SAILING HYDROFOILS

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Dave Keiper's "WILLIWAW"

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EDITORIAL

by John Morwood

October, 1970

In 1955, when the AYRS was formed, the members were given a challenge. They were told that people had sailed their boats off the water, being lifted by underwater "wings," called "hydrofoils." We showed them photographs of the Baker hydrofoils "flying." We also told them that it was possible to stabilise a single, narrow hull with hydrofoils and again showed photographs.

This book shows how our ingenious members took up this challenge. Year after year, members tried way after way of getting their boats to fly or, where stabilisers were wanted, we had examples of non-heeling sailing craft. Slowly, the design principles were worked out and the construction improved until we now have the interesting craft shown in our closing pages.

At this moment in time, we can hardly say that the hydrofoil boats which our members have produced have shown any vast improvement in speed over more conventional boats. The racing catamaran, for example, at present seems to be faster without hydrofoils than with them, even though flying. However, time will undoubtedly show still more improvement in hydrofoils in speed and, as stabilisers.

Reading over the material in this book, one is amazed by the collective inventiveness of our members. They will try *anything* and usually make it work somehow. We have every kind of inventor from the slap-happy type (such as the Editor) to the careful one who works out the principals and theory in detail, tanks tests his idea, makes his boat with loving care and sails it—*and all Amateurs.*

This book is a tribute to our members, showing them at their best in producing sailing boats which will give great pleasure to yachtsmen in the years to come.

AYRS sailing hydrofoil group

By the time of this publication, this Group, within the AYRS, will have had its first meeting, but it is hoped that any further members who may be interested will make contact. The purpose of the Group is to exchange knowledge on all aspects of the subject, to plan and hold at least one foil-sailing meeting each year, and possibly to combine in some of the more ambitious foil-sailing developments. Could anyone in any country who is interested, contact James Grogono for information at 38, New Road, London, E.1.

"Sailing on hydrofoils"

Early next year Kalerghi Publications are bringing out a hard-back foil-sailing volume with a wide coverage of the whole subject. The main contributors are Dr. Alan Alexander (on theory), Don Nigg (foil-sailing development in the USA) and James Grogono (current problems and applications). Many of the best foil-sailing photographs have been assembled for this volume, and the Editor (James Grogono, 38, New Road, London, E.1) would be interested to hear from any potential contributor or foil sailor who has material for consideration, in particular any photographs of so far 'unknown' foil-boats.

The Amateur Yacht Research Society

Some people who buy this book will not previously have heard of the AYRS so it is worthwhile saying something about us.

We are a Society of people who either individually or in groups of two or three, try experiments with boats or make studies of yachting performance. We do it for our own pleasure and satisfaction.

It is a World Wide organisation with members in nearly every country. If therefore, anyone makes an experiment anywhere in the World, whether he is a member or not, we hear about it and publish an account in our quarterly magazine. The next thing we hear is of someone else, most often in a completely different country making an improvement.

Our book "Self-Steering" is another example of our members' work, similar to this one. Since 1956, we have had members making special studies of how best to make a yacht steer herself on a fixed course to the apparent wind and, in 1967 we gathered everything which we had published into a book which we brought up to date in 1970, adding the new gears which our previous work had "triggered off."

The other aspects of yachting in which we are interested are as follows:

1. Methods of recording completely a yachts' sailing performance on a "polar curve graph sheet." We have produced a blank sheet which simply invites people to take "the sailing figures" of their yacht and put them on it. If yachtsmen will take to this idea, we will have a method of comparing one yacht with another which is far more accurate than racing, which is more a trial of the skill of the crew than of the potentiality of the yacht.

2. We have conjectured an immense number of ways to set canvas efficiently to drive a boat. The only way so far which has proved successful is the rig used on a "wing mast" in the C Class catamarans but other rigs may see the light of day in the course of time.

3. We have studied catamarans, from those of Nat Herreshoff in the 19th Century right up to modern times, working out the principles of design.

4. We "Pioneered" the trimaran, suggesting that it was the logical development from the catamaran.

5. We have studied yachting accidents in single hulls aud multihulls, yacht electrics and ventilation and a host of minor conveniences and efficiencies for all yachtsmen.

6. We have studied "Ocean Cruising" as best we can, giving the seamanship of the great sailors in yachts from Slocum to the moderns in the Single-handed and two-man races.

The list of the publications we have produced will be found at the end of this book and many can be bought from us still. Our present policy is to assemble books from our members' writings, rather than to keep all the past publications in print.

To us, the picture which emerges from our publications and books is of a large group of highly intelligent inventors, innovators and researchers who get far more out of sailing than simple fresh air. Their imprint upon sailing will last for centuries.

If you are not now a member of the AYRS, you should join us now and, though you yourself may have nothing at first to contribute, your support for those who are doing research will be of immense value to them in encouraging them to continue. From the patent files of all countries, one can find examples of yachting devices of value which have never appeared on the yachting scene. The inventor has become discouraged by the lack of comprehension of his fellow yachtsmen and allowed his idea to lapse. An example of this is an excellent idea for hydrofoil stabilisers in boxes sloped at 45 degrees at the ends of a cross beam from the US patent files of 1921.

SAILING HYDROFOILS

Introduction

The AYRS has been studying hydrofoils in all their applications for some 15 years. This book is an account of these studies. We have here, however, made a selection of the material to avoid repetition, while not being afraid to include some applications which will never be used as shown but have an application in some other direction which has not yet been developed. An example of this is the use of vertical sculling hydrofoils. These are not likely ever to be used in seriousness but a modernised version of the Chinese sculling oar would have definite value.

The ultimate objectives

At the moment, we are on the very verge of seeing some remarkable hydrofoil craft which fall into two classes, namely (1) the Flying hydrofoil craft where the whole boat lifts off the water, leaving only three foils to sustain it and (2) the Hydrofoil Stabilised craft, where a long lean boat is stabilised against the capsizing moment of the wind by a hydrofoil placed to leeward.

The fully flying hydrofoil sailing boat may, or may not, achieve speeds of 40 knots. Due to the limitations of hydrofoils in "cavitation," ultimate speeds of more than 45 knots are very unlikely indeed. Some development is needed, however, before such a craft is seaworthy.

The hydrofoil-stabilised sailing boat, on the other hand, if some 50 feet long could be ordered tomorrow. If built lightly enough such as in PVC foam and fibreglass sandwich, it will have a better "lift to resistance ratio" than the fully flying type up to speeds of 30 knots. It might well do 40 knots and be a fully seaworthy craft capable of righting herself from the upside down position.

The method of presentation

Hydrofoils show the AYRS method of producing development most excellently. An idea is produced in one country. The inventor and the invention are more or less scorned there but the AYRS publishes it. Suddenly, in some far remote part of the world, the idea turns up again, better made or more intimately studied. Then, it is tried in even more widely varying places, all the time getting more sophisticated (possibly even getting simpler).

We therefore feel that the best method of presentation is to follow the trains of thought as shown by publication after publication which we have brought out. It is indeed a fascinating process which assures us that we have a method which can be as fruitful of results as that of governments who will think nothing of pouring millions of the taxpayers money into schemes often to produce very modest results. Our method, though perhaps slower, produces results which we are happy to show in this book. The final fully flying hydrofoil configuration may yet be to come but, if enough people read this book, it will come very soon.

Cyclical invention

The AYRS studies have not, of course, been confined to hydrofoils. We have studied catamarans and trimarans at the same time, acquiring some little odium in the process. This triple study is, in fact, a unity as it is simply the quest to get rid of the ballast of the conventional yacht. Catamarans and trimarans have done remarkable voyages, several having sailed around the world, e.g. David Lewis in his catamaran *REHU MOANA* and Nigel Tetley in his trimaran *VICTRESS* (a non-stop voyage). But both catamarans and trimarans have capsized in the hands of less skillful sailors. Neither is really the family man's boat, except to certain designs.

The process we have been watching since 1955 is composed of three parts:

1 Spreading the buoyancy of the single hulled boat into two separate hulls, making a catamaran.
2 Spreading the buoyancy into three hulls, making a trimaran.
3 "Degeneration" of the floats of a trimaran into hydrofoil stabilisers.

The end of this process is a return to a single hull with the ballast replaced by hydrofoils. A cycle of development has been completed.

Both models and full sized hydrofoil stabilised craft have been made and shown to work, giving great speeds and full stability. The most amazing of all that we have seen is the little model made by Gerald Holtom sailing in a scale wind of 60 miles per hour. Time after time, the strength of the wind overpowered the foils and the model capsized and the mast and sail went into the water. But, such are the dynamics of the matter that the mast and sail went on down below the hull and the wind and waves brought them up again on the weather side and the boat sailed on.

Above, we have shown a cyclical development of three items ending (where we started) with a single-hulled boat. Dave Keiper, however, has shown that by adding fore and aft foils to a hydrofoil-stabilised boat, he can sail right off the water, at the same time lifting the weather foil out. Perhaps he has the configuration which will ultimately prove to be the most seaworthy and efficient.

CHAPTER I

THE NATURE OF HYDROFOILS

July, 1955

A hydrofoil is a thin sheet of material submerged in flowing water. It has all the main characteristics of an aerofoil working in air, but, because water is thicker stuff than air, the forces produced by a hydrofoil are very much greater than the forces produced by a foil of the same size and shape in air.

The value of a hydrofoil is essentially its ability to produce a force acting almost at right angles to the direction of the water flowing across it and this force is very much greater than the drag, or the resistance of the foil to the water flow. Thus, if we need a force to act on a boat which is travelling through the water, we can attach a hydrofoil to the boat and get it.

The main hydrofoils which are used by sailing boats are, of course, the fin keel, the centreboard, the leeboard and the rudder. The first three of these are used to produce forces acting to windward, preventing most of the leeway. The rudder, when it is slung separately from the keel, is a simple hydrofoil which is used to guide the boat. When it is slung on the after edge of a fin keel, however, complicated forces are brought into play which need separate consideration.

Fig. 1.

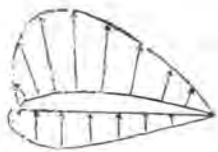


Fig. 2.

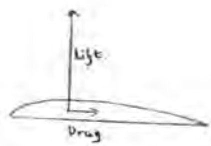


Fig. 3

Fig. 1 is a diagram of a hydrofoil with the water flowing past it. The lines, called "Streamlines," are the directions in which particles of water travel. It will be seen that the water flowing past is turned from its course. Now, when a moving body is turned from its course, it means that a force is acting upon it, and in this case, it means that the foil is exerting a force on the water. Since action and reaction are equal and opposite, the water is exerting a force on the foil.

It will also be seen in Fig. 1 that above the foil, the streamlines are crowded closer together indicating that the water is flowing faster there and below the foil, they are more widely separated indicating that the water flow is slower. In the 18th century, a man called Bernouilli showed that when a fluid flowed along a pipe with a narrow part in it and, for this reason, had to accelerate, the pressure in the narrow part was less than in the rest of the pipe. Similarly, if the pipe had a wider part, the pressure there was increased. The streamlines around the foil can be thought of as indicating the boundaries of imaginary pipes because particles of water do not cross them as they move across the foil so that, where they are closer together above the foil, the pressure becomes ess and, in the opposite way, the pressure below the foil increases. Fig. 2

shows how the forces at various parts of the foil act, each one at right angles to the tangent at that part.

The forces shown in Fig. 2 are far too complicated to study but they can all be combined into two forces namely (1), The "Lift" acting at right angles to the water flow and (2), the "Drag" acting along the direction of the waterflow. The ratio of the lift to the drag can be as great as 20 : 1 for hydrofoils of certain shapes but, in actual practice, the usual hydrofoil with its connecting link to the parent structure cannot achieve a lift/drag ratio of that value.

At the free end or ends of hydrofoils large eddies form which result in the loss of power. It is for this reason that a high "Aspect ratio" or great length of span across the water flow compared to the "Chord" or distance along the water flow is of value because, if the aspect ratio is high, there is more foil for the same loss of power at the end or ends.

THE TRADITIONAL HYDROFOILS

The centreboard

This type of mechanism for reducing leeway must be able to work equally well on either tack and thus it must be symmetrical about the midline of the boat. Though, in theory, it should be a perfect streamlined shape in the horizontal plane, in practice a thin plate with the fore and aft ends fined off to points apparently works just as well. The reason for this appears to be that a centreboard not only acts as a hydrofoil but it makes surface waves as well, which alter the characteristics.

The plan shape of the centreboard or the shape when it is looked at from abeam is capable of a certain amount of argument. The facts, however, are these: (1) The hull of the boat prevents the formation of a wing tip eddy at the upper end of the board so the aspect ratio of the centreboard is twice that calculated; (2) It is generally the case that an aspect ratio of 6 : 1 is as good as is needed for ordinary work for either an aerofoil or hydrofoil; (3) The greater the aspect ratio, the lower will be the centre of pressure on the centreboard which will cause the boat to heel more. Therefore, it is advisable to keep the aspect ratio just on the lower side of efficiency; (4) The ideal shape of the centreboard is half an ellipse but a triangular shape with the point downwards will have a higher centre of pressure and therefore will heel the boat less.

Taking all the above facts about centreboards into consideration, there is a good case to be made out for a centreboard being more or less a triangle with

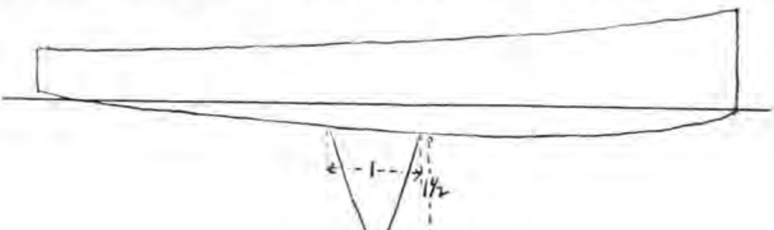


Fig. 4.

a vertical depth of $1\frac{1}{2}$ times the fore and aft length along the hull as in Fig. 4. This gives an aspect ratio of 6 : 1, using the formula $Span^2/Area$ and multiplying it by 2 because there is only one wing tip eddy. It might be worth while to round off the tip of the triangle to bring the aspect ratio to 5 : 1.

It is well worth remembering that the International Twelve Square Meter Sharpie class with a centreboard of about this shape is considered to be a "stiff" boat, though this is usually attributed to moderate sail area.

Ed.: Our view in 1970 *is that a* 1 : 1 *A.R. is probably best for a keel or C.B. See article by Edmond Bruce p.* 185.

The fin keel

In this section, we will deal with a fin from which the rudder is quite separate and is slung at a considerable distance aft. For this type of hydrofoil, everything which has been said of the centreboard is absolutely the same but,

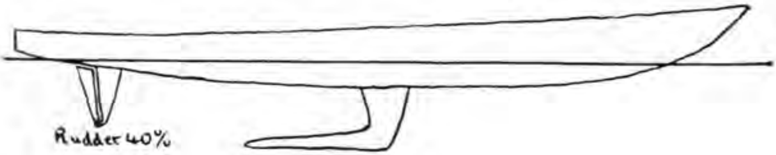


Fig. 5.

in practice, we find that the aspect ratios of fin keels are very much less, usually being about 1 : 1 or even less which, when doubled to allow for the absence of the top eddy gives at most 2 : 1 which looks poor indeed by aeronautical standards. However, in some tank tests by Edmond Bruce which will be given later, for a flat surface-piercing plate, it was found that the aspect ratio which gave the greatest "lift to drag ratio" was 1 : 1. Again, it is because surface waves are made that there is a difference from what is best for aerofoils.

The fin rudder combination

When the rudder is slung on the after edge of the fin as in the conventional deep keeled sailing yacht, all the general rules of shape as already described still apply but two extra features appear. The first of these is a greatly increased force acting to windward when there is slight weather helm. This is, of course, due to the whole hydrofoil becoming asymmetrical in a way in which the "lift" force is increased. Tank tests at the Stevens Institute show that this effect is greatest when the angle of weather helm is about 4°. The second new feature is concerned with the turning power of the rudder. Here, the rudder alters the water flow along the main fin so as to produce a turning force in the main fin itself as well as a change in the real centre of lateral resistance. The exact changes are rather complex.

The leeboard

This device achieved its greatest efficiency among the Dutch. On the shallow draught craft of Holland, it became an asymmetrical hydrofoil with the flat side to the outside and the curved side next to the hull and of occasionally quite high aspect ratio. As a hydrofoil, it differs from those which we have previously examined in cutting the surface of the water and because of this, it loses some power.

The separate rudder (Written in 1970)

A rudder slung on the transom of a boat such as is the normal practice among dinghys is a simple hydrofoil and is subject to all the forces already examined. However, like the leeboard, it cuts the surface of the water and thus makes surface waves *even though the tiller is in the centre line of the boat*. For this reason, Uffa Fox at one time slung the rudder below the hull of one of his dinghys and found that the steering had become so fierce that it was possible to capsize the craft at speed with the rudder action alone. This surely must have shown an increased efficiency.

In many modern yachts, the trend is to have a rudder separate from the fin but, for constructional reasons and to steady the steering, it is slung on a skeg. In this case, the total skeg-rudder combination should have an aspect ratio of 1 : 1, as with a fin keel. However, the very latest trend of having a V shape in the hull between the aft end of the fin and the skeg (traditionally known as "deadwood") to keep the turbulence created by the fin from giving extra resistance to the afterbody, brings in other considerations.

ASYMMETRICAL HYDROFOILS

Symmetrical hydrofoils produce very little in the way of lift for the drag they have at an angle of leeway of 5°. Asymmetrical hydrofoils, on the other hand, can produce as much as twice the lift for the same drag as a symmetrical foil. It would therefore be of great advantage if the fin keels of sailing boats could be asymmetrical with the lee side much flatter than the weather side because both the weight and wetted surface could be reduced and the sail area and heeling moment would become less with these.

The first attempt known to me of the use of an asymmetrical fin other than the Dutch leeboards was by Manfred Curry who devised a mechanism for warping both his centreboard and rudder to give a hollow to leeward and a convexity to windward. It is not known what happened to the idea or what success he had with it.

The next attempt, which proved to be successful, was on the yacht *Zeevalk*. Here, the fin keel had the trailing edge hinged like the aileron of an aeroplane wing and, on each tack, the flap was turned to leeward by about 5° so as to increase the windward acting force of the fin. The rudder was, of course, slung separately.

There are four other ways, however, of achieving the same object which spring to the mind. These are:

1 Having two centreboards in two cases or the same case either of which can be let down as appropriate.
2 Having an L shaped centreboard of wood worked by a handle at the side and kept in place by friction. One of the arms of the L would be for one tack and the other for the other tack. Both arms of the L could be raised as in the position shown by the dotted lines of Fig. 6.

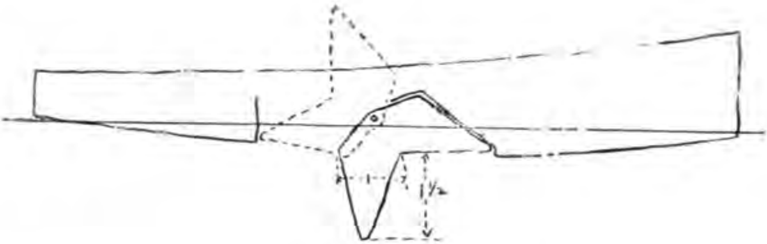


Fig. 6.

3 A "Turn over" keel which is shown in Fig. 7. The main part of the keel is here pivoted on a fore and aft horizontal axis so that it can be turned over on putting about so as to keep a flatter side always to leeward.

4 A "Turn around" keel as shown in Fig. 8 where the axle is vertical and the whole asymmetrical fin swings around a vertical axis on putting about.

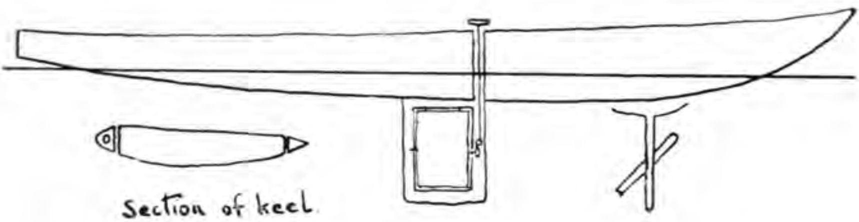


Fig. 7.

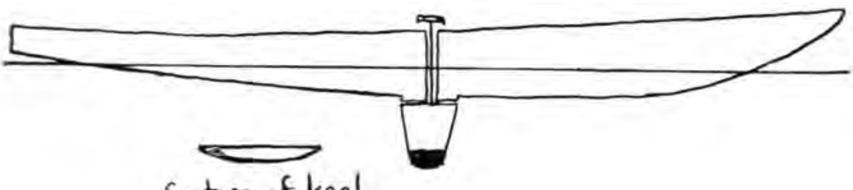


Fig. 8.

HYDROFOIL STABILISERS 1955

by John Morwood

Hydrofoils are used on many steamships to prevent them from rolling which they do very successfully. They consist of fins which can be run out from the sides of the ship, horizontally. Automatic devices alter their trim to the water flowing along the sides of the ship by twisting them about thwartships axes and the rolling can be reduced to about 5° on each side of the vertical.

It was thought that this same principle could be applied to a sailing boat, not only to prevent rolling but also to prevent heeling and, if the hydrofoils were to be given an angle of dihedral or slope from the horizontal so that the outside ends of the foils were higher than the inside ends, a keel or centreboard would not be necessary. A model was made and it worked perfectly, so last year (1954) a long hull, 19 ft in length and 2 ft 6 in in beam was made by Sam Catt and myself and fitted with hydrofoils as shown in the photograph and Fig. 9.

Manually controlled inverted T foils

In this craft of ours, the things like beer pump handles are connected to cross pieces which are, in turn, connected to the hydrofoil stabilisers which run beneath the water. The cross pieces are connected to the boat by two hinges. When one of the handles is pulled back, the hydrofoil on the same side as the handle swings forwards, thus increasing its angle of incidence to the water flow. The water flowing over and under it then lifts it up. As we have it fixed, these planes are quite large enough to heel the boat to windward when sailing *even close hauled.* Not only do the planes keep the boat from heeling but they push it to windward so that there does not appear to be any leeway.

Another factor in favour of these planes is that the wind pressure tends to lift the hull of the boat out of the water when it is going at any speed and put the weight on to the hydrofoil. Fortunately, the foil does not hold the boat back when weight is put upon it as much as does the hull, so the effect is that greater speed is obtained. This effect is quite evident if, instead of the lift of the lee foil being used to keep the craft upright, the windward foil is used to pull down the weather side of the boat. There is a very distinct slowing up which is probably due to the increased displacement.

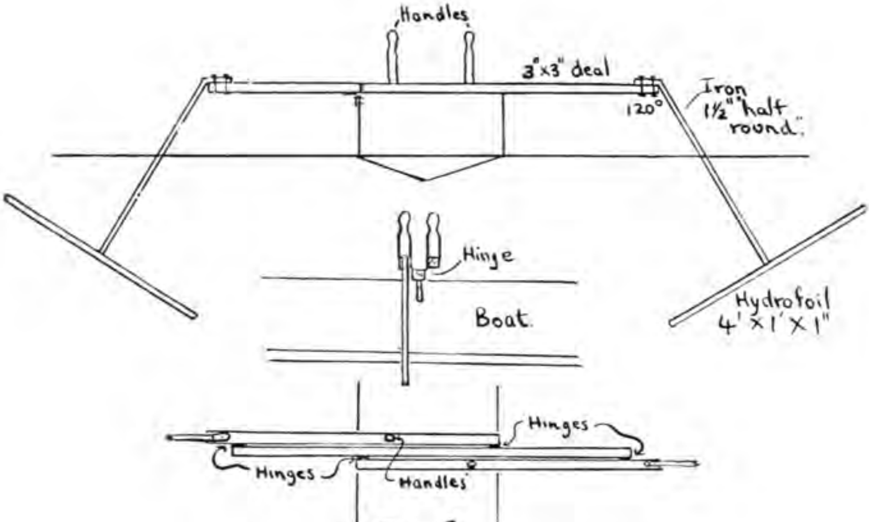


Fig. 9.

We have found this boat nearly normal to sail. It is not necessary to counterbalance the wind pressure by sitting out to windward so the attention which the hydrofoil handles need is no hardship and they need very much less effort than "over the side athletics." There is only one thing which has caused any difference in handling to a normal dinghy. That is a tendency for the hydrofoil to "Stall" when a strong puff of wind hits the boat when it is stopped. A slight easing of the sheets till the boat gathers way is then needed.

This hydrofoil craft of ours was a complete success. The hull we used was very heavy and the hydrofoils were, on the whole, much too big so we did not get any very great speeds from it but if any AYRS member wishes to carry on with this type of mechanism, he will undoubtedly travel at much greater speeds in much greater comfort than are possible with the ordinary dinghy now in use. The mechanism is fully capable of being used with any sailing craft with a great chance that speeds will be increased in stronger winds. Speeds will be less in light winds because there is extra wetted surface to be pulled through the water.

Though the full sized craft we made used hydrofoils which were operated by hand, the model which I had previously made had foils which worked automatically from the difference in pressure on the two foils as a result of the sideways pressure of the sails. No attempt has so far been made to try this out full scale.

It is felt that at least some of the success of these hydrofoils is due to the smallness of the iron connecting pieces from the outrigger to the foil. Where these pierce the water, there is only very little wave making which must only slow the boat very slightly and, of course, their wetted surface is very much less than the large flat plates which are usually used as connecting pieces on hydrofoil motor boats.

THE ALL HYDROFOIL SAILING CRAFT

A hydrofoil, running at 10 knots at a good lift/drag ratio will lift 2½cwt per square foot of its area. It must of course, be a good section of a good aspect ratio. The lift is proportional to the square of the speed.

Hugh Barkla, in his paper No. 3 of the ANUSC estimates that it is possible, with proper designing of the struts which connect the hydrofoils to the surface craft, to get a lift to resistance ratio of 10 : 1. The best that planing hulls can do is to have a resistance of 1/5th to 1/8th of the weight. Commander Miller, USN, in an article in Yachts and Yachting gives the best ratio which has actually been attained as 15 : 1. It is therefore, quite possible that the answer to really high sailing speeds is to be found in hydrofoils running below the surface of the water.

Fig. 10 shows 14 ways in which hydrofoils can be arranged. There are three main ways only, the other eleven being combinations of these. 10a is the most simple and efficient. It is the method used for my boat's stabilisers and it has two faults. The first is that its angle of incidence to the water flow must be constantly changing as the speed rises and falls. The second is that its area is fixed so that, if it is running efficiently at 20 knots, it is four times too big at 40 knots. The constant changing of the angle of incidence can be automatically operated in several ways, however, for example by the "Jockey" floats of the "Hook Hydrofin."

10b is a step ladder arrangement shown totally submerged but this state would only occur at low speeds. When travelling fast, one or two of the "rungs" would be out of the water but would fall down into it as the speed fell.

10c is a long foil only partially submerged but more of it goes under as the speed falls and more of it comes out as the speed rises. This type is being used by Ken Pearce at Canvey Island this year, (1955). It has the fault that air gets down along the upper surface of the foil and destroys its lift.

10cα shows a sliding foil with a vertical piece in its centre to avoid air entry down the upper surface. It would be a very suitable foil for a model using a strip of Dural for both foils.

10cβ, γ and δ are variants to allow of certain parts being more lightly made.

10d shows a V and a U foil which are simply two sliding foils placed at an angle of about 45° from the horizontal and joined together at the bottom either directly or by a horizontal piece. Three of the V foils are used in the Baker hydrofoil craft, two being at the fore end and one at the stern, the stern V being used for steering. The Baker craft is reported as doing 23 mph in a 15 mph breeze. The two limbs of the Baker hydrofoil V are placed at an angle of approximately 60° to each other.

10dα is a combination of the U foil of 10d. with a 10a foil of the high efficiency type. This would be a very suitable foil to have at the bow combined with high efficiency foils amidships. It could then act like the "Jockey," float of the "Hook Hydrofin." The high efficiency foil below the U would absorb most of the forward capsizing moment of the sails but the tip of the U

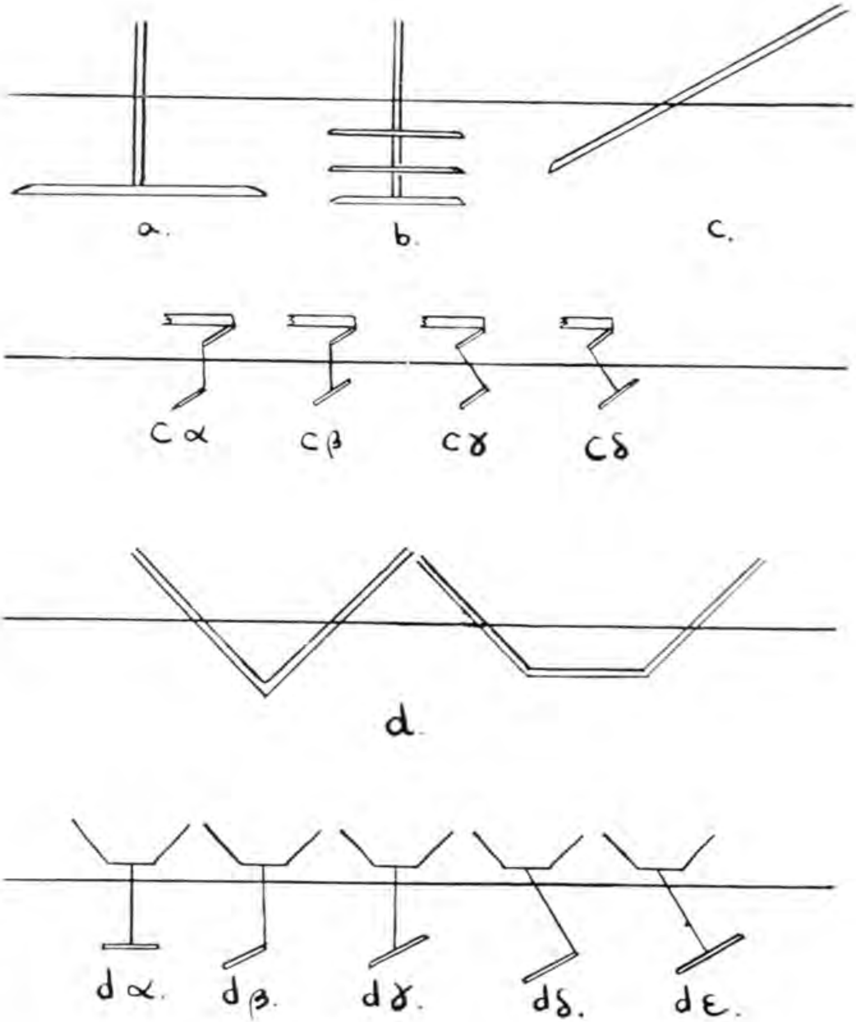


Fig. 10

foil could be made to just skip along the water surface and thus alter the angle of incidence of the main (high efficiency) foils. As the speed increased, the main foils would develop more lift and rise up which, because the forward U is in contact with the surface, would reduce their angle of incidence, thus keeping the craft in stable fore and aft trim.

10d β, γ, δ and ξ are midship foils with a U foil above to reduce foil area at speed and a high efficiency foil below which is angled to absorb the lateral force of the sails and keep the craft upright.

The lateral stability of foil borne craft

It is believed that the sideways stability can be fully maintained by using two main high efficiency foils in such a way that the lines of action of the lift which they create meet the midline of the craft above the centre of effort of the sails. If this is done, a foil borne craft cannot be capsized sideways. This is because, at a side force of the sails greater than a critical amount, the weather foil starts to exert a downwards force. This effect can be made greater by making the main foils so that their angles of incidence can be altered as with my hydrofoil stabilizers. It is reduced by such things as centreboards (which should not be necessary anyway) and large flat connectives. The Baker craft with three V foils could, of course, be capsized not only sideways but also stern over bows, though both are extremely unlikely.

The fore and aft stability of foil borne craft

The forward capsize may seem very hypothetical to some people but these craft can be made extremely light in weight and the sails exert their force high above the water so the possibility must always be kept in mind.

Fore and aft trim can be held in two ways. Firstly, it can be got by the use of a stern foil which carries part of the weight of the craft at slow speeds but, should the force on the sails ever start to lift the stern, this foil could be set at an angle downwards so as to pull the stern down. Secondly, it can be got by the use of a forward foil which, like a stern foil doing the same job, carries part of the weight, but in this case, no matter how the wind blows, only extra weight would be thrown on the foil. This means that the work which the foil is doing never changes its direction and so it should be easier to use. In my opinion, it is a better mechanical principle. It has, however, the faults that, firstly, the water has to be pierced in an extra place aft for the rudder and secondly, owing to the extra strut running down to the forward foil, the craft would be harder to steer.

The disposition of foils

The disposition of the foils to support the boat is still very much a matter of conjecture. The following methods have been or could be used:

1 Ken Pearce is using four foils, two forward and two aft—the most stable arrangement and very suitable for the sliding foils he is using.
2 J. A. Lawrence is using an oblique V main foil with a manually controlled aft foil. He may expect his craft to heel while on the foils.
3 A broad U foil with the straight piece stretching right across the craft would be a useful main foil of the heeling type.
4 The Baker hydrofoil craft uses two V foils forward and one V foil aft.
5 John Westell suggests two sliding foils forward and one high efficiency foil (10a) on the rudder.
6 The Grunberg method consists of two high efficiency foils amidship with two "skis" running along the surface of the water forward. The forward "skis" automatically adjust the angle of incidence of the main foils so that the hull "flies" at the correct height above the water.
7 This same principle could be employed slightly differently by using two foils of type 10dξ amidships combined with a type 10dα forward. At low speeds, such a craft would be using the U foils but at high speeds the main

foils would become of the highest efficiency and the forward horizontal foil would prevent the forward U foil from disturbing the water as much as it otherwise would. (For a model, I would use main foils of type 10cα of Dural).

8 The "Hook Hydrofin" has automatically controlled main foils and a fixed, high efficiency stern foil.

All these eight methods are fully automatic (so far as is known) and do not need any attention from the crew when sailing. The ability of some types to capsize either forward or sideways would have to be investigated. The following method is not automatically controlled:

9 Three high efficiency foils could be worked by a "joy stick." The rudder could be worked by the feet, leaving the crew of one with his other hand free to manage the sheets. In this case, the main foils would act as stabilizers at very low speeds and the sheets could be held by jamb cleats. It is not known whether it would be best to have the single foil forward to absorb the forward capsizing moment of the sails or aft on the rudder where at really high speeds it might have to exert a downwards acting force, thus holding the craft back.

The efficiency of foils

THE SLIDING FOIL. The main virtue of this type of foil is that its angle of incidence to the water flow can stay the same at all speeds. It will naturally be set to give the greatest lift/drag ratio. Both the lift and drag of foils increase with the square of the speed, if they are totally immersed. This means that, if we ignore the inefficiencies of this foil, it will have a constant drag quite irrespective of the speed. This can best be understood if we take the example of a doubling of the speed when the lift of the submerged part will increase fourfold resulting in only one quarter of the foil remaining in the water. The drag of this quarter will be four times as great as it was, so the total drag will be the same as at half the speed. The upper surface air entry, the decrease in aspect ratio and the surface waves keep this from occurring, however, the resistance in practice being approximately proportional to the speed up to the point where the tip of the foil only is submerged when it increases greatly due to the high loading.

THE HIGH EFFICIENCY FOIL. As compared with the sliding foil, this type will usually meet the water flow at varying angles of incidence. For this reason, it need be only half the area of the sliding foil to lift the hull out of the water because it can use a greater angle of incidence. The drag of each would be about the same, however, if the inefficiencies of both are ignored. However, it would appear from the aerofoil graphs at my disposal that, as the speed increases, the angle of incidence would become less and this would have such a marked effect on the drag that it would actually be less at twice the speed at which the hull lifted clear than it was at that moment. There comes a point, however, when this effect no longer appears and the drag once more increases in proportion to the square of the speed.

MISCELLANEOUS USES FOR HYDROFOILS

A hydrofoil to reduce displacement

It has been shown that the majority of the stability of normal keeled yachts is due to their shape rather than to the weight of the keel. The weight is used more to prevent a capsize than to increase sail carrying power, though it does have a marked beneficial effect on the latter. It might, in some circumstances therefore, be useful to have a hydrofoil on the keel as shown in Fig. 11 to reduce the displacement. It is unlikely that this would help when close hauled.

A hydrofoil instead of ballast

As compared with the last possible use, a hydrofoil which was hinged to the bottom of the keel in the fore and aft axis and acted vertically downwards could replace the ballast weight altogether. This arrangement is shown in Fig. 12.

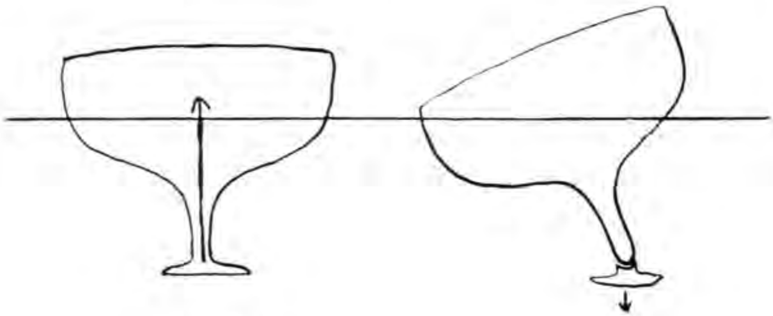


Fig. 11. Fig 12

The flap foil

Fig. 13 shows a diagram of what may be called a "Flap foil." The essential nature of this is a hydrofoil hinged at its forward edge so that the trailing edge can move freely up and down through an arc of a circle. Though the hinge allows this movement, the foil is fixed by it at right angles to the supporting bar.

Though it is quite possible that the flap foil may prove to have hidden possibilities, only three are at present seen where it might be of value. The first of these is shown in Fig. 14 where it is fixed over the tail end of a yacht and by the up and down movement of the handle, a driving force is created of the nature of up and down sculling. This could be considered to be a refined version of the Chinese "Uloh" or large sculling oar, though this was worked from side to side more like the method used to scull small boats. This device could, of course, be made fully efficient and has the added advantage that, if the handle were to be fixed so that it could not move up or down the lop of either a following or head sea would drive the boat along in a calm.

The second use for the flap foil is to fix one on either side of a yacht to get forward drive from a *beam* swell in a calm in the same way as was suggested for the stern flap foil. Flap foils of this kind could not only be used for this purpose but they could probably also be used as stabilizers. Thus, they could be left as fixtures on the yacht except at moorings or against a harbour wall.

Fig. 13.

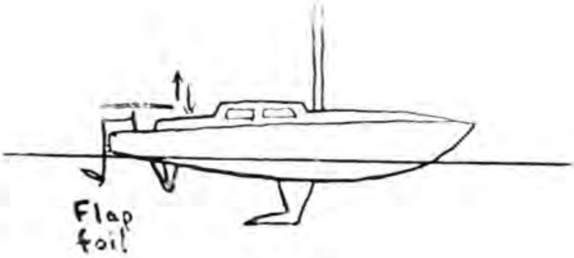


Fig. 14.

Water stilts

The third use for flap foils is shown in Fig. 15 though it is not anticipated that, when the wind fails, some member of the crew will be really sent over the side with one of these queer things to give the parent yacht a tow back home. Here, the arc of flap of the foils will be arranged to give only a very fine angle

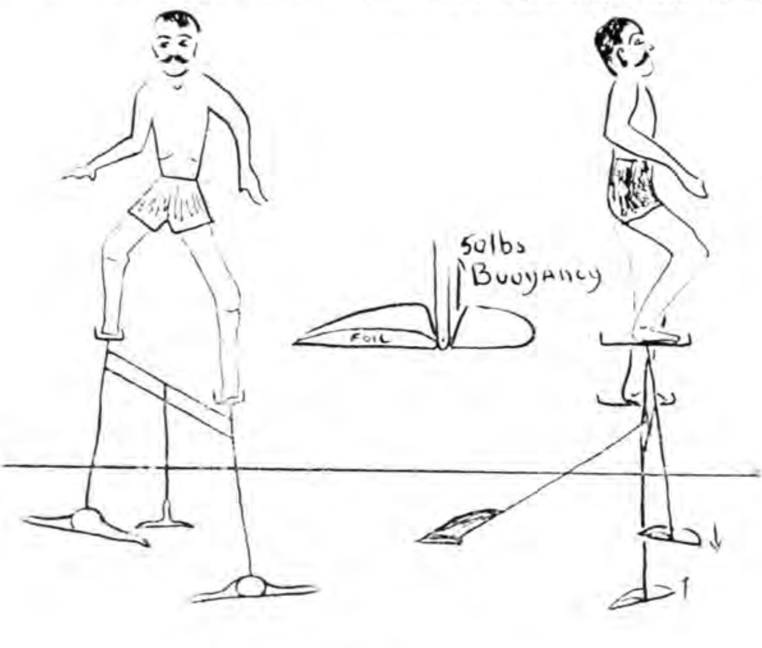


Fig. 15.

of glide on the downstroke. The manipulator (or should I say pedipulator?) of this amazing vehicle stands on one side till it almost sinks to the water and then transfers his weight on the other side. One side must be rising as the other side is going down and this can be arranged by having a streamlined float attached to the foil in such a way that the centre of its buoyancy is in front of the pivot. The float will then pull upwards, twisting the foil downwards when no weight is upon it. There is a stern foil with a small vertical fin to give directional stability. It should be possible to steer by giving one or two extra strokes on one side or the other.

