this assumption is grossly unfair to the " Cat," which will have much greater accommodation, etc., but some assumption *MUST* be made, and, from a resistance point of view the assumption of equal length is most logical.

The curves shown differ from ordinary resistance curves. These usually show the resistance of a body of fixed displacement at varying speeds ; here we have shown the resistance of a body with varying displacement at constant speed. We can thus see how the resistance varies when we transfer displacement from the weather hull to the lee hull, or, in the case of the " Trim," from the main hull to the lee float. The curves are shown for two speeds, viz. 5 and 10 knots, and, as stated, for hulls 30 ft. long and floats 25 ft. long.

It is assumed that the hulls do not interfere with one another, so that the resistance of the " Cat " is twice that of a hull with half the total displacement, and the resistance of the " Trim," when heeled, is that of the hull, plus that of the float.

The curves for residual resistance have, with considerable extrapolation, been deduced from the famous " Taylor " standard series, now more than 50 years old, but still commonly used by naval architects for rough evaluation of resistance. The values for frictional resistance have been calculated by means of the Taylor formula. The values for total resistance should not be regarded as absolute ; they may, in fact, well be over 50 per cent. too low. However, they have been deduced in a consistant manner, so may be used to compare hulls of generally similar shape.

In order to evaluate wetted surface it has been assumed that the 30 ft. hulls are of the " V " bottom type, with a bottom angle of 90°. The 25 ft. floats have been assumed to be asymmetrical with vertical outboard sides, and an angle of 45°. All this, of course, is very rough and approximate ; nevertheless it is felt that the broad conclusions drawn as to the relative resistances are mainly true.

It will be seen that, especially at 5 knots, the resistance is for the most part frictional, and the coefficient for skin-friction employed is that for perfectly smooth surfaces. Even a slight roughness will increase this coefficient by 50 per cent. and more. In that case the type with the greatest frictional resistance will suffer most.

We will now compare a " Cat " with a " Trim," both, as stated, 30 ft. long. We will further assume, that the " Cat " has a total

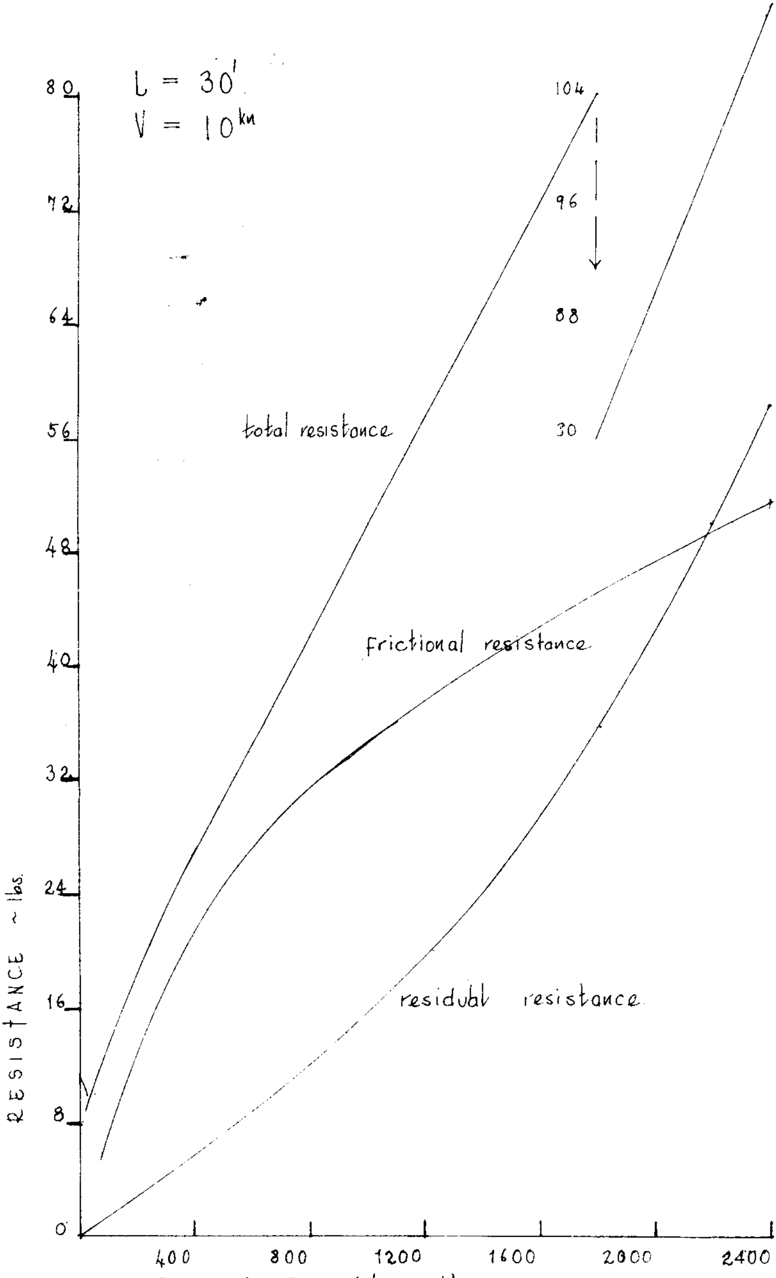


Fig. 1. Main hull at 10 kts.

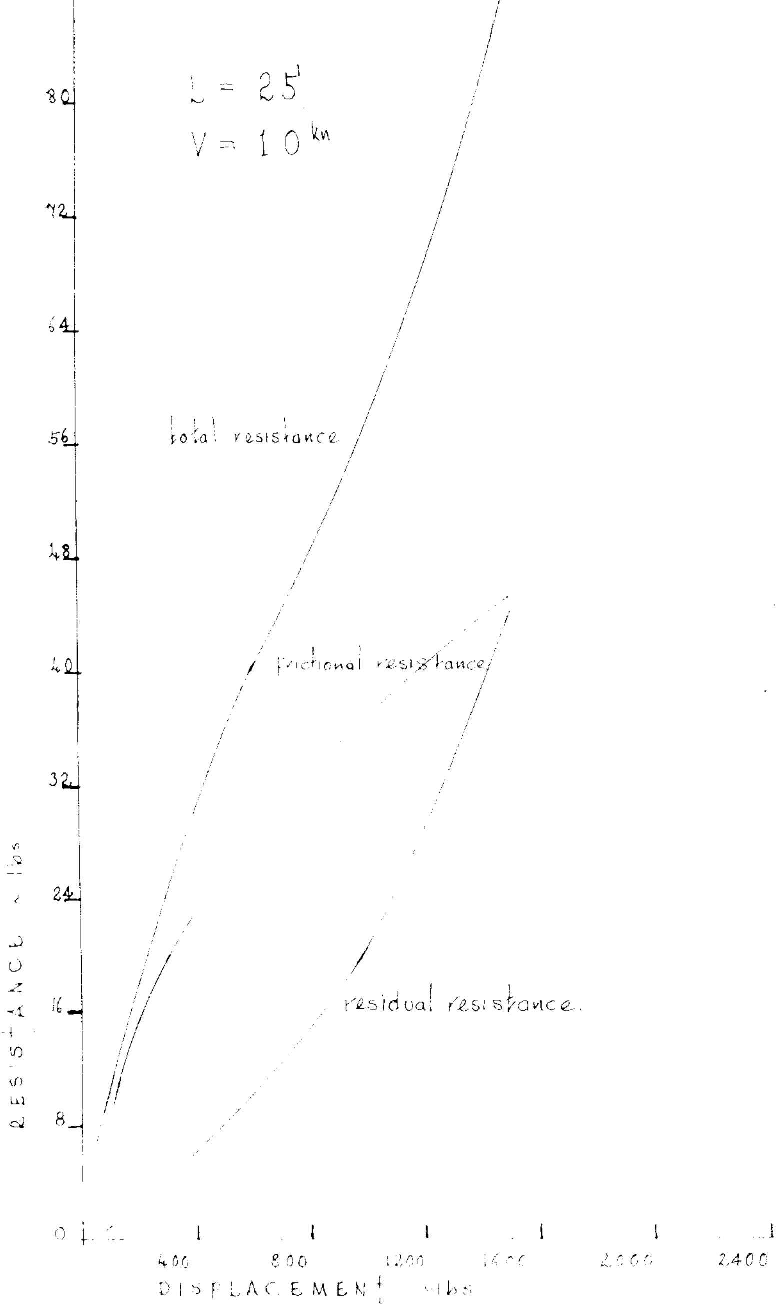


Fig. 2. Trimoran float at 10 kts.

displacement of 2400 lbs., and the " Trim " one of 1800 lbs. To find the resistance of the " Cat " we turn to Fig. 1, at 1200 lbs. displacement, and find a resistance of 56 lbs. For the two hulls of the " Cat " this makes 112 lbs. We further see, that at the displacement of 1200 lbs. the graph is practically a straight line, so that if we incline the " Cat," taking displacement from one side and transferring it to the other, the total resistance does not alter.

Turning now to the " Trim," we find that at 1800 lbs. displacement the resistance is only 80 lbs. Fig 1. That, we must remember, presupposes that neither of the floats touches water. If we shift say 500 lbs. displacement to the lee float, we create an extra resistance of 35 lbs. (see Fig. 2), whereas the resistance of the main hull, at 1300 lbs. displacement, now is 61 lbs., total 96 lbs. This is still substantially less than the 112 lbs. calculated for the " Cat," but we must remember, that the " Cat " can carry more sail, in the ratio of (displacement) $^{\frac{2}{3}}$. This works out at $\left(\frac{2400}{1800}\right)^{\frac{2}{3}} = 1.20$, and if we apply this ratio to the resistance of the " Cat " it becomes $\frac{112}{1.20}$ 93 lbs., so that now the " Cat " wins. If, however, we assume that we only have to shift 250 lbs., the total resistance of the " Trim " becomes 90 lbs.

We may conclude that at 10 knots speed there is not much to choose between the two types. Certainly the differences found lie well within the margin of error inherent in any calculations of this type.

We see that the frictional resistance of the float is large as compared with its residusal resistance. We may therefore assume, that a somewhat shorter float, which would have less wetted surface, but a greater residual resistance, might be better.

If we repeat the same procedure with the graphs showing the respective resistances at 5 knots, we find for the " Cat " a resistance of 2 x 12 = 24 lbs., and for the " Trim " only 15 lbs. If we transfer 100 lbs. to the lee float (and that would certainly be sufficient), we get an added resistance of less than 3 lbs., so that at this speed the " Trim " would retain its advantage.

Now, finally let us see what happens if we push both floats into the water when the vessel is upright, say 250 lbs. each leaving 1300 lbs. displacement in the main hull. Many " Trims " have been designed that way, with disappointing results. This is confirmed by our graphs, which show a total resistance of 61 + 2 x 22 = 105 lbs., as compared with the original 80 lbs !

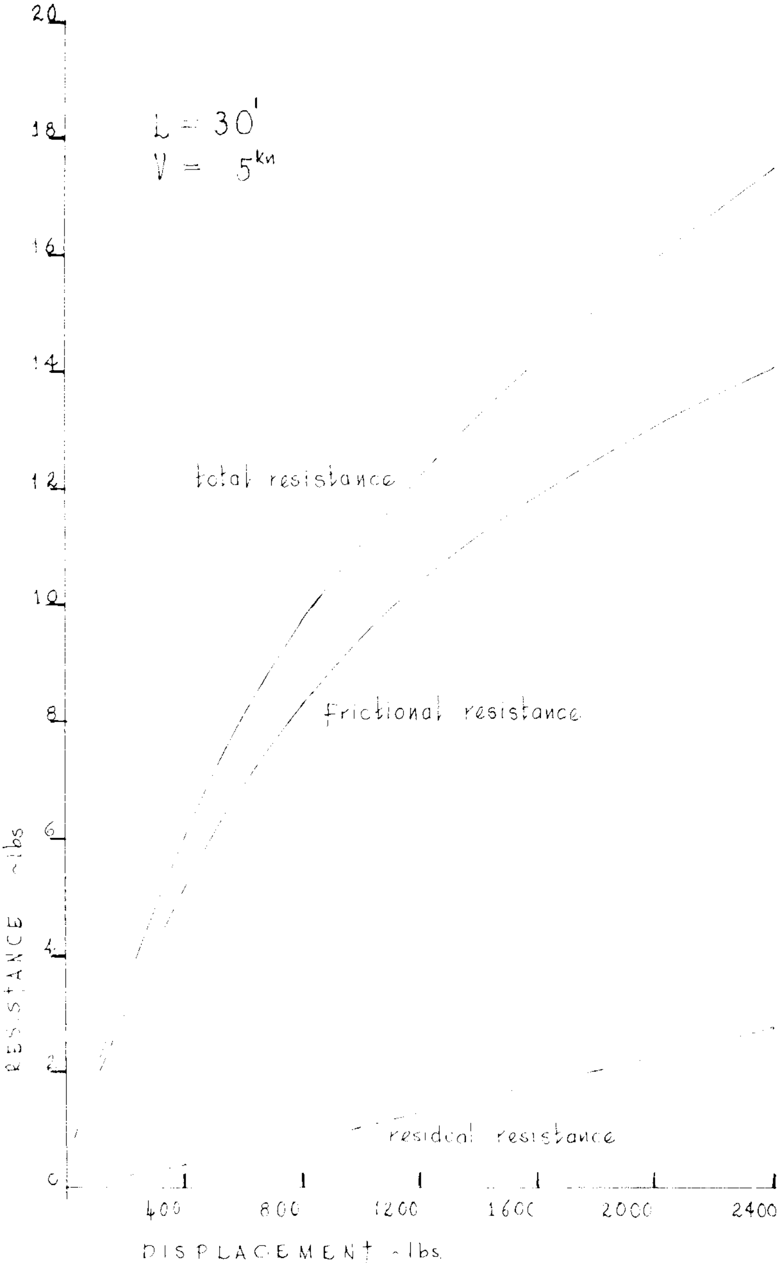


Fig. 3. Main hull at 5 kts.