CHAPTER 11

THE BAKER HYDROFOIL SAILING CRAFT

Made by: The Baker Manufacturing Company, Wisconsin, Illinois, U.S.A.

Written 1970

We show the two photographs we have of the Baker sailing craft. These were made about 1954 and 1955 but we have never had any account of how they sailed or of the technique of sailing them.

Baker Hydrofoil 23 mph in 15 knot wind
Photo Yachts and Yachting

The three "V" craft

This, apparently, was the earlier of the two craft and was the first application to our knowledge, of 60 degrees of dihedral to hydrofoils. This large dihedral was obviously used to prevent air entrainment down unfenced foils. We have no clear knowledge of the foil section but it looks as if it were a simple arc of a circle top and flat under surface.

As shown, the boat would have very little static stability, if any, and one guesses that the craft was got onto the foils by being pulled by a power boat and then cast loose. Once sailing, the dynamic stability is likely to have been adequate but we have no knowledge of whether or not the boat could put about or gybe without coming off the foils and therefore losing stability.

The "ladder foil" Monitor

This was made for the US Navy. It was a large boat some 30 or more feet long, with a good deal of stability in the hull due to the flat floor.

The "ladder foils" are a modification of those used by Alexander Graham Bell, the inventor of the telephone, in that a dihedral of some 40 degrees was used for the lifting foils which must have been aluminium extrusions. Bell's foils had no dihedral because the application was for a power boat.

"Monitor" The Baker Craft which has done 30 m.p.h.

As with the three "V" small sailing boat, there was stern steering but the details of the stern foils are not fully known. A single or double strut down to a horizontal foil is the most likely method.

Though we believe that, in the first sails with this boat, she was towed off the water, we have also heard that she was successfully sailed off the water under sail power and a speed of 35 knots was claimed. However, we have not heard how she behaved when putting about or gybing.

The Baker motor hydrofoil "HIGHPOCKETS"

This craft, using four "V" foils, this time apparently of about 90 degree dihedral, appeared to shoot over the water with very little wash. All four foils seemed to have been fixed and steering was accomplished by the outboard motor.

The foils again appeared to be of light alloy.

Seaworthiness

People talk darkly of "The crash dive" and other phenomena of hydrofoil boats. The crash dive is when the forward foils get negative incidence and drag the boat into the water. We do not know if the Baker craft suffered from any or all of these things. One suspects that the inability to put about or gybe was a serious drawback.

Subsequent history

Somehow, it is the fate of the majority of hydrofoil boats to achieve a modest fame because they work and then never to appear again. Obviously, the motor hydrofoils in large size are tremendously expensive and need a good paying route such as a passenger-carrying ferry to be "cost-effective." Sailing hydrofoils, too, can be too expensive for the average yachtsman and the psychological climate in 1955 was not conducive to accepting even catamarans as yachts, let alone hydrofoils. Fortunately, in 1970, when this is being written, the yachtsman is much more open minded. But, of course, the boat he accepts must suit the waters in which he sails and, to be of value as a yacht, a hydrofoil must be able to put about and beat to windward, either on or off the foils.

PROF. ARTHUR LOCKE'S HYDROFOILS

Monty Montgomery, the Editor of *Multihull International*, has kindly put his material at our disposal for this article.

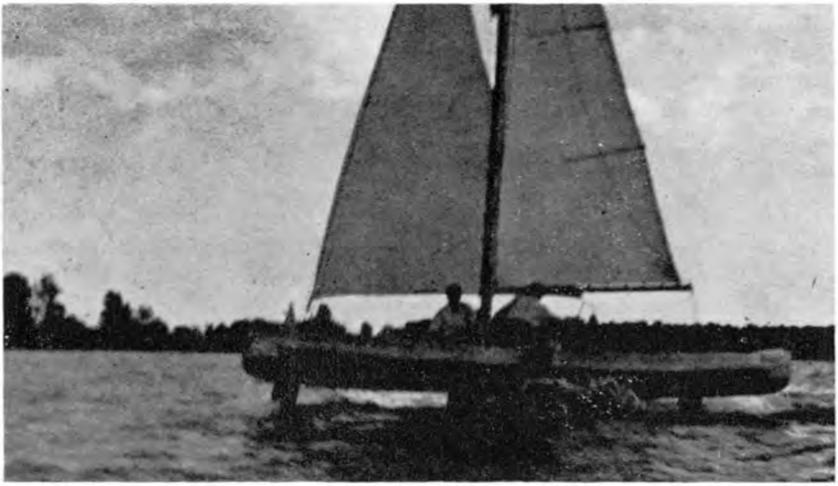
TWEEDLEDUM-TWEEDLEDEE is 34 ft, 10 ft beam, gross weight 3,200 lb, with a sail area of 500 sq ft was built in 1951 and is now owned by Byron Wright, of Armada, Michigan.

She is a catamaran and, to my memory, was fitted with a single large foil sweeping right across her from outside gunwale to outside gunwale at one time and flew on this but further details are not known to me.

TWEEDLEDUM-TWEEDLEDEE has been converted from an open day boat to a cabin cruiser and has had the sail plan increased to compensate for the 1,000 lb of extra weight. In a letter Monty had from Byron Wright, he said that she was timed last year at 20 mph on Lake St. Clair, but no mention of the foils is made and she must now be simply a catamaran.

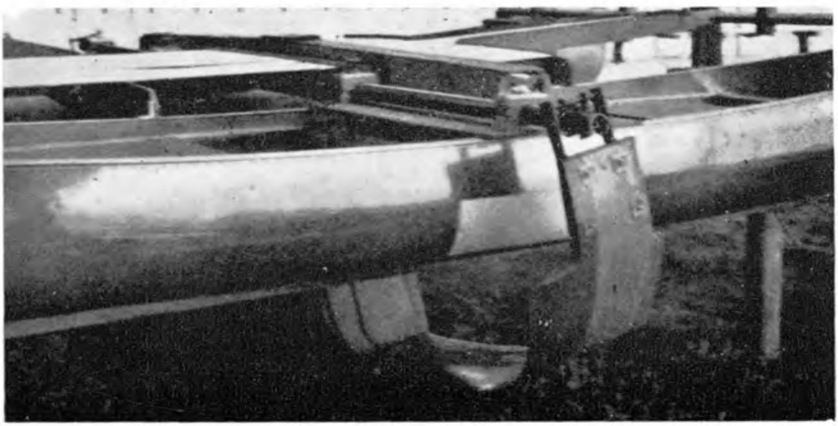
SKID

Arthur Locke also produced catamarans called *GAIL* and *YOSHI-MORU* but his foil-cat *SKID* was the only other one fitted with hydrofoils.



SKID flying in 1954

SKID at moorings



SKID's main foils

SKID was 20 ft × 12 ft, with a weight of 710 lbs and a sail area of 270 sq ft. The foils have 18 sq ft of area. She was built in and sailed on her foils in 1954. The photographs show her on moorings, there is a close-up of the amidships foils and she is shown sailing above the water in the North Channel of the St. Clair river, Algonac, Michigan on 7th September, 1964. The report on this event runs as follows:

"When on one port tack and heading about 300° near the middle channel light, wind speed 12-15 mph, the bottom of the port hull lifted about 2 ft completely out of the water—the hulls then levelled off, with the bottom of the hulls about 6 in clear of the wave tops, both hulls being level fore and aft, and athwartships in respect of each other. The vessel continued to sail in this attitude.

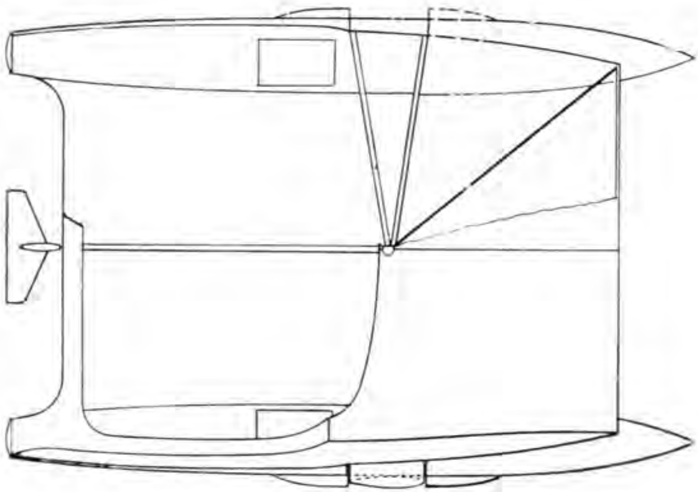
"The total time on foils was about one minute—there was no pitching or rolling."

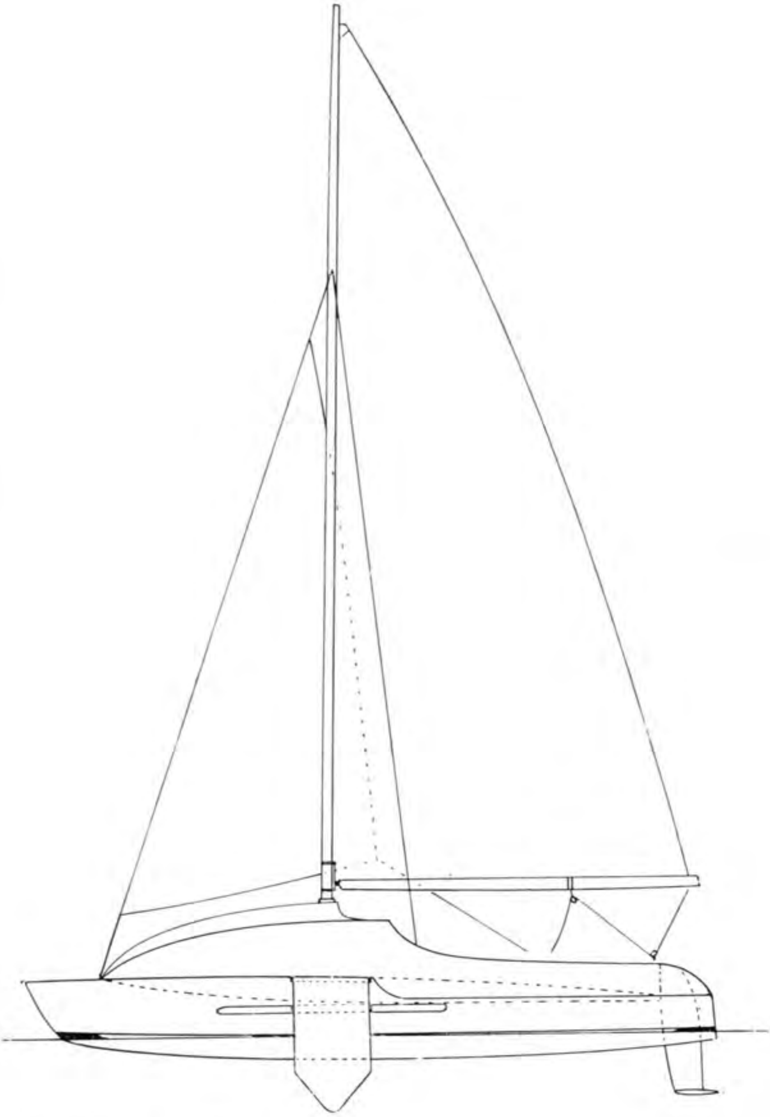
A CATOFOIL DESIGN

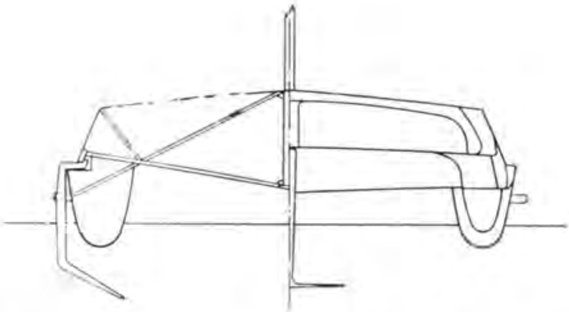
by Owen Dumpleton April, 1956

The accompanying plans show a design which was inspired by the Hydrofoil demonstrations at the Annual General Meeting of the AYRS. It is based on two standard *SHEARWATER II* 18 ft hulls.

The hulls are firmly bound by a light framework of hollow struts which are covered above and below by plywood. The bridge is exceptionally high to give extra strength for the same weight. It is my intention to make a scale model for testing in a wind tunnel with a view to deciding just how high one can build the superstructure. It might be possible to raise it enough to include some Spartan accommodation.







On either side of the hulls are two angled leeboards set at an angle of incidence which, with a T foil at the stern, could lift the hulls off the water to convert the craft into a hydrofoil boat. The forward foils are of the triangular plan form which maintains a constant aspect ratio whatever the immersion and they are clamped in position when sailing.

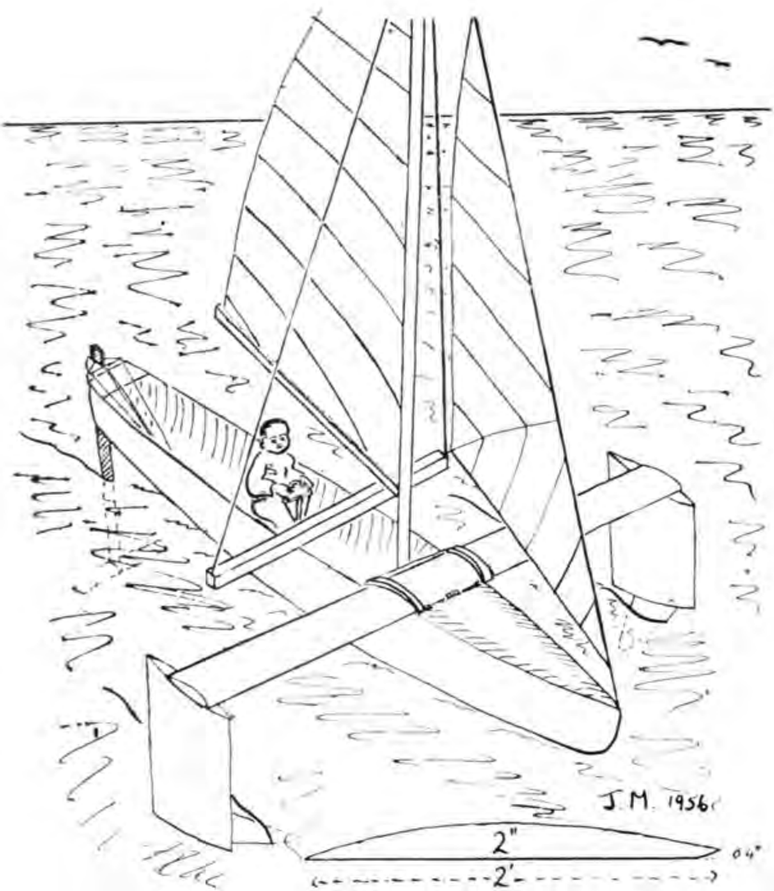
For gravity balance, the leeboards-foils could not be any further aft and their position as shown would imply a certain amount of the lateral thrust being taken by the rudder. As shown by Tothill, this is liable to cause rudder "Stall" when bearing away at low speeds. It would therefore be as well to leave provision for moving the mast further forward a few inches or possibly for fitting a bowsprit, although she might do as she is and would I think, be better balanced when on the foils.

A HYDROFOIL DESIGN IN 1956

The drawing shows a system of Float-hydrofoils which we worked out in 1956. We intended to have it built by the Prouts of Canvey Island but, like many an idea, it never saw the light of day.

The cross member is made of a sheet of plywood rolled into an aerofoil section over one or more cross beams. The wind should give a certain amount of lift from it when close hauled. From the model experiments, a beam of 14 ft is thought to be enough.

The floats in the original design were 3 ft long by 4½ in thick. The Prout brothers think that this is not big enough and are increasing them slightly all round. They reach to 1 ft below the bottom of the hull. Their lower edges slope upwards towards the front at an angle of 7° to give an angle of attack to the foils of approximately 5°. The lower surfaces are flat, and though I originally had them horizontal in the side to side direction, the Prouts suggest sloping them up in line with the lower surfaces of the foils. This not only makes for easier construction but it may help to prevent a slight jerk which appears in the model when the lower surfaces of the floats break the surface of the water. The float section is the same up and down its length with the greatest beam in the middle. It is pointed fore and aft.



The forward foils are triangular in plan form to keep the aspect ratio the same at all amounts of immersion and are set to the Baker angle of dihedral of 40°. Our first trial will be with foils 2 ft long and 1 ft 4 in in fore and aft length at the top. From the available information, this should give us enough lift to make the craft foil borne at 8 knots if its weight is 350 lbs complete. The wing tips are rounded to prevent some of the end losses of the triangular plan form. A certain amount of experiment with the foils may be necessary to get the best size and shape. For instance, the shape should give us the equivalent of an aspect ratio of 6 : 1 because we only have to suffer one set of wing tip losses but an increased aspect ratio might be better.

The foil section is shown on the drawing. The upper surface is an arc of a circle. The lower surface is flat but it is "Relieved" at the fore edge by a rise of 1/60th of the chord. The thickness is 1/12th of the chord but may, apparently, be 1/10th without losing very much, if anything.

The stern foil is a simple T foil connected to a "Joy Stick" to give rudder and incidence control by a Prout modification of the mechanism used on the "Hurricane" aircraft. The model does not need incidence control but it might help in getting the full sized craft foil borne. We are starting with a stern foil 3 ft in span by 6 in in chord which is probably too big.

Towing tests on the model show that at low speeds, stability is due to floatation. As the speed rises, the lower surfaces of the floats start to plane which they should also do when cut up to the 40° angle of the foils. Eventually, the craft is entirely foil borne.

When coming into shallow water, the two bars across the "Wing" can be swung back and the wing can then be twisted forwards on the hinges at its leading edge, lifting the foils and floats up enough to save them from damage but still allowing them to be used for stability. The stern foil can be sloped back by a similar mechanism to that used with outboard motors.

Owing to the considerable modification of my original plans and their interpretation in terms of constructional detail by Roland and Francis Prout, the final designs of the completed craft must be considered to belong to the three of us.

Letter from: Ken Pearce Northside, High Road, South Benfleet, Essex

January, 1956

Dear Sir,

ENDEAVOUR is now laid up for the winter season and experiments have been shelved until the weather gets a little warmer. Towards the end of last summer, I had one partially successful run on my hydrofoils with the boat practically clear of the water. Unfortunately, at this stage, the operating gear showed several failures and first one and then finally both forward hydrofoils collapsed under the hulls. With the weight factor so much in mind, one is always inclined to under-estimate the strains and stresses imposed upon a boat when the wind blows fresh.

Ken Pearce

Ed.—Ken's trials were made with 4 hydrofoils on his catamaran, one near each corner and each of a dihedral of about 45°. This is the same system which James Grogono used in 1969.

Letter from: Ken Pearce

14, Hermitage Avenue, Kiln Road, Benfleet, Essex

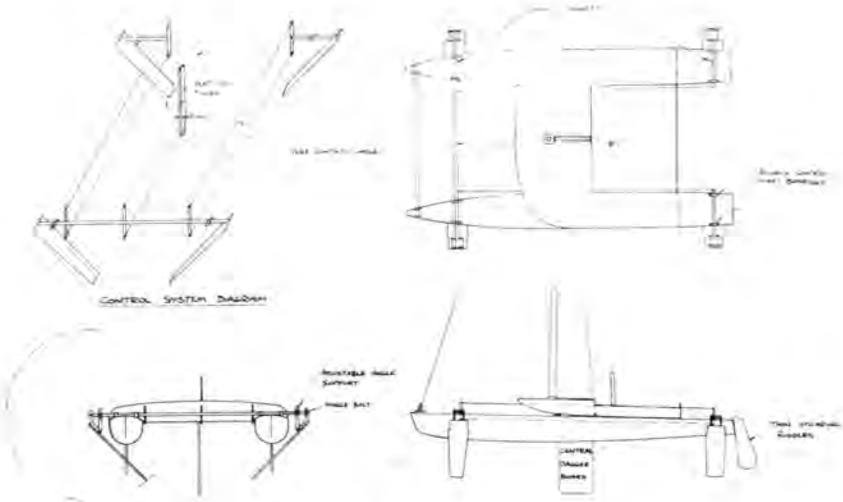
Dear John, August 17, 1970.

ENDEAVOUR REPORT

Many thanks for your letter of the 31st July, and I am enclosing herewith details of the Hydrofoils and operating gear that I built and fitted to my catamaran *ENDEAVOUR* in the Spring of 1955.

It was not until the racing season was over that my son and I were able to devote full time during September, October and November 1955, at Burnham-on-Crouch, to getting the craft sailing on the hydrofoils and this we were able to achieve on several occasions.

Four separate foils (details of which are enclosed on the drawings herewith, Nos. 1641/A and 1641/B) were fitted fore and aft to each hull. When the foils were first fitted, they were hinged on steel control shafts rotating in double bearings athwartships. When the boat was launched and it was sailing as a



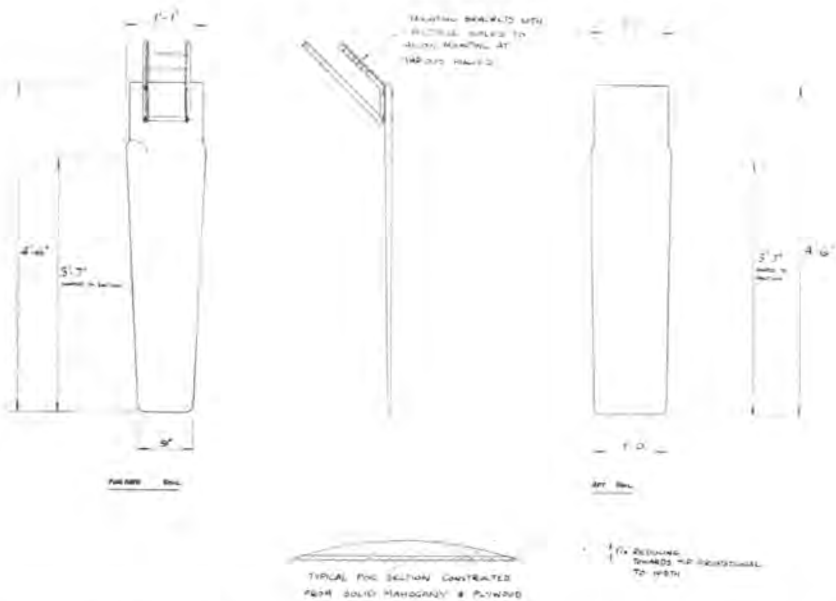
CAT ENDEAVOUR 18 x 10

normal catamaran and the wind became strong enough the foils were swung outwards on the hinges and fastened under the hulls. We were able to adjust the dihedral angle from 30° to 60° but 45° was found to give the best results. The control shafts that the foils were fitted to were connected together with wire cables, and then the master shaft fitted forward between the two hulls was connected by wire cables to a vertical tiller 4 ft high, hinged in the centreboard case. This enabled the crew to pull back the vertical tiller which swung the foils forward and increased the angle of lift. As soon as the boat had lifted on to the foils the crew could push the tiller forward to decrease the angle of incidence which would then allow the craft to go faster on the foils.

When she was sailing on the foils I was able to study their action through the water, and with the boat sailing on approximately 10 to 14 in foil depth, half of the back side of the foils, from water level downwards, was cavitating.

On one occasion, when the boat was travelling fairly fast, the tiller was pushed too far forward and the bows drove down in the water. We then fitted a tiller stop in the centreboard case to make sure that this would not happen again. We also decided to fix the aft foils at a selected angle and lock them in a fixed position, only controlling the lift of the craft by altering the angle of the forward foils with the vertical tiller, and this made it much easier to get the bows of the craft up and sailing on the foils only. The problem was to keep driving the boat very hard, enough to get her up on the aft foils as well, but as soon as there was a lull in the wind strength the craft would settle down by the stern and then we would have to start driving it hard all over again.

During the end of November we had one of the most successful sails on the hydrofoils in a very heavy breeze and choppy seas, and this caused the



forward shaft to bend until the foils were resting underneath the hulls. It was then decided not to do any more experiments as we had gained a lot of knowledge. It was our intention to re-design the whole set up the following year but this, in fact, we never got around to doing because of the introduction of the British Speed Trials in 1956. After winning the Speed Trials I felt that we were creating a tremendous interest in the yachting fraternity by persevering with *ENDEAVOUR* and re-designing and testing out new sail plans and rigging, steering gear and rudders, daggerboards and centreboards, etc. etc.

ENDEAVOUR's **Achievements**

1955 Sailing on Hydrofoils.
1956 Winner of the British Speed Trials at Cowes.
Holder of the British Speed Record (see Guinness Book of Records).
Winner of the Folkestone/Bologne Cross Channel Race.
1957 Full racing season.
Requested to take Prince Philip out sailing aboard *ENDEAVOUR* at Cowes.
1958 Winner of the second Folkestone/Bologne Cross Channel Race.

Letter from: T. K. Pearce. 25 Hall Park Avenue, Westcliffe-on-Sea, Essex.

Dear Mr. Morwood, September 14, 1970.

I have read Father's account of our experiment with *ENDEAVOUR* using hydrofoils and would confirm that it is an accurate statement of what occurred.

However, I am not able to state categorically that the boat hulls were completely clear of the water, as it was not possible to ascertain this from my position on board. There is no question that the bows rose clear from the water on many occasions, but as Father has explained, it was much more difficult to get her up on the stern foils. By comparison with modern catamarans i.e. *TORNADO*, *ENDEAVOUR* was quite heavy, and having a wooden bridge deck throughout, her centre of gravity was well aft of amidships, and this obviously put much loading on the aft foils.

When we attained sufficient speed there was no doubt that we were getting considerable lift from the aft foils, but is impossible for me to say whether the hulls were completely clear of the water or not, because of the water disturbance and spray at these times.

Trusting this letter will help,

TERRY PEARCE.

Letter from: Ken Pearce. 14 Hermitage Avenue, Kiln Road, Thundersley, Benfleet, Essex.

Dear John, September 15, 1970.

I thought I had mentioned in my letter to you that *ENDEAVOUR* sailed on hydrofoils on several occasions.

The facts are that it was not too difficult to get her up on the forward twin foils, but it had to be driven hard to get her up on both rear foils as well and the hulls clear of the water, but as soon as the wind eased she would settle down aft with 3 or 4 ft of the hulls trailing in the water and we had to drive it very hard again. There is no doubt whatever that several times she sailed on all four foils but not very high out of the water aft, but the hulls were clear of the water except for spray and odd waves.

KEN PEARCE.

SOME HYDROFOIL EXPERIMENTS

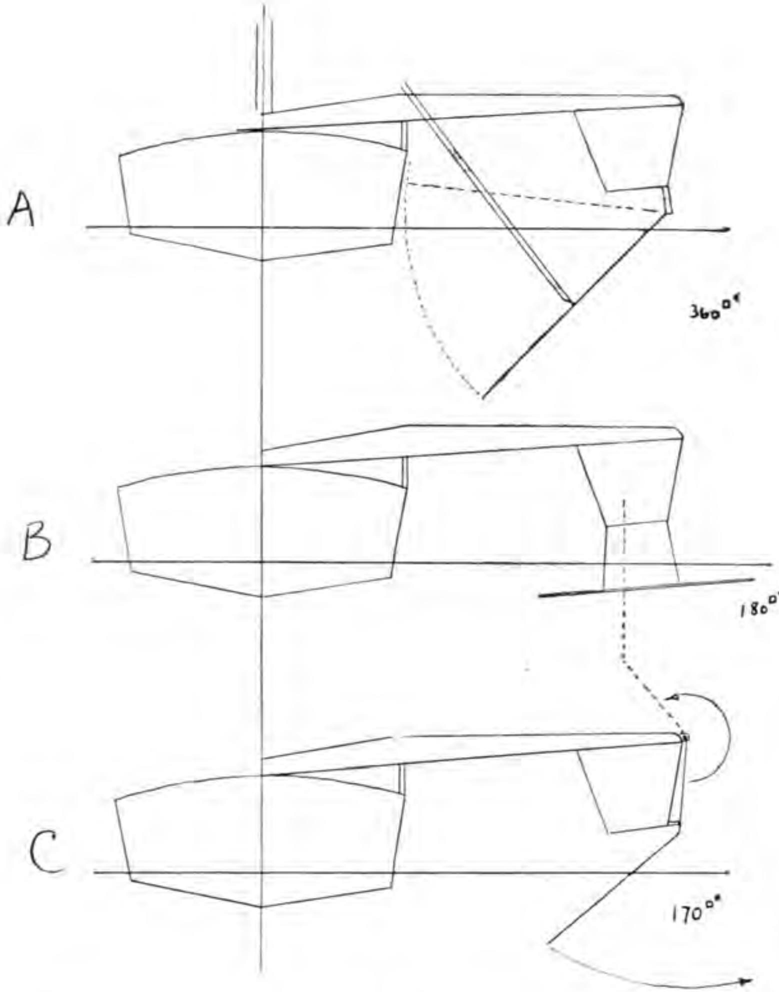
by D. R. Robertson August, 1956

In the summer of 1955 an attempt was made to get the highest possible speed from a 15 foot sailing canoe. The hull, which weighed 105 lbs, had been fitted with outriggers (30 lbs each) the previous summer but, although these gave good results, it was thought that if they could be held clear of the water with hydrofoils, an improved performance would result.

The sketches show the three hydrofoil configurations which were tested:

A. The boat handled normally both close hauled and reaching with relatively little change of rudder balance. By bearing away in gusts of 15 to 20 mph, the bow would lift about 2 ft. There was a lot of spray but not much increase of speed. With any reduction of wind speed, the bow dropped and resistance at low speeds was heavy.

B. With this type of foil, it was hoped that the lee float would be lifted clear and that the main hull would plane. At a wind speed of 15 mph, the lee float did lift out and momentarily there was a very considerable increase of speed and obviously much less resistance. However, as the lee float lifted higher, the weather float touched the water and this immediately stopped the boat and it fell off the plane. This rising and falling of the float and foil could be repeated over and over.



C. This was the "cleanest" and the easiest to retract for launching. Unfortunately, in a heavy wind there did not seem to be any appreciable difference in speed with or without the hydrofoil in use. It was possible that either (1) the foil area was too small, (2) the angle of attack (5°) was insufficient or (3) the foil section was too crude. This was a flat plate bent to a small curve. These could have been altered if the experiments had been continued.

By this time, the writer had come to the conclusion that the experiments were not going to prove as successful as had been hoped. The practical disadvantages of foils were found to be:—

1 Vulnerable when launching.

2 Difficult to lock in position if retractable, even with the minimum of way on.

Don Robertson with lee float lifted by a hydrofoil

3 A "messy" looking boat.

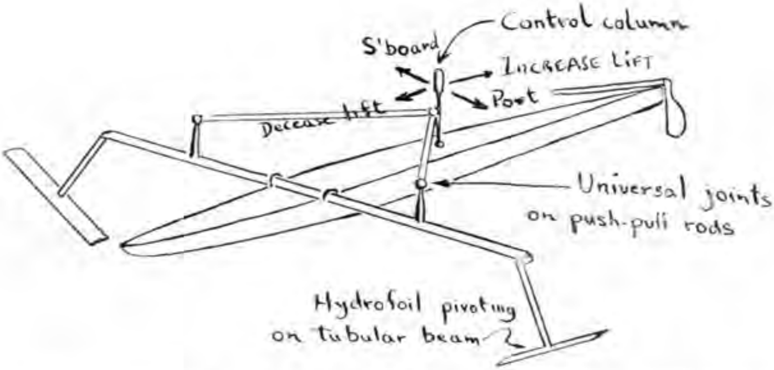
Apart from these snags, it was realised that with a really fast boat, the wind is always ahead and the boat is sailing close hauled. Under these conditions, the foils, which were designed to reduce the water resistance by giving lift, were more of a hindrance than an asset. It was therefore considered that more could be gained by attempting to reduce water resistance in other ways, for instance: very light weight, long thin hulls (catamaran) or possibly by getting lift instead of a downward thrust from the sails.

It is not suggested that the experiments described were in any way conclusive. In fact photographs have been printed showing hydrofoil boats clear of the water and if anyone would like to have the boat for further experiments, they are welcome to it a low price. It really is quite suitable for foil experiments as it has good lateral stability and yet is very light and strong.

Letter from: Alan V. Coles 7635, Herschel Avenue, La Jolla, California

Sir,

I have conducted some model experiments and have succeeded in producing a model catamaran which becomes foil borne on combined angled and ladder foils. Now, I have been considering making a sailing boat of the type made by Sam Catt and yourself (described in HYDROFOILS). However, I feel that a more natural control system for the foils could be arranged on the lines of the attached sketch. This system is that used for elevons in many aircraft and would give lift and roll control with instinctive motions analagous to flying an aircraft.



I have in mind a craft using one drop tank as hull with a single man crew sitting inside it. There would be the control column as I have just described it for the foils; the rudder would be controlled by a foot bar, leaving one hand free to manage sheets. Can anyone in the AYRS give me any experience in respect to the sail area which might be carried by such craft, if it would be feasible to sail it at all?

Alan V. Coles

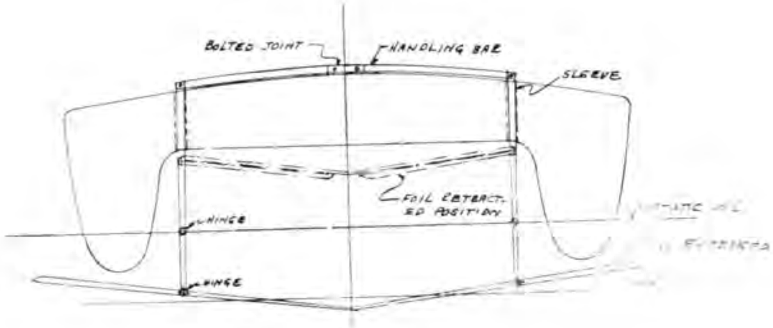
HYDROFOILS

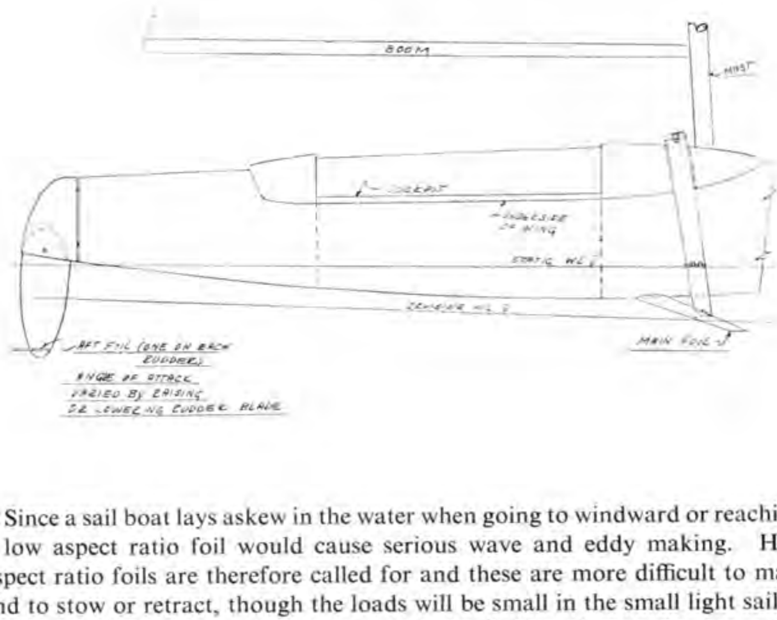
by Bob Harris — December, 1957

It is too early in the game to evaluate the use of hydrofoils on power boats, let alone sailers, but one thing seems to be emerging from what work has been done. Firstly, it is apparent that, in order to be efficient, they must be used at high speeds. Secondly, they are not a great deal more efficient than good planing forms except in rough water. This second fact is important, however, because the bane of sustained high speeds on the water is the sea. If big payloads can be carried through thick and thin, then the hydrofoils are justified, even though the foils themselves displace a good bit of the payload.

For sailing boats, I believe that, with hydrofoils, they will be able to attain their maximum speeds because it has been shown that the Lift/Drag ratio (L/D) is higher for the hydrofoil boat and for this reason, more weight can be lifted for the same horse power. If you can lift a boat clear of the water, in this way getting rid of wetted area and wave making resistance, the forward speed will be better.

The big drawback to the use of hydrofoils on a sailing boat is the fact that it takes considerable speed to get it up on the foils and it takes a sustained breeze to keep it there. Anyone who sails is well acquainted with the vagaries of the wind and will at once realise the difficulty of staying on the foils. Therefore, unless the foils can be easily retracted and extended, their use for a good all round racer is precluded. There will be very few times when a sailboat will be able to make maximum use of the foils, and, in the meantime, their weight must be carried about and they will surely be a strain on the arrangement of a good racer.





Since a sail boat lays askew in the water when going to windward or reaching, a low aspect ratio foil would cause serious wave and eddy making. High aspect ratio foils are therefore called for and these are more difficult to make and to stow or retract, though the loads will be small in the small light sailing hulls such as the Prout catamarans and the lighter planing dinghys. The catamaran or trimaran seem to offer the best possibility of retracting high aspect ratio foils because of their good beam.

Surface piercing foils seem to be best for a sail boat. This type requires a good deadrise or dihedral and some sweep back to avoid air entrainment. Their advantage lies in their ability to rise out of the water as the pressures increase, thus reducing their drag. The lee foil is also able to take up the side force more evenly and with less drag than a fully submerged foil. Such a foil is indeed difficult to retract but in Fig. 10, I have sketched a possibility for the catamaran which seems to lend itself better than other types for retracting since, as is shown in the sketch, the foils stow completely out of sight and out of water under the wing. As soon as time permits, we will try out this foil configuration and give a detailed report on it.

CHAPTER III

JEHU, 1957

by John Morwood December, 1957

This year, Sandy Watson has rigged up the AYRS catamaran in the Melagasy version of the Indonesian configuration. Commercial surfboards manufactured by Thamesply Ltd. and kindly presented to the AYRS were mounted at the ends of a Tchetchet-style cross beam system 12 ft wide. The connectives between the board and cross beam were boxed in enough to give about 60 lbs of buoyancy on each side. Sandy also redecked the main hull and moved the tiller forward by cross bars and lines, all most cleverly and neatly done.

Sailing the boat as a Melagasy outrigger

The design

JEHU's main hull is from the *SHEARWATER II* mould and has a *SHEARWATER* rudder. The mast and sails carry about 100 sq ft of canvas. The surf boards (4 ft by 1 ft), with upturned bows, were screwed and glued to the connectives on the cross beams without any angle of attack but they were given 30° of slope out (dihedral). The whole outrigger system was then mounted on the hull with 10° of slope from the horizontal to give the surf boards that angle of attack to the water.

Performance

It was quite obvious when we started to sail that we had hit an excellent configuration. The cross beams produced a very comfortable armchair for the person producing counterpoise and it was very easy to balance the craft so that only the after part of the inside edge of the lee surf board was touching the water. In strong winds, the surf boards produced good planing lift and made sitting the craft up unnecessary for stability but it added to the speed. Again, the Tchetchet cross beams were found useful as another comfortable seat again appeared further outboard.

Tchetchet-style cross beams and surfboards

Handling

Handling was very simple indeed. The main sheet could be tied at all times because of the enormous stability given by the 13 ft of beam, leaving only the jib sheet and the tiller to attend when putting about. It seemed that the fore and aft trim was satisfactory with a single person on the outrigger beam, though we have never been able to drive her to the limit. Sitting forward of the mast was very convenient as one was completely clear of the boom—an unusual and very pleasant thing.

Faults

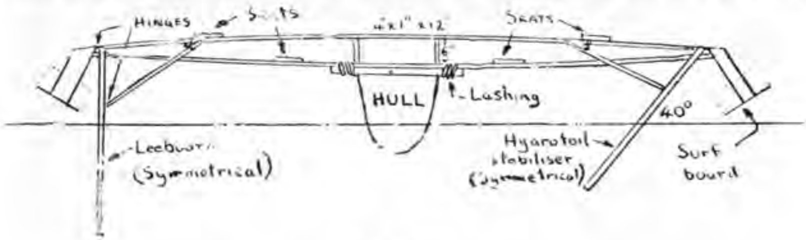
At first, when we had no centreboard, putting about was difficult. Lee boards were then fitted on each float and putting about became as easy as with a catamaran. The only minor fault still left is that the surf boards are only boxed in for their middle 4 in. As a result the water flow is able to get on top of the boards to produce extra wetted surface and an uneven water flow. The whole of the tops of the surf boards should have been boxed as shown dotted in the diagram.

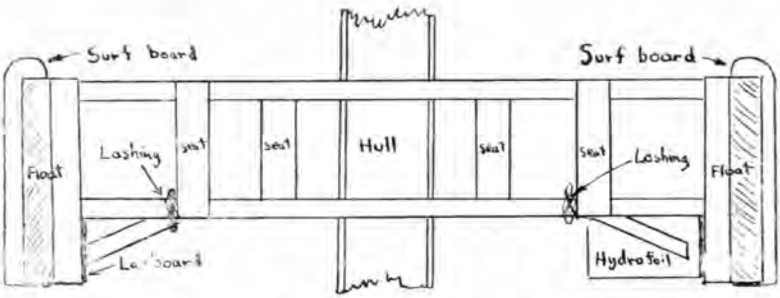
Summary

The Melagasy outrigger configuration with Tchetchet-style beam mounted on a *SHEARWATER II* hull makes a delightful craft to sail. It is essentially a single hander, though we often filled it with five or six children. It can quickly be taken apart into its two main pieces and easily transported on the roof of a car. The total weight is about 150 lbs. It is unfortunate that Sandy Watson was not at home for most of the summer and I, of course, have little time for practical sailing. Thus, *JEHU* has not been well enough tested but, in our seven or eight outings, she was a beauty.

JEHU'S HYDROFOILS

When fitting the lee boards to *JEHU*, the only logical way of having them retractable was to hinge them and retract them *inwards*. Hinged struts held them in position, either up or down. It was, of course, quickly seen that if they were angled in at the Baker angle of 40°, they would function as hydro-





foil stabilisers. We soon tried them as such and, to our delight, we found that the surf boards could be completely lifted off the water by the angled-in lee board. This occurred at a relatively low speed; about 4 knots. At speeds greater than 5 knots no sitting out was necessary and the craft sailed close hauled very nearly with the crew placed just as they wished and the surf board raised off the water.

Summary

JEHU's leeboards, when angled-in at 40° from the horizontal, appeared to function as excellent hydrofoil stabilisers. It is too early to say if there are any snags in this but there did not appear to be any. We certainly need more experience.

HYDROFOIL STABILISERS

I think that people have been frightened to use hydrofoils so far because they have felt that they must go the whole way at once and rise right off the water. This is, of course, a fascinating concept but we should not try to get there in one leap. The people who have tried it recently have all failed simply because, if one makes a craft for rising out of the water, there cannot be the development of the foils themselves which comes from sailing for pleasure with a mechanism which works. If we had a whole fleet of racing craft which used hydrofoil stabilisers, in only one or two years we would have the hydrofoils improved to such an extent that we would have our flying foil craft.

The logical method to try for this development is to fit hydrofoil stabilisers to either the *HORNET* or *INTERNATIONAL CANOE* both of which would allow their use for racing, as outriggers are not barred. Because the cost of the foils would be so small, it is unlikely that the rule makers would immediately ban their use as would happen, of course, if they were an improvement and expensive.

Hydrofoil stabilisers could also be added to the Melagasy Indonesian canoe by tilting the surf board at 40° and having a dagger slot just above it and below the buoyancy. Or the *JEHU* system can be used, which is easier to retract, if heavier and needing more beam.

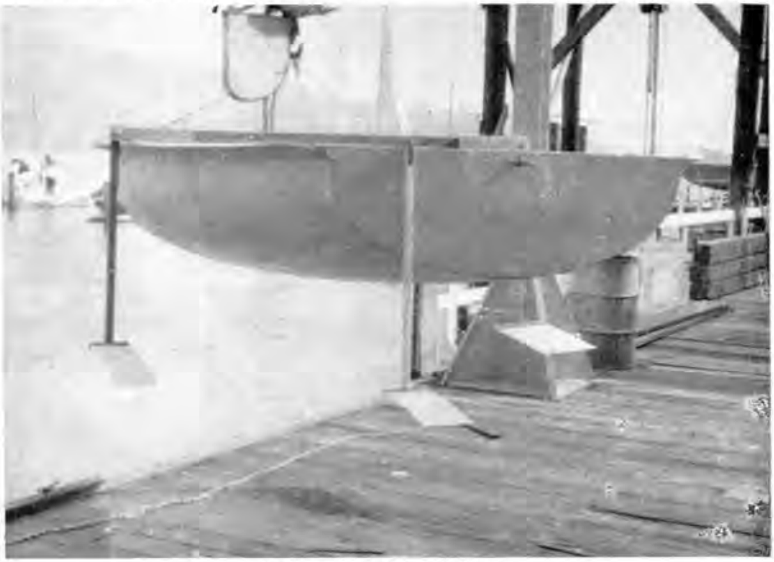
Summary

Hydrofoil stabilisers should be developed and used in such craft as the *HORNET, INTERNATIONAL CANOE* or with the Melagasy surf boards on a catamaran type hull. This would very soon develop hydrofoils to the stage where an all-hydrofoil craft would be possible. I am glad to say that Reg Briggs, of Folkestone, is now carrying out a series of foil tests on a *FLEET-WIND* dinghy which already have shown that heeling can be abolished by hydrofoils. The most successful foils will, I hope, be at the Boat Show for inspection.

A WAVE POWER DEVICE

February, 1958

The photograph shows Arthur Piver's dinghy *NUTSHELL* fitted with fins in a preliminary attempt to produce a self-propelled lifeboat. The object is to convert rolling and pitching movements into forward motion. The account of it is included here because, if it can be successfully developed, it might enable a sailing ship to get some *natural* motive power to help it along in a calm or in crossing the Doldrums.



Arthur Piver's flap foil boat

The fins

There are three of these made of plastic material, square in shape fixed at their forward ends to pieces of wood which are, in turn, attached to the vertical struts. There is enough flexibility in the fins for them to move up and down as the boat rocks, thus pushing the boat along. Plastic was used for the fins because Arthur Piver was not sure of the most effective angle for solid ones and he also felt that much power might be lost as the solid fin swivelled from one pole to the other. The plastic fins are ready to work with the slightest movement. However, I cannot believe that much power would be lost during the change-over, if any, because it would only go to the natural roll-damping property of the hull.

Performance

When the boat was rocked in smooth water, it moved along (much to the amazement of spectators). It "Fishtailed" as it did so, incidentally, which might indicate that another fin is needed at the stern, mounted vertically instead of horizontally like the others. However, it was decided that too little power for practical purposes was developed by wave motion from the form used.

Improvements

A much higher aspect ratio could well be tried in the fins which should, in my opinion, be solid. If one wanted to avoid the "Dead point," they could be attached by a strip of spring steel and stops would be needed in the strut. With these changes, I believe that considerably more power would be developed and, of course, it would greatly reduce rolling and sea motion generally. It is too early as yet to say that the principle is useless.

PARANG

("Knife" in the Malay language)

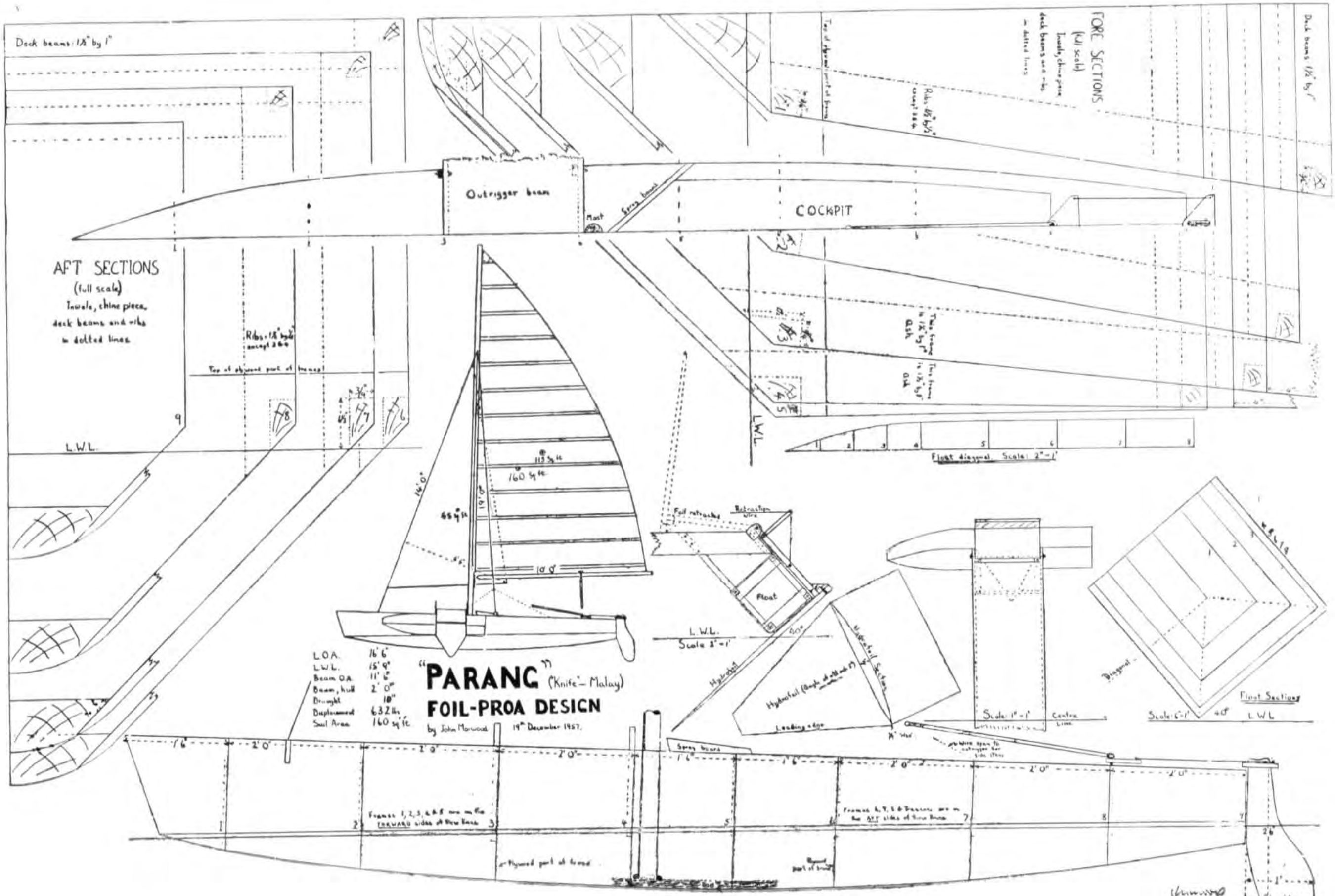
Designer: John Morwood — April, 1958

L.O.A.:	16 ft 6 in	Beam, hull:	2 ft 0 in
L.W.L.:	15 ft 9 in	Displacement (designed):	632 lbs
Beam, O.A.:	11 ft 6 in	Sail Area:	160 sq ft

The same hull is used for this design as for *TUAHINE* but, of course, it is sunk lower in the water. This is the Indonesian design with simple box-like floats on the end of the detachable outrigger beam. The floats have a square stern and a fairly fine entrance. They are set on edge so that their wetted surface can be adjusted to be the minimum.

The foils

The hydrofoils lift the floats off the water at speed. They have to be of fairly low aspect ratio to keep them from lifting up the whole craft. They also have to be retractable and capable of being used vertically for light winds.



Deck beams: 1/8" by 1"
Outrigger beam
Mast
Spray board
COCKPIT
FORE SECTIONS
(full scale)
AFT SECTIONS
(full scale)
Inwale, chine piece, deck beams and ribs in dotted lines
Ribs: 1/8" by 3/4" except 3 & 4
Top of plywood part of frames
L.W.L.
Float diagonal Scale: 2" = 1'
160 sq ft
115 sq ft
45 sq ft
14' 0"
18' 0"
10' 0"
Float
L.W.L.
Scale 2" = 1'
Hydrofoil
Leading edge
Scale: 1" = 1'
Centre Line
Float Sections
Scale: 6" = 1'
L.W.L.
Diagonal
L.O.A. 16' 6"
L.W.L. 15' 9"
Beam O.A. 11' 6"
Beam, hull 2' 0"
Draught 10"
Displacement 632 lbs
Sail Area 160 sq ft
"PARANG" ("Knife" – Malay)
FOIL-PROA DESIGN
by John Morwood 14th December 1957.
1' 6"
2' 0"
Frames 1, 2, 3, 4 & 5 are on the FORWARD sides of the lines
Frames 6, 7, 8 & 9 are on the AFT sides of the lines
Plywood part of frame

Expected performance

PARANG's tank tests are not yet to hand but they should be very similar to those of *TUAHINE*, though possibly the foils will prevent the bow-burying at speed. The resistance at full size will be much less than that of *TUAHINE* and I believe it will only be about half due to the lesser weight.

Summary

PARANG is an Indonesian type of outrigger which should be extremely fast. If the hydrofoils were made a little longer and a retractable stern foil added, the ideal sailing machine would almost be achieved. In light winds, speeds would be maximum due to the low wetted surface. In medium wind strengths, speeds would be maximum as then the craft would be riding on her main hull with only the lee hydrofoil keeping her upright. Finally in strong winds, the craft would rise right out of the water and sail on her hydrofoils.

CHAPTER IV

HYDROFOIL CRAFT

by Robert B. Harris — June, 1958

Introduction

Hydrofoils are lifting shapes used in water. They are similar in action to aerofoils. The term "lifting" may be thought of as describing the vertical force produced by these shapes when advancing in a fluid and it comes to us from aerodynamics where the "lift" is the force exerted on an air craft by the wings to raise it off the ground.

From our introduction to the subject by John Morwood in AYRS publication No. 2, *HYDROFOILS*, we have learned that these shapes are used for a variety of tasks as centre-plates, rudders, leeboards, fin keels, stabilisers and, I should like to add, propellors, impellors and turbines. Of particular interest in *HYDROFOILS* is the very practical suggestion of using asymmetrical hydrofoils as centreplates in single hulled sailing craft. In the writer's opinion, this offers unique possibilities.

The purpose of this paper will be to trace the history of hydrofoils from their earliest use in lifting boats off the water to present times. We shall also look into some of the basic problems facing hydrofoil designers today and the steps they are taking to solve them.

Advantages of hydrofoil craft

Hydrofoils have been developed both for surface craft and for flying boats and seaplanes. For surface craft, the advantages are:

1 The power needed to drive a hydrofoil craft at 40 knots is only half of that needed to drive a conventional planing type hull of the same weight.

2 A hydrofoil craft can be designed to ride *above* the seas and weather and be relatively little affected by them. This gives an easier, smoother ride with bumps due to waves only one fifth as great. This means that the hydrofoil craft can keep going at 30 knots while the planing hull has to slow down to very low speeds.

For flying boats and seaplanes Guidoni, one of the pioneers, gives the following advantages for hydrofoils:

1 Economy in weight. Owing to the fact that floats are only used for static support and do not strike the water until the speed has slowed down, the structure can be lighter than in the ordinary case.

2 Landing a machine in a rough sea is easier. In taking off, no bumps or shocks of any kind are experienced, the machine behaving as if it were supplied with the most efficient of shock absorbers.

3 There is no possibility of the machine assuming a stalling position in the water, as frequently happens with other floats. The machine has only a very small angle of longitudinal inclination in the first stage. When the boats are free of the water and only the foils are in the water, she can easily be controlled by the elevators. No lateral control is required in taking off as for an ordinary flying boat.

Early hydrofoil systems

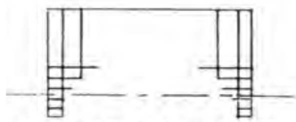
Comte de Lambert

The first known instance of a hydrofoil supported craft was a catamaran fitted with four transverse "hydroplanes" by the Comte de Lambert in 1897. It is reported that the craft rose clear of the water. However, this was probably due to the surfaces planing rather than foil lift; i.e., they were skimming on the top of the water, being held up by the water pressure on their *under* surfaces only. A hydrofoil depends for its lift on pressure differences between its upper and lower surfaces. So long as the resultant of the forces created by these pressure differences is upward and big enough, the craft to which they are applied will rise until these conditions change.

Forlanini

In 1898, Forlanini developed a hydrofoil craft which really flew and we have a record of the ladder type of foils used. Little is known about this craft however.

Fig. 1 Forlanini's Craft—foil-borne



Section through main foils

Crocco

Sparked by Forlanini's success, Crocco (also in Italy) followed soon after with the development of monoplane dihedral foils as shown in the drawing. This craft apparently did 50 mph "Monoplane" here refers to the fact that there was only a single wing below the surface as opposed to all the little winglets used by Forlanini.

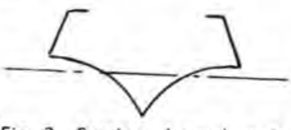


Fig. 2 Section through main foil Crocco's Craft

The Wright Brothers

By 1907, the Americans were beginning to sit up and take notice. The first Americans of any repute to experiment with hydrofoil supported craft were Wilbur and Orville Wright, who also used a catamaran. Little is said of their trials except that because of low water in the Miami River in Dayton, Ohio, where the trials were run, an early end was brought to their efforts. There is no record of any further work by these two.

Richardson

Captain H. C. Richardson, U.S.N. (retd.) followed in the U.S. in 1909 with the fitting of tandem bi-plane foils to a canoe. The canoe was towed, however, not self-propelled, and flew on the lower set of foils at 6 knots. Another hydrofoil craft was later made by Captain Richardson in collaboration with N. White. This time, a dinghy was used with foils which permitted incidence control for stabilisation and manoeuvering.

Fig. 3 Captain Richardson U.S.N. Rtd. Dinghy with incidence control foils 1911

Guidoni

Guidoni, an Italian, during the period from 1908 to 1925 fitted hydrofoils to seaplanes ranging in weight from 1,400 to 55,000 lbs and made some very important strides in their development. His primary objectives were (1) To reduce the take-off resistance of the seaplane; (2) Allow them to land at higher sea states and at greater speeds and (3) To carry bigger pay loads. Aircraft design and use were advancing rapidly at the time and it would have been an important help both for military and commercial users to be able to achieve this.

Fig. 4a Guidoni Seaplane, foilborne

Fig 4b. Guidoni: Monocoque Floating wing with foils

Guidoni also developed a hydrofoil section which, according to some authorities, comes very close to being the best all round section at various speeds, especially in regard to cavitation, at the same time having very good lift and drag characteristics. Guidoni's work was later considered of sufficient value for a complete re-evaluation by the British and during the period 1930-1940, a model test programme was instituted by the National Advisory Committee for Aeronautics at the request of the U.S. Navy Bureau of Aeronautics.

Dr. Alexander Graham Bell

in 1918, the labours of Dr. Alexander Graham Bell and Casey Baldwin paid off in the form of the HD-4. The craft had a gross weight of 11,000 lbs, took off at 20 mph with a thrust of one ton and forty square feet of foil area and reached 60 mph, then only using four square feet of foil area. Two Liberty aircraft engines of 350 hp each were used. The ladder foils with dihedral were reported to have produced a lift-drag ratio of 8.5 at 30 knots, an excellent mark even by today's standards which was got in spite of the cumbersome configuration.

Fig. 5 The Bell HD4 1918. Speed 60 knots

It would be difficult to draw any conclusion on why the Bell HD-4 did not prompt further investigation and support by the U.S. Navy Department. It was probably due to the cumbersome nature of the configuration, the fact that she porpoised in a seaway and the fact that a war had just ended.

From history, it would be quite safe to say that, in spite of the many remaining problems of foil-borne flight, such experimenters as Forlanini, Richardson, Guidoni and Bell had remarkably good results. If they had received government support or even substantial support from private quarters, hydrofoil craft might have been commonplace today. Guidoni did receive considerable governmental support and so was able to make substantial progress of both a practical and theoretical nature.

Principles of Design—Height control

The first principle of hydrofoil craft design is to find an efficient method of keeping the craft flying at a fixed height above the water surface. This can be done manually as was tried by Captain Richardson but it is found that the height maintenance is too delicate and needs too much attention for prolonged use. The helmsman gets too tired too quickly to keep going. Some automatic method must therefore be used and these fall into two types:

1 The foil area can be disposed vertically as in the "ladder" method of Forlanini, Guidoni or Bell. At any given speed, height will then be kept constant because, if the craft tries to sink, extra foil area will enter the

water and vice versa. The same result will be obtained by a single foil placed at an angle of "dihedral" to the horizontal and placed to break the surface at its outer end. The main advantages of dihedral, with the foils piercing the surface, lies in the fact that less foil area is needed at higher speeds. Lift is a function of area and velocity. With dihedral, the foils will reduce in area as the craft rises due to greater speed and hence lift. Dihedral tends to give more stable flight in a sea for, as the vessel heels, more area will be picked up on one side than the other, tending to right the craft. Dihedral also reduces air entrainment which cannot be tolerated at sea.

2 The foil can be placed horizontally but a mechanism is introduced which gives it a greater "angle of attack" to the water flow, if the craft rides too low. This can be done mechanically by "feelers" or "jockey arms" as in the Hook *HYDROFIN* or electrically by impulses from a "feeler" setting the angle of attack of the main foils. The "feeler" could also be placed above the water and take its level by Radar or be placed *below* the surface and take its level by an inverted depth recorder.

If this were the only factor involved, the design of hydrofoil craft would be very simple, so simple that there would be no trouble in making these efficient craft. The snag lies in what is called "Air Entrainment."

Air entrainment (ventilation)

This consists of air passing down the strut or foil to the low pressure area on the upper surface of the foil, causing a sudden loss of lift. The foil drops and may even get a negative angle of incidence, dragging the whole craft forcibly into that water, a condition known as the "Crash Dive." This may damage the craft and injure the occupants.

Some small fixed foil systems are liable to crash dive under certain conditions and, when the seas become dangerous, they must slow down and continue as ordinary boats. A following sea appears to be the worst for most types due to the sudden changes of the angle of attack. This may result in a crash dive if the loading on the aft foil is about 40% or more of the craft weight because the large aft foil area has a very great effect on trim.

The crash dive can be avoided by having variable incidence on the forward foils and this is found in many of the modern applications such as Von Schertel, Baker (*HIGHPOCKETS*), Grunberg and Hook. Only the Carl-designed craft and *BRAS D'OR* of Messrs. Saunders Roe are now using fixed foils where, by careful design, the crash dive has apparently been eliminated. A great fore and aft length for the craft will also eliminate the chances of negative incidence.

Sweepback

This feature is the slope of the hydrofoil aft of the thwartships axis of the craft, from its root. One of its advantages which is not readily seen is that a fore and aft section taken through a swept foil will have less thickness relative to the chord than a non-swept foil. The result is an increase of speed at which cavitation occurs.

Another of the advantages of sweepback has to do with air entrainment (ventilation). A hydrofoil can be operated through many degrees of change of angle of attack but a surface piercing foil will, at one critical point, suffer air entrainment. When the flow thus breaks down, a hysteresis occurs which means that the flow will not reseat itself until the angle of attack is reduced. The point at which the flow reseats itself is the minimum angle of attack at which the foil may operate at a given speed. Fences on the foil are often employed to delay ventilation but sweepback, combined with dihedral eliminate the need for the fences and further delays air entrainment. Sweepback also aids in shedding debris which, if otherwise allowed to remain on the foil would cause extra drag and cavitation.

Modern systems

By no means has it been decided that one hydrofoil configuration will suit all conditions, or that even one condition is best served by any one system. The trend, however, has been to reduce the number of surfaces, and their supports to the barest minimum in order (1) To reduce take-off resistance; (2) To simplify construction and (3) To facilitate retraction of the system above water.

Tietjens

In 1932, Dr. Otto Tietjens came up with what is probably the simplest configuration which can be visualised today, consisting of one main dihedral foil placed forward of the C.G. and a small stabilizing foil aft. 85% of weight was on the forward foils and 15% on the aft ones.

Von Schertel

H. F. Von Schertel of Germany tried two dihedral foils in tandem with 60% of weight on the forward foils and 40% on the aft one. After the last war, the Oerlikon Company in Switzerland proceeded to build a series of successful personal ferries to this system, the first of which paid for itself in the first year of operation on Lake Maggiore in Italy. Later, they built the

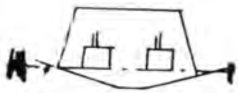
Fig. 6 Von Schertel 27 ton Passenger Ferry foil-borne
Speed about 40 knots

27 ton 72 passenger craft, shown in the photograph, one of which has now carried 115,000 passengers since 1956. Most of these craft had a design speed of 40 knots.

The early Tietjens and Schertel craft failed to avoid the crash dive but, by intensive research, a solution to this problem was found in putting streamlined collars on the foils called "fences" and having some degree of incidence control.

Grunberg

In 1938, W. Grunberg of France patented the first automatic incidence control system. The main foil is fixed and supports 80% of the weight in flight. The forward surfaces are planing surfaces which contour the sea, and about which the craft trims. For example, when approaching a sea, the forward surfaces lift and increase the angle of attack of the craft and the



View from forward Hull omitted for clarity

Fig. 7 Personal Ferry with Grunberg Hydrofoil system

main foil, thus tending to maintain the same angle of attack in relation to the wave slope. The disadvantage of the system appears to be that the planing surfaces skip from sea to sea, if the frequency is too high as in a short steep chop. This could result in pounding of the skids and insufficient damping. The problem of air entrainment remains.

The Hook Hydrofin

For hydrofoil craft without air wings, Christopher Hook's *HYDROFIN* comes as near to solving the problems of heave and trim as has yet been devised. Hook first thought of his system in 1941.

In the *HYDROFIN*, a pair of "Jockey arms" protrude forward of the craft, sense the oncoming seas and relate the message to the main "swept-wing" horizontal submerged foils. The jockey arms act as levers and are linked

The Hook *HYDROFIN*

directly to the main foils, thus changing the angle of attack. There is also provision for altering the ratio of the linkage so that the craft may fly at various altitudes. Since the link pivot positions may be altered separately, port and starboard, the helmsman may control the angle of bank in a turn.

Hook's *HYDROFIN* greatly reduces surface losses and avoids the crash dive (though air entrainment can still occur with loss of lift and a temporarily greater resistance till the air is thrown clear). Against these advantages must be placed the cumbersome and vulnerable jockey arms. It would seem quite possible that, if the jockey arms were replaced with electronic wave profilers set high over the water as from a bowsprit, the major disadvantages of Hook's basically excellent system would be eliminated.

Fig. 8 Miami Shipbuilding's ½ scale LCVP using the Hook system

Fig. 9 Miami Shipbuilding's full scale LCVP using the Hook system

The *HYDROFIN* foils can be easily retracted for cleaning. It is very important to keep the foils smooth because slight surface imperfections can cause cavitation and loss of lift. Retraction also means that the craft may be hauled on conventional marine railways, or the boat may be beached, provided the propellor and strut retract also.

Hook's untiring efforts in South Africa and Cowes will never be forgotten as he alone demonstrated the main advantage of the variable incidence hydrofoil supported craft. However, he was unsuccessful in finding interest in Europe and decided to try in the United States.

After entering the *HYDROFIN* in the New York Boat Show in 1948, valuable contacts with government officials were made. In due course the Miami Shipbuilding Company built a small *HYDROFIN* landing craft for load analysis and performance evaluation by the U.S. Navy. By 1957, a much larger craft had been built.

The Hook *HYDROFIN* is a near answer to the problem of hydrofoil craft in most circumstances of wind and sea but there still remains the desire for simplicity, foolproofness, low maintenance, light weight and better retraction quality.

The Baker craft

Gordon Baker, in the US during this time had been developing hydrofoil craft with surface piercing foils of a dihedral greater than 30°. One of his first was a hydrofoil sailing craft. The system was comprised of two surface piercing V foils forward of the CG and a single V foil aft. Once up on the foils, the sailboat hydrofoil performed well but, as soon as the wind fell off or it had to tack, she could come down off the foils. The same was true of a later sailing hydrofoil of Baker design employing two sets of ladder foils set athwartships as before with a set of V'd ladder foils aft. The CG is

Fig. 11 Baker Hydrofoil boat *HIGH POCKETS*

somewhat aft of the main foils. This craft reached 30 mph, and it is interesting to note that she used full length battens in her sails and had a pivoting main mast. The US Navy footed the bill for this craft but were ultimately much more interested in Baker's power hydrofoil craft *HIGHPOCKETS.* This craft consisted of four sets of surface piercing V foils, two sets forward and two sets aft with 50% of the load on each pair. Good L/D ratios were obtained in the cruising range, an important factor for economical considerations.

Gilruth

R. Gilruth and Bill Carl, also of the US and of the NACA started experimenting with foils in 1938. They successfully flew a catamaran hydrofoil sailing craft which took off at 5 knots and cruised at 12 knots. The main foil had an aspect ratio of 11 : 1, a 12 ft span, a 1 ft chord and the remarkable L/D ratio of 25 : 1. The foil section was one of big camber for high lift

Fig. 11 Gilruth hydrofoil catamaran sailing craft, foil-borne

at low speed, like NACA 65-506. Gilruth's work later formed the basis for high speed configuration proposals to the Office of Naval Research, which resulted in the first Navy contract in 1947 for research on hydrofoils.

The Carl hydrofoils

William P. Carl, President of Dynamic Developments Inc., following his work with Gilruth, took the studies of hydrofoil craft one stage further with the XCH4. This craft has flown well over 65 knots, and according to Mr. Carl, owes its success to its fixed foil system. Longitudinal dynamic stability is obtained from proper adjustment of foil areas and their proper location in relation to the CG. Transverse stability and area control are obtained from surface breaking dihedral and spacing of the main foils. Reduction of air entrainment and retardation of cavitation are due to sweepback of the foils. Water propeller shafts are abolished by using air propellers and there are only three struts in the water, one for each set of foils.

Fig. 12 The Carl XCH4—in sling

Fig. 13 The XCH4—foil-borne 60 knots

The XCH4 is 53 ft long. The manner in which the hull tapers to a fine stern is part of the design concept of the craft. Think of it, if you will, as the main payload being supported by the main foils with a strut extending aft to support a small stabilizing aft foil. The CG of the craft is slightly aft of the centre of pressure of the main foils. The fine stern is important in reducing buoyant forces which might otherwise produce a negative angle of attack on the main foils. The XCH4 has excellent heave and trim characteristics. For example, in a 3 to 4 ft sea, one may stand on one foot while travelling at 50 to 55 miles per hour. The vertical acceleration of the XCH4 when foil borne is only 1/5th of that of a conventional hull alone. It might seem that as each of the steps of the "Ladder" came out of the water, there would be a bump. This does not occur because, with dihedral, the upper foil will partially enter or leave the water before the foil immediately beneath it enters or leaves the interface.

It may be possible to foresee still another design concept in such a craft as the XCH4. This is, that at the speeds when the hydrofoils might otherwise become unstable or commence to lose lift through cavitation, the speed is great enough to cause a partial transfer of the weight to the wings. The stub wings of the XCH4, which act as foil supports could thus be designed to contribute stability and lift even to surface craft. This is not as far-fetched

Fig. 14 Grumman Aircraft Engineering Corp's Aluminium 15 ft Runabout fitted with Cowl Sea Wings

Fig. 15 Grummon 15ft Aluminium Runabout, foil-borne

as it might at first seem, considering that a hydrofoil boat is actually a low-flying machine, getting its lift from the foils instead of air wings. In fact, Bill Carl has patented the name *SEA WINGS* for his hydrofoils.

However, as Mr. Carl points out, there comes a point where one should leave the water and fly. He believes that the 60 to 70 knot range will be sufficient for surface craft. His latest hydrofoil system will permit the construction of vessels of from two to three thousand tons. This system is composed of two main foils set forward of the CG. These foils are swept back and all surfaces are lifting with the exception of the main support strut. Attached to each is a small trimming tab which is hand controlled and will allow a slight adjustment of flight attitude, although this is not necessary for stable flight. The tail foil is submerged and is set as far from the main foils as the vehicle will permit. Some adjustment may be made to it but not in flight. On the latest model, it is a swept back, symmetrical foil designed to carry about 15% of the total load.

Gibbs and Cox

Gibbs and Cox, Naval Architects in the US, during the early 1950's, developed an electrical impulse variable incidence controlled hydrofoil power craft. In this system, feelers out in front of the foils sense the water level electrically and pass the information to the main foil incidence control system which alters the angle of attack of the foils accordingly. A more recent craft has

Fig. 16 Gibbs and Cox incidence controlled boat (1953) foil-borne

Fig. 17 Gibbs and Cox incidence controlled boat (1957) foil-borne

a much more "sophisticated" electrical impulse system and is reported to be highly successful. It is, in fact, an electrical version of the Hook system and a vast improvement.

Conclusion

The modern hydrofoil craft are highly successful whether Gibbs and Cox's latest craft which is an improvement on the Hook system or the fixed, self-trimming systems like Grunberg, Tietjens or the latest Schertel, Sachsenberg system or *SUPRAMAR* craft.

However, it is particularly important to note that with a carefully designed and refined fixed system, the same required stability about all three axes is assured without the costly and difficult to maintain variable incidence controlled systems. With a simple, safe, fixed system, capable of high speeds, designers can now devote much needed attention to propulsion problems, new hull design concepts, large ship application and eventually large scale production for military, commercial and private use.

Apologies

We wish to apologise if we have neglected to mention anyone who has developed and tested a hydrofoil system and would greatly appreciate hearing from any such persons or group.

Acknowledgements

To Henry B. Suydam of the Preliminary Design Dept., Grumman Aircraft Engineering Corp. and William P. Carl, Pres. of Dynamic Developments Inc., for their valuable help in the preparation of this paper.

Thanks

Sincere thanks to Sally Spiegel for her patient drafts of this paper.

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CHAPTER V

THE DESIGN OF HYDROFOILS

by John Morwood 1958

Hydrofoils are the most exciting prospect for the further advancement of sailing and it is hoped that several people will be trying them out this year in one form or another. It is therefore worth while to give the main points in the design of surface piercing foils as a guide and in the hope that improvements will be forthcoming.

The section

A hydrofoil would ordinarily be given an aerofoil section were it not for the facts of (1) Cavitation, (2) Air entry and (3) It has to pierce the surface.

1. *Cavitation* occurs when the lessened pressure over the upper surface of the foil becomes less than that of the vapour density of water. When this happens, the water flow over the surface is broken by a layer of water vapour which appears like a bubble along the foil and the lift falls off.

2. *Air entry* occurs when air gets over the upper surface of the foil and is held there by the negative pressure.

3. A sharp entry is better for cutting the surface of the water than a rounded entry.

The upper surface

To avoid cavitation and air entry, the upper surface should be shaped so that there are no places where the pressure is very low, such as occurs with aerofoils at the leading edge. This is best achieved by having the upper surface the arc of a circle. The pressure drop on the upper surface is then more or less the same all over the area.

The lower surface

A flat lower surface is, apparently, quite satisfactory and is the easiest to make. The combination of a flat lower surface and an arc of a circle for the upper surface makes up what is called an "Ogival" section and is that usually used for surface-piercing hydrofoils with the modification as in the next paragraph.

The entry

An ogival section will have an even and low pressure drop over its upper surface to prevent cavitation and it has a sharp entry to cut the water. However, if one bisects the angle of entry of such a foil section of a thickness ratio of 12 : 1, one finds that the angle is about 15° from the lower flat surface and this would have to be the angle of attack of the water, if it were not to cause a downward pressure on the fore part of the upper surface. Now, for the best ratio of lift to drag, one wants an angle of attack of about 5° and this can be achieved by raising the lower surface by 1/60th of the chord at the fore end. The line bisecting the leading angle of the section will then be 5° and there will be no downward pressure on the upper surface. The final section is shown in the drawing.

Thickness

Hydrofoils of thickness to chord ratio of 12 : 1 are ordinarily used, though 10 : 1 has been suggested. The thicker foils will give more lift and therefore might get the craft off the water more quickly. But, they will also produce more drag for the same speed and cavitate sooner. A ratio of 10 : 1 might prove better for sailing craft which are not so likely to reach very high speeds.

The plan form

The plan form of surface piercing foils must depend on three factors;

1 Aspect Ratio.
2 The prevention of air entry.
3 Easy sea motion.

Aspect ratio

This is the ratio of the span of the hydrofoil to the average chord. In essence, it is a measure of the ratio of the lift of the foil to the loss of lift at the free wing end or ends.

Ed.: See Edmond Bruce's article p. 185

Air entry

This condition, technically called "air entrainment" occurs when the upper surface of the foil becomes covered with air which has got down from the surface. It is to be distinguished from "cavitation," already described. When air entry occurs, the lift falls off possibly to as little as one quarter of what it was before; that side drops and may achieve a negative angle of incidence and the craft may "fly" straight into the water amid showers of plywood and a tremendous splash. It is a condition to avoid.

Methods of Prevention

1. Messrs. Saunders Roe and others used to believe that air got to the upper surface of the foil by suction from the surface, and to prevent this, placed streamlined fillets (fences) across the foils. These were successful in preventing the "Crash dive" described above and so seemed to substantiate the theory. However, it now appears that these fillets can be extremely small and still work so, to my way of thinking, their function is to act as points from which the trapped air can escape when it has been taken down.

2. It is my belief that, with surface-piercing foils, there is no way of preventing air from covering the upper surface when it breaks through a wave. One's objective, therefore, must be to minimise the drop due to the loss of lift and to get the air off the foil as quickly as possible. I believe that both these things can be achieved by the use of a triangular plan form for the foil. This shape will only drop in proportion to the square root of the loss of lift of the foil as compared to a drop of far greater extent from a rectangular

foil and both the sweepback of the trailing edge and the broadening shape will throw the air away quickly. I also feel that the greater waterline length of the triangular plan form will have fewer surface losses. These are quite severe and have possibly been the cause of the difficulty which experimenters find in getting off the surface.

Easy sea motion

When a surface-piercing foil meets a wave, extra area is immediately brought into use and, because this area has had to be used to get the craft up in the first place, it must be lifting. Therefore, the craft will get a push up. This push will be mild or severe depending on the plan shape of the foil. To be most satisfactory, the plan shape has to be almost rectangular. A triangular plan form such as I suggest will produce a blow upwards from a wave. This might not be disagreeable but if it were, hinging the foil at its forward end and having a spring at the after end will lessen the blow, both by taking it on the spring but also by lessening the angle of attack of the foil. Indeed, such a spring would also increase the angle of incidence when the lift suddenly fell off with air entrainment and, as shown by Christopher Hook with the *HYDROFIN*, this will convert a "Crash" into a slight limp. The sprung foil may be avoided by increasing the angle of dihedral to 60° but this entails a reduction of lift and therefore an increase in size of the foils.

Incidence control

It is to be noted that the sprung foil, as suggested here with surface piercing foils, will be as effective as either the Hook system with cumbersome "feelers" or electronic incidence control. The "Crash dive" cannot occur and the incidence control will be good. Hydrofoils, apparently, do not "stall" and the flow will reseat itself if air entrainment occurs with an *increased* angle of attack, though, as stated by Bob Harris, theoretically, one should *reduce* this.

Dihedral

The most satisfactory angle of dihedral for lifting foils is about 40°. My own experiments showed that 30° was too flat for a model.