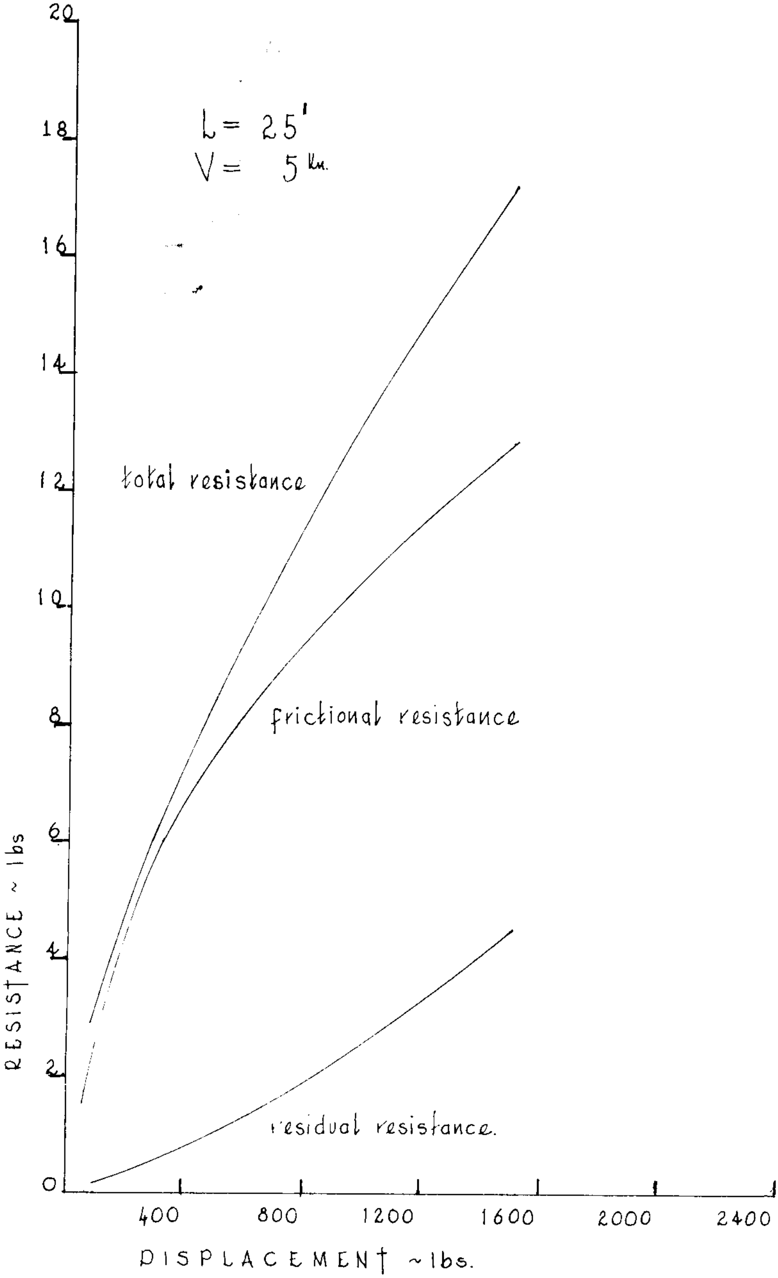
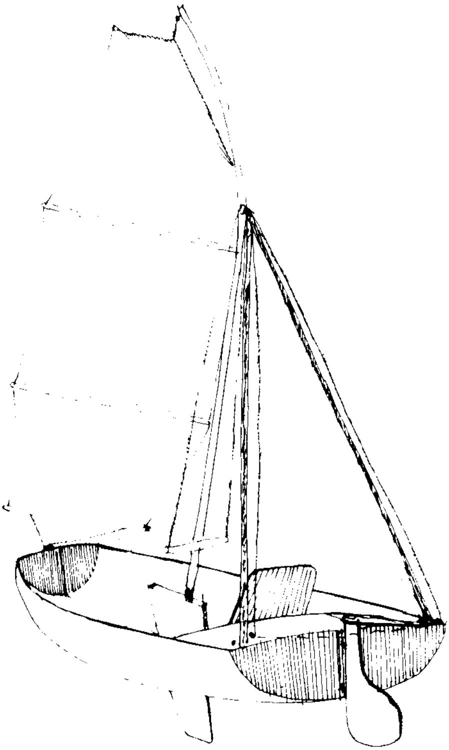


Fig. 4. Float at 5 kts.

Dear Sir,

In your last (most excellent) A.Y.R.S. No. 35, P. V. MacKinnon surmises, in his final paragraph (page 61) that the logical way to sail a wide beamed cat is from an enclosed cockpit situated on the centre line. I can give a bit of practical experience to confirm this.

Last year a friend and I rigged a tiny pram dinghy with a mast-aft rig and home made sail, just for fun. It went quite well so, both being ex-aviators, we decided to go the next step and sit facing forward, legs astride the C.B. case and back against a comfortable back rest about a foot ahead of the transom. The front leg of the tripod mast came down about a foot ahead of the " pilot's " face and to it we fixed a rudder bar at convenient hand height from which light lines went up the mast, down the rear legs and thence to an aft facing tiller.



The result was that, if a gust came from starboard and the boat heeled to port, one's instinctive reaction was to press down on one's right hand. This luffed the boat up.

It was great fun, very easy to get the hang of and I would say perfectly practicable for any craft whose lateral stability was good.

H. J. PARHAM, Maj. General.

Dear Sir,

The April publication was to me a very interesting one ; particularly for the conflicting views which it aired. The symmetry/asymmetry dispute now has a common basis of agreement, but the high buoyancy/low buoyancy dispute between Messrs. Montgomery and Allen on the face of it lacks any such basis. The *Ski-Cat* is simply a trimaran without a central hull ; i.e. it uses the trimaran principle that the float submerges before the (weather) hull flies. As to the *Flying Cat* its designer seems to overlook what Mr. Allen calls the " second target " offered to the wind when the boat heels, and also that as long as the cat does not heel there is no downward wind pressure in the sails and no need for the extra buoyancy required to support it. Opinions may differ about the efficiency of sloped sails but all agree that a sail sloped sharply to lee is downright inefficient.

WILLIAM GARNETT,
Hilton Hall, Hilton, Huntingdon.

Dear Sir,

First, may I congratulate you on the splendid edition *Ocean Trimarans*. As you say, the future of sail boat design seems as if it will tend towards this shape — and why not !

The whole object of a boat is to go from A to B in the minimum amount of time and the maximum amount of comfort. Here the trimaran scores off the catamaran but the space question presents a problem. The main hull shape has to be narrow to obtain speed ; however, there can be considerable space available from about chest height by covering the cross members as on the plan of *Nimble*. This can be used for bunks and, by putting in a catwalk, part of this space can be used for navigating and cooking.

So the trimaran " takes up a lot of space and tends to charge about at its moorings." For the weekend sailor, it should be possible to devise some quick release mechanism for the floats and the cross members, on the day sailers anyway. For the moorings, would it not be possible to put down four anchors or weights (which need not be heavy because of the light weight of the vessel) and use some sort of elasticised rope to absorb the shock of being swung to and fro on a fixed line ?

Arthur Piver's article was a real tonic. What a great spirit they had — no radio or chronometer but plenty of optimism. Is *Nimble* still in this country ? I should very much welcome the opportunity of seeing her if at all possible.

P. G. HAYNES,
Vilasar, Rushmere Road, Orchard Leigh, Chesham, Bucks.

Ed. *Nimble* is now at Newton Ferrers, near Plymouth, but is being taken to the U.S. as soon as a crew can be obtained.

Dear Sir,

Speaking generally of cats and trimarans in the small sizes, up to, say 20 ft. long, my own opinion is that at low speeds a good performance is dependent on having a small wetted surface which is as a rule dependent on light weight as well as shape. At high speeds, good performance is also dependent on light weight but additionally is greatly dependent on sail carrying power i.e., on stability.

Now, considering a cat and trimaran each of equal displacement, the trimaran can be designed I think with less wetted surface than the cat so the trimaran should give somewhat better performance in light winds and should also be more manoeuverable. Thus, unless heavily loaded, the trimaran's performance in light winds ought to approach more nearly to that of the single hulled dinghy than does the performance of the cat. However, it is in strong winds and at high speeds that the cat will beat both the dinghy and trimaran because of its greater stability.

By giving a trimaran an enormous overall beam or by fitting hydrofoil stabilisers, it might be possible in theory to obtain the same stability as the cat ; but this I believe to be a practical impossibility for the present, in the small sizes I am talking about.

We are then left with the conclusion that in these small sizes (and comparing craft of equal displacement) the cat will have a better maximum speed than the trimaran, although the latter should give a somewhat better performance in light winds and be more handy in such conditions.

Here in Holland where a good deal of sailing can take place in narrow waters it seems to me that the trimaran might be more suitable than the cat — unless of course you put an outboard motor on your cat for canal journeys.

Anyhow, there is more to be found out about trimarans than catamarans nowadays, so I am having a shot at designing a simply constructed trimaran, *Tuatri*, to be built in due course ; but this does not mean 1961 because the nephew for whom it is designed has just been posted abroad for 2 years.

G. H. GANDY, Cdr.,
Limburg Stirum Straat 6, Huizen, N. Holland.

GIZMO — A HYDROFOIL EXPERIMENT

BY WILLIAM C. PRIOR,
473, Falls Road, Chagrin Falls, Ohio.

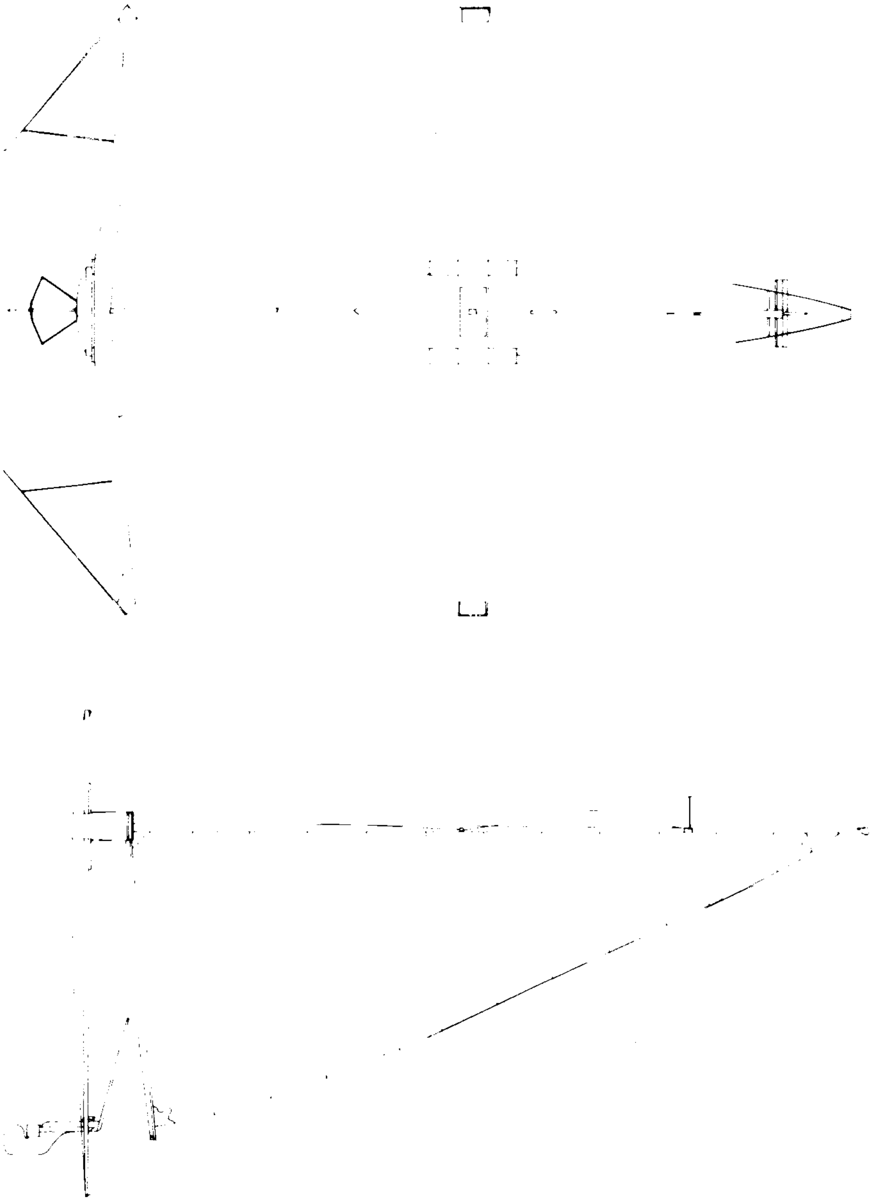
The drawing shows a diagram of a hydrofoil boat I sailed in the summer of 1958. You will see at once that it is a very simple design. The centre hull was a 14 ft. *Sailfish* hull which I had built from a large block of foam plastic and covered with fibreglass. The outriggers were an afterthought and the hydrofoils were an idea which has been rattling around in my head ever since the days I used to drag my paddle in a canoe (the other guy worked).

In spite of its construction, it did sail, although it took some doing to get the balance worked out correctly and I must admit that it was no idle breeze that day. Before I had much chance to evaluate the thing, the rudder fell apart and it was already well into a cold September so I did nothing more that year. The performance was quite spectacular, though, and very encouraging.

Since that summer, I have given a very serious study to the design of hydrofoils sailboats and have built a boat almost completely, which I feel should have excellent performance. I am finishing up the foils now and the boat should be under test soon. The boat will carry 177 sq. ft. of sail, weigh about 235 lbs. and have a two man crew. The foil configuration will be quite similar to *Gizmo*, the boat shown here.

The following existing sailboats actually fly ; perhaps A.Y.R.S. members know of others and it would be interesting to know of them :

1. Bob Gilruth's boat.
2. Baker's two boats, the 16 footer and the *Monitor*.
3. Professor Locke's boat.
4. John Lyman's boat.
5. *Gizmo*.
6. J. S. Taylor's boat in Australia (1960).



Gismo.

As can be seen, we got off the water last summer (1960), and several times we flew it with two people aboard. It was very fast and a real thrill to lift off the water and glide along on the foils, but overall, I was disappointed with its performance. My major complaint was that it was awkward. Between trying to handle two good sized sails and trying to steer, one's hands were full. My rigging was not simple and the boat invariably had an entirely different idea about where it was going than I had. It did not point well and if you could get it to go about at all, it certainly would not do it while airborne. Despite all this, it was a great improvement over the *Gizmo* and it outlines a little more clearly what can and cannot be done with foils.

William Prior's hydrofoil craft.

It must be remembered that this boat was designed as a test model, using aluminium tubes for a framework, so that the overall layout could be changed at will. I found that this gave me so much wind resistance in proportion to its weight that it responded like a feather with not enough inertia to carry it through manoeuvers. I am happy with the triangular configuration, although it could stand being a little more narrow.

The pontoon design will make the designers of high speed hulls wince, but I keep telling myself that above six miles per hour they are entirely free of the water anyhow. I used $\frac{1}{8}$ in. harbourite plywood and glued them together with resorcin cements. They were really light.

There is a lot of controversy about foils. I firmly believe that they must go deep, with as high an aspect ratio as you can practically construct. My front foils were cantilevered with four feet beyond the pontoon. My chord varied from three inches to one foot, with a modified N.A.C.A. section. I used a pine core with an aircraft aluminium skin glued around it and I had three small sheet metal " gates " (fences) on each. They were light, strong and did not present any problem with ventilation which did not creep beyond the first gate. The rear foil was a fibreglass submerged foil, but towards the end of the summer I had to change it over to a ladder foil to maintain a more steady attitude.

If anyone in the A.Y.R.S. would like more details, I would enjoy corresponding.

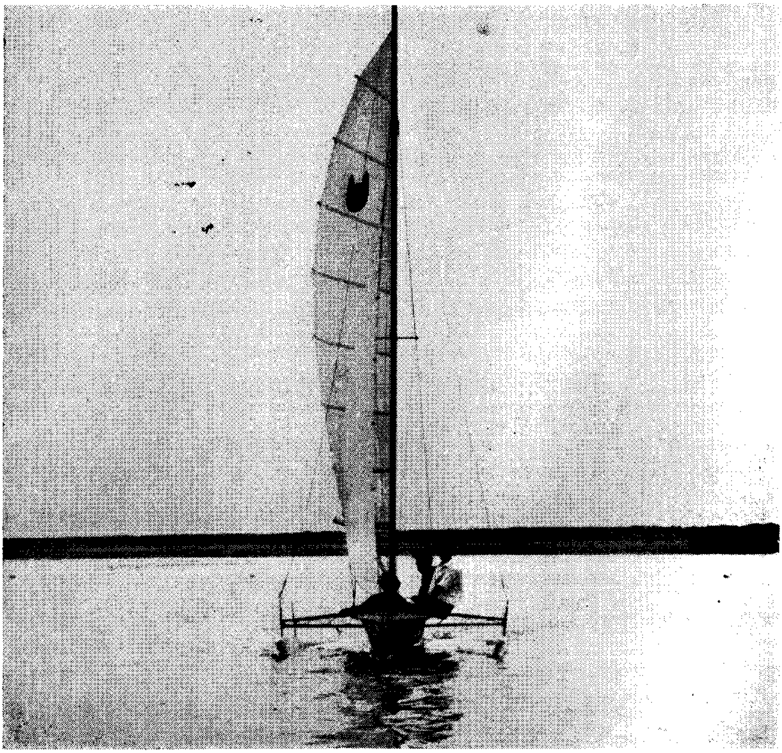
FLYING WING

A Hydrofoil Trimaran (Trifoil).

L.O.A.	20 ft.	Cockpit length	7 ft.
Overall beam	12 ft.	Draught	7 ins.
Main hull beam	2 ft. 3 ins.	Sail area	160 sq. ft.

Designer and builder : Erick J. Manners, A.M.B.I.M., 93, Ridgeway, Westcliff-on-Sea, Essex.

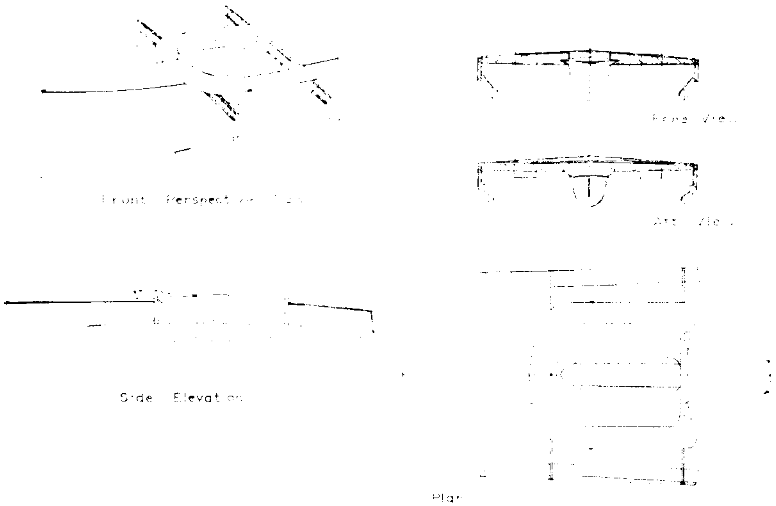
Following earlier model research, since 1954 Erick has been experimenting with hydrofoils on full sized sailing craft. In common with all other experimenters in this field, using fixed foils, he found himself up against the troubles of spasmodic negative dive and " air entrainment " as described by Christopher Hook in No. 19 *Hydrofoil Craft.*



Claimed by Manners to be the first hydrofoil stabilised sailing boat of its description, this earlier experimental Trifoil proves the dynamic lift but does not have the buoyancy reserve above the optimun water line as the production models have.

In 1957, he developed a very low aspect ratio asymmetric hydrofoil, which he describes as an " elongated, slender underwater wing," to which he has applied the name *Trifoil.* The value of this conception is that it produces a combination of buoyancy and dynamic lift and the low aspect ratio prevents air being trapped on the weather side of the foil. One can consider it as being an extension of the Micronesian concept of windward force from asymmetry but with less buoyancy, deeper immersion and dihedral to give dynamic lift.

Foil Performance. The *Flying Wing* has been tried out in many different conditions and in all, the dynamic lift completely holds the boat up in any sailing direction with remarkably little heel.



At present, in order to prevent a sudden squall upsetting the boat if caught without weigh on her, reserve buoyancy sponsons have been fitted part way along the cross beams parallel to the central hull. This seems to be a sensible precaution though, due to the low aspect ratio, one would think that the foils would function more effectively under this circumstance than when sailing. Except at exceptional angles of heel, far beyond the working optimum, these sponsons will never touch the water and consequently offer no drag other than wind resistance.

Sailing with the Trifoil. The hydrofoil arrangement gives the *Flying Wing* an exceptionally smooth ride with no " wave shock " from the floats. Nor is there a quick motion when a float meets a wave which can be annoying in a trimaran. Indeed, Erick has actually made trimarans with spring loading in the floats to try to overcome this.

The *Flying Wing* is fast and not only overtakes all orthodox comparable sized single hulled racing dinghies but, to their disgust, has also led racing catamarans. But quite apart from its speed potential, *Flying Wing* is dry and really comfortable. These features, combined with a cheaper production price have been the ultimate objective of this series of experiments.

Last year, the prototype was left out in five November and December gales but survived. One of these gales was recorded by the local weather station as Force 8 to 9 and was of long duration.

The *Flying Wing*, rigged with its mast was exposed to a seven mile fetch of shoal water. She remained virtually dry and completely unscathed except for a section of new canvas which had flapped to a pulp.

Manners Trifoil development.

One or two outboard motors can be fitted and considerable dynamic lift can result with a noticeable absence of wash disturbance. For winter storage and ease of long distance transportation, the port and starboard cross beams, each with their half of the cockpit may easily be made detachable. In this manner, they have been trailed behind a car.

Construction plans for this system are available at £7 7s. 0d. to build one boat only with a royalty of £3 3s. 0d. for each subsequent boat built or supplied.

Editor : In my opinion, the concept of this craft is outstanding and, though I have not sailed it myself, I feel that its development needs every encouragement.

THE ASPECT RATIO OF SURFACE PIERCING HYDROFOILS

In this publication, we have two different opinions about the ideal aspect ratio for hydrofoils. Firstly, we have the opinion of Erick Manners which is backed by the traditional outrigger floats of Dar es Salaam (and Madagascar) and by Micronesian asymmetry which has proved that aspect ratio can be very low and work satisfactorily. Secondly, we have the opinion of Bill Prior in relation to his flying hydrofoil craft who has proved that aspect ratio should be as high as is practically possible. Naturally, we would like to know where the truth lies.

I think that these two viewpoints can be both satisfied by the fact that there are two different forms of reaction from asymmetrical shapes in the water. Firstly, we can have surface wave reaction where the lee side of the low aspect ratio hydrofoil produces an upwards wave while the weather side produces a hollow wave. Secondly, we can have dynamic pressures on a fully submerged hydrofoil which are fully analagous to the pressure distribution over aerofoils.

In devising the ideal shape of hydrofoil, we therefore want two things : 1, A fairly long waterline length to give good surface wave reaction and 2, deep penetration into the water to give good dynamic pressures. Only trial and error will let us know what combination of these two features will give the best results. It will be remembered that my original guess was for a triangular plan form 1½ times as long in depth as in the top chord (A.Y.R.S. No. 19). Bill Prior obviously thinks that a higher aspect ratio is desirable for a foil-borne craft and only time will let us know what we should have.

HYDROFOIL SYSTEMS

By John Morwood

In this publication are to be found two hydrofoil systems. The first by William Prior of Ohio is a flying type which has risen off the water. The second is by Erick Manners which is a very low aspect ratio system such as is used traditionally in Dar es Salaam where the inshore fishing boats use similar foils which have a certain amount of buoyancy. Let us now examine all the variations of hydrofoil systems which could be found useful.

Sliding Foil Systems. In the surface piercing foil systems, the main difficulty is the air entrainment. This seems to be invariable and has occurred in the craft of Martin Ryle, J. S. Taylor and everyone else. One of the ways of dealing with this is by " fences " or thin " collars " around the foil which shed the air which slides down the foil. I have been told that these " fences " can be very small, as little as $\frac{1}{8}$ in. above the surface and still function, but know of no details of the work which showed this. However, the main serious cause of air on the foil appears when a foil surfaces from a wave. It then re-enters the water with the air on its upper surface and fails to achieve lift. It is not known if " fences " will shed air under this circumstance. Low or very low aspect ratio may be as efficient in preventing air entrainment as higher aspect ratio with fences.

Inverted T Foils. In A.Y.R.S. No. 2 *Hydrofoils*, we described a hydrofoil boat made by Sam Catt and myself which could be heeled to windward by the use of its lee foil. This was a slow heavy boat and a modern catamaran hull would be several times as fast. We used only 4 sq. ft. of foil area on each side so a fast hull would only need 1 sq. ft. per side or even less. Fig. 1 shows a simpler method

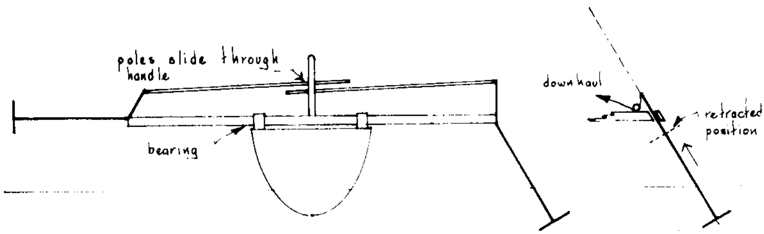
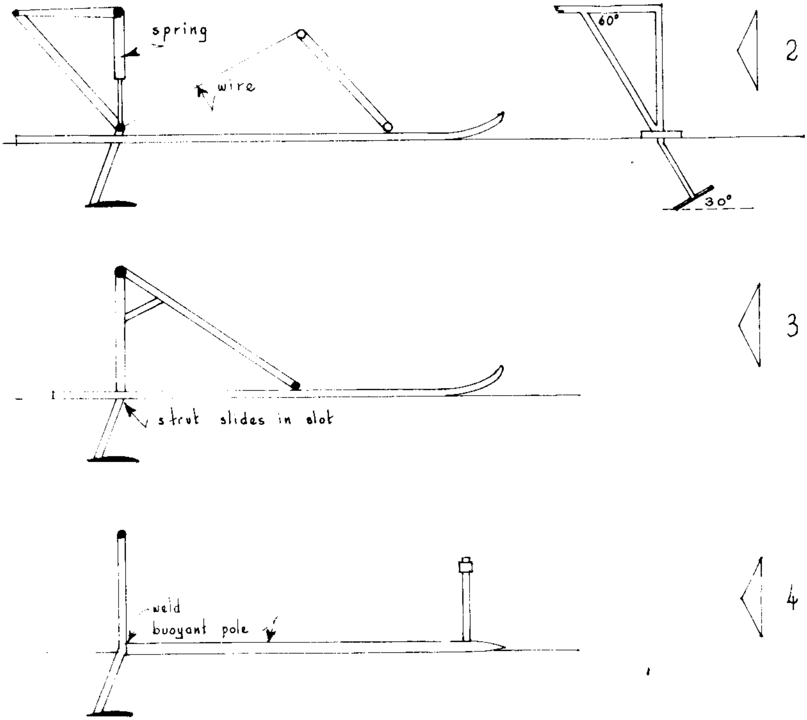


Fig. 1.

of using this system than we had and is also arranged so that the weather foil need not be in the water. This must be the ultimate in fast sailing other than foil-borne craft and, if anyone were to make this, he must beat all the catamarans and outriggers, even though some balancing would be necessary in light winds. It might be desirable to have the top pole in two parts to allow the foils to be sloped up fully for handling on the shore. The main drawing shows swivelling retraction while the little diagram on the right shows a sliding system.

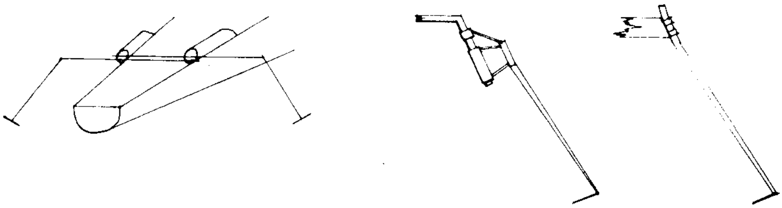
Automatic Variable Incidence. The above system, though obviously the fastest possible, is not really suitable for family sailing and some kind of a float system would be necessary for general use. Some combination of float and foil is therefore needed and it is natural to expect the float to do double duty as both stabiliser and controller



of the angle of attack of the foil as shown in Fig. 2. For simplicity, a water ski is shown rather than a float. In the sketches, the water ski is mounted on two angled struts so that it can rise and fall but the rear strut goes through the ski and is attached to the foil so that, when the ski is lifted, the foil get more positive incidence. The lift is taken to the rear cross bar by a collared spring. The wire shown (or a stop on the spring collar) prevents negative angle of attack for the foil.

This system is, of course, a variety of the Hook *Hydrofin* principle and the Figures 3 and 4 show two other varieties of the same. In Fig. 3, the water ski acts like the " Jockey float " of the Hook method and the ski is kept aligned to the water flow by the strut of the foil running in a slot in it. In Fig. 4, a light alloy pole is welded to the strut of the foil and controls the angle of attack while a bar running in a slot at the end of a forward cross beam keeps this movement from being excessive, at the same time keeping the pole aligned.

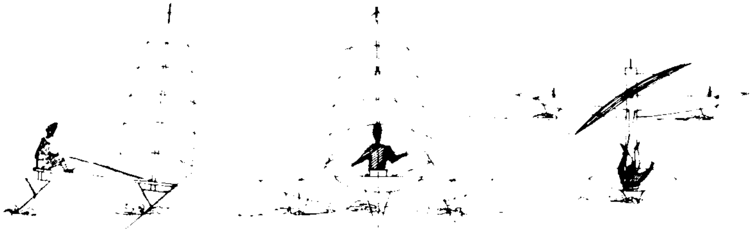
Differential Foil Systems. While one only needs lift from a hydrofoil on the leeside to keep a boat upright, there is a strong case for having foils on either side which, between them, exert a righting couple in the boat. The system in the left hand drawing shows one such mechanism. When given leeway, a boat with this system develops a lifting force on the leeside and a depressing force on the weather side, the lee foil lifting to give the differential angles of attack. This mechanism has the fault that when the craft gets sternway, the foils work in the opposite way and the craft will immediately capsize. One therefore might prefer a system which works even when the boat has sternway.



Differential hydrofoil stabilisers.

The two right hand drawings show hydrofoil stabilisers which will revolve through 360° and give lift or depression throughout. The middle drawing shows a system based on short connecting bars which are angled to each other, while the system on the right has the foil connective curved so that, when it is pushed up, the angle of attack becomes more positive. It might be necessary in both cases to connect the foil struts of each side together or to the boat.

A Micronesian Hydrofoil Design. Now that Captain Mellonie has shown that a squaresail can be successfully used on a boat sailed in the Micronesian way, the simplest possible foil boat becomes self-evident. Three hydrofoils, each sloping up to leeward are placed on the simplest possible Micronesian canoe. The two leeward foils are interconnected to provide steering. A semi-elliptical squaresail provides the power. Despite Prior's and Taylor's statements



Suggested Micronesian hydrofoil craft.

that craft can become foil borne at about 6 knots, one feels that the wind pressure has to be strong to get up but, even should this not be so, hydrofoil boats seem to exceed the speed of the wind and the side force must be considerable. It is felt, therefore, that sloping foils of this pattern are likely to provide the lift required, even though the side force must nearly be equal to the weight of the craft and crew.

One of the nicest things about the system advocated here is that the angle of dihedral of the foils can be varied without any mechanism or structural alteration. The dihedral angle needs to be small to get off the water but, at the highest speeds, it should be greater. What these angles should be, we don't know, but this craft can vary them between 30° and 60° by simply altering the angle of heel of the whole craft.

No devices or designs in this article have been patented and it is hoped that members will develop them still further than I have.

HYDROFOILS FOR A CATAMARAN

The previous hydrofoil craft appears to be a good way of getting hydrofoils to work but it would only be a hydrofoil craft purely and simply. On the other hand, many people now have catamarans and some might be prepared to fit hydrofoils to increase their speed in strong winds. The cost of the unit described here would be small and its weight need only be some 50 lbs.

The Configuration. This is a modified Grunberg system, using forward steering.