Foil area

The Bell "Hydrodome" had hydrofoils which developed 70 lbs lift per square foot of area at 10 mph.* These foils were nearly horizontal and the vertical lift of more sloping foils could well be taken as the cosine of the dihedral angle. For instance, foils at 40° of dihedral would develop about 45 lbs of of vertical lift per square foot of area at 10 mph.

Summary

Hydrofoils should be a simple ogival section with the fore edge raised by 1/60th of the chord. The thickness/chord ratio should be 12 : 1 or 10 : 1. A triangular plan form with a root chord to span ratio of 1 : 1½ may give a good aspect ratio, throw air clear and, if the after edge is sprung, give an easy sea motion. At 40° of dihedral, the vertical lift should be 45 lbs per square foot at 10 knots.

* This figure does not agree with that o: 280 lbs as given on p. 17

PARALLEL FOILS

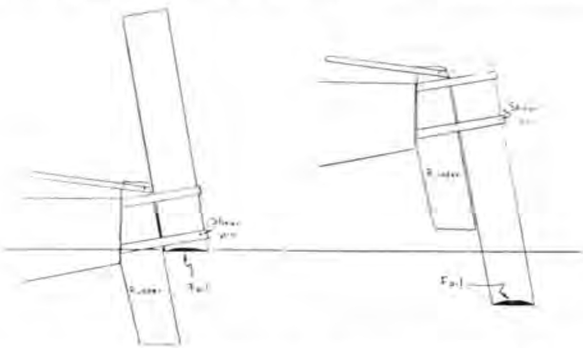
Surface piercing foils with dihedral have an inefficiency. This is the leeward acting force of the weather foil which has to be neutralised by the lee foil. This inefficiency has to be taken by a motor driven hydrofoil-borne boat but a sailing craft which has a side force from its sails may be able to overcome it.

The forward foils

A sailing hydrofoil craft could have its two forward foils sloping upwards to lee as in the drawing. The angle from the horizontal will then *both* give the extra foil area which is wanted when a foil is pushed further into the water and it will absorb the side force of the sails on the weather side as well as to lee. The result of this improved efficiency may be that the angle of slope of the foils could be reduced with a greater lift to drag ratio.

The stern foil

Ideally, one would want the stern foil also to slope up to lee as with the main foils. This is certainly possible as shown by the earlier Baker hydrofoil craft which has been shown, but it needs appropriate positioning of the

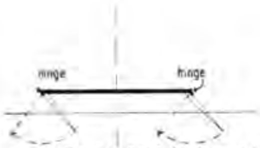


centre of gravity to absorb the forward capsizing moment of the sails. An inverted T stern foil might be best because it can take the forward capsizing moment of the sails by a negative angle of incidence. This is also an inefficiency when it occurs. A method of having a retractable stern T foil is shown in the figure.

The mechanism

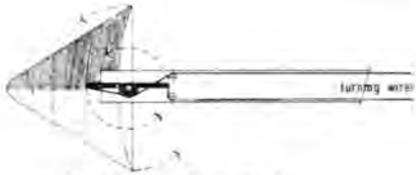
To get the foils to slope up to lee on each tack, a mechanism must be used of which there are two kinds:

1 The foils can be hinged at their tops so that they flap over on each tack. This system was invented (and patented) by Commander Fawcett. It could only be worked with symmetrical foils. The craft would have to come off the foils to put about or gybe.



Ed Fawcett's flap foils (symmetrical)

System for asymmetrical parallel



System for manual turning of foil

2 The foils could be fitted to a vertical axle which worked on bearings at the ends of the outrigger. These foils would have to be changed for each tack by hand but an asymmetrical foil could be used with a higher lift to drag ratio. It is possible that the craft might not need to come off the foils to put about or gybe.

A HYDROFOIL SAILING CRAFT

The delightful drawing by N. G. A. Pearce shows what I believe to be the ideal hydrofoil sailing craft with all parts in the water getting the greatest possible efficiency.

The hull

The hull has some stability in itself, though it would be on the narrow side. Outrigged buoyancy would not be necessary, therefore. The hydrofoils would give a little buoyant stability in light winds or at moorings. Probably all that was wanted.

The foils

All three foils would slope up to leeward, accurately to take the combined side force of the sails and the weight of the craft. Thus, they would be absolutely right for the work they are to do. Adjustment of the angle of dihedral in flight might, however, be needed so that the lesser side force with a reaching wind could be met by a lessened angle. Each foil could be turned about a vertical axle for putting about.

Sailing

As I see it, the craft would be got on her foils with a beam wind. The foils would be set at an angle of dihedral of about 30° and all made to slope up to leeward with them all aligned exactly fore and aft. The angle of leeway would thus make up their angle of attack.

As the craft gathered way, she would rise on her foils and the apparent wind would go forward, so that the sails would have to be close hauled, even with a beam wind. The angle of dihedral would then be increased to 35° or 40°.

Putting about

For this manoeuvre, the actions would be as follows:

1 Put the weather foil on the other tack by twisting it around aft. It would act as a slight brake when aft but would still be lifting. When turned right round, it would have to be given a slight angle to the water flow and not placed fore and aft like the lee foil.
2 The stern foil would then be twisted around and the craft would swing quickly through the wind.
3 Before the sails filled on the other tack, the weather foil might need to be given a slight "toe-in" to give it an angle of attack to the water flow.
4 As soon as the sails fill, the foil which is now to weather would be twisted to the other tack, the angles of attack of all the foils would be adjusted and the craft would be sailing.

Gybing

It might be thought that gybing would need some especial handling technique I cannot think, however, that it would be at all different from coming about. The craft would be sailing somewhat faster than the windspeed when the real wind was on the quarter and, during the gybe, the sail would be weather-cocking *to windward.*

Steering

Twisting the stern foil as drawn, would merely give a greater or lesser angle of attack to the water flow with an alteration in longitudinal trim. This might be adequate for steering but I rather doubt it. I believe that to steer with such a foil, the angle of *dihedral* would need to be altered rather than the angle of attack. Thus, by making the foil more vertical, the stern would sink slightly and an increased force would be produced *to weather*. The extra force would come from the more sideways slope of the angle of force on the foil. This action would also increase the angle of attack on the foil.

The sail rig

At the high speeds at which a hydrofoil craft would go, a good thrust to side force ratio of the rig seems to me to be more valuable than sheer sail area. It would also be necessary to have the rig easy to handle. I therefore feel that a simple fully battened mainsail (without jib) erected in the Ice Yacht manner would be best. The mast would need to be slightly raked aft.

ROCK AND ROLL BOATS

by Julian Allen

A man, standing at the end of a punt, can thrust a paddle straight down into the water; and it goes straight down. Or, he can thrust it down at a slight slant away from him; and the paddle slides away as well as downwards, pulling his hands after it. The greater the slant, the farther and faster does the paddle gain distance. This is shown diagrammatically in the three drawings on the left of Fig. 1.

A better shape for the purpose would be a blade mounted at right angles to the shaft as in the middle drawing of Fig. 1. Owing to the improved aspect ratio, it would develop a stronger pull.

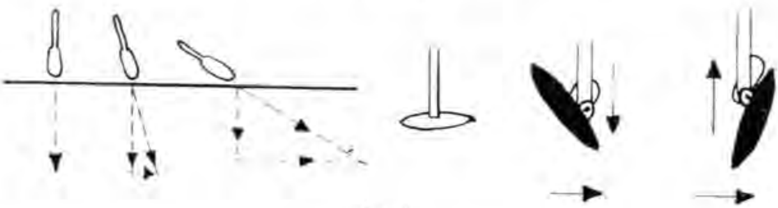


Fig. 1

These fixed types of hydrofoil use only the down thrust as a working stroke. In order to make the uplift of the vane also effective, all that is needed is to make the vane swing to the desired angle automatically by pivoting it just forward of the centre of pressure and providing suitable stops as on the right of Fig. 1.

This idea inspired my first attempt at flap-vane propulsion. I chose an angle of setting of the vanes which was rather flat to give ample horizontal distance.

A rocker beam was mounted on a twin hulled craft to see-saw transversely. This lifted and depressed the vanes attached to its ends by vertical struts when the man-power engine started "marking time" on the treadles on each side of the fulcrum. Every down-stroke as well as every up-stroke was a working stroke. It was as if the man with his two legs was a twin cylinder steam engine in which each cylinder was double acting.

The thing worked but very slowly and with great turbulence and wasted effort. This was because the vanes were set to work at an angle of 20° each

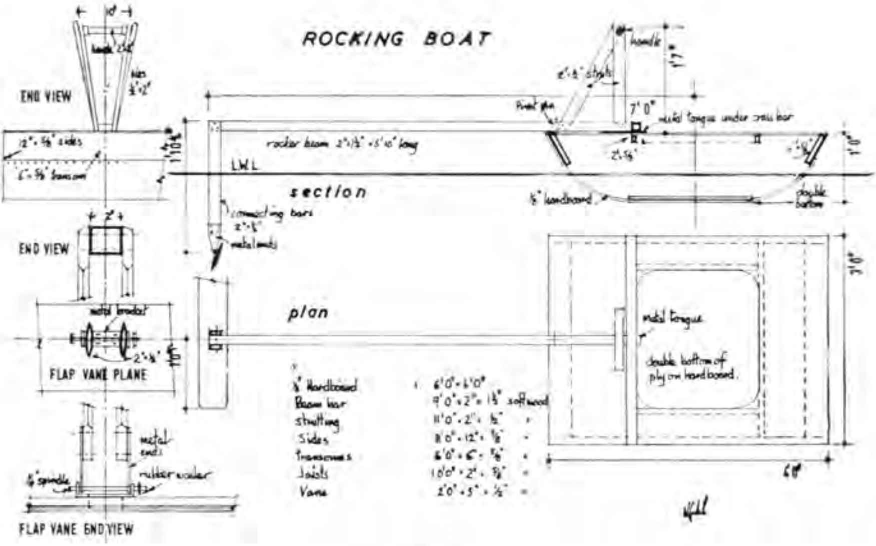


Fig. 2

side of the horizontal to gain the long forward component. It was quite obvious that the vanes stalled and never worked to their best efficiency. Still, the craft went out and came back under its one man power.

In the next craft, weight and complications were saved by using a single float with a fixed transverse beam; and by making the whole craft rock to work the vanes. Small balancing floats near the beam ends saved capsizing. The idea of long gliding strokes was abandoned and the forward propulsion came from the vanes set for an angle of 45°. It was obvious that propulsive effort must come from direct lift in a horizontal direction and not from a slight gliding angle. The glider was thus metamorphosed into a propeller.

This "Roll Boat" was a lot better in efficiency than the previous one but the outrigged vanes were always getting foul of mooring ropes so, to overcome this, I made a new craft to rock fore and aft. The single oscillating beam projecting straight forwards rigid with the boat, carried a single vane. It was easy to see where it was heading and, because it was pivoted to the bow, it could be swung laterally for steering.

Conclusions

1 The vanes must be weighted to have neutral buoyancy.
2 The vane should have a high aspect ratio to reduce the time and distance lost during the flip over. Very narrow vanes arranged as a biplane are worth trying.
3 The vanes may be regarded as the blades of a propellor making fractional revolutions, first one way and then the other. Conceived as a propellor, the angle of incidence should be a lot finer than 45°, say 15°. Four wood screws positioned to butt against the metal ends, shown in the drawing, would give a simple means of adjustment.

4 A harmony must be sought between the oscillation period of the boat and the resistance to oscillation of the vanes. If the vanes are too big or have too much pitch, the rocking motion lacks an even rhythm.

5 As the vanes use the same leading edge and opposite striking surfaces alternativety on each stroke, they must be symmetrical and of course, streamlined.

FUN, A 15ft. TRIMARAN

by Donald Robertson February, 1960

FUN, a 15 ft trimaran, was the result of some experiments which I had made with model sailing boats. I had never built a boat before but I regarded her as a full sized model that would carry me and allow it to be sailed to the best advantage.

The boat was built primarily to carry out experiments with different types of rig. These will be described in a later publication, but a number of other experiments were made on the hull itself.

The hull had an overall length of 15 ft with a beam of 3 ft 6 in. It was fully decked but had a small watertight cockpit for the helmsman's feet. Needless to say it was very unstable but there were two hollow seats which could be extended outwards on outriggers. These provided buoyancy when the boat heeled and a seat to sit her out. It required considerable agility to keep her upright but she sailed quite well. The rudder was controlled by a boom mounted across the boat pivoted at the centre and connected to the rudder head by a push pull shaft. This arrangement was used by Lew Whitman, the American canoe champion, and I found the fore and aft movement of the helm to luff up or bear away to be quite natural.

The boat had a large alloy centreboard but I tried a special wooden centreboard with a metal tip which could be turned, like a very deep rudder, from a lever in the cockpit (See Fig. 1). The object was to keep the boat upright by using the centreboard as a pivot and the tip as a lever as shown in the diagram. I tried it twice but found that although the boat when running could be rocked from side to side by moving the lever, the time when it was most required to keep the boat upright, i.e., when close hauled, it seemed to have little effect. It was realised afterwards that a movable fin of this type is only effective when moving at relatively high speed through the water. Incidentally I found also that I had not enough hands to control it and sail the boat! On running ashore and bending it, the problem arose as to how to sail home!

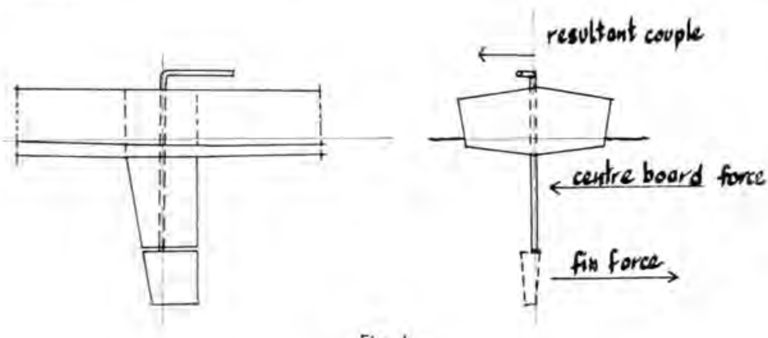
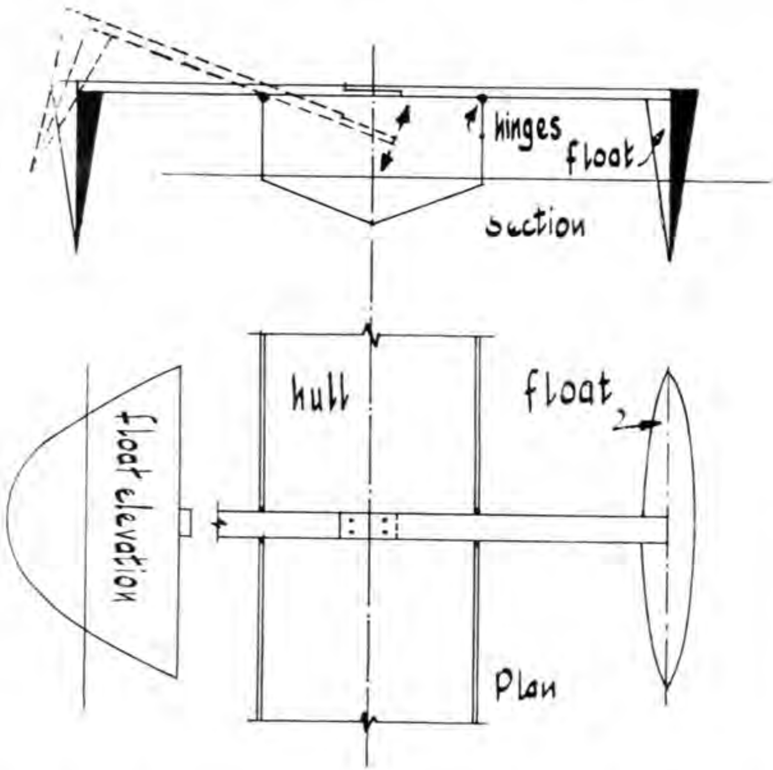


Fig. 1

TRIMARAN CONVERSION UNIT

Many people are interested in converting a Canadian canoe or a similar tender craft into a sailing trimaran and this would undoubtedly produce a cheap sailing craft.

Julian Allen sends us this drawing of one such conversion unit, which is self explanatory. Each cross beam is hinged at the gunwale and the float-leeboard can be retracted out of the water when not wanted or for beaching. The cross beams can be attached together rigidly when sailing.



This shape of float might be suitable for many boats but floats like those of the *PARANG* design, described in No. 18 would be more suitable for others and retractable hydrofoils would suit still more types. The rule here is that the greater the stability in the main hull, the greater should the float become like a hydrofoil and less like a float. The *PARANG* hull needs floats such as are in the design, whereas a converted Montague whaler would be more happy with hydrofoil stabilisers.

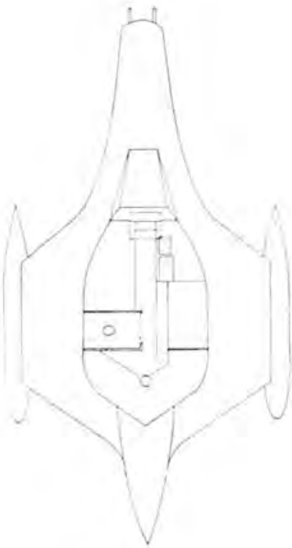
This whole matter is almost an unexplored field and members would be well rewarded by studying it. I feel sure that the light cruising yacht of the future will be like a whaler with a transom and stabilised by hydrofoils.

CEREBUS
36 Foot Trimaran Design
by William H. Baur

October, 1959

L.O.A.	36 ft	Beam O.A.	20 ft
L.W.L.	32 ft	Beam main hull W.L.	2.5 ft
Sail area	400-800 sq ft (Lapwing rig)	Displacement	3,000-4,000 lb

This is a first completed attempt at a yacht design and an excellent craft she is, in my opinion. The construction is to be fibreglass and foam sandwich throughout with government surplus aluminium aircraft wing tanks as floats, though sailing stability will be from hydrofoils.



PLAN

ELEVATION

SECTION

Main hull

The length-beam ratio is not what was desired but this is restricted by financial limitations as regards length and by accommodation considerations as regards beam. The accommodation plan provides for two long people, one short one and, if necessary, one very short one. There is a small chart table and bookshelves at standing height to port between the galley and the forward berth and there is full headroom for a 6 foot man. The racy-looking "dog-house" structure is a result, not of the influence of finny cars but of providing fully-sheltered louvered ventilation ports to either side of the companionway entrance.

The floats and foils

Primary stabilisation when underway will be from the hydrofoils rather than the floats. Also, since the floats are themselves tanks, a windward water ballast system will be provided for heavy weather where tacking is unnecessary. Provision will be made for experiments with other hydrofoil configuration.

The rig

This is the "Lapwing" rig as devised by H. G. Hasler. The long unstayed mast presents something of a problem which is believed can be solved by the use of slightly conical extrusions, an outer shell and an inner skin separated by struts and filled between with a dense foam plastic.

Auxiliary power

This is a lightweight 30 hp motor with an outboard drive which tilts up out of water when not in use, removing a large drag source.

Design procedure

William Baur, being an amateur designer, devised his own design method and, as this may be of interest to other amateurs, an outline of it will be given. The stages are as follows:

1 An overall stage, working out the configuration to produce an aesthetically pleasing form with an adequate accommodation plan.

2 The final drawing from stage 1 was traced onto graph paper and weight and displacement estimates were made by a counting of square procedure much as was described in the design method of AYRS publication No. 1.

3 The centre of buoyancy was then found by a sum of forces times their distances from a reference point procedure.

4 A curve of areas was then drawn and, as it was lopsided, it was smoothed keeping the total buoyancy and the centre of buoyancy the same.

5 Using the curve of areas so found, the whole craft was designed with box-like sections which gave an approximate LWL and profile.

6 Finally, the box sections were rounded keeping the areas about the same and the lines were faired.

AVOCET

February, 1960

Length	18 ft	Sail area	120 sq ft
Overall beam	12 ft	Weight (less rig)	210 lbs
		Weight of rig	50 lbs

Owner, Designer & Builder **Prof. Sir Martin Ryle.**

Basic design

In this design both heeling forces and side force are countered by a float-hydrofoil combination at either end of a wing which also provides accommodation for the crew. Crew weight can thus be used to full advantage. Of the various lift-producing hydrofoil systems, surface-piercing foils inclined inwards seemed to provide the simplest self-stabilizing arrangement, as well as eliminating the need for a centreboard. The most serious difficulty in their use, however, is to prevent air being sucked down the upper surface. This may be demonstrated in a striking manner by holding a paddle over the side at a speed of about 10 knots. With the paddle vertical very considerable

Martin Ryle's *AVOCET*

side forces can be produced as the angle of incidence is increased (and of course free vertical centreboards are used in the *SHEARWATER* and other catamarans). If, however, the paddle is held outboard at about 45° to the vertical, then as the angle of incidence is increased to obtain a comparable lift, the water flow suddenly breaks away from the leading edge and the lift practically vanishes.

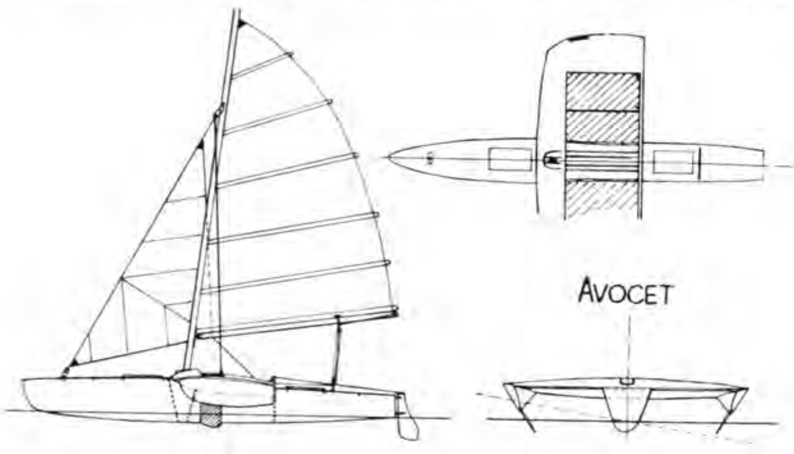
To avoid this difficulty the foils in *AVOCET* emerge through the centreline at the front of the floats, where the water-flow should prevent a low pressure area developing.

By sailing the boat with an angle of heel of about 10°, so that the lee float is immersed about 4 in, air entrainment is prevented, while the wave-drag from the immersed float is still small; with a crew of two the weather foil is then just clear of the water, and asymmetrical hydrofoils may therefore be used. By adopting an effective angle of incidence of about 9°, the lift per square foot is about three times as great as that of a conventional centreboard, and at speeds greater than about 10 knots, strong stabilizing forces are provided by the relatively small foil area.

Construction

In a trimaran the main hull operates at constant immersion (until appreciable overall lift is provided by the foils), but the requirements otherwise differ little from those of a catamaran. Because of its continued success a *SHEARWATER* hull was adopted, and an 18 ft one was specially moulded by Prouts with 3 in greater depth than normal. Bulkheads and strengthening frames were built at either end of the wing opening, and the bow and stern sections were decked with ¼ in ply. Large hatches were left in these for dry storage of gear (one could almost sleep in the forward compartment!).

By stepping the mast on the wing structure, all the main sailing forces are applied direct to the wing (horizontal and vertical foil forces, crew weight



and mainstay tension). The attachment of wing to hull therefore presents no problem; forestay and sheet forces simply tend to keep them together.

The leading edge of the wing consists of a main spar (two 2 in × 1 in spruce) and a 1½ in × 1 in spruce leading edge, all three surfaces being covered with 3/16 in ply to make a very rigid box girder. The under surface is extended aft with ¼ in ply to form the wing deck to a rear spar (two 2 in × 1 in spruce with 3/16 in ply on outside).

The central section is left open to the main hull, and since this is unencumbered with a CB case provides comfortable leg-room.

The wing is attached with two bolts at the leading edge, two at the main spar and four at the rear spar. When trailing, the hull is carried upside down with the mast and boom on a roof rack, the wing on a small (12 ft dinghy) trailer.

Floats

The floats are triangular in section, the angle increasing from 75° at the bow to 90° at the stern. When deeply immersed the underwater section is slightly asymmetrical, the outer surface being flatter than the inner, so that the bow is inclined outwards by 3 in.

The ¼ in ply is screwed and glued to a laminated stem and keel stringer; the deck, also of ¼ in ply, continues the upper surface of the leading edge.

The float and outer half of the leading edge provide a sealed buoyancy of about 400 lbs each side. The inboard half of the leading edge is used for stowage.

Foils

These are retractable through "CB cases" mounted against the outer skin of the floats. They make an angle of 55° to the horizontal when the boat is upright, but with the normal angle of heel this is reduced to 45°. They have a chord of 12 in and maximum thickness of ¾ in with the section described on page 61.

The angle of attack of the flat surface measured along a waterline is 7°, giving an effective angle of incidence of about 9°.

A Swift catamaran rig has been used, with sail area of 120 sq ft. A transverse tiller mounted on the rear spar of the wing operates the rudder with wires passing outside the mainsheet track. This arrangement has the advantage that it does not project into the cockpit and no tiller extension is needed, wherever the helmsman sits.

Performance

When first launched, *AVOCET* had strong weather helm, which almost prevented her from sailing to windward, but by reducing the rake of the mast, to bring the sail plan forward by about 8 in, her performance was completely transformed. She is obviously fast, exceedingly stable and goes about easily; even at speed she can be steered with one finger. No extensive speed trials have been possible this season and the only tests with *TRITON** were before the rig of either boat was moved forward. A few days were however spent in comparison with Peter Ward's *SHEARWATER III*: during most of this time winds were light, and *AVOCET* was definitely slower on all points of sailing. In stronger winds the difference did not appear to be so great but unfortunately on the two days when there was as much wind as *AVOCET* needed the *SHEARWATER* was not available for trials. On these two days the value of foil stabilizers really became apparent; as long as the lee float was allowed to remain deeply immersed (for example with insufficient sitting-

* A trimaran made by Dr. Anthony Ryle.

Martin Ryle's *AVOCET*

out when on a beat) its bow made a lot of fuss at speed, but as soon as one turned on to a reach the speed suddenly shot up and the wave noises would disappear to be replaced by a hiss as the foils kept the boat strongly stabilized with the lee float just touching the water.

At lower speeds, especially to windward a finer entry on the floats would probably have been an advantage, although this is difficult to achieve if the floats are not to extend beyond the width of the wing. Alternatively, the solution may lie simply in increasing the foil area, so that they become effective at lower speeds.

The stability is so good that a greater sail area could be carried, and it is hoped to extend this by using a large Genoa.

The photographs show *AVOCET* with two grown-ups and three children on board; though obviously deeper in the water, with slightly more wave-making from the lee float, her performance does not seem to be greatly affected, although some weather helm is produced.

PARANG

L.O.A.	16 ft 6 in	Beam	2 ft 0 in
L.W.L.	15 ft 9 in	Displacement	632 lbs
Beam O.A.	11 ft 6 in	Sail area	160 sq ft

Designer: John Morwood
Builder: Peter Cotterill, Box 124, Selukwe, S. Rhodesia

Members may remember the *PARANG* design on page 45. This has been built to the design by Peter Cotterill and his report is as follows:

20th April, 1959

"The foils work well in a reasonable wind and we have had her up with the floats well clear on a broad reach. There is then a noticeable increase in speed, with two up. Unfortunately, she is much too heavy at 400 lbs for light breezes which, with two up, brings the waterline well above the chine. She then sails about half the speed of a GP 14, does not point at all well and does not always come about.

Peter Cotterill with foils retracted

"In a stronger wind, she seems quite as fast as a 505 and points and tacks quite well, though at present, she tends to weathercock—presumably, the result of too large a mainsail.

"At present, I am fitting a dagger board and we hope to try her soon with the mast further forward.

"The short floats are obviously causing drag as a foot high spout appears behind each at quite moderate speeds. Therefore, as indicated by AYRS No. 23, I am constructing two double tapering floats 12 ft long, 6 in wide and

8 in deep which we plan to mount on $1\frac{1}{2}$ in light steel tubes to give 8 ft beam. The foils will be attachable when worth while winds are about.

"Once we get these modifications made, the boat should be fine—anyway, its all great fun."

10th May, 1959

"We are now making some progress. Without the foils and with the mast 2 ft forward and dagger board, the boat tacks easily and does not crab. With the board up, her behaviour is little worse than with the old foils in vertically. Even the weight saving of 40 lbs (the foils weighed 24 lbs each) improves her light wind behaviour considerably. She now floats about 1 in above the chine with a crew weight of 340 lbs.

"I agree that 40° dihedral for the foils is too flat for low speeds. I noticed that the speed of the boat dropped with the foils right down compared with when they were vertical. Once the boat rose on them, of course, the speed jumped up. I shall certainly try the long, 60° foils you suggest.

18th October, 1959

"I have not been able to get much lift from my present foils. They are similar to your *JEHU* configuration, 4 ft 4 in by 1 ft 1 in with ogival section, made from solid obeche covered with one layer of fibreglass cloth. At neither 45° nor 60° have the floats been lifted and the lift has not even stopped the float being submerged. The boat tacks as easily with the foil at 60° as it does at 85° and goes to windward quite well but in neither case as well as with the centreboard.

"The foils are set at about 2°-3° incidence and this may well be too low but even so, their drag is considerable. The speedometer only crept to 6 mph with the foil in but apparently similar strengths of wind gave easy 8 to 10 mph with the foils out. I am modifying one of the *PARANG* foils to fit one side and increasing the incidence on the foil on the other side.

"Your hull is easily driven to 10 mph in quite light winds. 12 mph requires considerably more wind and 14 mph, considerable gusts. Above 10 mph, there is a considerable bow wave and when this hits the cross beam, spray starts to fly. Bringing the crew back helps to reduce the wave but the speed remains the same."

November, 1959

"You will see from the pictures that the new floats are in operation. There is considerable improvement in entry and exit—there is no fuss at the bow and only a slight wake, the wake of the main hull being the major feature visible.

"We tried light metal tubes as cross beam but they looked so revolting that I have reverted to 2 in by 4 in beams. She points and tacks easily—about as well as a *FLYING DUTCHMAN*. The floats weigh 28 lbs apiece and are reinforced (to the chine) with fibreglass cloth.

"The foils work quite well at 60° but slow her in the light winds we usually have here. We tried her in a "gale" the other week but blew the mast out before we could try them. The boat is quite stable in 30 mph winds and it seems that the inherent stability is more than in a cat.

Peter Cotterill's version of *PARANG*

"It seems that the foils are not needed in strong breezes since the boat appears to "plane" at about 10 mph. Normally, the trailing edge of the floats are about 3 in in the water but at about 10 mph, the bows rise and both float ends are clear of the water. The bow wave from the main hull comes just midway along the floats.

"Having got the hull and floats behaving well, we are now having trouble with the mainsail which scarcely pulls on the sheet. Even so, at a recent regatta in very light winds, the boat appears to be faster than the *SNIPE* on all courses, about as fast as the *FINNS* but slower than the 505's and *DUTCHMEN* and we were sailing mainly on the jib."

Summary

The faults in the *PARANG* design are as follows:

1 The foils should be much lighter. I believe that Peter Cotterill's failure was due at least partly to the angle of incidence and that they should be placed fore and aft, letting the angle of leeway provide the angle of incidence. In this, I apparently also disagree with Martin Ryle, Bob Harris (*TIGER-CAT*) and others. Symmetrical foils like those of *JEHU* may be better than asymmetrical foils.

2 The floats should have been long and narrow.

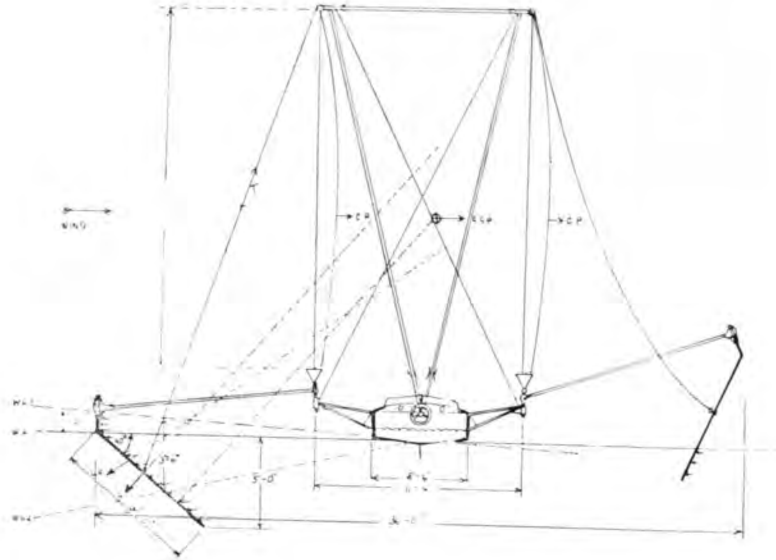
3 Cross beams are still a slightly difficult subject. Dural tubes, solid spruce and plywood box spars have all been used successfully.

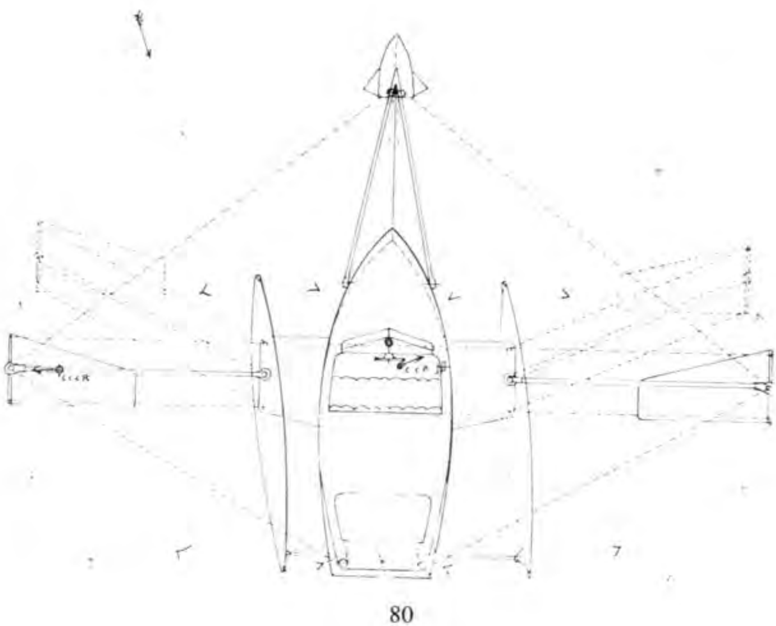
The *PARANG* hull shape as in *TAMAHINE* (AYRS No. 28) seems to be satisfactory in the lower speed range. The hog is too heavy in the design and 3/16 in plywood could be used instead of ¼ in for the planking. Weight is of paramount importance to all multihulled boats.

AN UNUSUAL DESIGN

The designs sent in by the true inventors are the most ingenious seen but, on the whole, tend to be "overinvented" with so many innovations on each that the practical realisation appears to be almost impossible. If, however, we examine such a design with an eye on each feature separately, we often see some very ingenious things which could be very useful.

Let us then look at this design by A. R. Gibbons as a collection of ideas rather than a boat which would be built.





The basic idea is of a hydroplane with sails of enormous size. In order to carry this amount of canvas, the craft has to be stabilized and this is done by hydrofoils with dihedral but they are placed so that only the weather one is used at any one time and it produces a force acting *downwards* as well as to windward. This is the opposite concept which we in the AYRS and all other people have used. It is possible that it could be made to work but a danger of capsize would always be present. Forwards capsizing moment is taken care of by a water ski arrangement ahead of the hydroplane hull.

The sails

These are two sails of excellent plan shape mounted side by side from V masts to their bent yards. They are fully battened and balanced to reduce the pull on the sheets.

Summary

A design is shown which will supply our more imaginative readers with food for some interesting thoughts on yacht development.

A CRUISING HYDROFOIL TRIMARAN

by Arthur Piver

The world would indeed be a dull place if we could not have our dreams which might come true. For the record, here is Arthur Piver's concept of what he would like to develop.

It is a hydrofoil trimaran of typically Piverish shape but with ladder foils. The progress towards this concept is almost quickly occurring and already.

Arthur has completed the main hull of his 30 ft cruising trimaran which could well be the basis for this craft.

It will be most clear to all our readers that the AYRS has always aimed at such a craft as this and, when it has been attained, I feel that even our most imaginative inventors will be hard pressed to find other fields to conquer. At that stage, surely the boat development stage of the AYRS will have been completed.

A WINGSAIL DESIGN

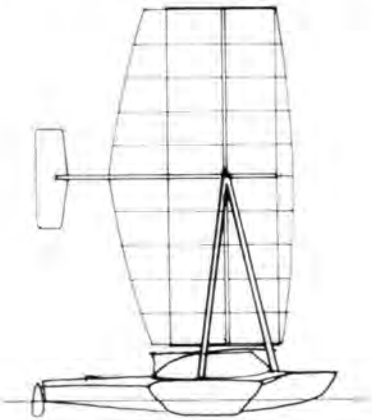
by William Baur

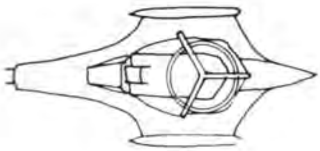
1684, Littlestone Rd., Grosse Pointe Woods, 36, Michigan.

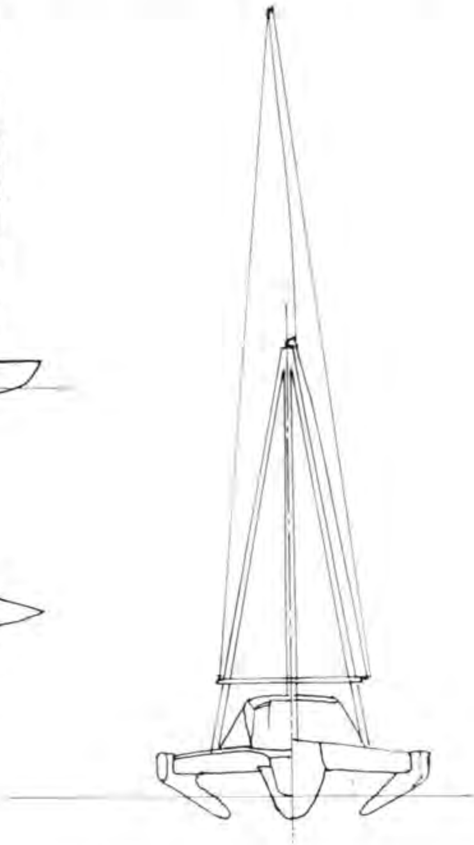
The drawings show a new rig I am considering for ultimate use on my trimaran. It may not look very pretty but it has some absolutely beautiful potentials. The buoyant hydrofoils are also drawn and they provide about 700 lbs each of buoyancy on a level keel.

The sail is the "oscillating airfoil" type described in Vol. 1 of Herreshoff's

Common Sense of Yacht Design, i.e., it is an asymmetric airfoil, rotated in tacking around its horizontal (chordwise) axis from one side to the other. Also, since it will be suspended from the aerodynamic centre and therefore is fully balanced, the tailsail can be used. I am trying to work out a means of aileron control whereby the sail can be made to fly itself over from one tack to the next without resorting to winches to haul the upper wingtip down.







The mast consists of a tripod with legs spaced around the cabin, making more room inside and eliminating interior structure support problems. The sail is of fairly heavy weight dacron and is given its shape by full length battens which will remain permanently in the sail. The battens will travel on slides up and down the mainspar which is suspended at its centre from the peak of the tripod mast and there are extra spars which merely help to prevent twist and to keep the proper shape. The sail can be reefed symmetrically about the tailsail boom by hauling the battens in to it, or it may be reefed to deck level when tacking is not necessary. The lower wingtip will fasten to a ring spar around the tripod to take some strain off the suspension bearing and a windward runner may be set up to the upper wingtip, if needed.

The sail can be connected to the rudder to provide a windcourse steering system and the coupling thereto could conceivably be servo driven from a compass to provide a sailing autopilot.

Another little beauty of the set-up is the possibility of a crows nest with control station up below the peak of the tripod.

If the main spar suspension bearing can be made with three angular degrees of freedom, the sail can be rotated to a horizontal attitude to function as a squaresail for tradewind running.

The only disadvantage I can see at present would be the weight of the rig—but then, I have additional available buoyancy from the bouyant foils.