The Main Foils. These are inverted T foils set at an angle of dihedral of 30° and fixed by pushing them into the centreboard slots from below. Air entrainment down the struts may be expected, being worse in a sailing boat than in a powered one, owing to the

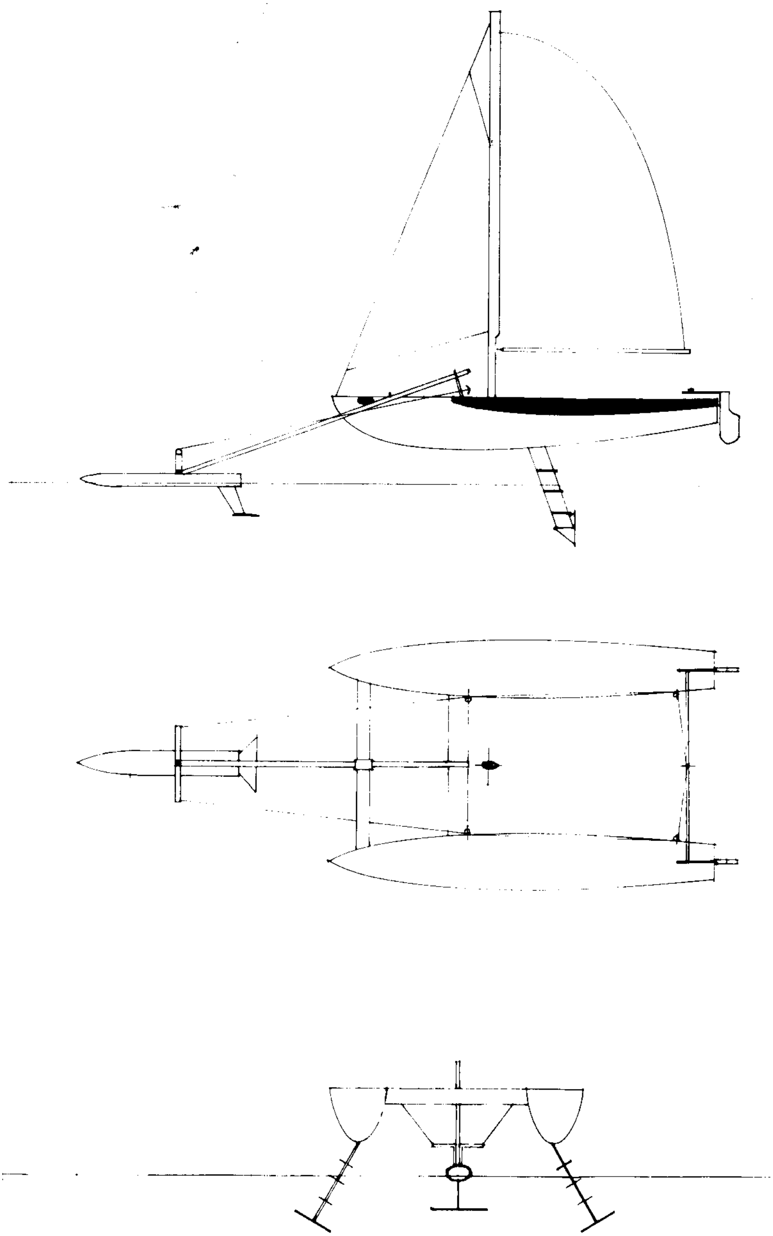


Fig. 16. Grunberg type hydrofoil conversion units for a catamaran.

leeway. It is therefore suggested that these be "fenced." The angle of attack which is best is not known but lies somewhere between 5° and 7°. Dihedral should be 30°.

The Forward Float. Many people nowadays seem so addicted to "planing" that they never even consider other forms. The original Grunberg forward float was a planing type. So is that of Christopher Hook but he, by using a flexible "heel" to his float reduces its resistance, at the same time having it follow the short wave slopes completely.

The float shown here is a bullet shaped float which, if 10 inches in diameter and 6 feet long (exclusive of the point) will have a buoyancy of about 200 lbs. when submerged. The parallel sided shape will have more stability of flow than a small catamaran shaped hull. This float may be expected to go *through* small waves but with no "wave shock" and little hindrance. The centre of buoyancy should be ahead of the pivot to keep the forward end from wanting to dive and vertical and horizontal fins at the after end will keep the float aligned to the water flow.

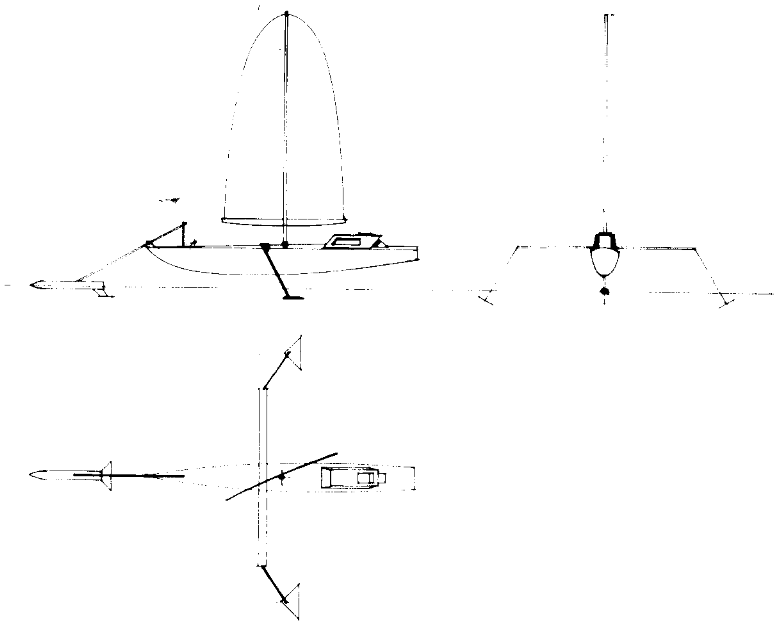
The Float Attachment. The float is attached to the catamaran by a single pole which passes under the forward cross beam, on which it can turn, the after end being attached to the forward end of the cockpit, either rigidly or by a spring in compression. This spring would allow some rise and fall of the float without affecting the catamaran. In light winds and when launching, the after end of the pole would be pushed down, thus raising the float.

Steering. At the forward end of the pole is a collar in which is set a short vertical rod at whose lower end is a joint which will allow the float to pitch and in whose upper end is a cross beam. This cross beam is, in turn attached by wires to the connecting bar of the tillers so that steering will be more or less normal.

Forward steering in conventional boats gives extra resistance to forward motion because it causes turbulent water flow. The steering is adequate, however. In the system suggested here, there can be no objection to forward steering from these causes and it avoids complex mechanisms being added to the rudders.

Summary. A method of adding hydrofoils to a conventional catamaran is suggested. The size of the forward float seems reasonable for a trial but a considerably smaller float might be possible.

We conclude this article by showing how the same system could be applied to a single hull.



Grunberg type hydrofoil configuration.

SAILING HYDROFOILS

By Erick J. Manners, A.M.B.I.M.

In the past I have carried out what at first glance might seem rather a bewildering variety of hydrofoil experiments. Usually one leads to another and each shows up its particular qualities. My observations remain that whilst there are other snags in small boats it is quite easy to get boats out of the water up onto foils when power driven but hardly practical to do so if only sail propelled. No one wants a small hydrofoil yacht that when it does get going, dives back into the water with every wind or wave variation.

Therefore I have mainly concentrated on 1, Trying to get only partial lift to reduce drag. 2, Using a foil to stabilize catamarans and particularly trimarans to reduce their natural heeling tendency and damp excessive movement. 3, To share the dynamic lift component with secondary reaction to help counteract lateral leeway. Outlines of some of my original hydrofoil experiments are illustrated in the accompanying athwartship section drawings about the centre of lateral resistance. Naturally whether handed, one or both, or portions only of the hydrofoils are used in different sailing situations will amount to an addition to the " art " of sailing. The hydrofoils are asymmetrically shaped and may be used reversed or handed. The improvements also cover methods of simply housing the underwater gear when not required.

Fig. 1. Shows an anhedral configuration which has the advantage of great ease and simplicity of operation. For example instead of considering only the operational foil to leeward the weather foil could be used when advantageous. In other words it is not thought to be very critical which side of the boat's mid longitudinal axis the operative component functions. On the other hand the leeward foil becomes more effective in lateral reaction the more the boat heels. In this same connection the hulls are " splayed " inclined outwardly with the dihedral I adopted in 1957 so that the working hull, asymmetrical when upright, is in effect operating upright with a symmetrical underwater section when sailing at optimum heel.

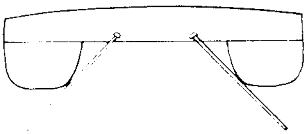


Fig. 1

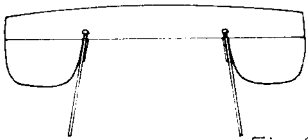


Fig. 2

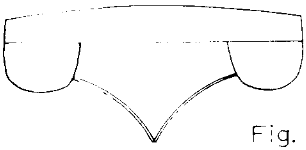


Fig. 3

Fig. 4

Fig. 2. Shows one of the same boats built in 1959 for hydrofoils at option but combined with provision to have ordinary straight down symmetrical inner side boards. This new arrangement has the big advantage of no turbulent underwater slots or leakage troubles as occur with the highly stressed twin cases going through the light hulls of catamarans.

Fig. 3. Shows another of my related hydrofoil configurations and where the dihedral may be of curved form. Fig. 4. Shows the method of hinging these up under the wing of the bridge deck when unoperational and like the other new features described here is the

subject of patent applications. Another development I experimented with is adjustment for varying the angle of incidence. Some foils were also made with a twist built in them with possible objectives that some readers may wish to ponder on as long as they do not hold me responsible for what may result.

WATER " BICYCLES "

BY JOHN MORWOOD

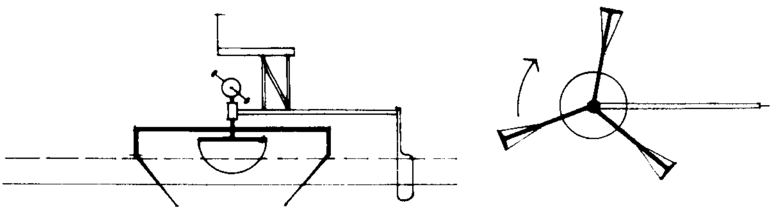
It is to be supposed that nearly all A.Y.R.S. members will have amused themselves at one time or another by inventing man-powered water vehicles. The two commonest varieties of these must be :

1. Buoyant water skis. The early varieties were hollow boxes. The modern ones are of plastic foam. No one seems to have liked either very much.

2. Small catamarans, powered by either paddle wheels or a propeller. These have a limited application as beach boats for hire.

Both these must be limited by the short length of the floats and the almost invariable necessity for a bad shape. As compared with these, hydrofoils and submerged buoyancy can be of good design and suffer no limitation of speed from their small size. It may therefore set some useful trains of thought going to conjecture some ways of using them.

When the Prout brothers were Olympic entrants in the paddling canoe classes, John Westell designed hydrofoils for one of their kayaks and they tried them out. They found that, though they were able to get considerable dynamic lift, they were not able to get off the water and the drag of the foils made them slower than normal. The trouble lay, of course, in the lack of speed in the craft and foils (about 8 knots). The answer to this problem obviously lies in keeping the craft stationary and having the foils moving. This leads us to the first principle.



Water " Tricycle."

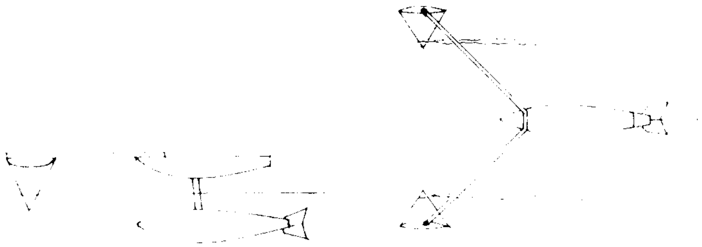
Man-powered Foil Craft. Three hydrofoils, either surface piercing or inverted T foils are made to rotate around a very small boat of "*Coracle*" size. A rudder placed outside them will partially prevent the craft itself from turning. Because all the power available is given to the hydrofoils and none is taken up by the boat, it might be possible to lift the boat off the water by manpower. Now, if the craft is given a slight heel backward with sliding foils, forward with T foils, the craft should be able to make some forward progress. The rudder should then be able to keep the craft from revolving altogether.

Water Hobby-Horse. In A.Y.R.S. No. 2, "Water stilts" were shown with a side by side combination of submerged buoyancy and hydrofoils. Perhaps it might be a more satisfactory method of doing this to have the float-foils placed fore and aft and make the craft pitch

Water "Bicycle."

in order to get forward speed. The craft would then be unstable laterally but steering the forward float-foil might let one keep upright, though lateral surface floats would be needed to start off.

Submerged Buoyancy. Edmond Bruce has shown in the test tank that submerged buoyancy has less resistance than any form of surface craft and indeed this has been proved elsewhere as well as being obvious from considerations of surface area and wave making. A practical method of using submerged buoyancy is shown. Surface piercing hydrofoils forward relate the submerged shape to the surface

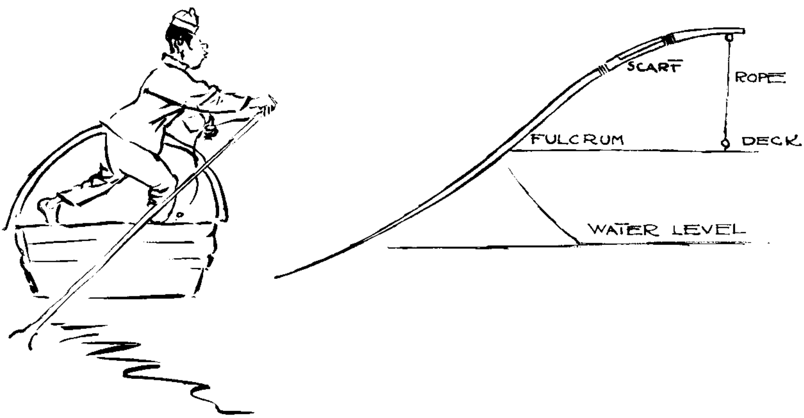


Submerged buoyancy.

and small floats on these will keep the craft upright when stationary, though the main buoyancy will, of course, come to the surface and get a considerable angle of heel when no one is aboard. The craft shown here would be best propelled by either oars or engine and would not sail as well as some other craft shown in this publication.

Marine Drive. Oars and paddles are not 100 per cent. efficient but produce a " Slip stream " in the form of " Puddles " which are driven astern in the water. The loss from this source is not great, however, and may not amount to more than 10 per cent. The exact figure is not known to me.

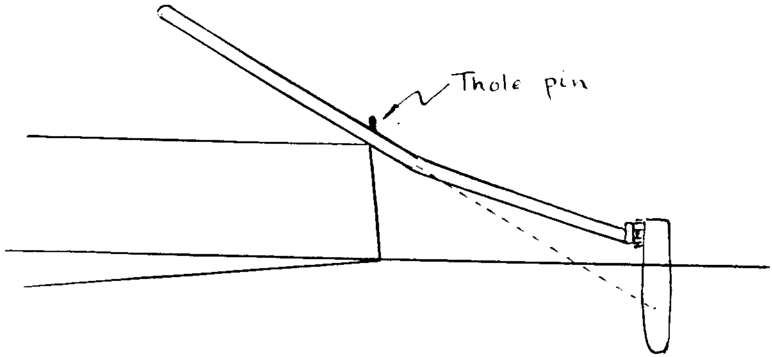
Propellors are less efficient than oars and seldom exceed 70 per cent., the loss arising from a combination of " slip stream " and tip eddies. Paddles wheels are even less efficient because of " Splash " as well as the two losses of the propellor.



Uloh—Drawn by G. R. G. Worcester.

In theory, the most efficient form of marine drive is to be found in hydrofoil action which may be classified generically as " sculling." The two traditional sculling methods are 1, the simple sculling with an oar and 2, The Chinese " Yuloh " drawn by G. R. G. Worcester, which is a large oar on a pivot, tied down by a long cord at its forward end. An angle in the oar and the skill of the manipulator give the angle of attack on each stroke. The large junks were driven by several of these yulohs, six or seven being often used.

An efficient hydrofoil should give a thrust to drag ratio of 10 : 1 at least and some modern applications are supposed to achieve this.



Modernised Uloh.

The modern applications of which I know are as follows :

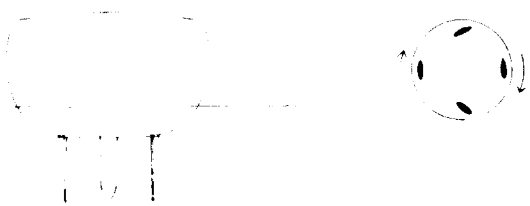
1. The Hotchkiss " Impellor." This is a sculling oar with a fabric blade of low aspect ratio which takes an angle of attack on each stroke. The oar is nearly horizontal and is worked like a tiller, giving a reasonably good speed, it is claimed, though not as fast as orthodox oars.