CHAPTER VII

GIZMO—A HYDROFOIL EXPERIMENT

by William C. Prior

473, Falls Road, Chagrin Falls, Ohio

July, 1961

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

GIZMO side view

Bill Prior's *GIZMO* on 14 ft *SAILFISH* hull

year. The performance was quite spectacular, though, and very encouraging.

Since that summer, I have given a very serious study to the design of hydrofoil 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 AYRS 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).

THE PRIOR HYDROFOIL CRAFT (No. 2)

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.

Bill Prior's second flying hydrofoil

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 ⅛ 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 NACA 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 AYRS 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 in
Main Hull Beam	2 ft 3 in	Sail Area	160 sq ft

Designer and Builder: Erick J. Manners, A.M.B.I.M.

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".

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.

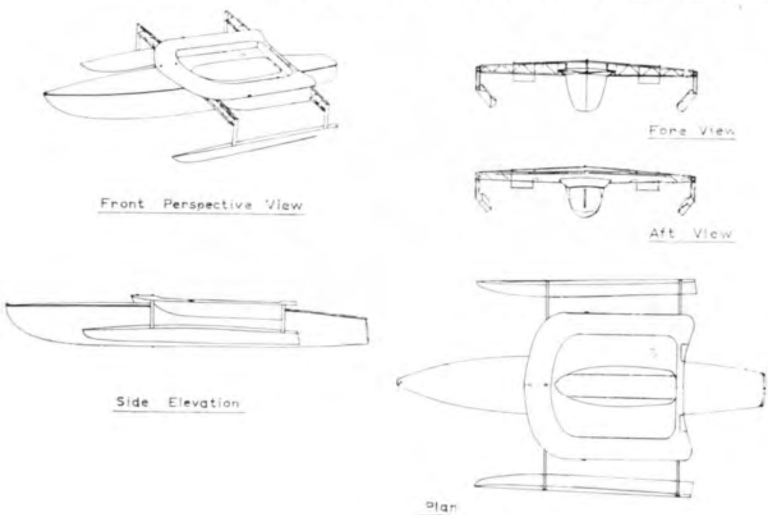
Foil performance

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.

Erick Manner's *FLYING WING*—Trifoil

Erick Manner's *FLYING WING*

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.

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 (Chapter V). 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

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 ⅛ 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. In 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

On page 14 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 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

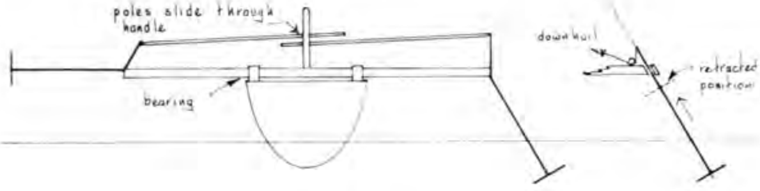


Fig. 1

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 gets 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 Figs. 3 and 4 show two other varieties of the

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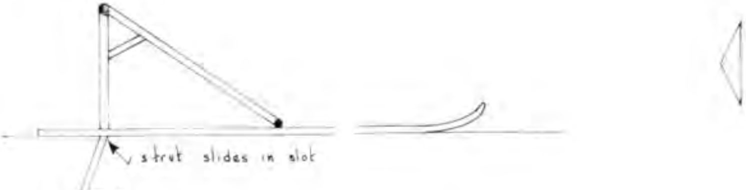

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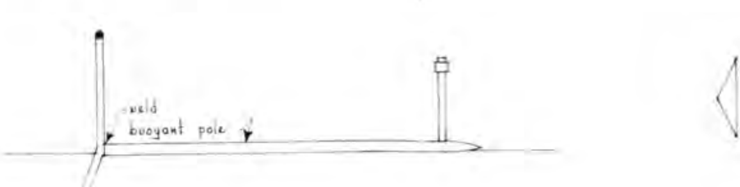


4

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 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 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.

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.

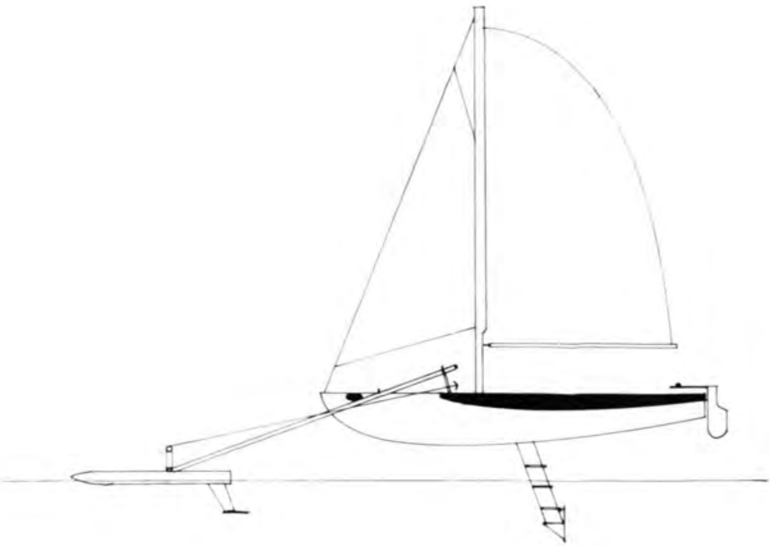
The main foils

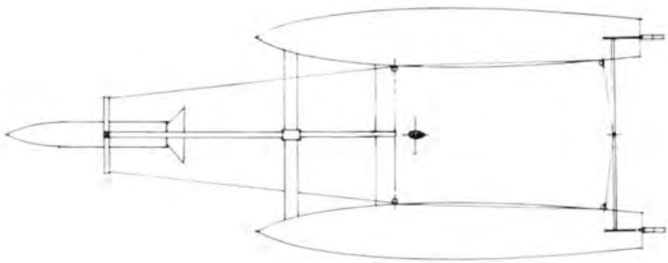
These are inverted T foils set at an angle of dihedral of 30° and fixed by pushing them into the centreboard slots from below. Air entrainment down the struts may be expected, being worse in a sailing boat than in at powered one, owing to the leeway. It is therefore suggested that these be "fenced." The angle of attack which is best is not known but lies somewhere between 5° and 7°. Dihedral should be 30°.

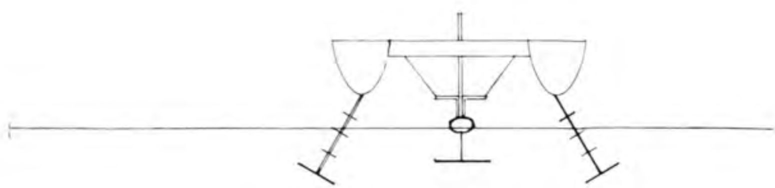
The forward float

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 in in diameter and 6 ft 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.







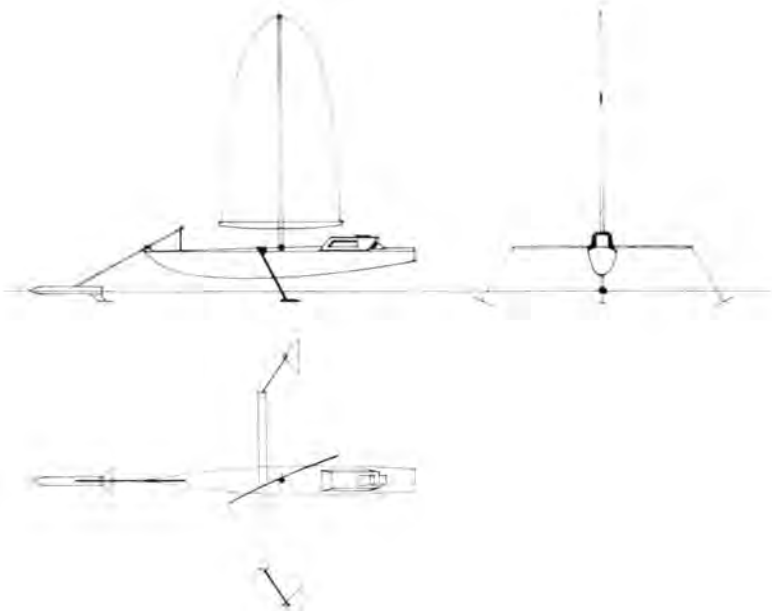
The float attachment

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.

WATER "BICYCLES"

John Morwood

July, 1961

It is to be supposed that nearly all AYRS 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.

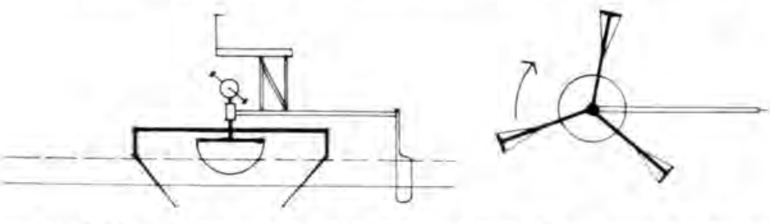
2 Small catamarans, powered by either paddle wheels or a propeller. These have a limited application as beach boats for hire.

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.

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 able to keep the craft from revolving altogether.

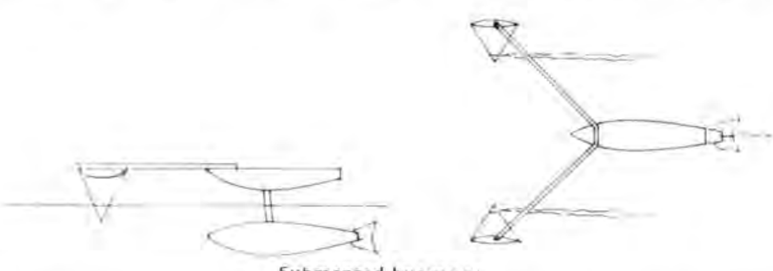
Water hobby-horse

On page 22 "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 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.

Water "Tricycle"

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.



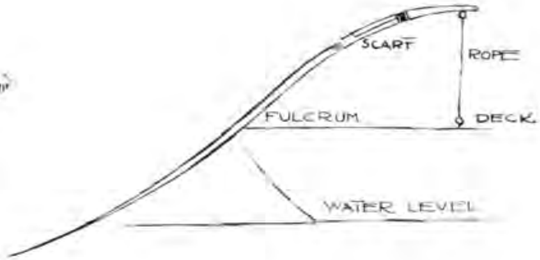
Submerged buoyancy

Surface piercing hydrofoils forward relate the submerged shape to the surface 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.

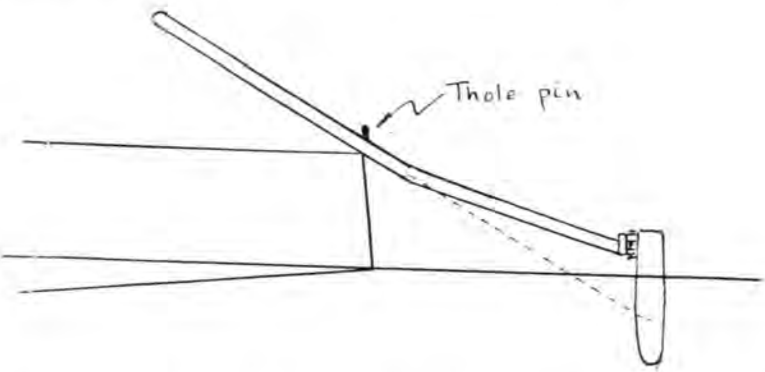
Marine drives

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. Paddle-wheels are even less efficient because of "Splash" as well as the two losses of the propellor.



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.

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. The aspect ratio was again low.
3 Julian Allen's "Rock and Roll" boats. The aspect ratio was higher in these craft but again, no great merit was claimed.
4 Several versions of "Flap foils" conjectured on pages 21. and 22

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

Voity-Schneider propellor

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 and the three rotating foils appear to have any chance of a useful application.

LETTER

July, 1961

Letter from: Martin Ryle — 5a, Herschel Road, Cambridge

Dear Sir,

AYRS members may remember my boat *AVOCET*, described on page 73, 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 in below the bottoms of the floats were used and first trials with a horizontal foil 18 in by 6 in 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 in 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 me:

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 in out of the water (while normally it is immersed 1 in) but the water is sucked up for the last 6 ft 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.

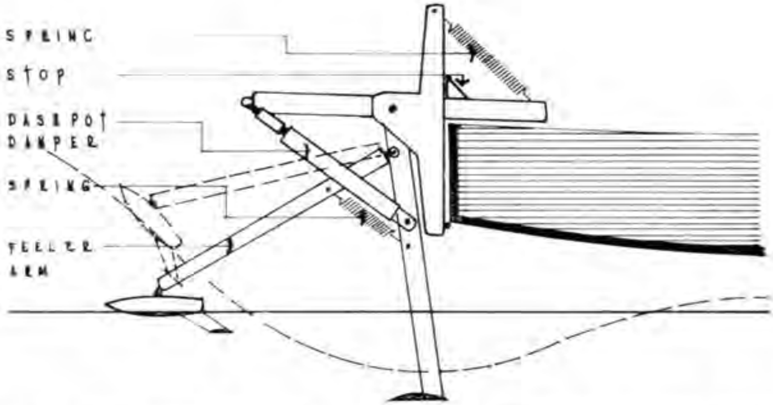
That was about all for this season except that as a general family and high speed boat, I think *AVOCET* is very good. Sailing single handed is great fun and and we certainly had some very fast sails both with one and two up. I want now to try a modification of the main foils to give more deeply immersed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

Martin Ryle

THE HOOK HYDROFOIL

Due to the efforts of AYRS members, the trimaran is now an established configuration and this leaves us only the job of developing a satisfactory hydrofoil craft. Various governments have spent many millions of their money on these craft but so far no one has really shown that they are fully satisfactory for pleasure or commercial use. Both the Baker V foils and the Karl *SEA WINGS* are being sold commercially. No reports on their value have as yet been given to the AYRS. However, from the films shown to us by Christopher Hook, it is quite obvious that his system is fully seaworthy in a seaway and that is where the other systems are suspect.

On pages 96 and 97 a hydrofoil system is shown of roughly the Grunberg configuration, using a float forward. The drawing here shows the same system using a Hook hydrofoil mechanism forward which can be steered. The essence of the mechanism is that the "feeler arm" works the hydrofoil strut through a spring. However, the foil strut movements are heavily damped so that the craft is not shaken by small waves but merely rides over



them. This is carried out in the drawing by a "dashpot" damper which is fixed to another strut which is horizontal. Now, in any seaway of reasonable size, occasional exceptionally high and vertical waves are met to which the normal working of the jockey float and feeler arm will not give enough response. This situation is catered for in this drawing by having the feeler arm run up against a stop in the damper strut from the foil and this can tilt the horizontal strut against the spring placed over the bow of the boat.

It is believed that the original patents of the Hook "Hydrofin" have run out as they were taken out in 1941 but it is not known if any subsidiary patents cover any of the ideas suggested here.

A FOIL CRAB DESIGN

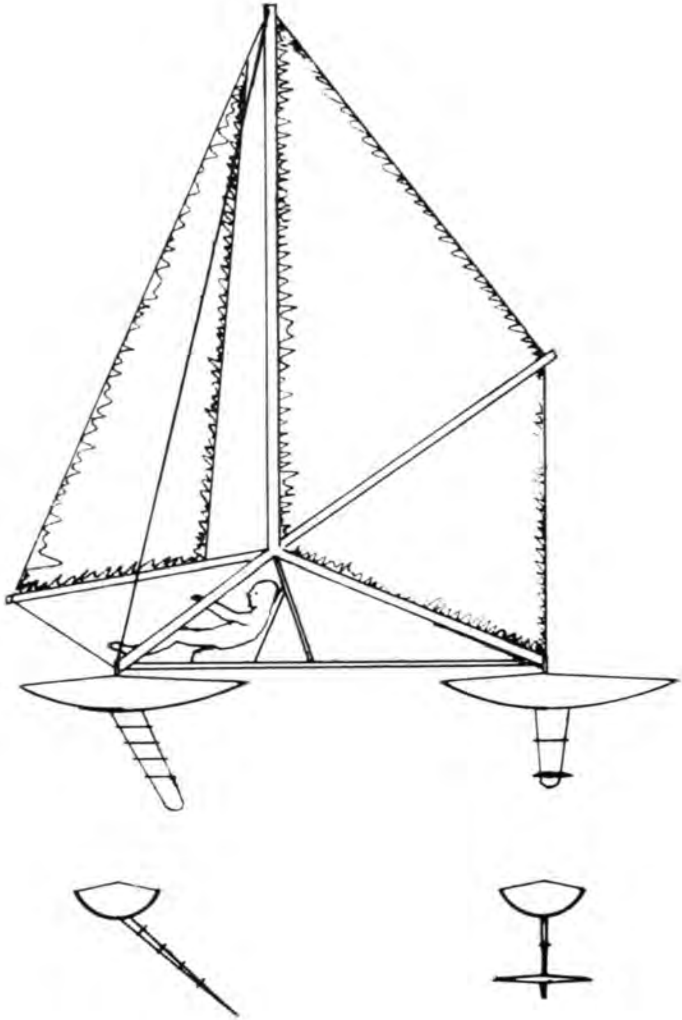
Letter from: William Garnett Hilton Hall, Hilton, Hunts.

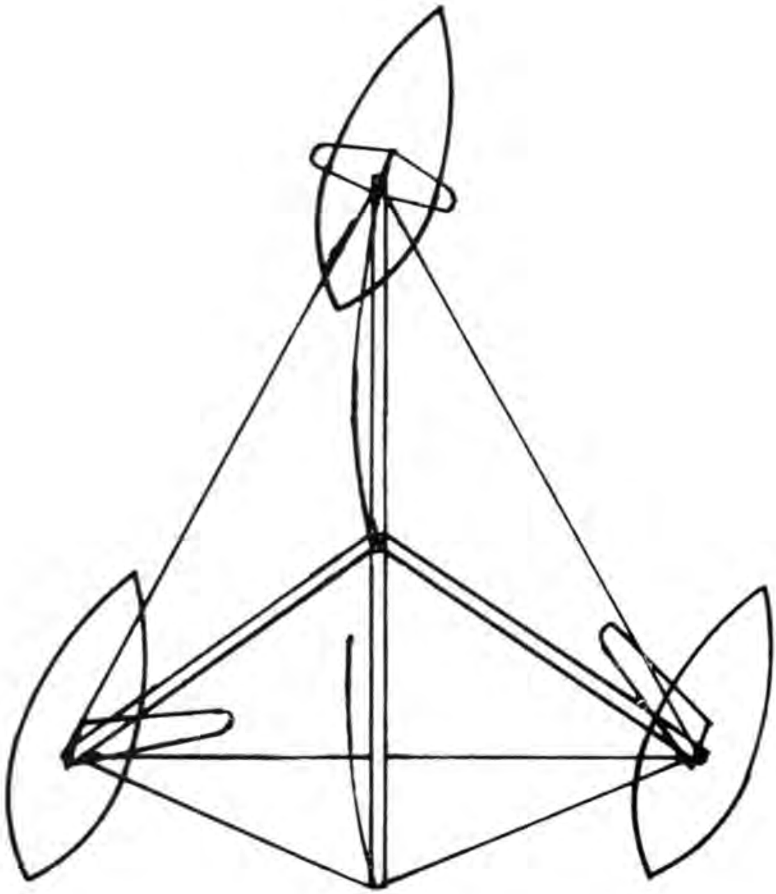
Dear Sir,

In his *Sand Yachts* article Ian Dibdin compares the merits of front-wheel and rear-wheel steering. Mention should also be made of the third type which steers on all three wheels. Known as the *CRAB*, and developed at Gransden by Peter Shelton, this type works on the principle of a fore-and-aft sail fixed to the chassis, needing no manipulation, so that the yacht is always "crabbing" sideways. The two front wheels are steered by left and right hands and the rear wheel by two pedals, one to straighten it (like hauling in the sheet) and the other to turn it more to the side and luff up. All wheels have slight trail, so that the human element acts as a differential between them.

The *CRAB* combines the advantages of both the other types with several of its own. It is more manoeuvreable than either, and safer. It may be luffed, backwinded or even braked to a standstill; jibing is easy; there is less variation in sail balance, and it puts about through half the angle (because its sail line is dead fore-and-aft). Owing to their high speed land yachts often sail closer to the relative wind on a downwind beat than any waterborne craft on a close one, and this suits the uniform flat trim of the *CRAB*.

The diagrams give my impression of a new type of craft in which the *CRAB* principle is applied to floats and foils. I find that model angled and swept foils trail out sideways from a vertical king-pin without apparent flutter, and a





small amount of built-in lift is obtained from the natural toe-in of a pair of these foils trailing free. Probably a sensitive control of the front foils would enable the craft to rise to the waves and so avoid air entrainment, but if this occurred the air could be quickly shaken off. The frame is a tripod held in compression by stays all round. A seat is mounted on a centre bar and supported from the focal point. The backstay is sprung out on a spar to give leech tension to an enlarged mainsail and a bowsprit stayed between masthead and the two front feet perform the same function for the foresail. I have not marked in the linkages, but these could be by a system of parallel arms and wires. The live weight is rather far forward, but if "fore" and "aft" are taken in the line of the craft's course then the more it "crabs" the further this weight moves aft.

Perhaps some reader who has had experience of foils will send me his comments.

William Garnett

A DESIGN FOR AUTOMATIC INCIDENCE CONTROL OF HYDROFOILS

by M. A. T. Trasenster

Lane End, Itchen Stoke, Alresford, Hants.

The basic principle of the system involves the use of drag elements to control the angle of incidence of the hydrofoil.

A variety of layouts are possible using this principle. Fig. 1 is the simplest, but obviously involves a considerable amount of appendage drag. In Fig. 1 the hydrofoil is free to rotate about an axis 2 transverse to the direction of travel. The angle of incidence is controlled by two drag elements projecting from the upper and lower surfaces of the hydrofoil. When the hydrofoil is running low in the water the upper element 3 is dimensioned so as to cause

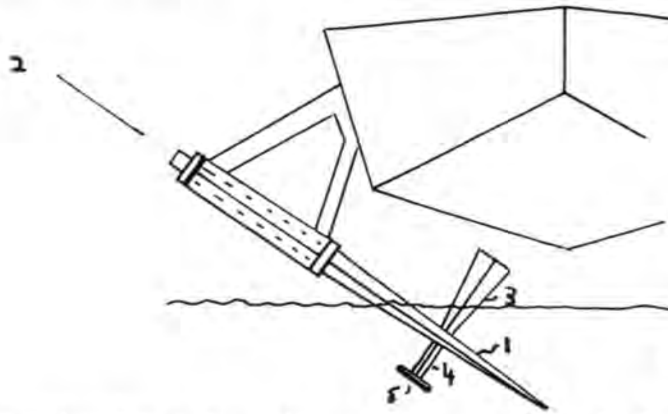


Fig 1

greater drag than the lower element, so increasing the angle of incidence and giving the necessary lift. When the upper element breaks through the water surface it will be subject to less drag, and the drag of the lower element 4 fully submerged will then tend to reduce the angle of incidence until the assembly is in equilibrium. Any rise or fall from this position of equilibrium will be automatically counteracted. A trim fin 5 is incorporated with the lower drag element.

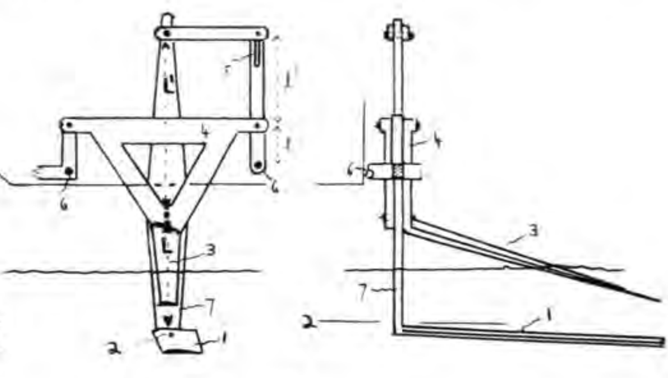


Fig 2

In order to avoid unnecessary drag the linkage shown in Fig. 2 can be used. The supporting strut 7 operates as the upper drag element and the main hydrofoil 1 acts as the lower drag element. The hydrofoil 1 is rigidly fixed to strut but constrained by the linkage so that it can only rotate around transverse axis 2. This axis is proportionately dependent on L and L^1 to l and l^1 so that trim can be arranged by altering the length of l^1. The linkage is attached to the hull at points 6. A subsidiary surface piercing foil 3 may be attached to the link member 4. The drag component of the subsidiary foil tends to increase the incidence of the main submerged foil.

The drawings in Fig. 2 are taken from an assembly mounted between the hulls of a twin-hulled craft. Overriding control, damping and resilient suspension can be fitted to the assembly. Retraction of the hydrofoil assembly is also fairly easily incorporated.

CHAPTER IX

THE DIBB HYDROFOIL TRIMARAN April, 1963

L.O.A.	21 ft 6 in	Displacement—hull	650 lb
L.W.L.	20 ft	,, —floil	250 lb
Beam, hull	1 ft 6 in	Mast height from deck	27 ft 6 in
Beam, O.A.	12 ft	Sail Area	190 sq ft
Draft	8 in	Camber	1 in 9
		Effective Aspect Ratio	5 : 1

Designer, builder and owner: George Dibb, 1 Heywoods Close, Teignmouth, Devon.

This remarkable boat, years before its time, was described in our publications Nos. 43 and 49. The original description in 43 was more concerned with the invention and development of the semi-elliptical squaresail than in the "Floils" which is the name which George gave to the buoyant hydrofoils. No. 49 described how Fred Benyon-Tinker and Dennis Banham found her in sailing trials.

We are not here concerned with the sail which was clearly shown to be very powerful and close-winded but needing more skill to use than the fore and aft rig. On putting about, the sail slammed across the boat forward of the mast, like a softish gybe and by attention to the geometry, this could have been made softer. The main fault was that the sail was not "fail safe". That is, that when the sheets were freed, the sail came more fore and aft instead of more athwartships as with the fore and aft rig. However, despite all the unusual forces produced by the sail which often produced stern boards of many knots, the craft itself never gave one moment's anxiety, being utterly stable and seakindly. This was, of course, due to the design of the "Floils".

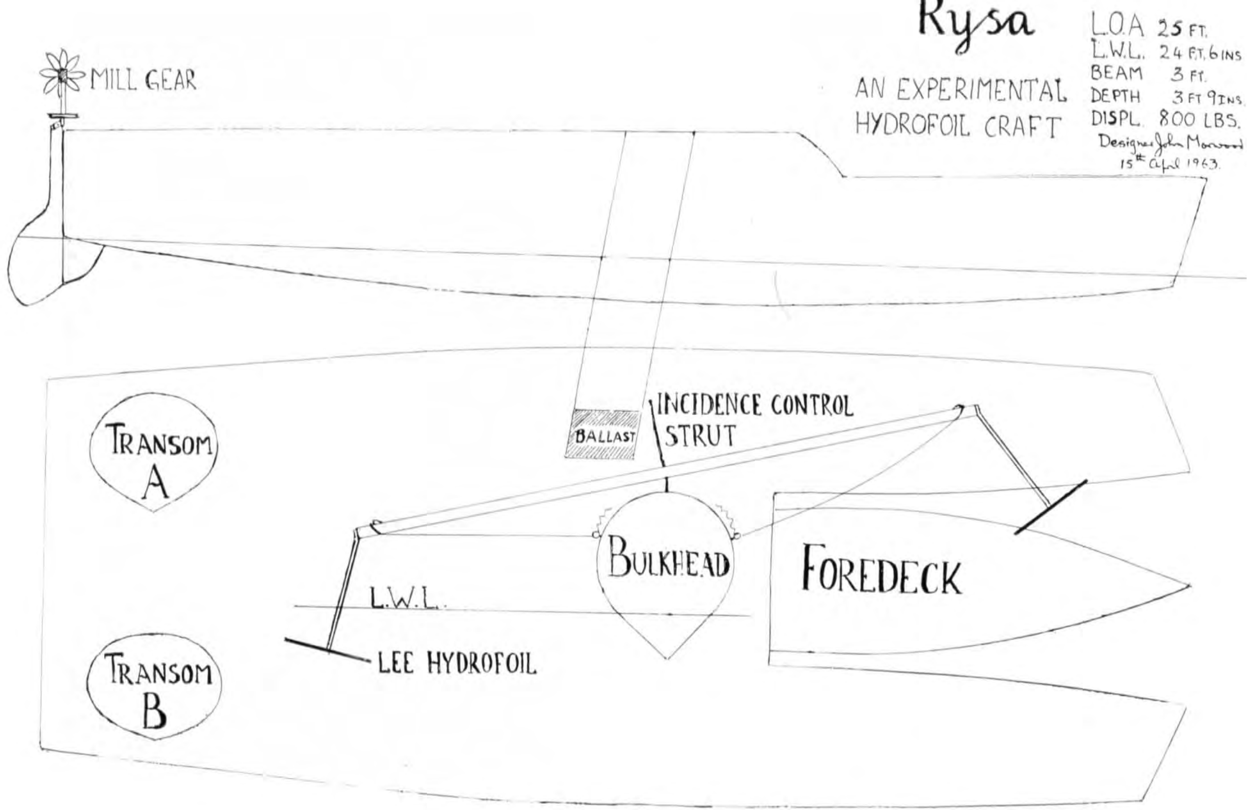
The "Floils"

These are low aspect ratio hydrofoils with flat outer faces and arcs of circles for the inner faces. The leading edges are swept-back and rounded, blending into straight lower edges. The trailing edges are as shown in the photograph. The buoyancy of each is 250 lb, with the wing just clear of the water. The dihedral angle is 45° and the "toe-in" is 5°.

Sailing performance

George Dibb writes: "She is beautifully stable—it is nice to be able to walk about 'big ship' style—and yet she has a nice soft sort of motion. She is very light and responsive to the rudder but holds her course steadily. The hydro-dynamic floils seem to be quite efficient, holding her up to her course with virtually no leeway (there is, of course, no centreboard). In very light airs, she whispers along beautifully and is very fast when the wind really blows."

The AYRS Sail — George Dibb.


Rysa
AN EXPERIMENTAL
HYDROFOIL CRAFT
L.O.A. 25 FT.
L.W.L. 24 FT. 6 INS.
BEAM 3 FT.
DEPTH 3 FT 9 INS.
DISPL. 800 LBS.
Designer John Morwood
15th April 1963.
MILL GEAR
TRANSOM A
TRANSOM B
BALLAST
INCIDENCE CONTROL STRUT
BULKHEAD
FOREDECK
L.W.L.
LEE HYDROFOIL

RYSA

(An Experimental Hydrofoil Yacht) July, 1963

L.O.A.	25 ft	Depth	3 ft 9 in
L.W.L.	24 ft 6 in	Displacement	800 lbs
Beam	3 ft	Sail Area	200 sq ft

Designer: John Morwood

Woodacres, Hythe

RYSA is a design which shows the fastest possible configuration of a sailing yacht. The version shown is a daysailing and camping cruising yacht, though the headroom at 3 ft is a bit spartan for most people. However, without the ballast and rudder skeg, she would be faster than any catamaran or traimaran in existence.

The hull

At the lower side of the design is an outline looking like the profiles of two yachts laid on their sides joined together like Siamese twins. If this outline is cut from a sheet of plywood 26 feet long by 10 ft wide, it can be bent around a shape shown as the "Bulkhead" and, being held together at the keel, the shape shown as the "Transom" can be fitted in at the stern, the "Foredeck" can be fitted on with deckbeams and one has a single narrow hull whose profile is shown at the top of the plan. Transom A has less wetted surface than Transom B.

The centreboard

This projects 4 ft 6 in below the hull and is 1 ft 6 in in chord, giving an aspect ratio of 3 : 1. In the version shown, the centreboard is ballasted which seems the best way to use ballast to me because, when the board is down, extra stability is needed. However, the amount of ballast used is only enough to give stability for winds up to about 5 mph. At greater windspeeds, the craft would heel excessively were it not for the hydrofoils. For a racing version, the ballast need not be used.

The rudder

A skeg and fixed rudder are shown. A racing version would have a drop rudder. A Mill self steering gear is shown because I believe it to be the best one for racing and cruising alike. It has the advantage that the boat is always under manual control as well as control by the gear.

The hydrofoils

These are two simple inverted T foils mounted at the ends of a 14 ft strut which is mounted by its centre to the hull by a universal joint. The foil strut is tilted to lee by a stay so that only the lee foil is in the water at any time. A small strut on the foil strut gives the incidence control. This is the simplest possible hydrofoil arrangement using inverted T foils and it must work well.

Cockpit

No cockpit is shown because it is possible to sail this boat from *inside the hull*, thus saving the windage of the crew. Alternatively, a one foot wide well could be cut in the round of the deck for a distance of 10 ft so that the crew could move fore and aft.

Assessment

Though the hull of the plan may not be the best possible shape, even with transom A, the weight, wetted surface and windage must be far less than a 25 ft catamaran and the speeds to be expected must be far greater than anything we have yet known with catamarans or trimarans. As a cruiser with ballast, she should sleep two people.

Rysa as a flying hydrofoil craft

The name of this craft is *RYSA*, indicating that it not only is an AYRS conception (because *RYSA* is an anagram of AYRS) but that it may be the flying hydrofoil craft we have been looking for. The craft can be converted to the flying version as follows: the foil strut is jointed at its centre so that both foils can be brought into the water at the same time. Then, the Hook system shown on pages 53 and 54 is attached to the stem which has been designed straight for this purpose. We now have a flying hydrofoil craft which has every promise of working.

Summary

An experimental craft is shown which will be very cheap and easy to build. It should sail at speeds far in excess of the 25 foot catamarans using its hydrofoil stabilisers and may reach speeds of 30 to 40 knots as a lifting hydrofoil yacht. For the less ambitious yachtsman, it will make a fast inshore cruising yacht with Spartan accommodation for two people. At the time of writing, I am trying to get a prototype made for trials.

Ed.: The hull construction proved excessively difficult and was abandoned.

A MICRONESIAN HYDROFOIL CRAFT

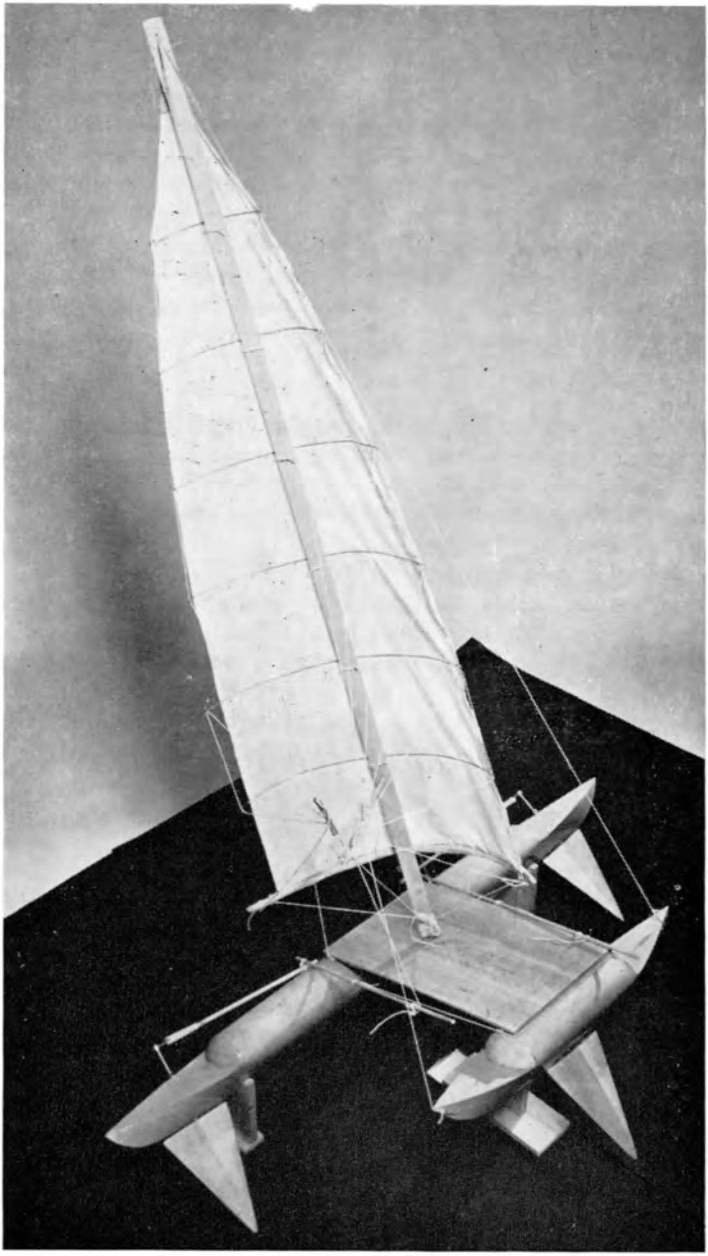
by John Morwood

L.O.A.	20 ft	L.O.A. Float	10 ft
L.W.L.	17 ft	Beam Float	3 ft
Beam (Hull)	3 ft	Sail Area	200 sq ft
Beam O.A.	14 ft		

This craft was originally conjectured and described in publication No. 63 *Floats, Foils and Fluid Flows.* Having now made a model of it and shown it at the 1963 London Boat Show, I am more than ever convinced that we have here the ultimate in theoretical sailing efficiency.

The hulls

These are made of sheet plywood more or less to the *RYSA* forebody design but with a rounded "forefoot" at both ends of the large and small hulls. The two hulls are asymmetrical about the fore and aft as well as the athwartships axes. The beam of each hull is the same because the float will be very little, if at all, immersed when its relative beam begins to hold it back.



All foils slope up to leeward—Proa type hydrofoil

The bridge deck

In the model, this consisted of athwartships balsa wood planking but in a full sized craft it would be a plywood sheeting on either side of planks on edge to give a strong box girder construction.

The hydrofoils

These are all the same size and shape. Of triangular plan form the upper chord is 3 ft long and the span is 4 ft 6 in. The thickness at the base is 3 in. The lee side is flat and the weather side is an arc of a circle (ogival section).

The foil on the float is fixed but the other two foils are steerable, though only the after one on each tack is used as such, the forward foil on the main hull being fixed by dropping its tiller on a peg. On an even keel, all foils slope up to leeward as suggested by Commander Fawcett at 60°.

The sail

On my model, the sail is a semi-elliptical squaresail, whose braces all come to a sprit at right angles to the sail. This rig is similar to Captain Mellonie's.

Unfortunately, in my rig, the braces to the top "yards" go up at a very acute angle, which might not give them very good control.

The theoretical evaluation

In this craft at low speeds, the hydrofoils might give excessive wetted area but the wetted area of the hulls would be small and might balance this. The semi-elliptical sail would be efficient, making the overall efficiency of the craft good.

In sailing as a displacement craft, the side force of the sails would largely be taken by the foils and converted into half its value as vertical lift which would be useful.

Rising from the water

If the craft is now allowed to heel, the dihedral angle of the foils would decrease from 60° to about 45°, thus converting the side force of the sails into the same amount of vertical lift and, if the wind and righting moment of the crew are great enough, there is every hope that the craft would leave the water and run along on the three foils.

The craft as a flying hydrofoil

Once up on the hydrofoils, one would then attempt to get the craft back on an even keel when it would become the nearest thing to "The Theoretical Yacht" which it is possible to imagine. Steering is by the aft foil and the crew would be at the end of trapezes, outside the float.

Possible faults and difficulties

1 Getting the structure light enough.
2 Getting the sail to sit well without twist which would be in the opposite sense to that of a normal sail, i.e., the head would be more fore and aft than the foot.

3 The steering might be difficult for several reasons:

a the "overbalanced" steering foil can develop a violet luffing force if there is a fraction of lee helm. A "stop" would prevent this. Weather helm is not so unbalanced but more normal steering might be achieved by a piece of shock cord acting against it.

b The sail force comes much farther aft of the centre of lateral resistance than with any normal boat. I cannot guess the effects of this.

Summary

A Micronesian hydrofoil craft is described which could be the nearest possible craft to "The Theoretical Yacht."

Ed.: One wonders how much Capt. Mellonie's catamaran and this design contributed to the origin of Dick Newick's CHEERS.

TRIM

LOA	16 ft 0 in	*Floats*	
LWL	15 ft 9 in	LOA	11 ft 0 in
BOA	11 ft 0 in	Beam	13 in
B. Main Hull	2 ft	Cross-section Square	9 in × 9 in
Draft Main Hull	8 in	Sail Area	150 sq ft

Owner and Builder: Albert J. Felice April, 1964

91 Sanctuory Road, Zabbar, Malta, G.C.

In 1960 I read about and joined the AYRS, the idea being to improve my three year old hard chined Catamaran. In the back number Catamaran Developments I read about Lord Brabazon's clean entry genoa, instead of a main end jib. I also fell in love with Parang, the Morwood hydrofoil trimaran, but I preferred a rounded bottom and longer floats. The finished plans looked like a Morwood-Brabazon with Felice flavour. *TRIM* is my third multi-Hull and my first really successful one, thanks to the AYRS.

I chose the mast-aft rig for its efficiency and for its cheapness. It is little different from the Mediterranean Lateen and I had it made for only seventeen pounds including the cost of the cotton.

The Hull is 2 ft wide, with almost semicircular bottom, 7½ in deep. It is so made that the five millimetre plywood can be bent easily.

The floats are box shaped as in Parang, but have asymmetric prows which give some dynamic lift when tilted. They are designed to be clear of the water when horizontal.

The wing is two feet wide, but the foil cross beam is 8 in above the level of the deck and the hind one is 4 in. To make comfortable seating for the crew, a plywood sheet is stretched along the bottom of the first cross beam to the top of the second. This necessitated a sloping cockpit hatch which lessens wind resistance and gives a dry ride. Also because of the mast's position, another cross beam had to be attached at the back to strengthen the floats and attach stays.

The rudder is a normal lifting one but with a T-shaped tiller. To this are attached two ropes leading to wooden loops worn on the helmsman's feet and leaving the hands free.

The hydrofoils resemble Parang's but they are more swept back and are attached by double brackets. These hydrofoils work well in strong winds but in lighter ones they make a lot of lee-way. It may be that when the craft is tilted the angle of attack is increased.

The 26 ft mast is of solid spruce, made from splicing two ex-navy masts. It works well, but an aluminium one would be much lighter but prohibitively expensive.

The boom is along the back of the sail and so gives a good clean flow with almost no boom eddy. When other craft have to back the jib, all I have to do is to push the boom forward to one side and the craft promptly turns the other way. The flow of the sail can be adjusted simply by trimming the sheets. When before the wind, however, a wisker-pole has to be used. Sometimes I wonder if a highly roached main sail may not be better, because of the larger sail area possible.

The craft is fast and dry, much faster than the dinghies. However I never reached the fantastic speeds which are claimed for a Shearwater probably due to the smaller sail area and more wind resistance.

Albert Felice's *TRIM*. Note long floats

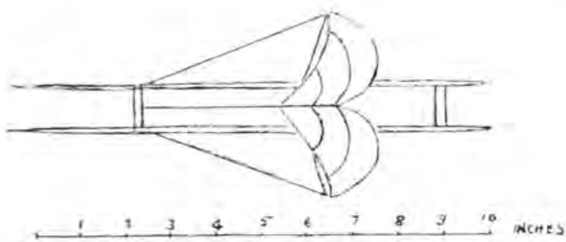
Sailing *TRIM* with mast-aft rig

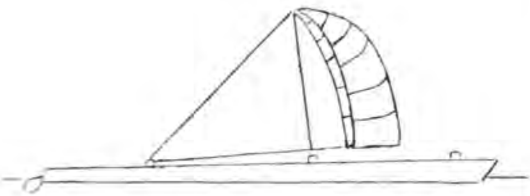
DOWNWIND YACHT DESIGN
NOVEMBER 1963-MARCH 1964

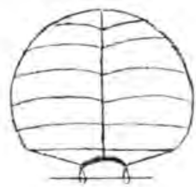
by Michael Costagliola October, 1964

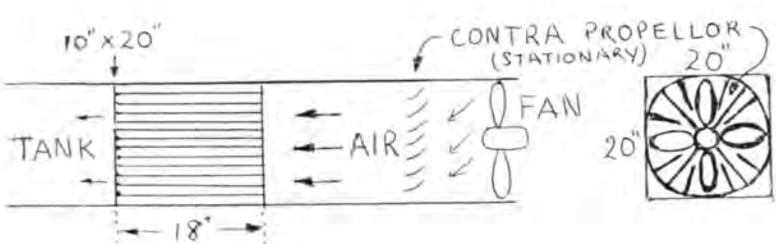
The fan

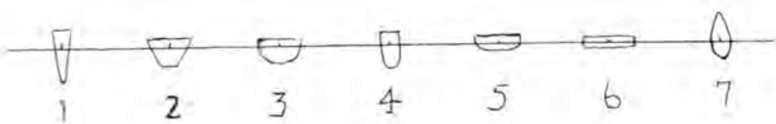
We use a 20 in 4-blade fan for power, with a set of vanes to take out the spiral flow. This is followed by an 18 in section of hexagonal honeycomb ($\frac{3}{4}$ in) cells) with an exit aperture of 10 in × 20 in. The vanes are curved metal slats from a Venetian blind. The honeycomb is a manufactured paper product, stiffened with a plastic coating. The wind produced by this little tunnel is amazingly straight and uniform. We demonstrate this by a trail of soap bubbles in the stream. The windspeed is over 8 knots.











The hulls

To provide the utmost freedom and creativity, we have established the following classes:

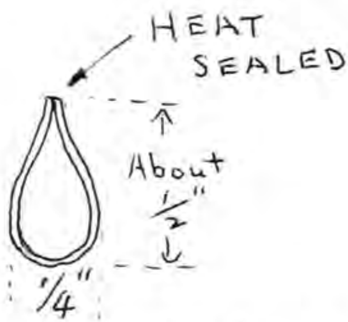
Class "A" Multihull	7 in to 12 in in length.
Class "B" Multihull	Below 7 in in length.
Monohull	up to 12 in in length.
Experimental Class	up to 12 in in length.

This class includes hydrofoils and other craft unclassifiable in the first three groups.

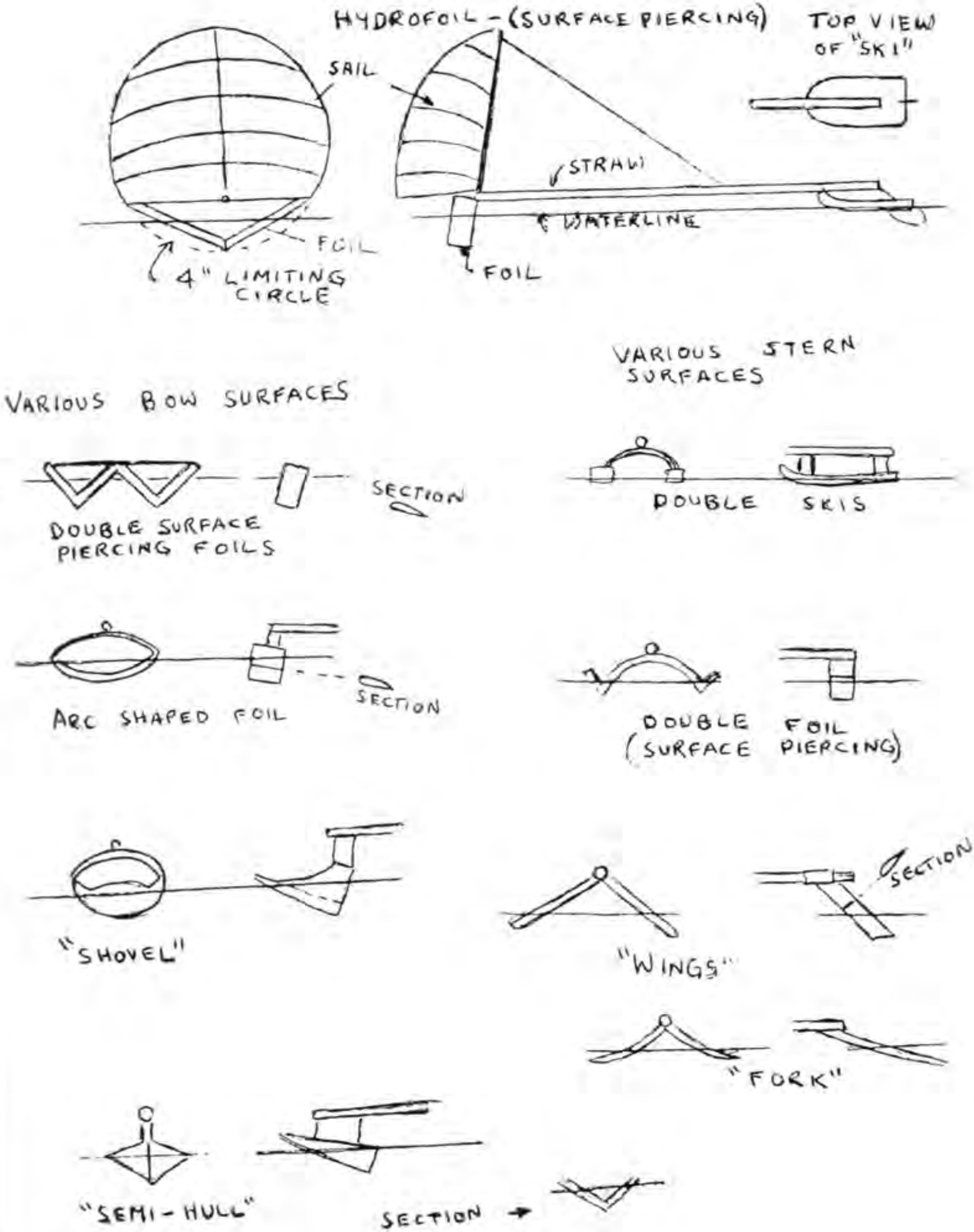
The multihulls

The first boats built were Catamarans made from drinking straws paper, cellophane or other plastic. These are easy to build but have problems of water soakage. Some early boats were of the "Ski" type made from styrofoam which is the lightest structural material but it absorbs some water and cannot be made as smooth as one would like.

These crude boats were followed by balsa catamarans, both solid and hollow. Various sections were tried from extreme "Plank on edge" to the ski type as in the drawing. Each of these shapes had promise at one time or another. Assessment was impossible because of varying sails, lengths, weights and surface finishes. One controlled test was, however, made with two models that were identical except that one had shape 3 and the other shape 4. Shape 3 was conclusively superior. Both were subsequently beaten by a hollow balsa cat with shape 2. But it was 10 in long as compared with the 8 in length of the other models. This cat also had excellent directional stability.



The next significant step was made on January 1st, 1964 with the construction of hulls from a plastic film of 1 thou "Mylar" coated with 4 thou polyethylene which is used to plasticize pictures, identity cards etc. It is easily cut and heat sealed with a soldering iron. A basic tube is formed as in Fig. 3 and heat sealed at the ends to make a catamaran hull which is extremely light, saving 35 per cent to 40 per cent in weight over balsa. The Mylar gives a surface which is the ultimate in smoothness. The most successful multihulls of this type have been long, slender, displacement catamarans. A typical winner had 10 in hulls with about ½ in beam of hull and a weight of 0.006 pounds.


HYDROFOIL - (SURFACE PIERCING)
TOP VIEW OF "SKI"
SAIL
STRAW
WATERLINE
FOIL
FOIL
4" LIMITING CIRCLE
VARIOUS BOW SURFACES
VARIOUS STERN SURFACES
DOUBLE SURFACE PIERCING FOILS
SECTION
DOUBLE SKIS
ARC SHAPED FOIL
SECTION
DOUBLE FOIL (SURFACE PIERCING)
"SHOVEL"
SECTION
"WINGS"
"FORK"
"SEMI-HULL"
SECTION

Monohulls

Monohulls have been built of styrofoam, balsa, thin veneer, plastic and plastic film over a framework. The most successful have been pure planing types with flat, V or arc bottoms. Most competitors avoid monohulls as they require more labour and are trickier to design than catamarans. Due to the tendency to pitch-pole in the strong breezes used, monohulls must either be abnormally long (compared to a conventional boat), carry ballast in the stern or carry a stern outrigger with a skeg or rudder on the end. To date no monohull has been able to beat the catamarans but the field is largely unexplored as yet due to the general preoccupation with catamarans.

Experimental class

This class has led to some of the most interesting developments and even "Breakthroughs" in the art. Various kinds of planing surfaces, floats, foils, skis, pontoons and other devices have been employed. One of the most important and unusual features of this field of experimentation is the surface tension effect which, in these light models, can be greater than the weight of the boat. Foils have difficulty in lifting a hull which tends to stay "glued" to the surface. One answer is to make the foils with enough flotation to support the boat at rest and eliminate the hull. Foils can be made from styrofoam or the Mylar tubes. Some configurations are shown in the sketches.

One unusual and spectacular effect that can be achieved is to combine a high-lift sail with a hydrofoil boat such that the forward foil will completely leave the water. The boat will sail down the tank with the bow up at an angle of 30° to 40° from the horizontal. This is not conducive to speed but is fascinating to observe.

The Experimental Class designs to date have not equalled the speed of the displacement or planing catamarans. The hydrofoils have sudden bursts of speed but have erratic and unpredictable behaviour. Balance, trim and stability are extremely critical in these unusual craft.

There are two unique aspects of hydrofoil design for this application which should be remembered:

a The driving force acts at some distance above the water, instead of underwater, as in power craft.

b The wind strength diminishes as the boat goes down the tank. It may be far fetched to conceive of a hydrofoil that would be properly trimmed for a wide range of breeze and speed. Various forms of automatic compensation for varying wind force have been considered but not built as yet.

The speeds achieved to date do not exceed 30 per cent to 33 per cent of the wind speed. There is every reason to believe that we will eventually get to 50 per cent of wind speed with improved designs, techniques and materials.

CHAPTER X

OPINIONS ABOUT HYDROFOILS

by Edmond Bruce April, 1965

A properly oriented hydrofoil produces a large reaction component of force at right angles to its direction of motion, relative to the water. This is in addition to a drag component which opposes the motion.

A hydrofoil's use as a rudder for steering a boat is commonplace. It is used often as a lateral plane area on sailing craft to permit progress to windward. The additional possibilities of using hydrofoils, as lifters of hulls above water and for the stabilization of heeling, has appeared in a number of AYRS writings.

The present writer would like to express his opinion about the limitations in the use of hydrofoils as lifters of sailing hulls. Nevertheless, praise is in order for their success in avoiding heeling at all speeds, without adjustment. This was achieved in the writer's experiments, first with models and finally on a full size sail-boat.

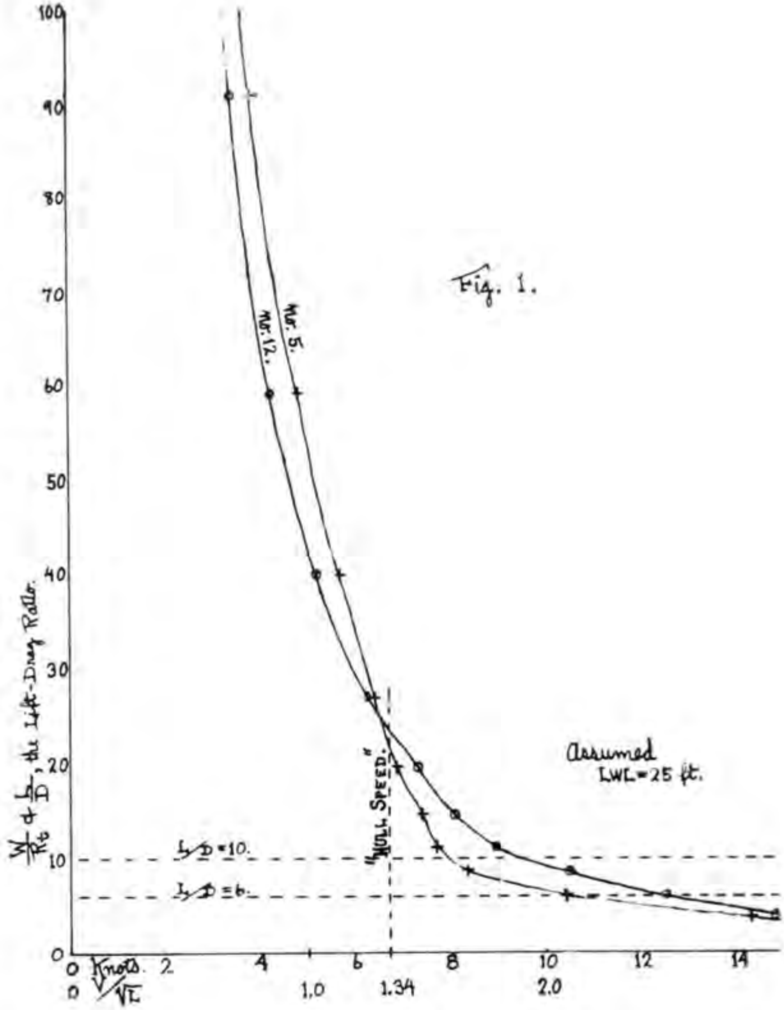
Lifters

Lift resulting from buoyancy is free. Lift obtained from hydrofoils must be paid for by induced drag. A precise criterion as to which method is better for a boat, when employed separately, is to compare the lift-drag ratio of the hydrofoils, of adequate area, with the buoyancy-drag ratio of the displacement hull, at a given speed. The latter ratio is synonymous with the weight/resistance ratio of the hull. Buoyancy just equals weight when dynamic lift is not present. This ratio is the reciprocal of the resistance/weight ratio commonly used in performance curves plotted against, say $V/\sqrt{L}$ or $V/W^{\frac{1}{6}}$

Referring to Fig. 1, there are graphed, as examples, the weight/resistance ratio versus $V/\sqrt{L}$ for Models No. 5 and No. 12 of the writer's article in AYRS No. 45. The speed in knots is indicated for an assumed water-line length of 25 ft. Also appearing are dotted lines which are independent of speed, one of which represents Lift/Drag = 10. This is about as well as deeply immersed, lifting hydrofoils have done in the presence of strut drag, rudder drag and other limitations. The dotted line indicating Lift/Drag = 6 represents an exceptionally good planing hull rather than foils.

It is seen that, up to "hull speed" of $V/\sqrt{L} = 1.34$, the lifters are completely out-classed by buoyancy. Merely lifting a hull out of water does not mean success. It takes about double hull speed to make the lifters show some profit over these particular hulls. Sailing craft, in variable winds, must efficiently cover a wide range of speeds to be satisfactory. Racing motor-boats are designed for top speed. The verdict or a compromise is up to the reader.

At this point, I would like to promote thought on some different approaches to lift. Since the wind is the source of all sailing power, it appears that hull lift could be accomplished more efficiently by properly angling the sails



somewhat horizontally. An angle of attack would be provided which gives a lifting component to the sail force as well as driving and side-force components. This type of lift is familiar to ice-skate sailors. Thus sail lift would be employed rather than the indirect dynamic lift of the water. This water lift, with it's induced drag, results from the hull's forward movement with an angle of attack. Surface gravity-wave drag, which can be high in water, is substantially non-existent in the air. Therefore less drag results if the hull avoids an angle of attack with the water but uses sail lift instead.

Another type of lift, that appears intriguing, is to convert a sailing hull's side-force into lift rather than using it's precious driving force. This will be described in greater detail in a following section.

Stabilizers

Now let us turn to heeling stabilizers. Many visitors to the writer's laminar-flow towing tank, during the last four years, have seen demonstrations of a model having a special single outrigger attached to an excellent main hull. This model is completely non-heeling on any course or with any wind strength. This is obtained dynamically without the help of buoyancy or weight. It is also the highest pointing and fastest model to windward, under comparable conditions, ever tested in my tank. This includes numerous catamarans and trimarans.

Much has been written in AYRS publications concerning different forms of righting devices to counteract heeling. Some have used buoyancy to leeward or weight to windward at the end of an arm of some sort. A few have suggested hydrofoils angled from the vertical as a combination lateral plane and heeling stabilizer. In some cases, even the sail plan has been tilted from the vertical to help achieve counter-heeling.

In re-studying the merit of these arrangements, the angled sail method was not viewed with favour except possibly to provide lift instead of reefing. The driving component, on a windward course, falls off as the *square* of the cosine of the angle of tilt from the vertical.

Buoyancy at the end of a leeward extending arm seemed inferior to out-of-water weight to windward. The latter avoids additional water drag. This is probably the reason why the Micronesians preferred keeping their single outrigger to windward.

The suggestion of an angled hydrofoil as a combination stabilizer and lateral plane was most interesting. It became the subject of the following experiments:

Single outrigger

A sailing combination, employing a single outrigger, is shown going to windward in Fig. 2. A cross-section is drawn which is in a vertical plane containing the sail's centre of effort, C.E. This out rigger configuration has been chosen among several possibilities because of it's simplicity. Also, the

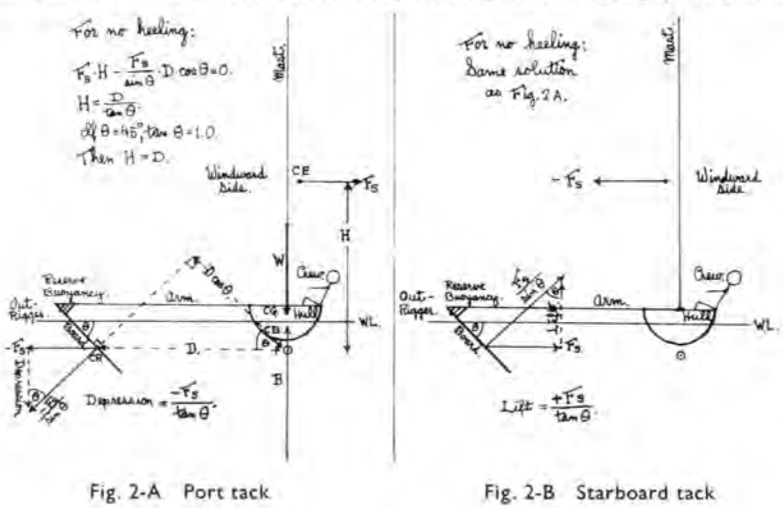


Fig. 2-A Port tack

Fig. 2-B Starboard tack

need for an end-for-end reversal of hull motion when tacking, such as is associated with some single outriggers, has vanished.

Let us examine the magnitude, direction and location of the forces involved. A sail force vector, in a horizontal plane, is always countered by an equal and opposite horizontal component of the total water force, after acceleration ceases. Among the vertical components, the weight force vector is always downward. It is opposed exactly by the vector sum of the forces of buoyancy and of dynamic lift (+) or depression (−). If these forces, projected on the common sectional plane, are so positioned that the lateral heeling moments, including the sail, are just countered by the lateral righting moments of the remaining forces, no heeling would occur.

Referring again to Fig. 2, one is permitted to sum up the moments about any point whatever, within the projection plane, since the result will be the same. For simplicity, point O is used. It is the depth of the centre-of-resistance, C.R., of the thin, flat board, assumed to dominate, but under the centre-of-gravity, C.G., of the complete hull. The moments of both weight and buoyancy disappear, for this case, since their moment arms have no length.

Note that the crew counter-balances the outrigger weight. This keeps its floatation out of water to avoid water drag during steady progress. This floatation is used for static stability when at rest. It also makes a smaller contribution toward stability during acceleration. However, since the sideways component of steady state motion is so rapidly accomplished, no more than a slight lateral bobble would occur even if the floatation were not in the water during this period.

The board may move in and out of the water by wave action, thus changing its immersed area over quite a range, without changing the righting force or its moment. As the board comes out of water, its side-slip increases. This is equivalent to a larger angle of attack in respect to the resulting direction of travel. This larger angle of attack compensates for the reduced area. The righting moment is substantially unchanged up to the point of "stalling." This does not occur until the angle of attack becomes greater than about 15°. The original angle of attack should be only about 4° to produce the largest lift-drag ratio of which the board is capable.

In the full size experiments, over half of the board area could come out of the water and still provide good compensation for the heeling moment of the sail. Beyond this point, the crew weight should be shifted toward the outrigger. There is ample time to do this as is the case when any small boat heels.

The solution appearing on Fig. 2-A shows the requirements for no heeling at any strength of wind or boat speed. If the board's plane angle from the vertical is 45°, the horizontal distance of the board's centre-of-resistance from the hull's centre-line just equals the height of the sail's C.E. above the board's C.R. At this separation, the waves generated by the outrigger and by the main hull do not strike the opposite hull. If either did, this would result in increased resistance overall. With an arm longer than this, one would actually heel to windward, rather than to leeward, in a puff of wind.

Fig. 2-B shows that, on the opposite tack, non-heeling continues to exist. This single outrigger need not reverse its hull travel, when tacking, as has discouraged so many admirers of such craft.

There is an odd difference between the two tacks. The whole system is slightly dynamically depressed when the outrigger it to windward. The system is slightly lifted when the outrigger is to leeward. In practice, little difference is noted between tacks. The board is a bit more efficient when its pressure side is uppermost. This largely compensates for an increased apparent weight on this tack. Water does not tend to go around the lower tip of the board from the upper high pressure side to the other side at lower pressure. It is much like dirt in a shovel. This was observed on the model with powdered rosin suspended in the water.

Note that the above mentioned lift or depression is generated from the sail's non-productive side-force. The previous criticism of lift from planing hulls and foils was based on its dissipation of the sail driving-force component. This side-force concept deserves more study by all of us.

A small difference in balance between tacks appears in Fig. 3. This can be rebalanced by slightly altering the position adjustment of the pivoted board, as shown, by an opposing pair of control lines. The board's centre-of-resistance should be swung a little more forward when the outrigger is on the opposite side of the boat than the wind. Snappy tiller action is advantageous during tacking as is true for any light boat.

Surface piercing foils often have two types of difficulties. One is "cavitation" and the other is air "ventilation." A large area board is used to reduce the pressure per unit area to avoid cavitation. Air ventilation down the low pressure surface, if present, often can be blocked by a "fence." This may be obtained through slightly immersing the outrigger's buoyancy form by a shift in the crew weight toward the outrigger. Neither of these two potential difficulties has appeared either in the model or at full size. Without the reserve buoyancy in the water, the board will totally ignore the presence of waves.

The entire outrigger should be as light as size and ruggedness dictate. While not employed in these tests, an inflated vinylized nylon shape might be excellent as the outrigger's light-weight reserve floatation. As to size, I believe that the buoyancy form should be small enough to allow large waves to gently break over it rather than absorbing the shocks of riding the wave profiles. The float, used in the present experiment, was larger than appropriate for racing. A cruiser, insisting on complete safety off-shore, may desire a large outrigger. Its totally-immersed effective buoyancy might be made equal to its out-of-water weight to provide the same degree of stability on a lateral roll toward either side when dynamic stabilization is not available.

For practical reasons of lateral spread, John Stoddart has kindly suggested that users may want to make the outrigger's arm a hinged, folding pantograph. This would be useful in entering slips or when auxiliary power is employed in narrow channels.

I will not burden this writing with the extensive details of tank test data. Model work led to a full size trial on the International 12 ft Dinghy described by the writer in AYRS No 40. This was chosen because of the extensive data that exists on this hull. Any sailing craft could have been used. One having a high value of length over beam would be preferable for speed since main hull lateral stability is no longer important.

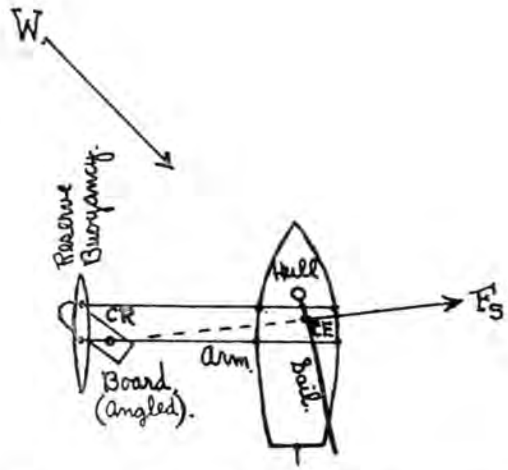
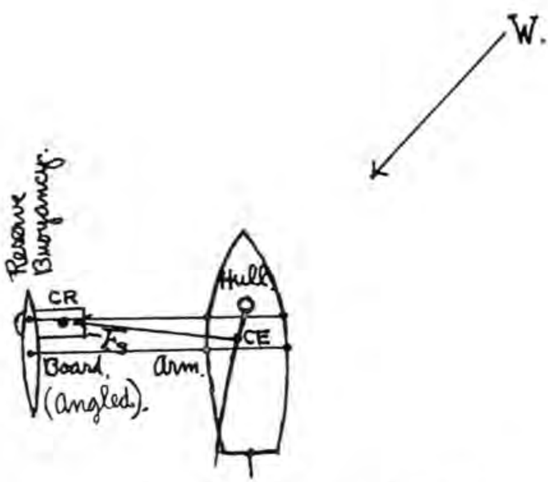


Fig. 3-A   Port tack.   Board adjustment for balance



Starboard tack.   Board adjustment for balance

Every performance characteristic of the model, including increased speed to windward and when reaching, was confirmed at full size. Fig. 4 is a photograph of the dinghy model with outrigger. Fig. 5 is a photo, including a smile of success, of it's full size counterpart under sail and using a 13-pound aluminium ladder as the outrigger arm. The reserve-buoyancy form and the board, for this experiment, were made of water-proof plywood. The hull's regular centre-board was not used.

The principal gain in speed seems to result from increased sail drive through non-heeling. For example, if a conventional, strong-wind, leeward heel

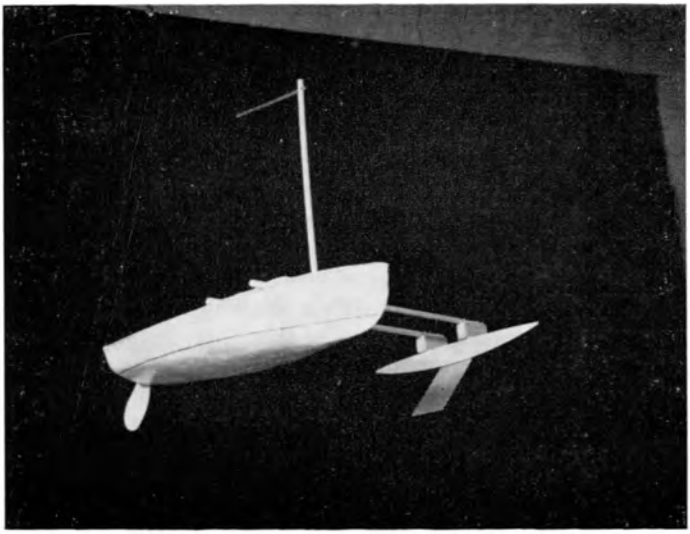


Fig. 4

Edmond Bruce sailing with a single canted leeboard of, say, 20° is avoided, the sail drive would be greater by approximately 13 per cent. A 30° heel avoidance would gain 33 per cent. These gains are far larger than possible reductions in hull resistance through being sailed upright. Avoiding wave-interference between main hull and outrigger is worth something in speed. Also, a minimum of increased weight and wetted surface is tolerated when only a single small outrigger is used. All of these factors give the structure advantages over catamarans and trimarans.

My hesitance in showing the tank curves, of the original boat versus this hull and sail with the added non-heeling outrigger, is that, for best windward sailing, the original boat had a centre-board which tested to be too small. This was rectified in the outrigger with a startling improvement. For this reason, a comparison would appear to be excessively optimistic.

I must mention the only criticism I have heard about this outrigger project. A teenager remarked, "What are you trying to do, ruin sailing? I like to heel."

Further experiments

Since sails with curvature are better than flat sails, the same should be true of boards. This has been the experience in two of my other tank projects, one of which is now being observed in full size tests. As a result of model work, a study at full size of curved, thin-plate, angled boards on outriggers is planned for the future.

Two boards, each shaped for a particular tack, will be used one at a time. These will be located at each end of a self-sliding, lateral arm. Each will have its own separate reserve buoyancy. This is because self-buoyant, *thick* foils, in water (also in air), are known to "stall' too easily at sail-boat speeds, thus ruining their lift-drag ratios.

The above thick foil "stalling" or "separation" is revealed in low-speed wind tunnels. In high-speed wind tunnels or in aeronautics, this does not occur so easily. A model airplane with the thick wings of its full size counterpart probably will not fly. Thin wings must be substituted. Nature provides insects and the smaller birds with thin wings. Fish have thin fins except the largest.

With the above automatic sliding outriggers, a high degree of directional stability will exist since the board in use will be extended with its resistance far to windward on either tack. The sail force will lead away from this centre of water resistance, not towards it.

Even if AYRS members like to heel, as did the mentioned teenager, the improved speed to windward and especially when close-reaching, for the same sail area, should prove interesting. With the heeling stability that has been achieved, one wonders what is the upper area limit for an enlarged sail plan.

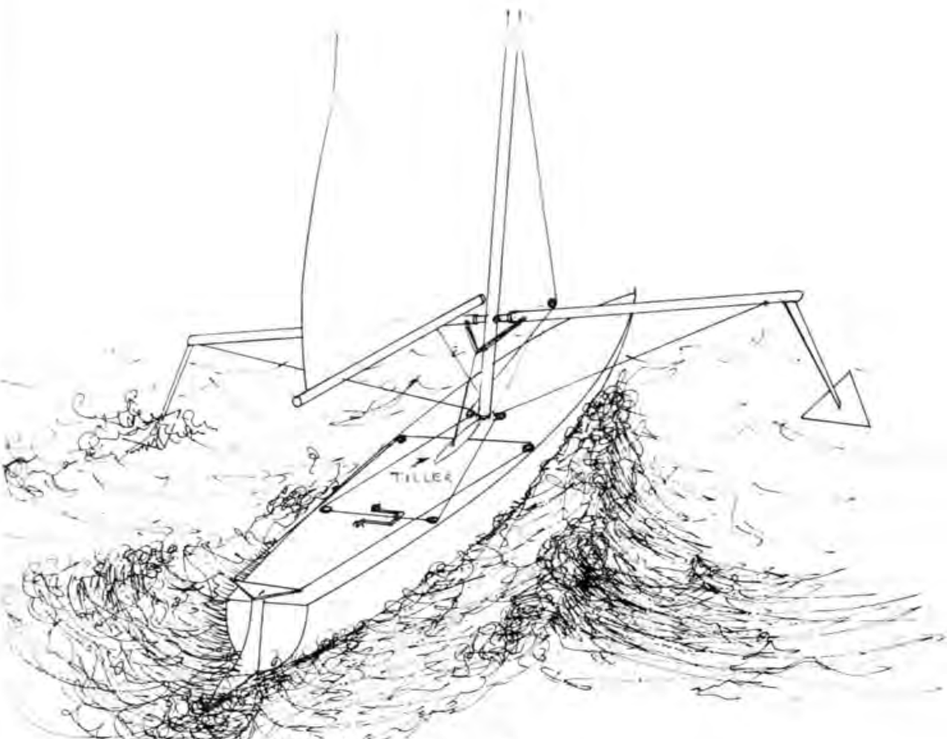
CHAPTER XI

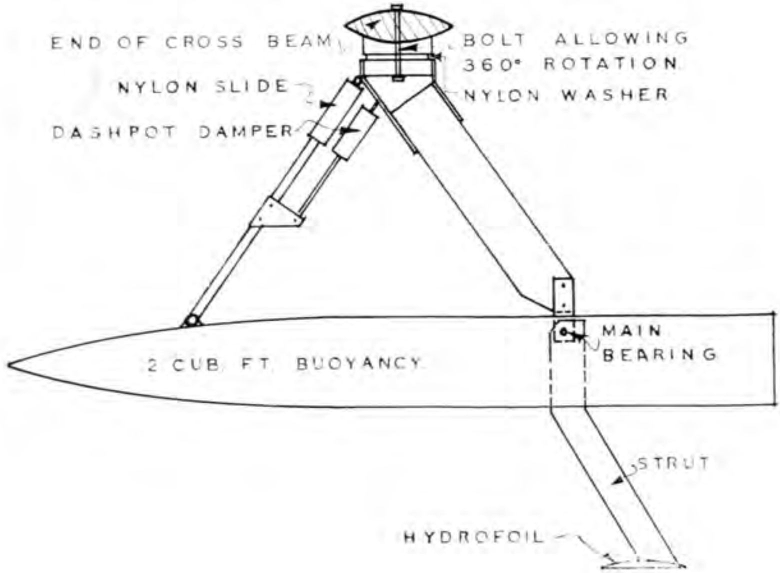
HYDROFOIL STABILIZERS

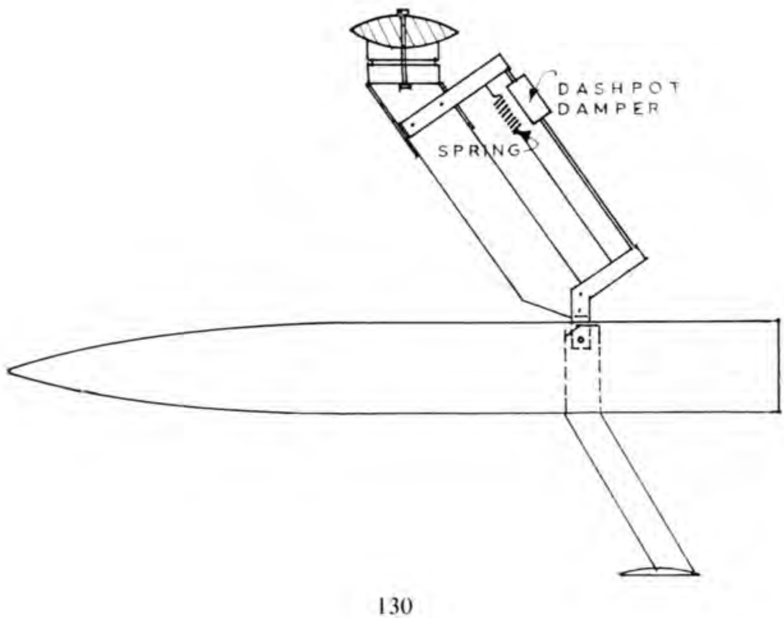
by John Morwood — April, 1965

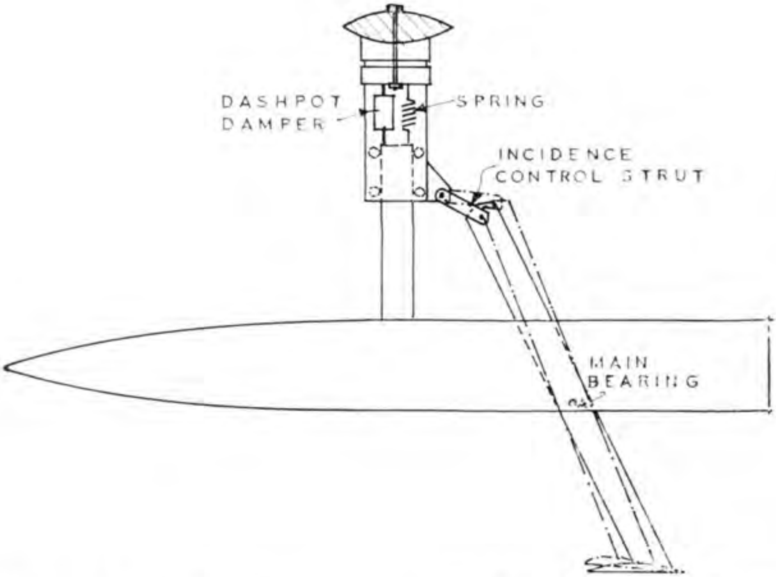
It appears that the stabilizers of my *RYSA* design are not quite clear. The drawing shows how the angle of the thwartships beam is controlled by two wires and an overcentre strut. To complete the idea, mast running stays are shown connected to the wires of the opposite sides, thus abolishing shrouds. The tiller lines and the incidence control of cross beam are controlled by a single horizontal "joy stick."

In my opinion, outrigged buoyancy will not be necessary for light winds because the capsizing rate will be slow enough to let the crew balance the craft upright. However, at least some people disagree with this and so I show three different methods of combining outrigged buoyancy with an incidence control mechanism which might be suitable for cruisers.




END OF CROSS BEAM
BOLT ALLOWING 360° ROTATION
NYLON SLIDE
NYLON WASHER
DASHPOT DAMPER
2 CUB. FT. BUOYANCY
MAIN BEARING
STRUT
HYDROFOIL


DASHPOT DAMPER
SPRING



Letter from: Andrew Norton c/o A.Y.R.S., Woodacres, Hythe, Kent

Dear Sir, April, 1965

Since writing to you for information on the ideal shape of hydrofoils, I have surveyed as much research literature as I could procure on the topic. I subsequently designed and built a model hydrofoil craft 4 ft in length. It had fixed foils, two at the front and the main load carrying foil aft of the C of G of the boat. The two front foils were designed to work initially as hydrofoils and later at full speed as planing surfaces. The change of incidence on all foils is due entirely to the attitude of the craft, although they have some initial positive incidence when at rest. The main foil which runs underneath the craft is designed solely as a hydrofoil with the immersed area varying with speed, i.e. as the lift increases, the boat rises and removes some of the foil from the water.