2. Arthur Piver's plastic blades on his dinghy, described in A.Y.R.S. No. 17 *Commercial Sail.* The aspect ratio was again low.

3. Julian Allen's " Rock and Roll " boats. The aspect ratio was better in these craft but again, no great merit was claimed. A.Y.R.S. No. 19 *Hydrofoil Craft.*

4. Several versions of " Flap foils " conjectured in A.Y.R.S. No. 2 *Hydrofoils.*

5. The Voith-Schneider propellor. This consisted of several high aspect ratio hydrofoils mounted on a disc which spun around



Vioth-Schneider Propellor.

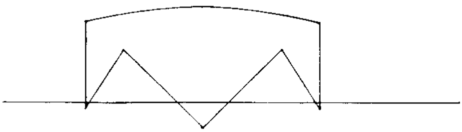
level with the stern planking of the hull. By twisting the hydrofoils on the disc, they drove the boat forward. Efficiencies greater than that of propellors were claimed for this system but it is vulnerable and was never widely used.

6. The three spinning hydrofoils of the early part of this section may be thought of as a means of propulsion.

Of all these five methods of marine drive, only the refined Uloh sculling oar but with a high aspect ratio blade and the three rotating foils appear to have any chance of a useful application.

TRIMARAN AND HYDROFOIL CRUISER DESIGN

The present trend in Trimaran Cruisers is to build out the cabin accommodation over the water, still keeping the narrow hull of the day sailer. This is a perfectly good arrangement, of course, but there is also a good case for flaring the topsides as in the sketch to give



Possible Trimaran Section.

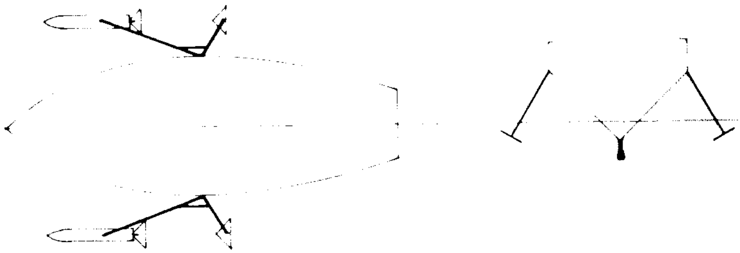
extra cabin room. This means that there has to be some ingenuity to design the fore and aft hull lines but the problems should be easy to solve. Arthur Piver tells me that the internal room of such a craft is excellent. The plan form shows the enormous deck space available.

The dimensions of the main hull shown here are as follows :

L.O.A.	24 ft.	Beam on L.W.L.	3 ft. 5 ins.
L.W.L.	22 ft.	Displacement	1 ton.
Beam	10 ft.	Headroom	6 ft. 3 ins.

As a trimaran, the total beam would be only 14 ft. 6 ins. or a build-out of only 2 ft. 3 ins. on each side. This would make a very nice craft. Let us, however, leave this matter to the designers and consider the hydrofoil cruiser.

Ballast. Not all of us are completely convinced of the safety of going offshore in a capsizeable craft of any sort which is not self righting. This concept therefore places the weight of the outrigger cross beams and floats in a ballast keel below the boat, giving a draught



Hook type hydrofoils.

of 3 ft. The outrigger cross beams and floats are surprisingly heavy and may amount to one third of the weight of the whole trimaran or even more in some cases. This gives us an adequate ballast ratio for sailing without any other form of stability whatever.

The Hydrofoils. The craft without hydrofoils is capable of sailing. The use of the hydrofoils, however, allows us to increase the sail area and will give us an upright ride. The type of foils favoured at the moment are the inverted T type and these may be set in any of the ways conjectured in this publication which prove their effectiveness on small boats. For the present purpose, we show a modified Hook system with a bullet shaped float.

The Foil Retraction. Nowadays, the only nasty thing which people can say about catamarans and outrigger craft is that they have a lot of beam. Yacht clubs, which are very pleased to welcome the 40 to 50 foot yacht with up to 15 ft. of beam, will refuse to allow a 16 foot catamaran with 8 foot of beam. This is simple prejudice. However, a hydrofoil craft such as is conjectured here would have to have retractable foils to avoid making holes in other craft below the waterline, while at moorings. It is I believe a legal fault to sail with a fisherman anchor awash for this reason and hydrofoils of this pattern should be retractable.

The right angled V hull section makes the hydrofoil retraction simple and easy and also provided ready made " legs " if the craft is to be kept in a tidal harbour. To retract the foils only means having them hinged at the top attachment and having some means of keeping the struts vertical.

Summary. A hull section is suggested for use on trimarans (and possibly catamarans), which gives extra accommodation. A hydrofoil cruiser with a ballasted main hull is conjectured which could have useful applications.

LETTER

Dear Sir

A.Y.R.S. members may remember my boat *Avocet*, described in publication No. 29, which uses inclined hydrofoil leeboards in each float of a trimaran configuration.

On the whole, the trials this summer have gone quite well. Deeper main foils, some 2 ft. 10 ins. below the bottoms of the floats were used and first trials with a horizontal foil 18 ins. by 6 ins. on the bottom of the rudder were carried out. Gooseneck type fittings on the rudder track were used to take the lift.

Originally, I planned to use variable incidence on the rudder foil, controlled by lifting the tiller in order to help in getting unstuck. This never really worked because of friction in the control system when sailing hard, which prevented the very rapid adjustment needed. As it turned out in the later trials, I rather feel that the whole speed of response of a foil-borne craft is so rapid (since lift disappears if you gain or lose 12 ins. in height) that the human brain is inadequate even with an ideal control system.

The subsequent tests were done with fixed incidence of the rudder foil, with fairly rapid adjustment of the angle so that tests at different angles could be done before conditions had changed. In one of the early runs, the incidence was set too high with most interesting and alarming results. After accelerating to quite a high speed, with dynamic lift beginning to appear, the stern lift suddenly took control. The consequent decrease of main foil incidence would then let the bows drop, with an enormous bow wave of solid water. The speed did not drop as much as one might expect and one could even get a horrible oscillation, (including some roll to confuse things) at about 1 cycle per second as the main foils and rudder foil won alternately. It was this high speed of oscillation which finally decided me against any controlled flying and made it clear that one must have an inherently pitch-stable system.

The obvious solution was to reduce the angle of incidence of the rudder foil, so that its proportional change of lift with incidence was a lot larger than for the main foils, as in aircraft.

Having done this, *Avocet* behaved extremely nicely over a wide range of wind speeds, though we never got her right up. Frequently, she would go along extremely fast with considerable dynamic lift as indicated by her waterline being about where it is at rest with no crew aboard, i.e. the foils were providing lift for a crew of two.

The limitations to getting right up seemed to be :

a) Insufficient lift far down so that in rough water the hull clearance was too small. This was aggravated by the fact that the dynamic roll stability of the present foil system is poor so that one tends to go along with the lee float just immersed with consequent drag in rough water.

b) Air entrainment often occurs in rough water. You can see long plumes of air streaming off the bottom of the lee foil and the lift is obviously much reduced.

c) The hull shape aft is probably not well suited to lifting clear. The transom often travels 1 or 2 inches out of the water (while normally it is immersed 1 inch) but the water is sucked up for the last 6 feet of hull and fills the gap. One should possibly have a more planing hull but there will then be difficulties in suiting the angle of incidence for best foil performance and for planing.

That was about all for this season except that as a general family and high speed boat, I think *Avocet* is very good. Sailing single-handed is great fun and we certainly had some very fast sails both with one and two up. I want now to try a modification of the main foils to give more deeply immersed lift and better dynamic stability i.e. more rapid increase in restoring forces with both angle of heel and angle of pitch.

Yours sincerely,

MARTIN RYLE,

5a Herschel Road, Cambridge.

AN ANEMOMETER FOR LOW WIND SPEEDS

BY OWEN DUMPLETON

The measurement of low wind speeds by ordinary methods is difficult as these either produce forces which vary as the square of the velocity or involve friction losses which increase as speed decreases. It is therefore of great value for yacht wind tunnels and amateur free-sailing tests to have a method of speed measurement which is more sensitive at low speeds than in the higher speed range. The anemometer described here has this characteristic and depends for its action on the rate of heat loss produced by the air flow over an electrically heated element whose electrical resistance varies with its temperature.

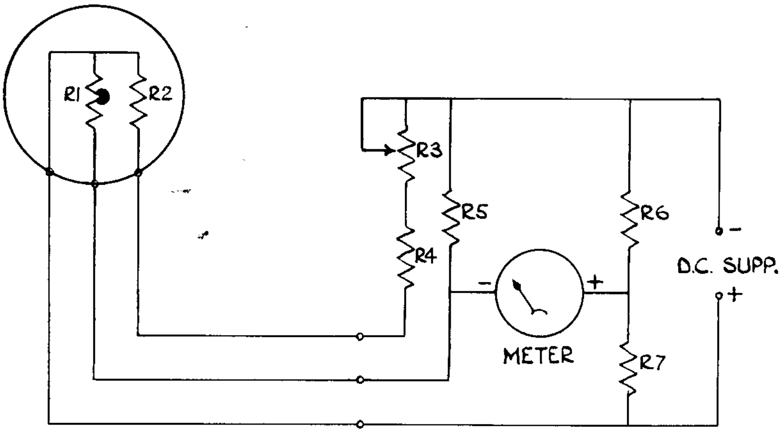


Fig. 1

Circuit Values for 12 v. D.C. supply:

R1 Thermistor, Brimar type CZ 10.
R2 Heater wound on R1, 20 Ohms.
R3 10 Ohms linear variable, 2 Watts.
R4 22 Ohms vitreous, 2 Watts.
R5 1000 Ohms 5%, $\frac{1}{4}$ Watt.
R6 47000 Ohms, 5%, $\frac{1}{4}$ Watt.
R7 4700 Ohms, 5%, $\frac{1}{4}$ Watt.

Circuit. The thermistor is a temperature-variable resistor with a cold resistance of about 8000 Ohms. It is heated by a winding of fine gauge resistance wire (R2) until it reaches a temperature, in still air, such that its resistance drops to 100 Ohms. R3 is adjusted to obtain this condition. R1 and R5 constitute the top half of a bridge type circuit, and R7 and R6 form the bottom half. In still air, therefore, the meter current is zero when R3 has been correctly adjusted (i.e. R1/R5 = R7/R6). When a current of air flows past the element, heat is carried away by convection and the resistance of R1 increases. The bridge is now unbalanced and a current flows through the meter.

Calibration. The sensing head was moved through still air at known speeds by swinging it round on the end of its wire. Fig. 3 shows the meter readings obtained at various speeds. The operating temperature of the element is always well above that of the surrounding air, and the circuit values are so chosen that the meter goes off scale before the temperature drops so far that small variations in ambient temperature become important.

Construction. The element is mounted between two Perspex discs, each 1.4 inch in diameter and 0.05 inch thick. The distance

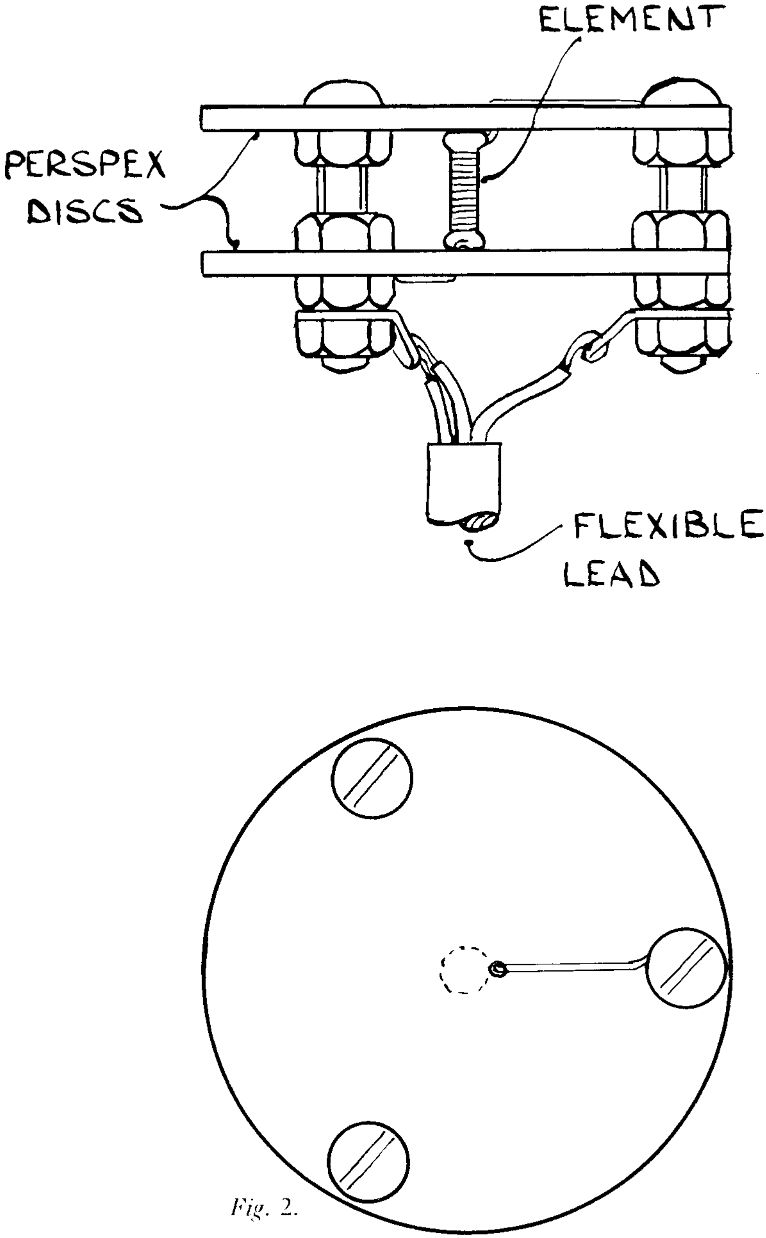


Fig. 2.

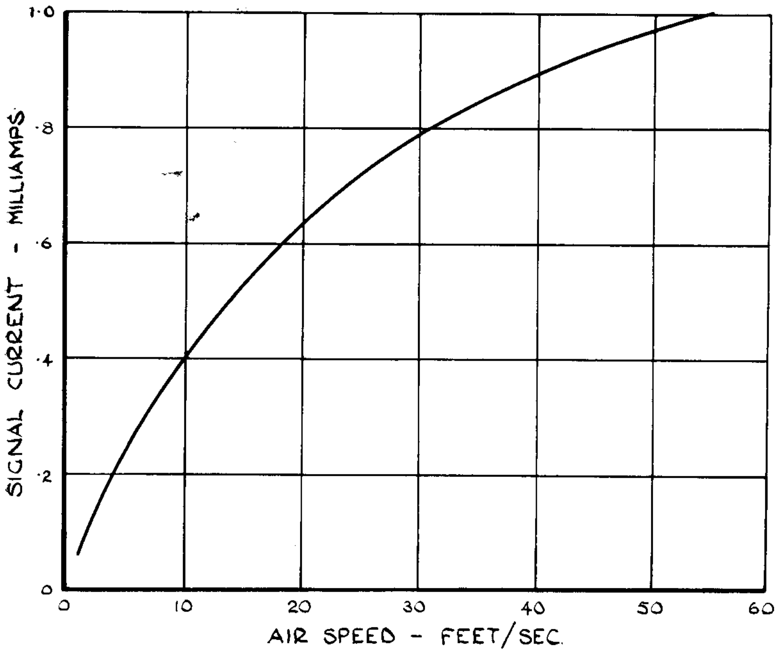


Fig. 3.

between the discs is fixed at 0.3 inch by means of three screws, each 6.BA brass. These screws also serve as electrical terminals.