Andrew Norton's model hydrofoil

The progress of the model is as follows:

1 At rest.

2 The front foils produce lift and change the attitude of the hulls. This increases the angle of attack of the main foil.

3 The main foil lifts the rear end of the model.

4 The front foils now plane on the surface completely clear of the water, the immersion of the main foil being dependent on the model speed.

The model was driven by an air propeller and it was towed. It seemed very stable during the limited testing it was given. It suffered a lot of damage due to hitting rocks on its tests runs, which were carried out on the river Esk. However, the tests give some confidence in the proposed hydrofoil configuration, particularly motor propelled. By altering the line of thrust of the air propeller, I managed to produce a reasonable heeling moment which went some way towards simulating the effect of sails. (The motor driven propeller was mounted on a pylon 12 in above the deck). This, of course, opened up a rather larger test programme and points to future development as under conditions of "motor at full power and boat at rest" the side force caused too much heel as, apart from the wooden support structure for the foils, I had no buoyancy in what would be the float position on a trimaran. However, if the boat was towed off before applying full power to the propellor, it heeled but continued to stay foil borne. At the present time, I have not continued development on this model. If you consider that yourself or any members might be interested, I am prepared to discuss the design in more detail and even continue with the development, when I have finished my current model which is intended to be a cruising trimaran.

Letter from: Bill Holroyd "Larn," Montrose Road, Arbroath, Angus, Scotland

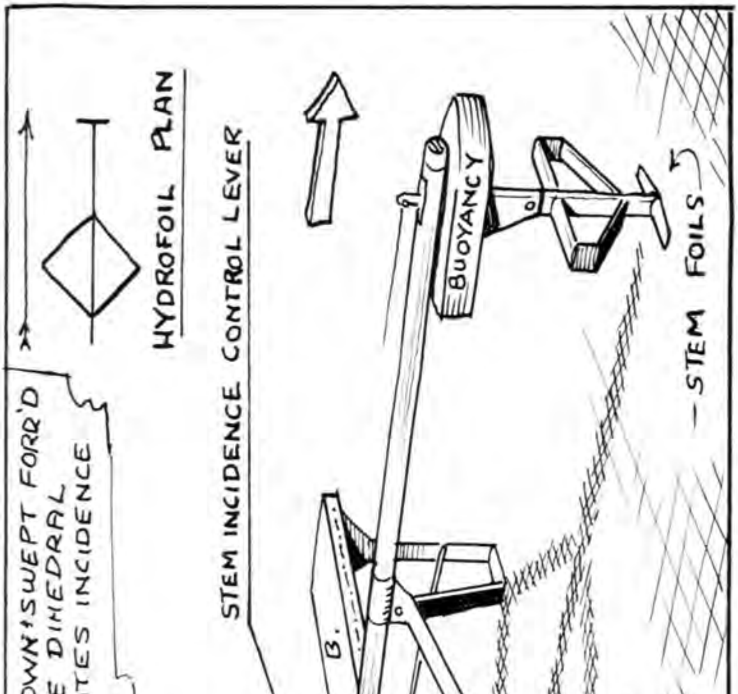
Dear Sir, April, 1965

I am afraid my hydrofoil experiment petered out after considerable work and expense. It was probably too ambitious and complex for both my capabilities and my pocket! It was a test bed of different foil arrangements with no hull and an unorthodox approach.

I had a single foil on the stem which anticipated one or two I've seen since and which was adjustable in pitch. I hoped this incidence would be transmitted to all the craft and the rear fixed foils and this seemed to be so but the experiments didn't continue long enough to confirm it completely. The forward foil shape was as in the drawing.

The "Hull" was a mast and the foils were attached using a "Dexian" wing of the plan view shown. Plastic buoyancy floats were fixed below the "Dexian."

The object was to study (1) sweep forward sloping foils, (2) sweep back sloping foils, (3) the normal high speed foils and (4) the front climbing foil. I had the lot plus the unusual front single foil arrangement.



ABOUT 15 FOOT

The craft was tried out in Montrose basin over a course of two months and we ran into a series of difficulties and mishaps. I tested it with a diving suit on in case of capsize but the craft was certainly stable even at 1 knot. The main trouble came from the engine mounting and adjusting mechanism as the engine would not function fixed because of the back pressure on the exhaust when too deeply immersed. This necessitated a method of raising and lowering the engine as the craft rose or fell on the foils—we could not then afford to get a long shaft engine which was suitable.

I was stranded, swept away, dowsed and frozen on my off days which were few. The attending boat twice was holed and repaired and eventually sank when returning to Arbroath—fortunately my pals were picked up by the Montrose lifeboat. While awaiting a suitable engine we once tried towing the craft against the fast rip on the Esk and the whole thing came up on the foils at a very low speed (it was unmanned) and taught me that the best way to test hydrofoils is in a fast river tied to a bridge and unmanned—in this way it can be studied at leisure. We ran out of time and money and my pals (understandably) ran out of patience. We used a *SEAGULL* 4½ hp mainly and I hadn't the money to buy a more powerful one.

Despite all our failures, I still believe the arrangement was sound though we didn't get a real chance to assess its capabilities or study the foil arrangements. I believed that a foil sloping down and forward into the flow would minimise bubble interference but did not carry on long enough to be able to do any proper observations.

I learnt a lot the hard, cold way. Now I believe that the minimum and simplest of foil arrangements are best and that the way to achieve this is to have adjustable telescopic foils which reduce appropriately in size with speed increase. This can be achieved by a device similar to the demand valve of an aqualung breathing apparatus—at depth, air pressure activated by deeper water pressure opens out the foils and the foils contract as they near the surface because of decreasing water pressure. It would be tricky mechanically but effective and automatic.

Well, there's the sad story and I hope Sir that I've entertained you if not enlightened you in any way.

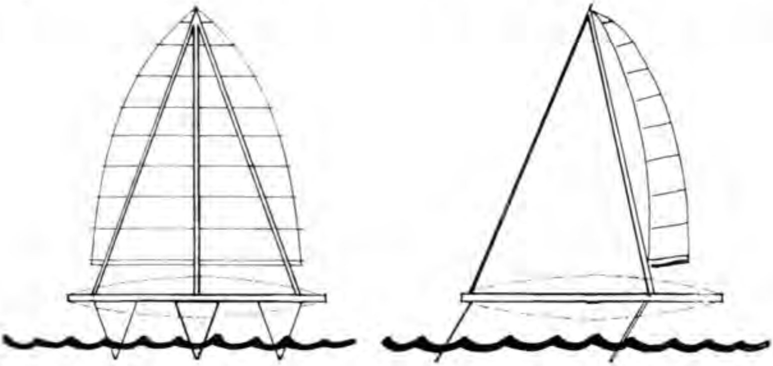
Other foil ideas

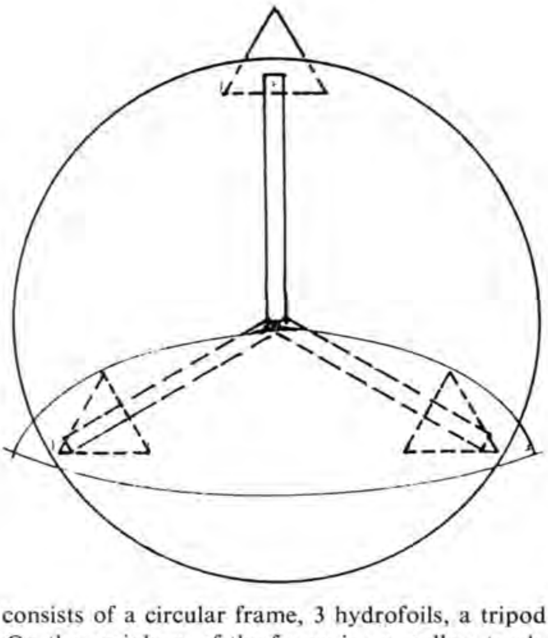
1 Would not a Venetian blind arrangement of foils fixed across a dock entrance break down waves in bad weather and be much cheaper than dock gates or breakwaters? It may be better to have inverted foils to disintegrate waves upward in spray. It is worth a thought.
2 Another idea is to use small foils on fishing nets to keep the trawling bags open by pulling outwards without the use of poles or stiffeners of any sort.
3 I haven't seen a foil yet with a tail plane stabilizer as on aircraft. This could be useful for certain purposes.
4 I also worked out a method of foil propulsion that you may enlarge on. It is difficult to illustrate but is based on the flapping foil except that a number of foils flap not up and down but across and are complementary to each other. This arrangement could be set along the transom and be protected inside a "box." The fluctuating foils suck in and squeeze out water at high speed. This is rather complicated mechanically and may not be worth experiment.

Letter from: Helge Ingeberg Eiksveien 52, Oslo 7, Norway

Dear Sir,

Dozing by the fire—when the new baby isn't crying—I have come to the conclusion that the simplest design for trying out aero-and hydro-foils would be something like the "Flying Flounder" shown on the enclosed sketch. Being no drawer of drawings, as Chesteron would say, I must resort to words.





This thing consists of a circular frame, 3 hydrofoils, a tripod mast and an AYRS sail. On the periphery of the frame is an endless track—split tube—in which runs the "boom" and the boom sheets, which leave the track inwards at the point of the windward foil. Further, there are two sheets for the sail to adjust inclination and angle, or let fly. Whether of the cruising or racing type, this design would give me a lot of space, of which I'm very fond. Can you give me any ideas on suitable proportions for sail and foils.

P.S.—Alternative name, if successful, could be "Soaring Sole."

HYDROFOIL STABILIZERS

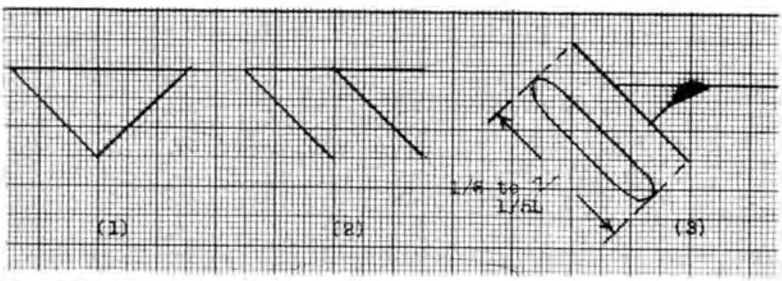
by Bruce Clark

115, McGavock Pike, Nashville, Tenn., 37214, U.S.A.

October, 1965

Hydrofoil stabilizers have intrigued me ever since reading about Dr. Morwood's *JEHU*, but I owned a 17 ft foldboat (decked canoe) for a year before it occurred to me to try converting it into a hydrofoil stabilized sailboat. Since then, Norris Van Gelderen (a Miami, Florida canoeing-sailing friend and correspondent) and I have tried 3 different foil configurations on two decked canoes and one Canadian canoe, with excellent results.

Hydrofoil stabilizers proved to be almost as easy to make as leeboards (though a little more bunglesome to transport). We used 1 × 8 (¾ in × 7½ in) pine boards, dressing them with a draw-knife, plane and sander to the foil section given on page 61. Joints were made with screws and glue, reinforced with fibreglass. A 1½ in × 2½ in cross beam was used between the foils, variously but securely fastened to the several hulls. A pair of door hinges made a convenient attachment, as the foils could be removed by pulling the hinge pins, and adjusted by shimming between the hinge plates.



The full history of our various trials would be boring, but results were always good enough to encourage further efforts. At first, I had so little faith in foils that I put styrofoam floats on top of each foil. The float dragged so much that it was difficult to get up enough speed for the foils to take over, in strong winds. The foil configuration (1) was hard to tack, as it did not give as good a pivot as do leeboards (the long straight keel of the foldboat and its small rudder didn't help). Foil configuration (2) didn't have as good stability as (1), (3) proved best. A 15 ft rigid decked canoe with a little keel rocker and a deeper side mounted rudder just behind the cockpit proved much better, also. However, a straight keel canoe with foil (3) will usually tack satisfactory, if a foil is kept immersed during the whole operation —i.e. flipping quickly from one side to the other.

We were interested in comfortable sailing, with as little interference as possible with our canoe's suitability for paddling. Anyone who wants speed can certainly get it with a sailing canoe, and with hydrofoils, more speed with less hiking athletics! Any canoe can carry at least 50 per cent more sail area with foils than with leeboards, and will be easier to sail, too. A very narrow canoe would be harder to keep upright in a calm than in a good breeze! I'd suggest a Beam to Length ratio 1 : 6 or more. Maximum foil beam of 2/3 Length seems about right.

All in all, I have been highly pleased with sailing canoes, and I wish I had discovered them years ago; I've missed a lot of good sailing because I hadn't! They can be lighter, less complicated, easier to transport and launch, anywhere, anyhow, than any sailboat I have had any experience with. (My foldboat travelled over 2,000 miles on the roof of my car, complete with foils and a 65 sq ft sailing rig, and sailed and paddled on many interesting bodies of water). Even with leeboards, a properly rigged sailing canoe seems less tippy than a paddling canoe and sails surprisingly well. With foils, a sailing canoe seems almost as stable as an ordinary sailboat and can sail much better than the leeboard equipped sailing canoe.

The possibilities of hydrofoil stabilized sailing canoes are not necessarily limited to small craft. In larger sizes, they could be made self-righting, and much more easily and surely than cats. The foils could then be mounted a bit deeper, as might be desirable, though the weather foils should be out of the water for windward work. Foils on larger canoes could be arranged to pivot on a bearing, with a spring to hold them in proper position. This would make them less vulnerable to damage.

I do not know whether hydrofoil stabilized canoes can be designed that will beat the best cats, size for size; probably not. However, for a given amount of money, a considerably longer canoe could be built, which would give the canoe quite an edge. A hydrofoil stabilized canoe has several advantages over cats and trimarans, not the least of which is that they can be rather better looking!

To help others convert ordinary canoes into sailing canoes, (with leeboards or with hydrofoil stabilizers), I have prepared a set of plans, showing 5 rigs, with optional jib, giving sail areas of from 30 to 131 sq ft. The short-masted luff spar Bermudian rig is featured (as being one of the most suitable for a light canoe) and directions are given for 1 piece solid or hollow masts. These plans are $3.75 postpaid, by first class mail in the U.S., or by printed paper rate elsewhere.

The AYRS Cruising Yacht Design Competition 1966

This was a competition whose entries were to be sailing models of full sized yachts, the model being limited to 36 in in length and 500 sq in in sail area. There were some other rules such as limiting the mast height and requiring 1 lb of internal weight and 6 in of headroom. The modelling had to be realistic.

There was some doubt at first if the trials would be valid. However, we were assured that, if the wind speed was suitably "scaled" we would get a valid comparason.

The Trials

These took place on Sunday, April 3rd, 1966 at the Round Pond, Kensington Gardens, London. There were 2 trimarans, 2 catamarans, 4 single hulled boats and G. F. H. Singleton's buoyant foil-stabilized craft, whose photograph is shown here. In the races in winds of 10 mph, gusting to 14 mph corresponding to winds of 34 mph gusting to 48 mph, Mr. Singleton's model won two races. A very neat trimaran made by Donald Maclachlan won two others. At a single "sail off" the Maclachlan trimaran won the competition.

G. F. H. Singleton's hydrofoil *FOILER*

The Singleton Foiler

The photograph shows the beautifully made main hull with the accommodation we required, the rigid cross beam and foils. The foils were of "Ogival" section, of semi-elliptical plan form, high aspect ratio and a few degrees of "toe-in". The dihedral was 45°. There was some buoyancy in the foil which produced good stability when the boat was not moving.

Performance

We all thought that the Singleton *FOILER* was the most stable of all the boats in the very strong winds. It was capsized by 20 mph gusty winds, corresponding to winds of 68 mph but behaved perfectly in our trials. Self-steering was good, too. Comparison should be made with Gerald Holtom's models near the end of this book.

CHAPTER XII

October, 1966

Letter from: Donald J. Nigg 7924, Fontana, Prairie Village, Kansas, U.S.A.

Dear Sir,

You will recall that we corresponded on the subject of hydrofoil sail boats in the Spring of 1963. You were kind enough to send me quite a bit of helpful information on the general subject. As you can see from the photograph enclosed, my experiments have been reduced to successful practice. After due consideration of what had been done in the field, I decided to do something a little different than other experimenters had attempted, in-so-far as I know.

Don Nigg's Flying hydrofoil

The idea of a front steering three point suspension system began to emerge as a challenge early in the study. Iceboaters shifted to this approach some years ago with good success. The two obvious advantages are first, the better weight distribution among the three support points where the skipper must sit in the rear, as he must, to see his sails; and second, the weight of the skipper provides a restoring moment against heeling even when he is sitting on the centre line of the craft. In the case of the rear steering three point suspension, he is sitting on the fulcrum and it is difficult to even hike out to make use of his weight. The most formidable design problem in the front

Don Nigg's *EXOCOETUS*

steering approach is the pitch stability and the pitchpole moment of the sail thrust vector. A solution to this was finally worked out on paper and it seems to be proving out in tests. This solution appears to be unique, and is the subject of a patent disclosure at this time. Perhaps a contribution to the art has been made on this point.

The boat, in its first form, flew brifly during the end of the 1964 sailing season. Bow wave problems made it advisable to modify the shape of the front portion of the floats. In the Spring of 1965 the boat was again launched with this one major change. The transition from displacement mode to planing mode to hydrofoiling mode was now smooth and quite satisfactory.

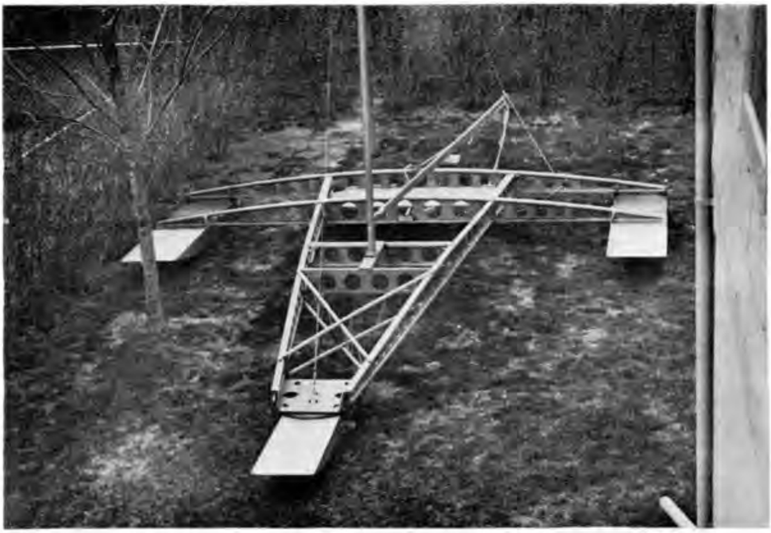
EXOCOETUS hydrofoil frame and sail

The boat took off quite readily and seemed to be running fine. On the third time up it was necessary to make a rather sharp turn upwind to avoid an obstruction. The strain in torque on the front end was too much and the whole front section literally twisted off. As the nose dropped, it put the rear foils in negative attitude and this tore the rear cross-beam apart. The thing came to rest in three distinct pieces! A whole new frame was necessary. The new frame was not ready until the 1966 sailing season. This time all stresses were calculated and a safety factor provided. The first frame was strong enough at the outset, but after modifying the floats, the attempt to regain the original weight resulted in the removal of too much material and it was just too weak for the high stresses developed in these boats. I might note here that the original foil design and sail design were unchanged in all this. Only the frame was affected.

The photograph was taken early in May this year, and represents one of dozens of successful flights. In this particular picture, the craft is slowing down for a landing in a cove and is probably going between 21 and 15 knots judging from the height above the water. The original design figures were set up for normal operating speeds in the 20 to 30 knot range. At this speed the boat is a foot or more higher above the water than in this picture. At 25 knots, the calculated rise is 30 in from the rest position. Not visible in the picture is a 90° Vee foil on the front strut that is completely submerged in this picture.

Mrs. Nigg with foils

The front foils visible in the picture will rise completely free of the water and the high speed foil supports the front end at full operational speed. It has a ½ span of 16 in and a chord of 2½ in. It is made of aluminium, while all other foils are of oak or mahogany. The rear foils are 5 ft long and taper for the bottom 3 ft to a 3 in chord at the tips. They have a 11½ in chord at



Bow view of frame

the root. The total foil area is about 11 sq ft to give the realtively low take off speed of 6½ kts, calculated. This velocity can be achieved in a 12 knot wind.

After the floats leave the water, the drag curve actually has a negative slope between 6½ and 12 knots resulting in very fast acceleration. This is achieved by virtue of the fact that the design provides for foil area reduction and foil angle of attack (drag) improvement that overcompensate for the v^2 term in the drag equation in this velocity range. The velocity term begins to predominate, and at 24 knots the theoretical hydrodynamic drag is again that at take off. See what has happened? We have a mathematical model that will go 24 knots in a 12 knot wind. This is why I had to build it to see what it would do. The sail thrust exceeds the drag throughout this range. You can't argue with this because all sail calculations were based on the curves in your very good book on the subject! As a further tribute to this efficient little sail based on your work, yesterday the boat got off the water with two adults aboard. (Gross weight 510 lbs—really too much for any safety factor in the stress analysis).

Statistics for *EXOCOETUS:*

LOA 19 ft Beam 16 ft Weight 214 lbs

Foil sections, NACA 66-S209 and plano-convex, 45° dihedral.

Foil loading, 400 lbs/sq ft at 20 knots.

Sail 85 sq ft, 20 ft sleeve luff, 7 ft foot, loose footed, full battens, 6 oz cotton—homemade.

Thank you for your encouragement.

Letter from: Paul Ashford Holly Lodge, Strumpshaw, Norwich NOR 77Z

Dear Sir, October 1966

TRIPLE SEC, which I had at Weir Wood in 1964 (see AYRS No. 52) is now sailing with a single outrigger 10 ft × 10 in × 10 in with Edmond Bruce's inclined foil on the float. The main hull and float are about 7 ft apart, centreline to centreline, with Bermudian sloop rig on the main hull centreline.

TRIPLE SEC—bow lifted

So far, she has been sailed on only four occasions. On the first two sails, there was a strong and gusty wind and she was reefed. On the second day, we had one sail with the foil off the float, using the centreboard I put in the main hull last year. This showed the inclined foil to be worth a lot more in stability than a crew sitting well out. In fact, the effect is quite uncanny.

Bruce foil to weather—bow depressed

Generally, I think she is greatly improved over last year's trimaran configuration and, when a few teething troubles have been ironed out, I think she will be very fast.

Handling is good. She is very light on the helm on either tack. Tacking toward the float is very easy, the main hull sailing round the float making a lot of ground on the turn and starting the new tack without loss of speed. The opposite turn, in which the float swings around the main hull, can be accomplished with certainty if the jib is kept aback but she seems to lose most of her way, which has to be regained on the start of the new tack. I intend shifting the mast toward the float, which I think may improve this.

I hope to be able to attend Weir Wood this year, by which time we should be getting more tuned up.

Foil to leeward

Bruce foil in working position

The Cruiser possibilities seem most attractive. Congratulations to Edmond Bruce on what I think will prove a great breakthrough and my thanks to you for publishing the good news.

TRIPLE SEC

The photographs

These show the line of action of the foil meeting the mast: the waves from the hull and outrigger intersection and the way the hull is depressed, when to leeward and lifted when to weather so that the forefoot is clear of the water.

Another view of the foil—the working position

The foil is pivoted in a bolt through the outrigger keel member, and restrained from wringing the bolt by timbers which hook over its top edge at the sheer. While easier to construct, Paul thinks that this arrangement produces more drag than would arise from the slot if the foil were housed internally in the outrigger like a normal centreboard.

Ed. Further trials described on pages 159-161.

Letter from: David A. Keiper

October, 1966

Dear Sir,

I have my hydrofoil sailing yacht design under construction now. I'm in the midst of planking it, and expect to be trying it out sometime this fall on San Pablo-San Francisco Bay, and the rougher waters outside the Golden Gate.

It wasn't until May that I had a particular design that appeared to satisfy the many requirements of such a yacht. In addition to designing a foil system that should give a lift/drag ratio of 14 or 15 at take-off, I had to work out a rigid but lightweight method of construction, and an improved sail rig.

The craft is 31 ft long overall, and I'm expecting a total displacement of 3000 lbs, including two persons and their supplies. Calculations indicate that a 13 knot wind will be required to become fully foilborne. Lacking that wind, the boat can be operated as an efficient trimaran by retracting the foils. The abbreviated pontoons are located forward of amidships and serve for initial stability and for structural fastening points for shrouds, bow foil and lateral stabilizing foils.

The aluminium foils have a 6 in chord length, and will be set with minimum dihedral of 30°. The bow foil will span the width of the boat and will thus have a very high aspect ratio. It will be set for a fairly high lift coefficient at the take-off speed of 12 knots. The rotatable stern foil-rudder combination

Framing of *WILLIWAW*

will have lift coefficients considerably less than the bow foil, thus giving submerged foil stability at the lower speeds. Stern foil lift is distributed lower than that for the bow foil, such that as speed picks up, the craft leans forward to reduce lift coefficients to proper values at high speeds. Lateral foils will be inverted 'Ts' with dihedral to oppose the extreme side forces encountered.

I have no plans for incidence control of the foils on this craft. I'm afraid of gadgetry at sea, my yachting experience winning out over my "physicist" propensities. Longitudinal stability calculations indicate that sail pitching moment is no problem. Fresh storm waves could turn out to be a problem if one runs straight downwind. However, I've put considerable reserve buoyancy in the bow in order to counteract negative incidence that might occur on the bow foil. Normally, one would tack going downwind to get optimum performance. The highest cruising speeds would be obtained with the true wind just aft of the beam, and the boat synchronized with the waves.

I'm planning on a sloop rig with loose-footed mainsail to allow camber control, and to get hard driving force from the lowest portion of the mainsail. The mainsail will be set close to the wide, clean and uncluttered deck to get maximum efficiency.

I enclose a photograph (bottom view) of the hull construction. Curved frame members and planking are of ¼ in plywood. Angle blocks spaced every 6 in along the frames fasten frames and planking together. Bottom and transom will be of ½ in plywood. There will be a thin fibreglass skin over the whole boat.

By the next issue I hope to be able to report on its performance. See pages 152 and 244

A METHOD OF USING FULLY IMMERSFD HYDRO-FOILS WITHOUT MOVING PARTS
by R. R. A. Bratt, M.A., A.M.I.Mech.E.

Before describing what has seemed to me a useful way to utilise hydrofoils it will be well to state briefly the principles involved.

The dynamic lift of hydrofoils is used to greatly reduce the wetted area and water disturbance of a craft. The reduced resistance makes possible the use of much lower power or an increase of speed or both.

The requirements of a hydrofoil system are that the boat travels parallel to the mean surface of the water in its speed range, and that it is stable, i.e. the boat must not hunt, or porpoise or suddenly dive if the trim is disturbed.

There are two fundamental types of hydrofoil: surface breaking and totally immersed.

Surface breaking foils follow the surface of the water by rising as speed is increased so that a smaller lift area remains immersed at higher speed.

Totally immersed foils have potential advantages of a smoother ride and less disturbance of the water surface since the lifting surface itself does not anywhere disturb the surface. The lift of a fully immersed foil is precisely comparable to an aeroplane wing and the convenient way to keep the lift constant with varying speed is to change its angle of incidence. The angle of incidence can be changed as in an aeroplane by tilting the whole craft or by just tilting the foil.

To maintain constant depth just below the surface of the water a surface sensing device is required. This is commonly in the form of a sort of water ski which is linked by a mechanism to the foils or control foils. A more or less complicated set of moving parts is involved.

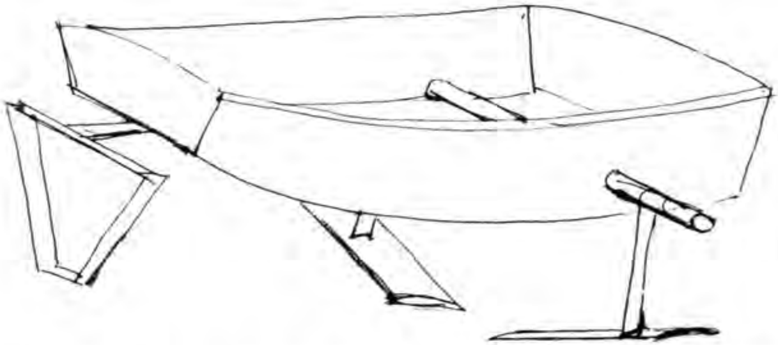
Moving parts are not necessary, however, if the angle of incidence of the load carrying fully immersed foil is controlled by a fixed surface breaking control foil. I successfully tried this in 1960. My eight foot dinghy with me in it towed by a motor boat rode above the surface of the water at about 12 mph. I cannot say that I felt very safe, but that is presumably a matter of development work and not inherent weakness. In any case the dinghy had no rudder or other moving control at all.

The unit consisted of a pair of main foils each 9 in × 24 in set at a dihedral of 10° or so each. These were mounted each on a single stalk near its centre. The two foils side by side, with a gap between them, but equivalent to an aeroplane wing. A front surface breaking V foil acted as stabilizer.

The front foil 3 in × 10 swg aluminium cambered and formed into a flat bottomed 60° V with 18 in sides, and 4 in bottom.

To perform more than my crude experiment it would be necessary either to fit a rudder behind the main foils or make the stabilizer rotatable as a front rudder. It is possible that ailerons would be an asset for turning especially as the centre of gravity is inevitably so far above the lifting surfaces, but if the device is usable it would seem a retrograde step. Careful design should make them unnecessary.

A word on stability. An aerofoil or fully immersed hydrofoil can carry a stabilizer either behind or in front. The fundamental requirements for stability when the stabilizer is behind as in an aircraft are (a) that the stabilizer has a small negative angle of incidence and that the centre of gravity precedes the centre of pressure (b) that the moment of the stabilizer be large relative to the moment of initia of the craft. When the stabilizer is in front of the main foils as in our hydrofoil system the angle of incidence of the stabilizer must be greater than the angle of incidence of the main foils. (b) holds good and of course the stabilizer must be powerful enough to cope with the changing position of the centre of pressure on the main foil as it changes speed and angle, and with the changing position of the centre of gravity if the passengers move.



Consider the mechanics of the hydrofoil system proposed. At rest the V shaped front stabilizing foil lies fully immersed in the water at (for the sake of argument) 5° or 6° incidence, the main foil at zero or perhaps 2° incidence. The centre of gravity is slightly in front of the main foil so that only a small load is carried on the front foil which has the double task of stabilizer and surface senser. As the boat gathers speed first the front foil begins to lift because it is lightly loaded and at a larger angle of incidence. As it rises it causes the main foil to present a larger angle to the water, and the main foil will begin to lift the boat from the water. As the speed increases so the main foil will rise. At the same time the front foil will cease to rise or rise less fast as both foils turn to a smaller angle of incidence. It will be seen that the front foil will have a more nearly constant running depth regardless of speed, while the main foil will run nearer the surface at high speed and deep at low speed. The effect of movement of centre of gravity will be to make the craft run higher or lower in the water. In very short or frequent waves the front foil will be back in a trough without raising the bow of the boat. In longer waves the bow will tend to follow the contour of the wave but flatter. As it does so the main foil will change incidence slightly without having time to raise the boat. In large waves the craft would follow the shape of the sea.

As any aeroplane modeller knows, whether the system is inherently stable or whether it dives or porpoises depends on correct proportions and there are known rules to follow.

I doubt if this system would be readily adopted for sailing boats because it will not accommodate big variations of fore and aft overturning moments. I can visualise some potentially useful variations and adaptions.

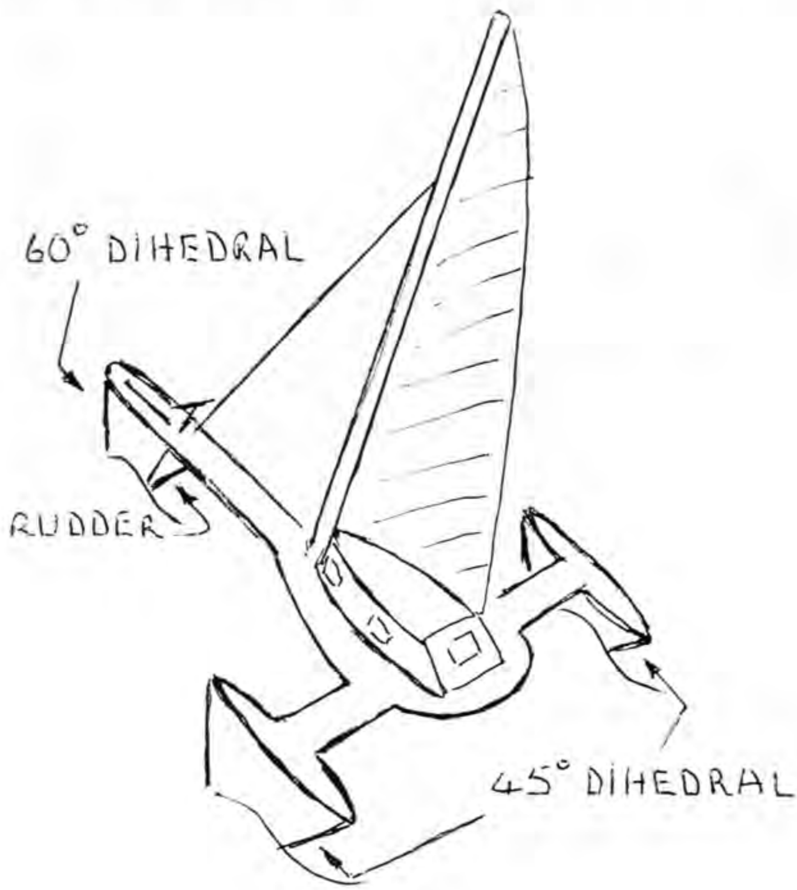
The Rewards of a successful Flying Hydrofoil

October, 1967

These are great. Cheap, light, sailing boats with small sail areas should travel at from 24 to 40 or possibly even 60 knots. Atlantic crossings should be possible in a few days, even to windward with such speeds and efficiency. The drawing shows a concept of a 60 knot "Trans-ocean" hydrofoil sailing craft with buoyant, low aspect ratio foils. A half-scale version would have a buoyancy of 840 lbs and, if made at 200 lbs or less would carry two people.

LOA (excluding cabin)	50 ft	Beam OA	30ft
Buoyancy	3 tons	Sail area	300 sq ft

Each float-foil is an equilaterial triangle of 14 ft sides and 14 in maximum thickness, which gives a buoyancy of one ton. All three foils slope up to leeward, the aft ones at a dihedral of 45°, the forward one at 60° from the horizontal. On putting about, the foils flap over for the new tack in the



manner suggested by the late Commander Fawcett many years ago. The rudder is placed at the aft end of the forward foil whose dihedral angle of 60° should let it work well.

The sail is loose-footed and sheeted to the cabin side to give the correct shape. The platform at the base of the cabin partially prevents the boom eddy and acts as a "Walk way."

Letter from: David Keiper

December 1966

Dear Sir,

Your poem, "The Downhearted Boat-Builder" (AYRS 57), stirred me to renewed efforts to complete the 31 ft flying hydrofoil (page 147), now named *WILLIWAW*. It cheered me up to think that I've had less surface area to plank, fibreglass, and paint than a standard trimaran, and also no built-up cabin structure. I enclose a photograph. The hull weighs only 1,300-1,400 lbs, but is extremely rigid because of its proportions and its doubly-curved plywood. Practically all of its weight contributed structurally, including inside shelves and benches. Headroom inside is 5 ft plus a little. The living quarters appear spacious, since they run the full length and width.

Dave Keiper's *WILLIWAW* being built

I have sailed the craft once so far, in a light air, without hydrofoils. It balances and manoeuvers well. However, it is so easy to get confused about wind direction, because it generates its own wind going upwind, and kills its wind downwind. When a Force 3 wind is generated close-hauled, with 380 sq ft of sail, the craft heels about 15°, and the underbelly adjacent to the leeward pontoon begins "planing." (Normally, a leeward hydrofoil would prevent such a heel.) This planing effect is interesting, because it seems to stiffen the boat up against further heel. It makes me wonder if a racing trimaran could use to advantage such a pontoon planing effect after it has heeled to a certain angle.

Hydrofoils will be fabricated for *WILLIWAW* next month (Jan. '67). The hydrofoils will add 400 lbs to the craft, but this isn't much more than the weight saved by not having large pontoons.

HYDROFOILS FOR A RACING CATAMARAN
Devised by J. Robert Williams

P.O. Box 84, Coconut Grove, Florida, 33233, U.S.A.

Here, we have a unique application of hydrofoils to a sailing craft. In light winds, the boat—a *PHOENIX* catamaran—sails quite normally but when the sailing speeds increase up to and beyond a $V/\sqrt{L}$ of 4, an inverted T hydrofoil is put down on the lee side of the boat to absorb the total capsizing moment of the sail force. This results in increased speed and a smooth ride because the boat is lifted above most of the waves.

The foils

There are two of these (one for each tack) mounted near the bows. Each is an inverted T type with a foil area of only ½ sq ft mounted on struts which can weathercock to the water flow. The angle of attack is set by hand but

Phoenix Catamaran—foil retracted

need not be continually watched. It is usually set at about 10°, which allows for a downward pitch of the bows to that extent without negative incidence. There is no lateral force taken by the foil because of its turning to the water flow and the normal centreboards are used.

Advantages

The original intent of this experiment was to gain an increase in performance, primarily in the upper speed range through:

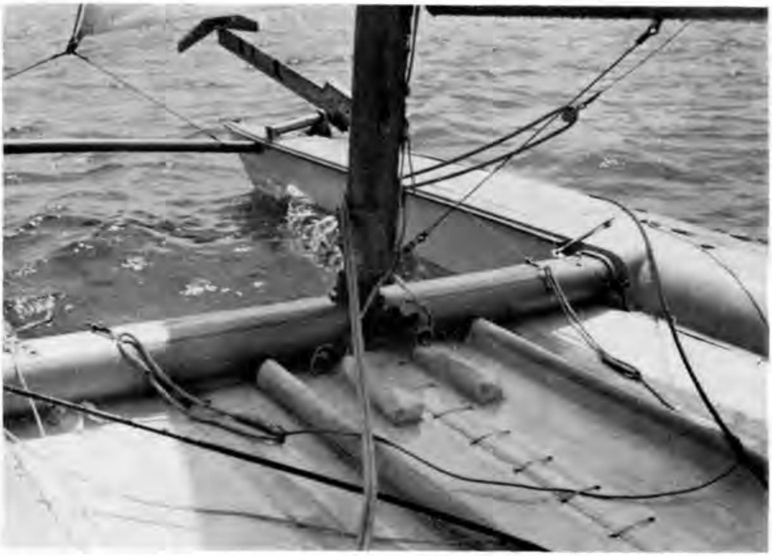
1 Reduction of wetted surface.
2 Drastic trim change to promote dynamic lift on the aft hull sections.
3 Retaining the original windward and ghosting performance by having a fully retractable system.

Advantages not foreseen were:

4 Reduction in spray (virtually no spray at full lift).
5 Eliminating of lurching, surging forward motion caused by blue water contacting the main cross beam and trampoline.
6 Ability to span or leap across troughs and operate in rougher water at higher speeds in greater comfort even at only partial liftout.

Disadvantages

1 Difficulties in docking (not manoeuvring) with the long overhang of the foils in the retracted position.
2 The bows are protected from damage at the expense of the strut-foil joint.



William's foil, retracted

The angle of attack of the foils

The foils shown in the photographs (lee one only) provide partial lift-out from 17 to 23 mph. Between 25 and 28 mph, the lift of the operational foil is such that it can be flown if not properly set. The system is somehwat self-correcting since a portion of the load is carried by the hull and, as the stern rises, this serves to decrease the angle of attack of the foil.

Sailing trials

In use, these foils become operational at wind velocities in excess of 11 to 12 mph. They then become a reaching or running necessity.