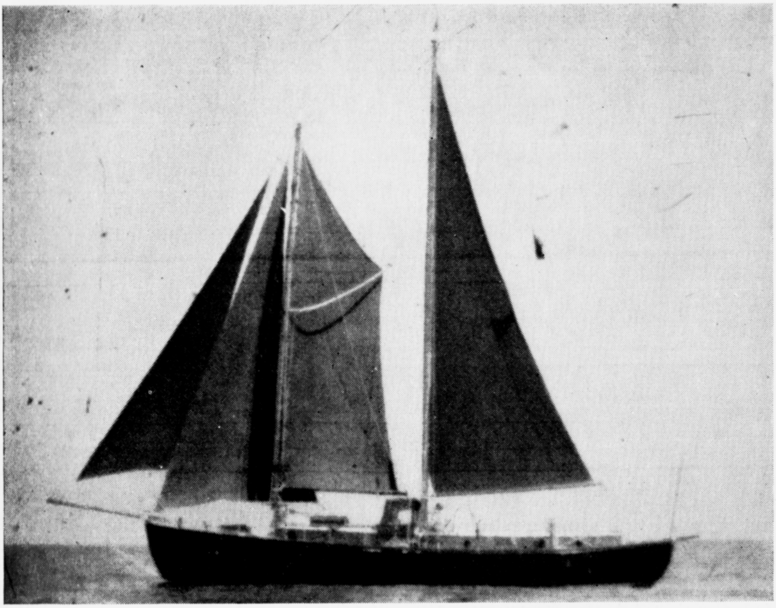
For some free-sailing measurements of the air speeds around the sails of a schooner described in the following article, the instrument was hoisted in the rigging by means of a small nylon span and a normal halliard, being held down by its electric cable.

Reference :—H. L. Penman & I. Long (Rothamsted Exp. Station) " A Portable Thermistor Bridge for Micro-Meteorology among Growing Crops " *Journal of Scientific Instruments and of Physics in Industry.* Vol. 26, No. 3 March 1949.

THE " GARLAND " TESTS

By Owen Dumpleton

In the issue of *Light Craft* dated March, 1958, John Morwood accused me of being an " armchair guesser " about wind velocities around sails. This jibe stung, because it was true, so I prepared to do a little research (amateur) on the subject.



Garland.

Ed : With the exception of the Warner and Ober paper (J.A.N.A. & M.E.) no one to my knowledge has done work of this kind. We were all therefore more or less " Armchair guessers." Frits Fenger and doubtless others have used anemometers in their rigging but the results have not been published. Also, their anemometers were nothing like as valuable as the one used by Owen.

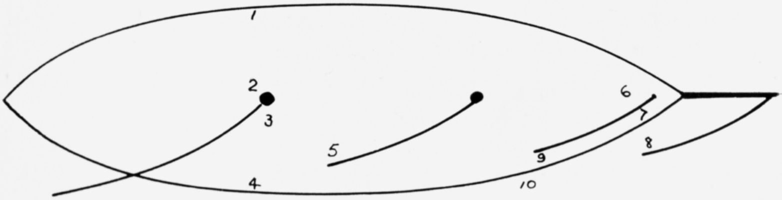


Fig. 1.

Another member of the A.Y.R.S., Mr. B. E. A. Vigers provided facilities aboard his schooner, and I made up the small portable anemometer described previously. Measurements of wind speed were taken some 15 feet above the deck at the points shown in Fig. 1, with the results shown in Table I.

TABLE I.

Reading Group	Course from wind Points	Wind speeds in feet per second. The numbers give the positions of Fig. 1. 1	2	3	4	5	6	7	8	9	10
1	6	11	9	14	18	13					
2	6	9	9	14	14	12					
3	4	7	8	12	12	11	9		14		
4	4	14	14	18	18	18	10		16		
5	4							10	18	18	18

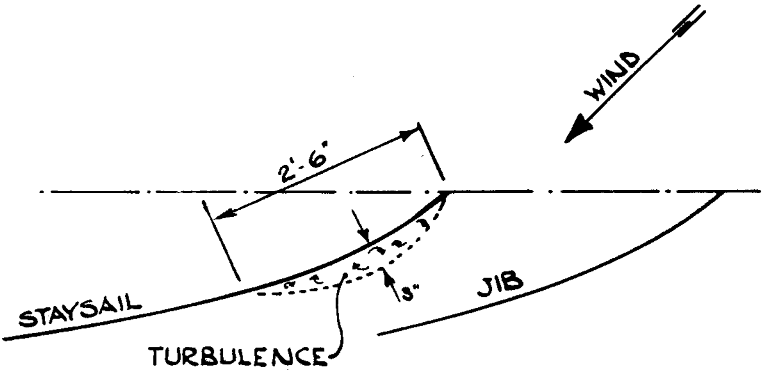


Fig. 2.

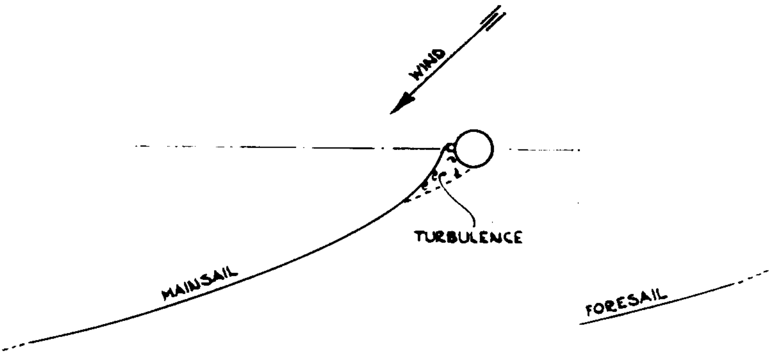


Fig. 3.

Point 7 in group 5 seemed to be inconsistent, so a further detailed exploration was done in that area, with the result shown in Fig. 2. There was an eddy on the lee side of the luff, which could not be seen by observing the sail itself, but which contained a well defined reverse flow area, such as one sometimes hears of as a " mast eddy." A comparison was made with conditions just to leeward of the main mast, but the eddy there was distinctly smaller than that found on the staysail (Fig. 3).

Summary of Results. 1. The wind speed to lee of the main sail is some 140 per cent. to 150 per cent. of that to weather. This effect is fairly constant from a few inches to several feet away from the sail. Only the close hauled and slightly free conditions were investigated.

2. The mast eddy on the lee luff of the main is not much bigger than the mast itself in the 8 to 10 knots apparent wind.

3. There is an eddy just to lee of the fore-staysail luff, which is some 3 feet across and 4 or 5 inches thick at its mid point i.e., the eddy is not a " mast eddy " at all and is actually several times bigger in the absence of a mast. We tried the effect of adjusting the jib sheets. The eddy then became smaller as the sheets were eased but, by the time it had been reduced to a size comparable to the main sail luff eddy, the jib was obviously setting very badly.

4. The speed to lee of the staysail is some 150 per cent. that to weather when the jib appears well set but can be reduced to a value below the weather side speed by sheeting in the jib too hard.

5. An exploration was done with a light steamer to determine the stagnation point of the air approaching the main. This was found to be well towards the fore side of the mast. There was no evidence for thinking that a stagnation point occurs anywhere on the sail itself.

6. The wind gradient in the Solent is very small, being only about 5 per cent. greater at 50 feet up than at 6 feet above the deck. The following readings were taken up the mast clear to weather :

Height from deck :	5 ft.	10 ft.	15 ft.	25 ft.	40 ft.
Wind speed, ft/sec.	9	10	10	11	11

Conclusion. The first conclusion from the figures in Table I is that the Bernouilli effect which was the subject of the letter in *Light Craft* is more important than I had thought but less important than John had thought. Much more theorising could doubtless be done on these results, but I would prefer to leave this to other A.Y.R.S. members.

Thanks are due to Mr. Vigers for the use of *Garland*.

TECHNIQUES FOR HANDLING TOWING TANK DATA

By Edmond Bruce,

Lewis Cove, Hance Road, Fair Haven, N.J., U.S.A.

In A.Y.R.S. Publication No. 30, the writer described a laminar flow type of model testing tank which he has employed successfully for a number of years. Measured data for the model, used as an example was presented by plotting the resistance-to-weight ratio in per cent., R/W, versus the ratio of speed in knots over the square root of the water-line length in feet, $V/\sqrt{L}$.

The described form of plotting data is the time honoured method proposed by William Froude nearly a century ago. It was intended for the purpose of " scaling " the model to the full size boat. This was done, for pressure resistances, by holding the ratio $V/\sqrt{L}$ constant. For example, if the boat had a length 16 times that of the model, the appropriate " corresponding speed " should be 4 times that of the model.

Since model and boat are identical in relative shape, the ratios Velocity / $\sqrt{\text{Beam}}$ or Velocity / $\sqrt{\text{Draft}}$ would be equally correct for scaling. Since length, beam and draft are all proportional to $\sqrt[3]{\text{Weight}}$, for similar shapes, the ratio Velocity / $\sqrt[6]{\text{Weight}}$ is also correct for scaling.

One sometimes sees data for differently shaped models plotted as R/W versus $V / \sqrt{L}$ and the curves used as comparisons of their merit. Such comparisons may be positively dangerous and misleading in the opinion of the writer. I wish to warn the membership of A.Y.R.S. against this procedure by a demonstration of examples. I will also propose a method which is believed to be more accurate, for comparisons, and yet simple.

Between two differently shaped models of identical weight and having the same driving force, certainly the faster model is the better, under these conditions, regardless of the linear dimensions. Use of the ratio $V / \sqrt{L}$ appreciably penalizes length as will be demonstrated later. For a given design, there is always an optimum length for a stated speed.

The ratio $V / \sqrt{B}$ has been proposed for " buried chine " planing boats but it is not attractive for other planing types and in all cases it unjustly penalizes beam. $V / \sqrt{D}$ likewise penalizes draft. None of these penalties is desirable. Among the scaling ratios mentioned, the use of $V / \sqrt[6]{W}$ would be the best for model comparisons. For extreme accuracy, this ratio with equal weight models would be perfection.

Undoubtedly, Froude selected $V/\sqrt{L}$ as his scaling factor because full-bodies displacement hulls encounter a resistance barrier when the water-line length of the hull equals the length of the surface wave generated in the water. This occurs when $V/\sqrt{L} = 1.34$. This no longer concerns us at the higher speeds of catamarans, of planers, etc. or at the very low speeds of any hull. It is my recommendation that the speed-weight ratio $V/\sqrt[6]{W}$ be used for comparisons and for scaling. It is particularly advantageous for planers where the wetted dimensions can change rapidly with speed.

I will illustrate the above contentions by test data on two totally submerged, cigar-shaped models which were internally ballasted so as to just neutralize their buoyancy. These models were equipped with tail horizontal and vertical stabilizing planes to avoid the type of flutter seen in flags. These examples were chosen to emphasize my point. It becomes more apparent since masking by surface wave formation is avoided through submersion. However, frictional resistances of submerged models are somewhat greater than good forms, of equal weight, operating at the water surface.

The submarines, under discussion, have equal volumes and ballast. Model A is short and fat with a length-to-beam ratio of 3.0. Model D is much longer and more slender with a length-to-beam ratio of 13.7. Both have nearly equal frictional resistances at all speeds since the increase in wetted surface with length is nearly compensated for by the decrease in the laminar frictional coefficient with length. Therefore, the variation in model total resistances at various speeds is due almost entirely to pressure resistance variations.

Let us examine the attached sketches. Fig. I shows the speed in ft. per second of these two models of equal weight versus R/W in per cent. Model D is definitely faster than Model A, boat against boat.

Fig. 2 is a corresponding plot but speed is now indicated by $V/\sqrt{L}$ which is proper for scaling but is a handicap to length. Now we find the comparative situation completely reversed. Model A appears to be faster.

In Fig. 3, the data is plotted as a function of the speed-displacement ratio $V/\sqrt[6]{W}$ and is the form preferred by the writer. These curves are completely correct for pressure resistance scaling and also are quite accurate for comparison of performance where the weight difference between models is not too great. As mentioned previously, equal weight models will result in perfect comparisons.

Towing tank workers sometime prefer having data in the form of "dimensionless coefficients." The advantages of this are greater

Submarine Models with Tail Stabilizers and No Buoyancy.

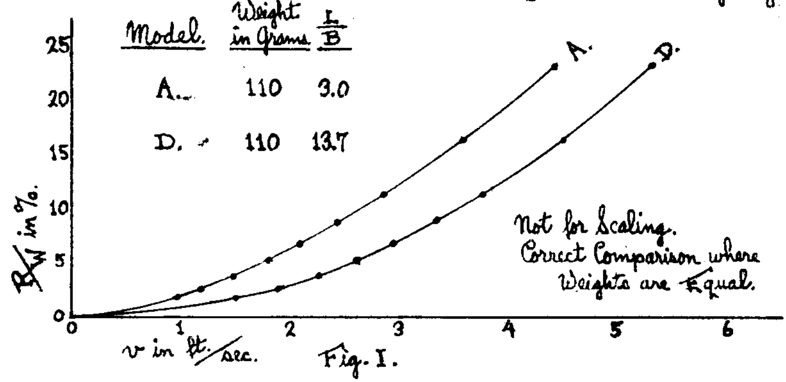


Fig. I.

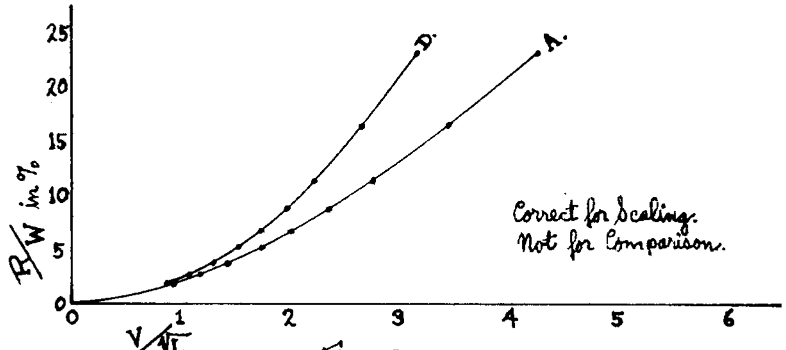


Fig. II.

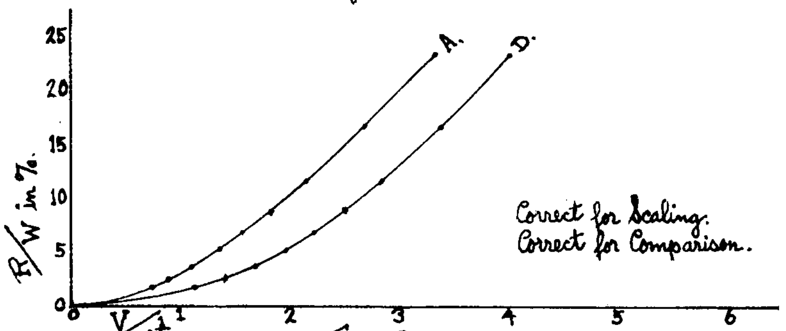


Fig. III.

sensitivity and numerical comparisons. Let us examine some of these possibilities.

The curves in Fig. 1, 2 and 3 are approximately square law with speed. These agree with Newton's equation of fluid resistance. The rising steepness of such curves washes out the detail of small variations which may be of interest. The basic equation,

$$R = C \cdot \frac{\rho}{2} \cdot S \cdot v^2$$

can represent our data if C is not a constant but a coefficient which is sensitive to variations which we may wish to analyze. Thus,

$$C = \frac{R}{\frac{\rho}{2} \cdot S \cdot v^2}$$

is quite often used. In this equation,

R is the resistance in pounds.

S is the wetted surface in square feet.

v is the velocity in feet per second.

ρ is the fluid density in slugs per cubic foot.

The previous equation is not satisfactory for fast planers since the dynamic wetted area becomes very small and the static wetted area is meaningless. Also weight, which is equivalent to displacement volume, at low speeds, is not mentioned. Coefficient comparisons for fast boats can be made much better on the basis of weight. Fortunately, the surface area S is proportional to $W^{2/3}$ so we can write,

$$C = k \frac{R}{W^{2/3} \cdot V^2} \quad \text{where V is in knots.}$$

This can become :

$$C_T = C_P + C_F = \frac{R_T / W \text{ in } \%}{(V / W^{1/6})^2}$$

Thus the numerator and denominator include the coordinates used in Fig. 3 and can be calculated from that data.

The total resistance coefficient C_T versus $V/W^{1/6}$ is plotted in Fig. 4 for models A and D. C_F, the frictional resistance coefficient and C_P, the pressure resistance coefficient are shown also. These were obtained from separate skin tests.

The pressure coefficient for model A is much greater than its friction coefficient which indicates less cross-section and more length is advisable. The falling pressure coefficient with speed, for model A, is present because some models at speed tend to carry wedges of water fore and aft which improve their stream-line shape. This can be seen by sparingly placing powdered rosin in the water and mixing well.

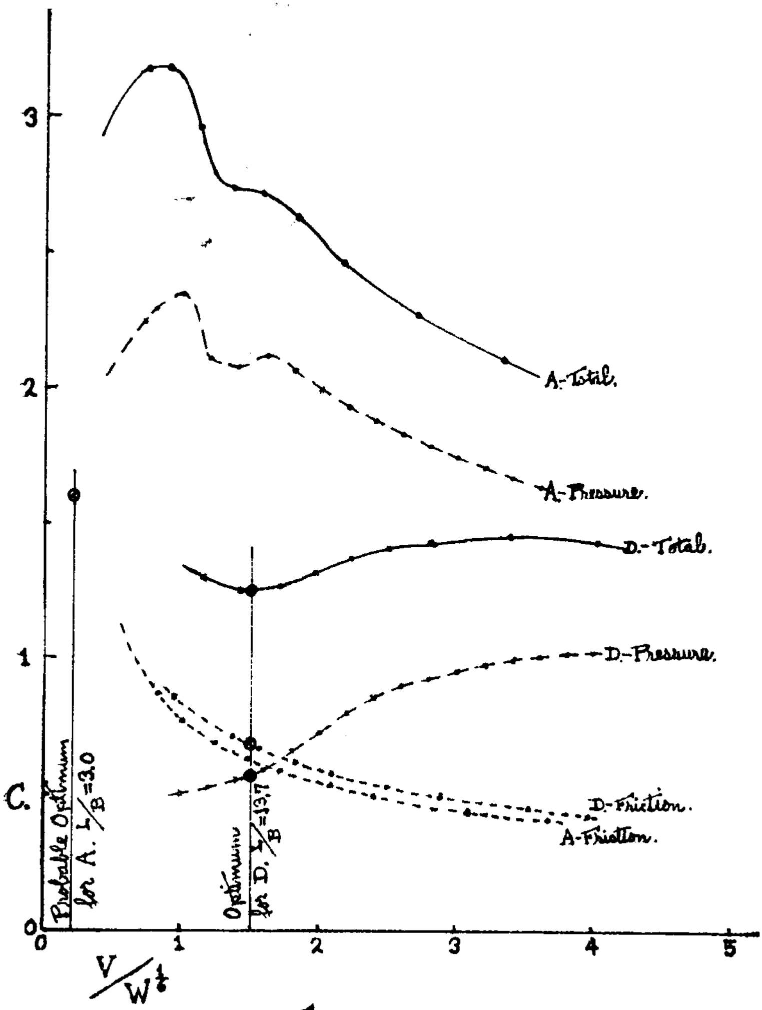


Fig. IV.

The curves for model D are of great interest. Note that its total coefficient is at a minimum at a speed-displacement ratio of about 1.5. This is undoubtedly this model's optimum speed. Also note that the negative rate of change of the frictional coefficient is just equal to the positive rate of change of the pressure coefficient at this speed. While the coefficients are nearly equal, I believe it is these complementary rates of change that are the criterion. This probably occurs also for model A at lower speed than was measured, an estimate of which is marked in Fig. 4.

These related conditions exist in all my best models whether they are displacement types, planers, or any other type. It is the best method of boat data analysis of which I am aware. Such an intimate insight is lost if one deals only with the steep curves of the type shown in Fig. 3.

Again I wish to emphasize that the determination of the lateral lift-drag ratio in windward tests of sailing craft is highly important. This was explained and discussed in my article in A.Y.R.S. Publication No. 30. I consider this to be the field in which the greatest advances in sailing craft may come in the near future. "America Cup" designers take notice !

Dear Sir,

Your letter of 11-4-60 poses questions that have interested me for some time. I try constantly to make step-by-step experimental checks as guides to my theoretical endeavours to avoid bad assumptions. The worst "scientific" assumption I ever heard of was that of an "ideal" fluid without viscosity of which so much classical hydrodynamics is based. It wasted years of effort of many able mathematicians who were not experimenters.

I once assumed that, for a fixed displacement, a hemisphere might have least frictional resistance at low speed. I could not check this experimentally. I finally obtained agreement between theory and experiment on the following basis :

As one stretches a hemispherical shape into a hemi-ellipsoid, holding the displacement constant, the rate of increase in surface area is less than the decrease in the frictional coefficient with increasing length within the initial range. Thus a slightly elongated form has minimum frictional resistance. The need for stream-lining comes from pressures.

For a given speed, an optimum cross-section balances the pressure resistance against the frictional resistance and minimizes their total. I have written up separately in an attached section how this was measured in case it is worthy of publication. You may decide it is unorthodox and too technical although I have attempted to minimize the mathematics even though it is elementary.

Incidently, pressure resistance is normal to an elementary surface area and frictional resistance is tangential. This is all one requires.

As to " Mach " angles, if a stick is placed vertically in water and moved slowly horizontally, ripples appear always ahead of the disturbance. Gravity waves always follow the disturbance. They obey very different laws. Ripples have an almost constant speed of propagation, therefore the classical " Mach " angles and velocities appear. The angle becomes smaller with speed. Individual gravity waves advance at the speed of disturbance with a pattern which is due to wave interference and " Mach " angles, as ordinarily defined, do not appear.

Empirically, the fore-and-aft location of the maximum beam seems best in my models when adjacent to the first depression in the gravity waves alongside. Without other evidence, I am of the opinion that it is the " constant cross-sectional area rule " of super-sonic aerodynamics trying to work.

Submarines and fish always require their maximum beam forward of amidships because there are no gravity waves which only appear on the water's surface. It is these surface waves which force departures from the true stream-line shape. For surface vessels I believe the following :

At low speeds, buoyancy produces marvellous lift-drag ratios or in other words weight-resistance ratios. These ratios drop off with increasing speed. Planing can never help us until this ratio drop to at least 10. When a catamaran or any other displacement craft falls much below this ratio, it had better convert to planing to improve performance. This may be the reason for the desirability of flattening aft at high speed. First the rounded chine is best since it makes less fuss struggling through the transition range to full planing, where the sharp chine boat is miserable. Full dynamic planing without appreciable buoyancy is necessary to make the sharp chine boat desirable.

Upward curvatures aft cause suction. This can be detected in displacement models at low speed since their centre of buoyancy is not vertically aligned with their centre of gravity. Making the sum of the moments equal zero also reveals the location of the suction. Even slow displacement boats benefit by straight " runs " aft. Squatting often adds wetted area aft but reduces it forward resulting in little change in area where dynamic lift is absent. Compensation also seems to occur between the crests and hollows of the waves alongside. My opinion was formed through the fact that the M.I.T. tank uses change in wetted area obtained through analyses of photographs to determine where the inseption of dynamic lift sets in.

I hesitate to be specific about the speed ranges where the various transitions take place in my models. Such things as a means of reducing friction per unit area could upset the entire spectrum. Also, I do not have faith in expressing this in terms of Froude's scaling ratio although I resorted to this in my A.Y.R.S. article to avoid complicated explanations. Possibly the resistance-to-weight ratio would be better once one got used to it. Such a ratio reveals that a full bodied boat should resort to planing at lower speeds than would be desirable in catamarans. Other examples could be cited.

A TEST PLATE FOR SAILS AND HULLS

By Dr. G. F. van der Wal

Praedimussingel 13, Groningen, Holland.

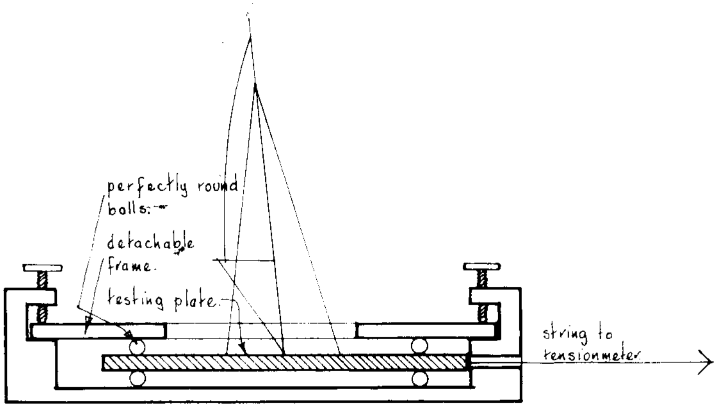
This system was suggested to me by a sailing friend who is an engineer. The testing plate (hatched in the sketches) is shut up between two fixed horizontal plates by means of six steel balls, three below and three above, each set of three being arranged in an equilateral triangle. The important point of this system is that it guarantees *free* movement in the horizontal plane and excludes all other movements. It would, of course work equally well for the testing of hulls and keels as for sails.

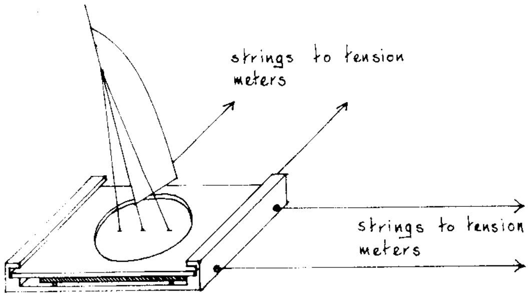
In the testing of sails, the covering plate must have an opening large enough to permit the mast, sail and rigging to pass through.

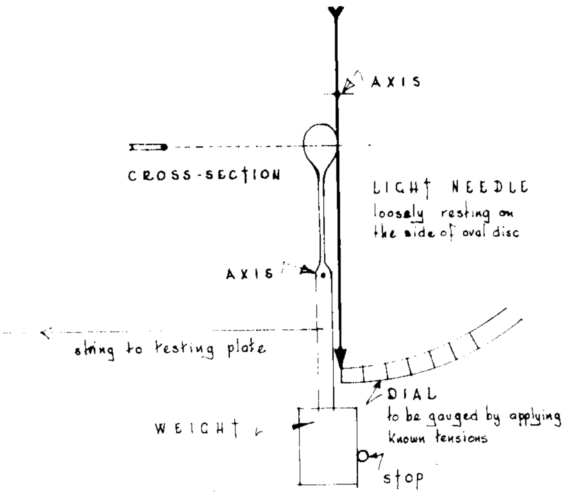
The system for measuring the tensions has to meet the requirements that it must be sensitive and accurate, yet must not allow more than very slight movement and rotation of the model. Perhaps there are on the market excellent instruments for this purpose. If not, we can help ourselves as follows :

1. Before starting the test, we must load our not too perfect tension meters to a value slightly smaller than the values to be expected. So we need some gadget or other which enables us to shorten the strings at will.

2. We should try to make a good guess at the position of the Centre of Effort of the model. Either by altering the position of the model or by altering the position of the strings, we should try to make the vertical projection of the Centre of Effort equidistant from two parallel strings.


perfectly round balls.
detachable frame.
testing plate.
string to tensionmeter


strings to tension meters
strings to tension meters


AXIS
CROSS-SECTION
LIGHT NEEDLE
loosely resting on the side of oval disc
AXIS
string to testing plate
DIAL
to be gauged by applying known tensions
WEIGHT
stop

3. In this, we shall seldom succeed completely. Therefore, we should make the distance between two parallel strings as great as reasonably possible. The greater this distance, the smaller the rotation.

4. The strings should also be as long as is reasonably possible. The longer they are, the smaller is their departure from the correct direction both horizontally and perpendicularly to the side of the test plate.

5. After a test, we should be able to reproduce the exact position of the model during the test. A good way of doing this might be to have adjusting screws perforating two sides of the case ; one screw near the end of each string. By turning these screws, they would be made to press against the sides of the test plate. By adjusting them until each tension meter indicated the tensions read during the test, the exact position of the test plate during the test would be reproduced, providing that the string had not shrunk or stretched since that time.

TESTS OF MODEL SAILS IN A SMALL WIND TUNNEL

By R. J. Harrington Hudson, M.Eng. A.I.N.A.

Rosemary Cottage, Galmpton, S. Devon.

The tunnel is provided with a 24 inch diameter fan, Fig. 1, and a working chamber in which a graduated turn-table is mounted. This turn-table, with a trough in the centre, carries the model and the instruments for recording lateral and vertical forces on the model sails, shown in Fig. 2.

Six forces are recorded :

(a) Lateral forces at bow and stern,
(b) Lateral force at mast head,
(c) Forward thrust at bow on centre line of model,
(d) Vertical forces, depression at bow and depression or lift at stern.

All horizontal forces are measured with simple bell-crank levers accurately balanced. For recording the lateral force (b), at the mast head one of the bell-crank levers is mounted on an arm the same height as the mast. This arm may be set to any desired angle of heel and always remains parallel to the mast. The four bell-crank lever gauges are connected to the model by light struts. Vertical forces, (d), are measured by suspending the model at bow and stern from the ends of balance arms, seen in Fig. 2. Lateral and vertical forces are *weighed* by inserting shot in the six weighing pans and, in Fig. 2, a small

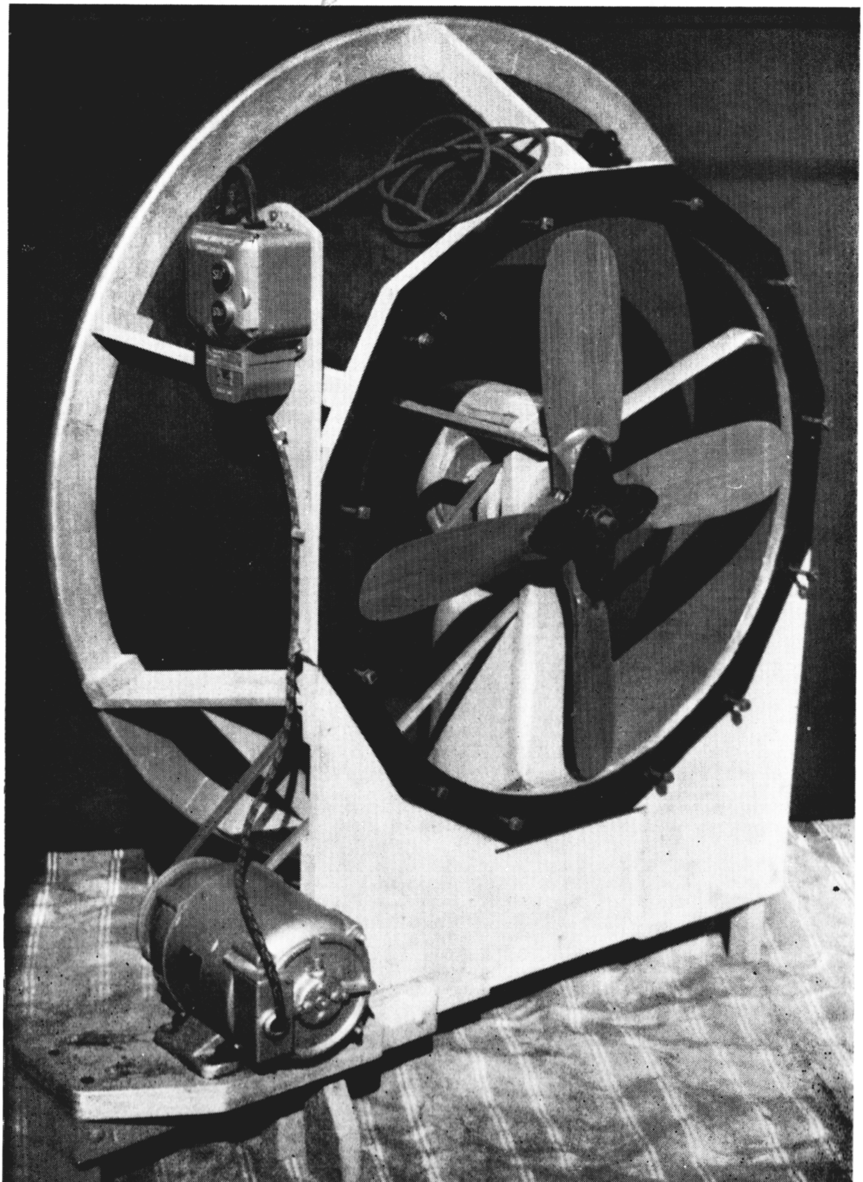


Fig. 1.

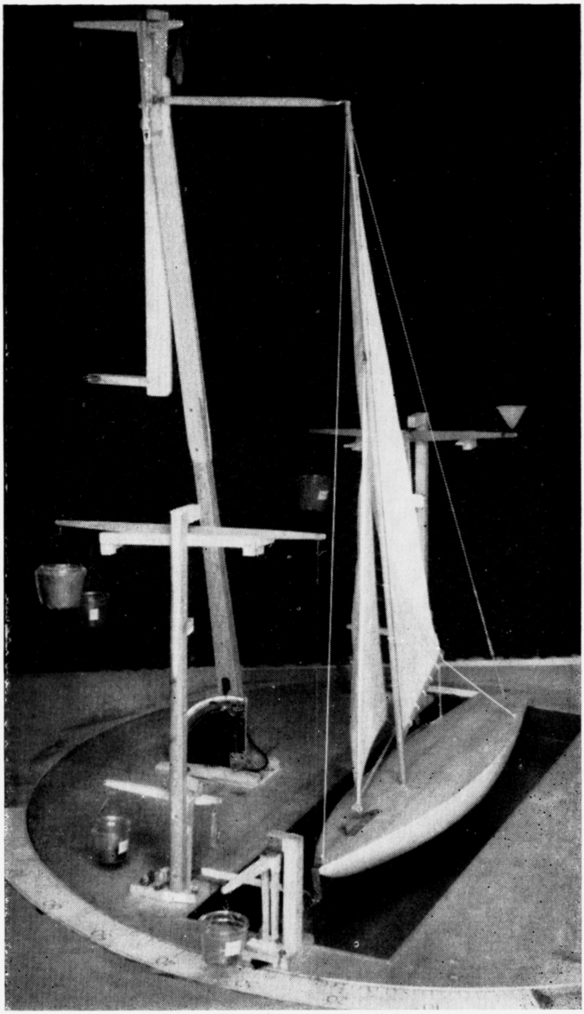
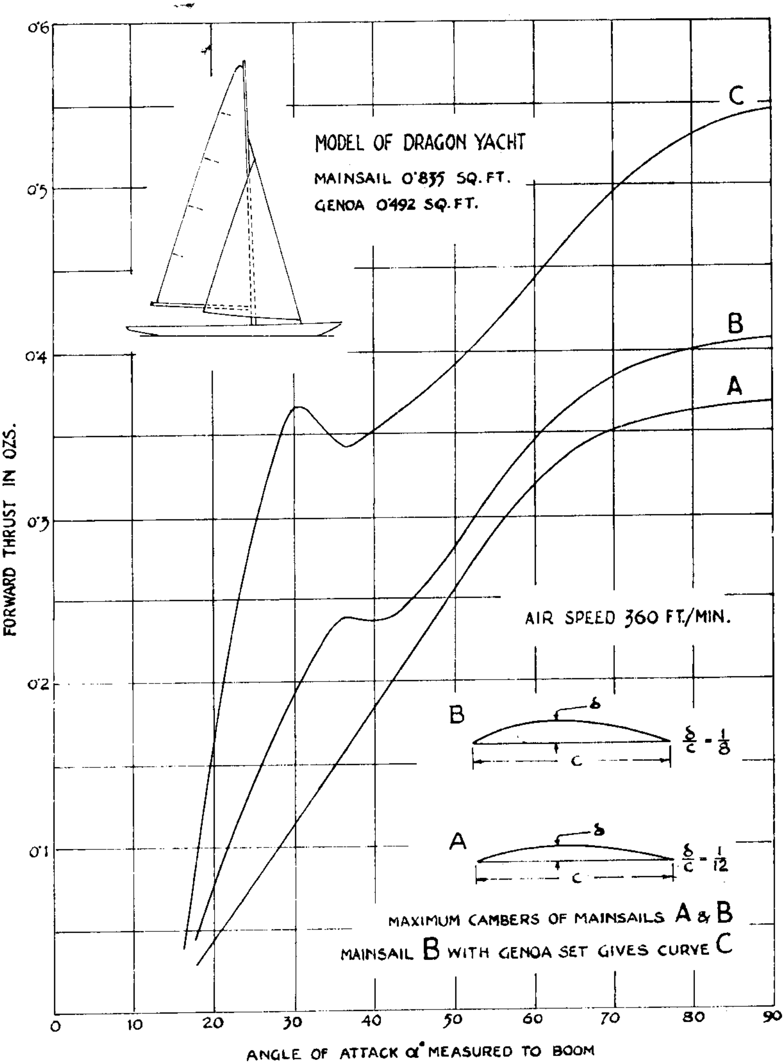


Fig. 2.

auxiliary weighing pan may be seen, directly over the stern suspension, used when it is required to record *lift* of stern. All gauges are mounted on the leeward side of the model.

The instrument used to measure wind velocities in the tunnel is a Short and Mason anemometer.

In order that the small scale sails may take up as nearly as possible the same sail-form in camber and set as the full size sails under similar conditions of sheeting and angle of apparent wind, it was considered that an identical model of the yacht, with sails and stability scaled down accurately, should be made to heel in the wind tunnel to the same angle as the full size yacht under similar conditions. The



airstream in the wind tunnel is accordingly regulated by a consideration of this scaled down stability and heeling moment.

A scale model of a Dragon class yacht was used with sails made to accurate dimensions by a leading model-yacht sailmaker. The curves in Fig. 3 show the results of testing two mainsails alone, each 0.835 sq. ft. Mainsail *A* cut flat with maximum camber 1/12 and mainsail *B* cut full, maximum camber 1/8. The Genoa, area 0.492 sq. ft., may be regarded as a normal cut. The close hauled sheeting of the two mainsails and of the mainsail and Genoa remained untouched throughout the tests. The curves indicate some interesting points :

(1) The superiority of mainsail *B* over mainsail *A*, especially up to $\alpha = 35°$.

(2) The complete absence of stall in mainsail *A*.

(3) Stall occurring at about $\alpha = 35°$ in mainsail *B*.

(4) When the genoa is set with mainsail *B* the stalling effect is increased and occurs about 5° earlier, i.e. when $\alpha = 30°$ and the forward thrust or drive is nearly doubled.

The effect of altering the position of the fore tack on this scale model Dragon yacht has been investigated. The model was heeled to 20° throughout the test and wind speed regulated in the tunnel by a consideration of scaled down stability to represent the full size Dragon yacht heeled to the same angle under similar conditions. Positions were fixed along the fore deck, Fig. 4, the first, *O*, corresponding to point 50 ins. forward of the mast, each position progressing forward by 6 ins. to the final position, 6, which is 86 ins. forward of the mast. The genoa tack was then moved, step by step, from the position *O* to position 6 and the forward drive measured for each position as the angle of apparent wind varied from 30° to 60°. The main sheet remained close hauled with boom at 5° throughout the test and special gear was used to maintain exactly the same sheeting of the genoa when the tack was moved. The curves seem to indicate that :

(1) When sailing close hauled the most efficient position of the genoa tack lies between 4 and 6.

(2) When slightly off the wind, the most efficient position comes inboard, between 3 and 4.

It may be noted that the designed position of the fore tack on the Dragon plans lies approximately at 3.

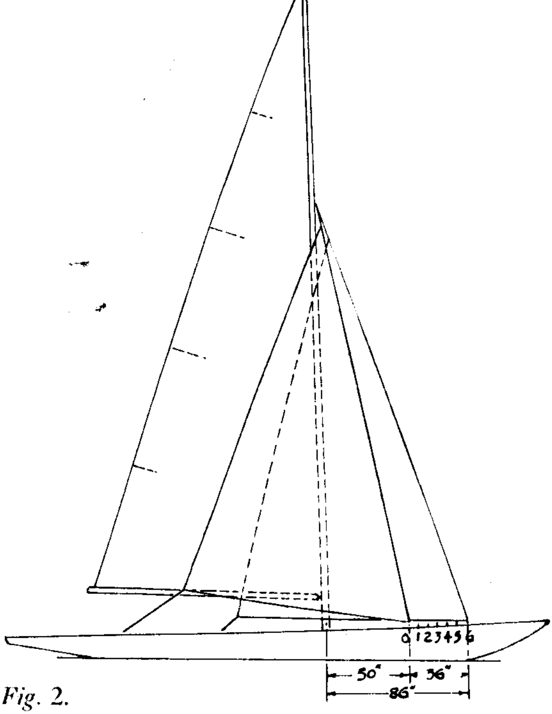
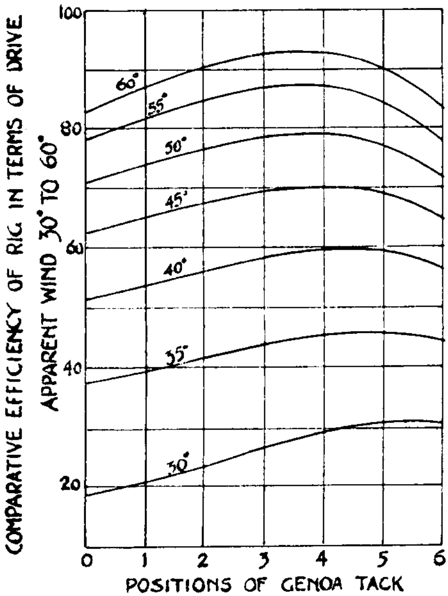

0 1 2 3 4 5 6
50"
36"
86"

Fig. 2.


COMPARATIVE EFFICIENCY OF RIG IN TERMS OF DRIVE
APPARENT WIND 30° TO 60°
100
80
60
40
20
60°
55°
50°
45°
40°
35°
30°
0 1 2 3 4 5 6
POSITIONS OF GENOA TACK

The limitations of a small scale wind tunnel, even with accurate gauges, are fully realised and it seems likely that tests should be confined mainly to obtaining comparative results or information regarding the characteristics of a sail which may lead to larger scale or, better still, full size tests. These full size tests, when compared with the tunnel tests, might also determine the correction factor for scale effect in relation to the density of the air. In spite of the limitations it is thought that the simplicity and the wide variety of tests which may be carried out at low cost make these small scale wind tunnel tests on sails worth while.

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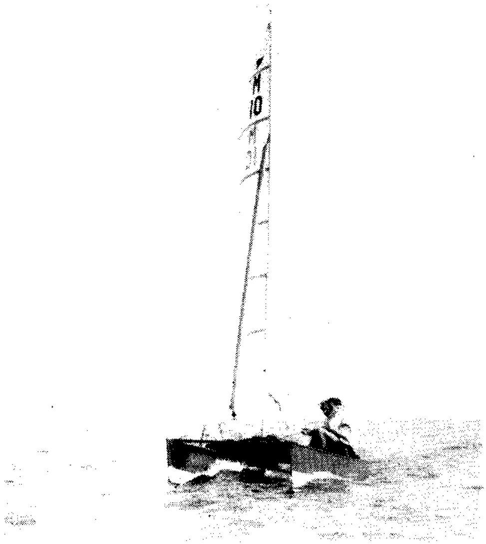

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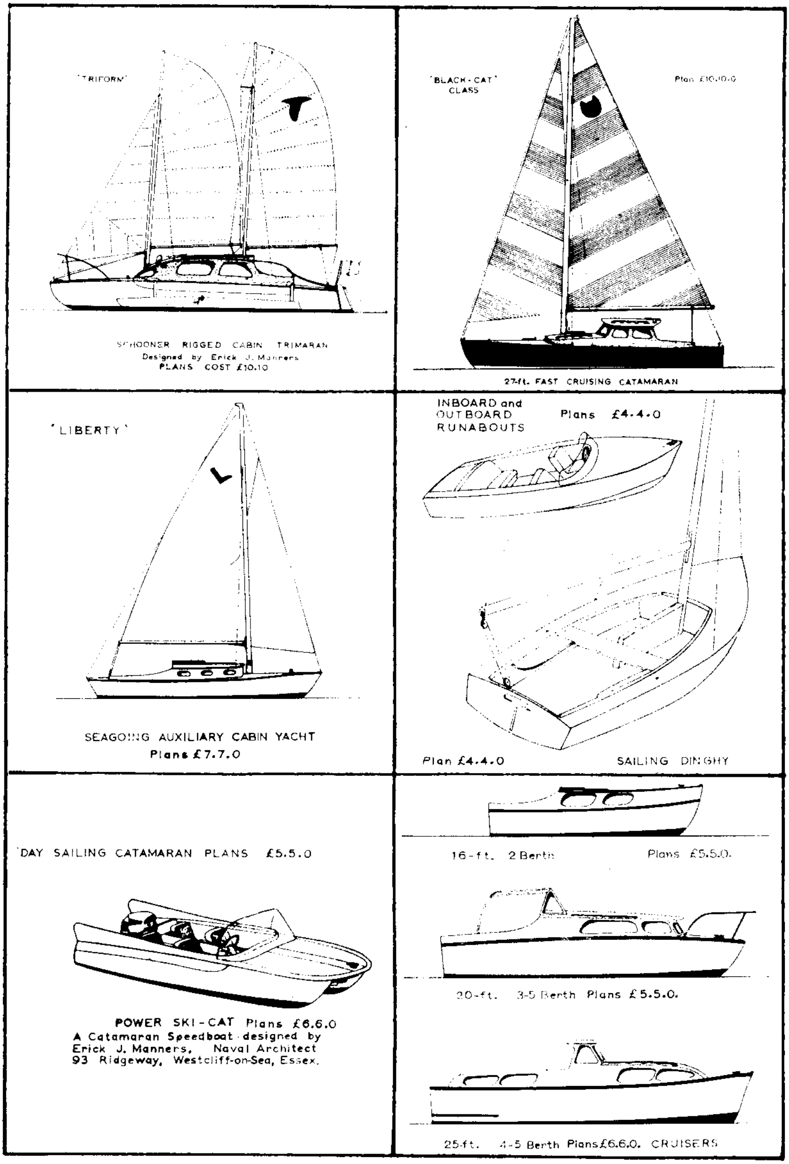

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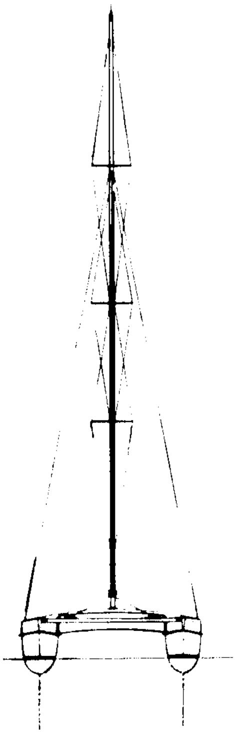

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by Robert Harris

(Naval Architect)

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