It has been found best to retract both foils in light airs or when going to windward. At the windward mark, the lee hull for the next reach or run is selected and that foil only is dropped. The pitch control is set positive at 10° or so. As the boat falls off the wind, the speed increases and the lee bow starts lifting. The wetted surface is now a bit less and the speed increase

The Williams foil lifting the lee bow

continues. A manual reduction in the foil pitch to offset the induced pitch caused by the high attitude of the bow. As the bow is lifting out, the heeling force is predictable until the boat starts sliding off in a planing attitude—at which time, the weather hull flops down and the heeling force diminishes as the speed increases.

When top speed has just been reached, the pitch control should be adjusted. The foil should be set as fine as possible while still supporting the bow but should not allow it to start dropping. Some extra incidence is used for practical reasons since, if a puff should squeeze the bow down and the pitch control was too fine, the foil attack angle might go negative with predictable results.

The weather hull has not yet been flown with the heeling force in the full planing state. In fact, since only the lee foil is used, the boat sometimes runs with a weather list.

Foil in sailing position

Construction

The foils, struts etc. are made from light alloy. Owing to the speeds obtained, several parts failed from the unexpected loading. The foils can be lowered or retracted at 10 mph.

Summary

Mr. Williams has produced great benefits for the high speed sailing of his *PHOENIX* catamaran by the use of a foil outside the lee bow. These not only produce increase in speed but almost complete freedom from spray. The system may be of great benefit to any racing cat where the rules allow it.

Letter from: Clayton O. Feldman

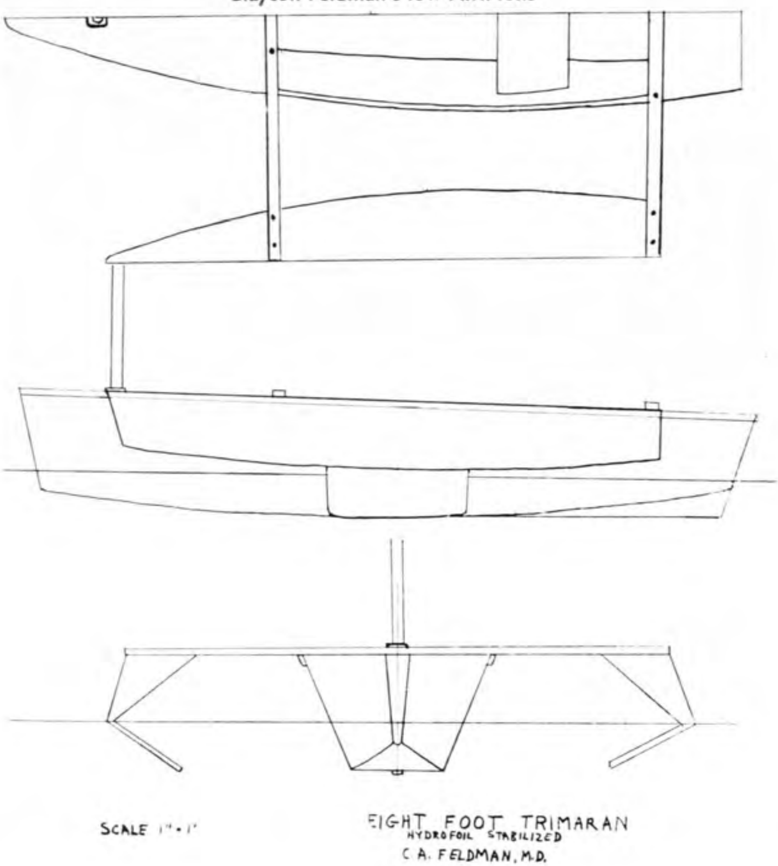
2271, Constitution Drive, San Jose, California, 95124.

Dear Sir, December 1966

I could not resist sending you some photos of my second trimaran—a little eight footer—mostly to show that the small tris can be pretty (as I think this one is) as well as functional. They show the form fairly clearly. My wife and I made the sail, and this, our second sail-making venture also, was considerably better that the first one we made. The whole thing can be put

Clayton Feldman's low A.R. foils

Clayton Feldman's low A.R. foils



together in fifteen minutes and the main hull is easily manhandled by myself from cartop to the trolley.

She sails very nicely and a bit faster than the popular eight foot "El Toro" prams so ubiquitous in this area, in spite of the fact that her small size make her very weight sensitive.

She has one interesting feature in that, while she may heel a few degrees in a crisp breeze, a sharp puff tends to make her sit up squarely rather than heel further, her low aspect ratio hydrofoil fins apparently doing the work. The fins also substitute for a daggerboard, the lack of which seems to be no great loss, as her pointing ability is just as good as the centreboard dinghies on the reservoir—and besides, in that tiny hull it's either a daggerboard case or me!

Clayton Feldman's foil-trimaran

The vital statistics are as follows:

LOA	8 ft	Floats LOA	6 ft
Beam OA	5 ft 10 in	Floats beam	9 in
Beam, hull	2 ft 0 in	Foils	18 in long
Beam, hull at LWL	17 in	Foils	9 in deep
Beam, hull at bottom	12 in	Foils dihedral	45°
Weight	65 lbs	Sail area	38 sq ft
Cost £50.00			

The January issue of the publication was superb. I can hardly wait to start designing an overnighter-daysailer for the Bay. I hope that the membership list so thoughtfully supplied will lead to regional meetings in this area.

CHAPTER XIII

TRIPLE SEC. WITH LOW ASPECT RATIO FOILS

by Paul Ashford October, 1967

Holy Lodge, Strumpshaw, Norwich. NOR 772

This season's experiment arises from last year's trials with a single Bruce foil and 10 ft long outrigger which are reported on pages 144-147. Further sailing fully confirmed the early impressions of the value of the foil and I am sure that this configuration was a considerable improvement on the original trimaran and is well worth further attention, particularly for a light and exciting racing craft.

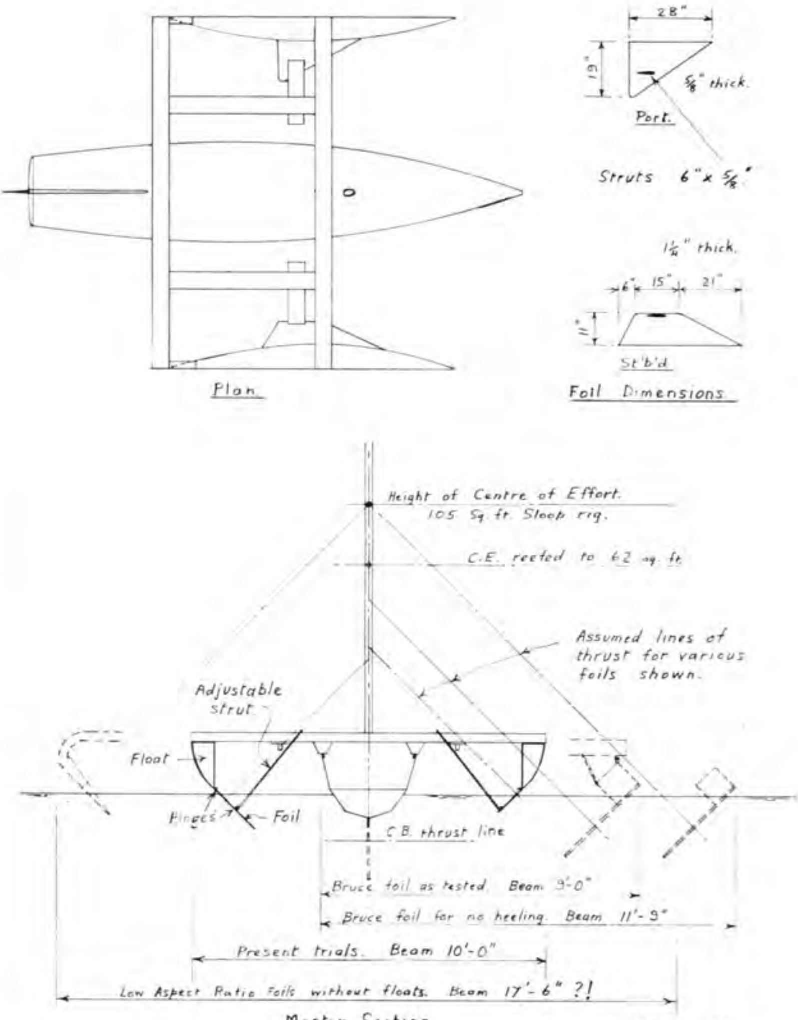
However, I was left doubtful whether the single outrigger would provide a safe design for a larger cruising boat. When sailing with the float to windward, stability was provided partly by the action of the foil and partly by float and crew weight. When the wind was strong enough to lift the float, about half of the foil would rise slowly from the water without significant loss of foil stabilizing, but beyond this point, the foil would let go suddenly and although this has not yet led to complete capsize, it came fairly close to it on occasions.

Furthermore, I felt that the foil when fully immersed was unnecessarily large and wasteful of wetted surface, but with the single outrigger to windward, one needs some spare foil area so that the float can begin to lift before the foil lets go of the water. The answer seemed to be to return to the trimaran configuration using a smaller foil on each float, with the added gain that foil action would on both tacks reduce hull displacement drag.

In fairness to Edmond Bruce, I must admit that I did not fully follow his design set out clearly on page 123 which requires that for complete stabilizing, the line of thrust of the foil should pass through the centre of effort of the sail plan. On *TRIPLE SEC*, this line of thrust passes nearly 3 ft below this point. This was obtained with an overall beam of 9 ft, neglecting 1 ft 6 in seat projection. To obtain full foil stability, this beam over both hulls would have had to be increased to 11 ft 9 in. This seemed rather excessive on a 14 ft boat. Since I did not try it, I cannot say whether the general qualities of the boat would have been impaired by it.

This year, I am using the original pair of asymmetrical floats 8 ft long but with an increase in cross-beam length from 8 ft to 10 ft, and the floats placed a foot further forward. The drawing shows the general arrangement. The foils are hinged to the float bottoms and supported by variable length struts so that dihedral can be varied, and, by insertion of packings between the aft crossbeam and float, an angle of attack can be given.

From rather limited trials, the impression has been gained that the best all round results are obtained with a dihedral of 45° and the foils angled up about 2°. The actual angle of attack is increased by leeway. Reduced dihedral brings the foils nearer the surface and this produces considerable surface disturbance at fairly low speeds. On occasions, a steep, almost



'TRIPLE SEC' - FOIL TRIALS

Paul L. Ashford
Aug. 1967.

breaking wave has appeared over the rear edge of the foil at speeds of 2 or 3 knots, but the wave pattern improves as speed increases.

Two different foil profiles are being tried. Both appear reasonably effective for windward sailing without using the centreboard. The leeway angle is judged to be somewhat greater but not excessive with the lower aspect ratio foil. If the lower aspect ratio foils were fitted on both sides, this would give the advantage that the boat could be beached on the centre hull with a fixed foil dihedral of 45°, and also that the windward foil would lift clear of the water at a smaller angle of heel.

The floats are on the small side for a trimaran relying on float buoyancy for stability and a very useful increase in stability is given by the foils. The trials confirm that low aspect ratio foils do work but for windward work, full foil stabilizing cannot be expected without a considerable increase in beam as shown in the drawing. The present arrangement probably roughly doubles the stability obtained from the given float buoyancy compared with the use of a centreboard. Some fast "planing" has been enjoyed on a close reach.

The struts, which are not free to weathercock to the water flow, have been given a slight angle of attack to try to avoid a capsizing moment. This seems to work fairly well, but the presence of the strut tends to confuse judgement of the foil performance. I think they must add to drag as they throw up a good deal of wake and spray. The starboard lower aspect ratio foil has this week been glued rigidly to the float so that the strut can be dispensed with. I am looking forward to trying this out very soon.

The boat handles and tacks well but a disappointing feature with cruiser development in mind is that it heaves-to badly, swinging uneasily back and forth, pivoting on the leeward foil and making a great deal of leeway. Lowering the centreboard corrects this behaviour but it is unfortunate that it seems necessary to provide a centreboard for heaving-to which is definitely not required for sailing.

A LOW ASPECT RATIO BRUCE FOIL CRUISER

by Robert D. Perkins

I have been experimenting with various types of foil stabilizers since 1960 using 3 to 4 ft scale sailing models as test vehicles. In the Fall of 1962, D. N. McLeod, a brilliant, young engineer from Brockville, Ontario, suggested that I try out what have become known as Bruce Foils. It did not occur to either of us that this type of stabilizer would work if it were kept to windward. My first model, therefore, was a 3 ft proa. I tested it in January at 5° below zero in a plastic wading pool in my garden and despite clouds of steam and cold winds, etc. it proved a qualified success.

The following summer, a larger 50 in model was built. The stabilizer was simply an elongated foil drawn out to form a shallow triangle 32 in long and 8 in deep. This model refused to capsize even in gusty winds of approximately 35 miles per hour and moved very quickly.

Robert Perkin's Bruce foil cruiser model

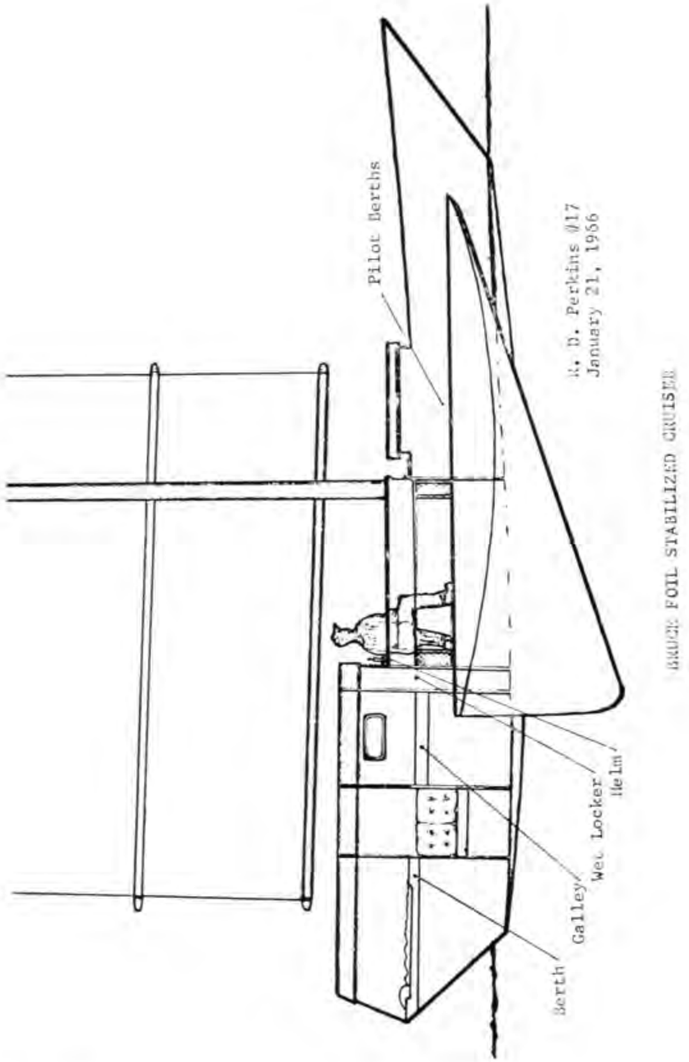
I then started construction of a full size, 23 ft day sailer which was to be used to develop a larger cruiser-racer. Before I had completed the main hull Edmond Bruce's lucid article was published. In my opinion, his was the most important and significant paper prepared to date by any member of the Society—a real breakthrough. After reading Mr. Bruce's paper, I decided to abandon the proa form and to develop a boat which would tack in the conventional manner. The practical advantages of low aspect ratio foils I had been using soon became apparent. They are stronger; they are more easily attached to the outrigger beams; they draw less water; they can be made weedless; they do not have to be adjusted fore and aft on opposite tacks; they are more easily retracted in shallow water. My fifth model, 40 in long carrying 600 sq in of sail, was exhibited at our annual AYRS Club meeting at the Barrie Yacht Club last year. In breezes of five to ten knots, it pointed very high and moved so quickly that several members who set out after it in catamarans and trimarans were unable to catch it. It sailed out of sight and was lost permanently.

The cruiser

The cruiser shown in the enclosed drawings is 38 ft long with a water line of 30 ft. It displaces a little more than 4,000 lbs and carries 600 sq ft of sail.

Construction

Half inch plywood is used throughout. The sides (five 4 ft × 8ft sheets of plywood) have a constant width of 4 ft from stem to stern. The curved bottom section is achieved by covering the flat floor with styrofoam which is, in turn, covered with fibreglass.



Hull shape

The bottom of this boat is shaped in accordance with current AYRS theory for optimum speed having a sharp, narrow bow and a broad partially immersed stern. The maximum beam at the water line is 32 in and the section at the point is almost semi-circular. The long, high dory-like overhang of the bow is designed to avoid bow burying at speed without slowing the boat.

Self-righting

The boat is self-righting on either tack and will bail itself almost empty depending on the load carried.

Rig

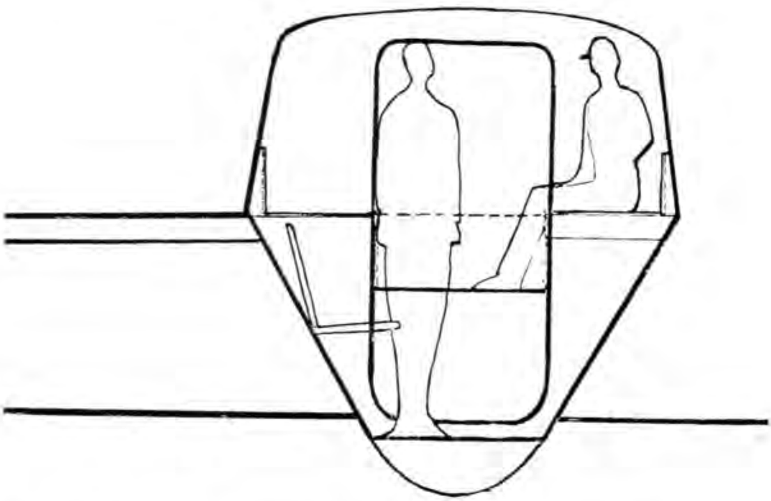
A modified junk rig mounted off-centre is to be used. This rig permits easy handling of the 600 sq ft of sail and keeps the centre of effort low (distance between the centre line of the boat and the centre line of the float is only 20 ft). The modifications to the junk rig which I will be testing over the next month or so should overcome its unwillingness to go to windward.

Accommodation

There are two berths in a separate cabin at the rear of the boat with ample locker space. In the main cabin there is a hanging wet locker immediately inside the entrance, a galley, seating for four people, a chart table, and an inside helmsman's station with clear visibility forward. The cockpit which is amidships is protected by a bulwark and is well above the surface of the water so that it should remain dry and comfortable in rough weather.

The stabilizer

The stabilizer shown is one of four which will be tested shortly on the 23 ft boat. It is flat bottomed with its maximum buoyancy placed well forward. Tests on all of the models indicated that the foil will be driven under in strong winds in the few seconds before the boat gets under way when it is to leeward unless there is ample buoyancy placed well forward. The flat bottomed form has been chosen because it planes readily reducing resistance.



The foil, as indicated in the diagram, is retractable inwards. In the retracted position it acts as a displacement form and it is hoped that it will develop some lift towards the port side of the boat so that in very light conditions when the stabilizer is to leeward the foil may be kept completely out of the water.

Conclusion

The cruiser is not, of course, in its final form. The 23 ft boat is now complete and in the next few months I will be running tests with various size foils. The outrigger arms on this boat are completely adjustable and the mast may be moved to any position so that it will be possible to predict exactly the position and size of all the components of the stabilizing system on the cruiser.

A FOIL TRIMARAN

Devised by Henry W. Nason

366, Farmingham Avenue, Plainville, Connecticut 06062, U.S.A.

Having first made a Polynesian outrigger, it was thought that the float was not quite the perfect solution to stability. This led to the study of hydrofoils and all the problems of stability in general. The result was the usual conclusion that hydrofoils are the perfect solution for stability when underway but some outrigged floatation was needed for static stability and in very light winds. The result of this line of thought was a small float acting as a surface senser for a fully submerged hydrofoil with incidence control and retraction out of the water for beaching and in light winds.

In practice, what has been achieved is trimaran stability in all strengths of wind with tiny floats and foils. The future possibility of making the craft a fully flying hydrofoil is, however, a possibility.

Fig. 1 shows the principles involved. The float or floats are mounted on pantograph arms with dashpot dampers to prevent too quick an action on the foil and the rising and falling of the float actuates the angle of a ttack of the foil.

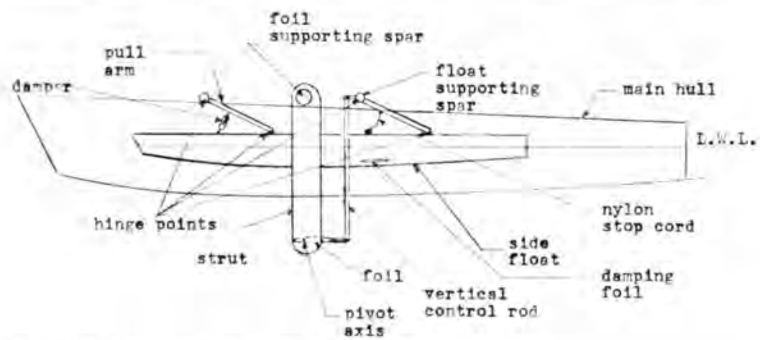


Figure 1.- General arrangement of parts

Experiment one

A 13 ft canoe has this arrangement mounted on one side only and this boat sailed well on the very first test. It will be seen from Fig. 1 that the foil will stay horizontal on swinging the foil struts up aft, thus allowing retraction while travelling.

Experiment No. 1

Experiment two

Here, an *AQUACAT* hull with no inherent stability was fitted with the float and foil system on either side. However, the wing tip floats shown in the photograph were not at first fitted and the foil incidence variation was only 5°. There were four capsizes on the first trial and there was not even enough stability when travelling slowly.

Experiment No. 2

The reason for these capsizes was not at first realized. In experiment one, the system was self adjusting—more heel pushed up the float and gave more incidence to the foil. In experiment two, the foils were set at angles to oppose each other and the lee foil was not powerful enough to overcome the upsetting angle of the weather foil. On the second trial with experiment two, a continuous trim adjustment and foil incidence angle indicator were added and, with adjustment, the boat speeeded up and levelled out. No more capsizes were experienced but at zero speed, the boat heeled too easily and wing tip floats were added.

Experiment No. 2. Adjusting the foil

Performance observations

1 The foils start giving stability at very low speeds.
2 Usual foil deflections were about 3°. The foils were, however, larger than the calculated necessary area which would have given 5° deflections. In speed boat wakes, the deflections were 7° to 8° with quite a bobbing of the float.

Experiment No. 2. Coming about

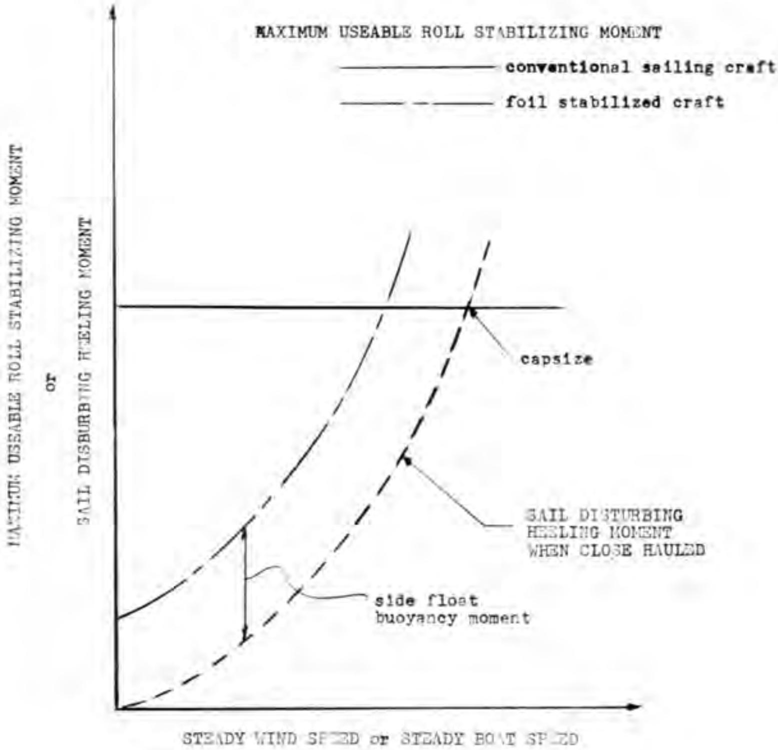
3 In severe wave conditions which caused the floats to bob, the boat was quite steady, presumably due to the difference in frequency in roll of the main hull and the float-foil system. The variations in foil attack must have caused extra resistance and damping of their action would be of value.

4 Coming about was easy. Sufficient speed was always maintained to remain foil borne in the sense that the tip floats never struck the water before full speed was resumed on the opposite tack.

5 The boat sailed close hauled with good stability from 2 knots to the strongest winds sailed (about 22 knots).

Summary

Hydrofoils are the most natural method of roll stabilization of a sailboat since they are effective when you need them and are not particularly effective when you don't. In contrast, the common methods of roll stabilization have far too much stability margin at low boat speeds in light winds and have a narrow reserve stability in strongest winds. However, a hydrofoil stabilized boat must also have a specific amount of conventional stability which is always there for transient conditions such as coming about, starting up and slowing down.



Experiment No. 2. Conventional Stability

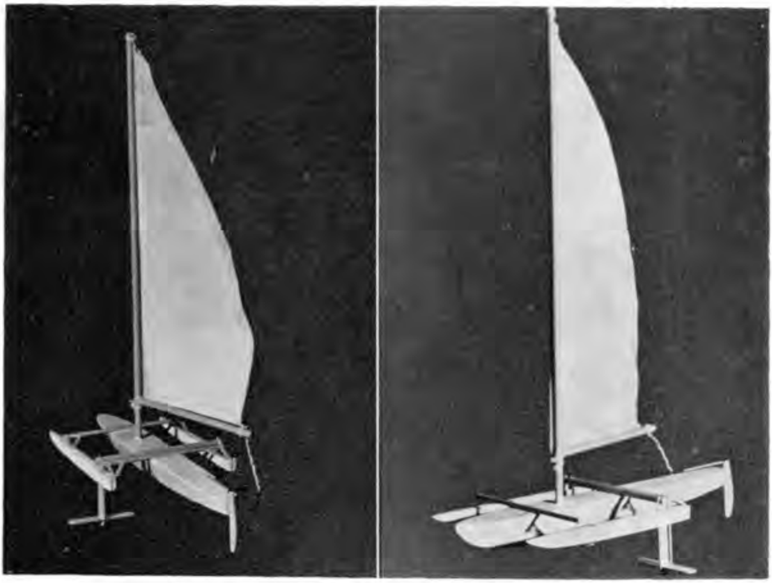
Letter from: Henry W. Nason

Dear Sir,

Received your letter of February 4, and appreciate your consideration of the problem and have read the very helpful article in publication No. 50. A waterline beam to depth ratio of 4 : 1 will give me a roomy main hull and at speed I should make up the 5 per cent loss with foil dynamic lift.

Trying to improve on an ancient art like sailing is a difficult thing, and it gives oneself respect for his predecessors. I seem to be continually making starts and stops. It is not possible to completely evaluate all schemes which come to mind either experimentally or theoretically and one must make many decisions somewhat on intuition alone. I find I must now modify the write-up I just sent to you a few weeks ago. A better arrangement of the components appears possible. Although, I have been aware of this arrangement for some time, I had not modelled it and so could not fully evaluate it. A series of photographs are enclosed of the model. It is not a working model. Sizes are scaled to an 18 ft boat.

The strut will be enclosed in a slot cut in the aft end of the float. Foil actuation is the same in principle as before. Neglecting structural and weight effects, the best position of both the foil and float is out as far as possible. The farther the float is out the more effective is its buoyancy for common stability and the more favourable the relation between roll sensitivity and height sensitivity. Also the farther out the foil is the smaller it can be. Thus to mount the foil and strut in the inverted T arrangement and centred with the float is the best compromise. Placing the strut in a slot in the float will eliminate the wave drag of the strut and will result in less interference between the main hull, the floats and the struts. The strut is less exposed to floating objects. Since the slot is open to the rear there should be less fuss than with the conventional daggerboard or centreboard slot. The open slot will allow



The Nason Foil Model

foil and strut removal from the water as before. Although, I will only be able to lengthen my float from 6 ft to 8 ft, its centre of buoyancy will be forward of the foil and will give a small measure of large wave anticipation. This anticipation is hardly needed on such a small craft which is not flying, but is more than before.

At first thought, it might appear to be a disadvantage to have the float slot moving with respect to the strut. My first thought would be that it would wear away the strut and bind. However, I don't see why one could not take advantage of this rubbing by installing a water lubricated flat damper. My son is buzzing about looking into this. Another benefit would be from a load stand-point. The strut could support lateral forces on the float and vice versa. They would become mutually self-supporting. There are many plastics that may be suitable for a flat damper. There are floor tiles made of ashphalt and vinyl which can take a lot of scuffing. A continual scraping noise would be objectionable, but water is a very good lubricant and the bottom part of the slot damper will always be immersed and possibly a proper material would be quiet and give the required damping force.

The struts, foils and floats will be a little more difficult to make. However, the general appearance is much improved and the arrangement will, I believe, give superior performance.

Letter from: O. Holtman Stoeberghlaan 16, Voorschoten, Holland
July 5, 1967

Dear Sir,

In 1963, I intended to sail and built a boat. The first catamaran was square box section, 12 ft long, weighed 300 lbs and had 100 sq ft of sail. Then, I found the AYRS publications and I accepted the following ideas:

1 L/B ratio = 12 (Bruce).
2 Unequal hulls (Morwood).
3 Rotating mast.
4 Half-circle bottom.
5 Aluminium, expanded foam.
6 The Bruce foil.
7 Boom vang.
8 Very sharp bow.

I took an aluminium race-canoe, rounded the bottom with foam and covered it with glass fibre and polyester resin. I had two tubes 6 ft long and laid them across the hull. To these tubes, I fitted two smaller tubes, also 6 ft long and, fitting snugly in each other, they made cross beams 11 ft long. The thicker tubes protruded on both sides of the hull and the stays were fastened to the after one while the mast stood on the forward one . . . The smaller tubes protruded only to port, thus making the craft a single outrigger

O. Holtman's Bruce foil boat

and to their ends, the 8 ft outrigger hull was attached. The small hull was made by the "opening up" system and had a 90° V form in the middle. The bow was very sharp and the transom squared off. As published in AYRS No. 51 on page 66, the New Zealand Maori knew exactly the right dimensions.

My heart bounced. My mouth was dry, as I took the rudder and sheets. After 100 yards, alone, I cried "Hy doet het" which is Dutch for "It works."

Tacking was difficult and I replaced the tubes to put the mast 1 ft out of the middle of the hull towards the outrigger. On holiday in France, the 420's and the *FLYING JUNIORS* tried to catch me but I was faster. I was helped with tuning and the results were flattering for the Maoris. When the wind was more than force 4, I had to sit on the tubes to balance the boat.

In the North Sea, I sailed against a *SCHAKEL*, 15 ft 7 in long, 30 per cent more sail than my boat but weighing 300 lbs to my boat's 200 lbs. Again, I was faster. I sailed very close hauled, thanks to the Bruce foil. The effect of the foil holding the mast upright could not be measured by me.

I'm convinced of a few things.

1 The unequal hull is fast—perhaps the fastest.
2 Building and tuning are easy.
3 The weight is low.
4 Taking apart takes a short time.

The canoe is too light for two persons so I'll change it for a *SHEARWATER* hull. The sail area will be 150 sq ft, the weight under 200 lbs. The mainsail and jib will have the same height and both will be loose footed. There will be one boom from the clew of the main sail to the tack of the jib and the clew of the jib will open automatically 9 in at the mast. I will then have only one sheet to turn the whole sail area and mast. There will be four stays to the ends of the cross-arms with the mast standing between them with no forestay. The mast will stand on the gunwhale of the *SHEARWATER* Hull at the outrigger side.

Thank you for all the information and the pleasure of reading.

P.B.K. 12 Canoe with Hydrofoil Stabilizers

Designed and Built by P. Dearling and M. Sutton-Pratt

11, Vale Close, Strawberry Vale, Twickenham, Middlesex

Hull	17 ft 6 in Length	Foils—Incidence 4°
Hull	2 ft 6 in Beam	Foils—Dihedral 45°
Sail area	85 sq ft	Non-Adjustable
Total Beam	9 ft	
Total weight	175 lbs	

During the summer of 1966 we decided to fit stabilizing foils to a standard P.B.K.18 canoe hull and add approximately 85 sq ft of sail.

All previous attempts to sail the boat had been with a sail area of about 25 sq ft and leeboards.

We got the idea of foils from reading an article by Mr. N. Van Gelderen of Miami, U.S.A., who was at the time successfully using foils of the Bruce Clark "Y" type on a smaller but similar canoe. Making the foils was fairly

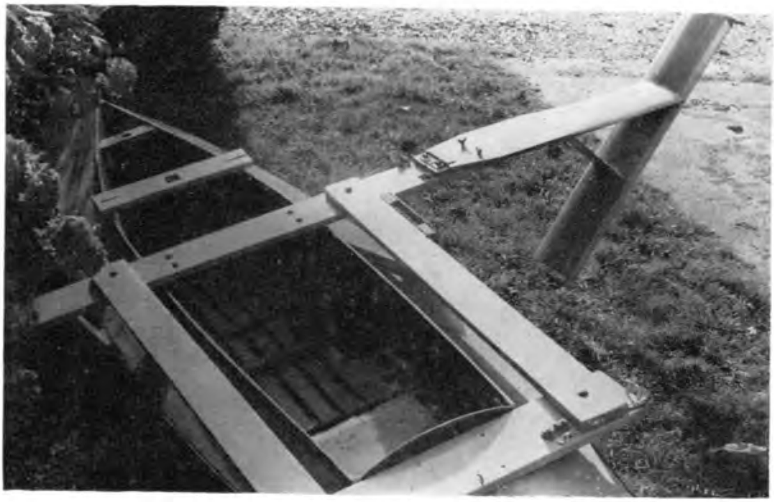
Paul Dearling's canoe with Bruce Clark foils

simple and we feel that any success we achieved with them must have been due mostly to the excellent descriptions and sketches we received from Mr. Van Gelderen.

With the present foils and sitting-out "benches" (mounted above the side decks) we feel that a sail area of between 120 and 140 sq ft could be carried successfully. The present hull however is unsuitable for further development and next year we hope to transfer the foils to a purpose-made hull and continue with our experiments.

Any advice or exchange of correspondence would be more than welcome.

Bow view



Bruce Clark foil: 1967

CHAPTER XIV

October 1966

Letter from: Donald J. Nigg 7924, Fontana, Prairie Village, Kans., U.S.A.

July 22, 1966

Dear Dr. Morwood,

In my last letter to you, Dec. 22, 1967, I indicated that construction had started on a new monohull design for a flying hydrofoil. It was to be a design suitable for home construction and further development by others. This craft was completed and launched in May of this year. Unfortunately, five weeks were lost early in the tests due to a broken mast, but the boat is now again operational.

Don Nigg doing 20 knots on a close reach

We have now accumulated enough sailing hours on this new boat to say that it is performing pretty much as calculated. Several minor changes have been worked into the design—primarily to improve the ease of handling. The final plans are now drawn up and are available. I have kept a file of the persons who have written inquiring about plans over the past two years. These persons have been notified directly as the plans are ready, with their cost.

The same hydrodynamic principles demonstrated to be feasible by the experiments with *EXOCOETUS* (page 139) have been applied to this new craft. These principles are dealt with in depth in the article "A Sailing Hydrofoil Development" appearing in the April 1968 issue of *Manine Technology*, a publication of the Society of Naval Architects and Marine Engineers. The big differences in the new craft concerns the structure. Whereas *EXOCOETUS* was an experimental platform supported by three floats when at rest, the new design utilizes a monohull with a buoyant crossbeam. This provides a number of practical advantages, and looked like the way to go for establishing a development class. It has been suggested that such a development class might be called the "Ayrsfoil" class, and since I haven't any better ideas, the name is alright with me. Unless a better idea comes along, this is probably the class name that will appear on the plans.

Now for some details about the design. It was decided at the outset that most persons who would want to build such a boat are undoubtedly already small boat sailors, and probably own a dinghy with a mainsail in the range of 100 to 150 sq ft. If a basic hydrofoil design could be developed to give good performance with this size sail, then experimenters could share the rigging and sail with their existing boat and thereby drastically reduce the cost. This brings the material cost down to between $150 and $200, depending on

A broad reach with a moderate breeze

how fancy the builder wants to get. The model in the photographs is shown with the sail and rigging from a Y-Flyer, which has a mainsail area of 125 sq ft. The boat, less optional rigging and sail, weighed in at 266 lbs complete. With crew, Y-Flyer rigging, and Y-Flyer mainsail the gross weight was 477 lbs. This is about 40 lbs more than the original objective and a little cleverness in weight reduction by the builder would no doubt pay off in performance. The waterline length is 16 ft, and the cross-beam is 20 ft. Total submerged foil area is 15·3 sq ft at take-off and 2 sq ft or less through the design centre cruising range of 20 to 30 knots.

The sealed hull is ¼ in marine plywood with the skin carrying the torque loads, and an internal structure coupled with the skin carrying the bending loads. The crossbeam is eliptical in cross section. On the minor axis, a fabricated beam carries the vertical bending loads, while the ⅛ in skin carries the torque load associated with foil drag forces. The crossbeam is secured by four bolts and two stays, and is removable for transporting. The front steering feature has been retained, and the foil details may be seen in the photograph. The yardstick shown beneath the front foil system provides size perspective. All foils are quickly removable for dry storage or transporting. The lifting foils are all oak except the small high speed aluminium foil at the base of the front foil system. The horizontal foil shown at the top of the rear foil system is not a lifting member. It is made of pine and

Don Nigg's foils. Note yard rule

performs the dual function of a structural member, primarily for the foils when detached, and a safety feature to be described. All foils have a 7 per cent fineness ratio and are plano-convex, i.e. flat on the underside and a circular arc on the upper surface. Again, this favours the home builder while remaining competitive with other hydrodynamic shapes.

The crossbeam is sealed and provides roll stability while floating at the dock and at very low taxi speeds. The horizontal member in the rear foil system has the same foil shape as the rest of the foils. However, it is set at an angle of attack near the stall point for maximum lift, and its use as a foil surface is two-fold. At the dock, the buoyant crossbeam provides the stability allowing one to walk all over the boat; even out to the beam ends. At taxi speeds up to about 2 knots, the ends of the crossbeam frequently touch the water momentarily as the result of sail forces and crew weight off centre. These horizontal foils are out of the water when the boat has zero heel, both at rest or at low speeds, as seen in the pictures. At about 2 or 3 knots, they begin to develop enough foil action to provide an increasing amount of roll stabilization and tend to keep the ends of the crossbeam from dragging in the water.

Take-off attitude—Climbing out

The take-off speed is 5 knots, and at this speed the regular rear foils are providing most of the lateral and roll stability, along with the off-centre crew weight, and the boat does not have to drag these high-incidence-angle safety foils through the water as it takes-off. Once foil borne, they provide a real safety feature in the event of a sudden roll transient. They provide great lift when driven into the water and prevent the possibility of hooking the end of the crossbeam in the water and thereby setting up a potential cartwheel capsize condition. The test trial results of this roll stability sequence has been especially gratifying.

As a generality, the craft handles better than *EXOCOETUS*. It was felt that lowering the minimum required wind from 13 knots to 10 knots and lowering the take-off velocity from 6½ to 5 knots would greatly increase the number of days in the season when flying the boat would be possible. These changes meant larger foils and sails, but appeared to be worth it.

A larger sail results in a higher centre of effort and thus a wider beam to retain roll stability. The increase from 16 to 20 ft in beam width more than compensated for the larger sail. It resulted in a basically more stable craft, and hence one easier to handle.

One penalty that might not be obvious is some sacrifice in higher wind conditions. It is paradox of these craft with their nearly flat drag-velocity curves that one needs a substantial breeze to fly at all, and then one doesn't need a whole lot more to attain full capabilities of the boat. Overpowering soon becomes a problem. The larger sail areas quickly become a burden as the wind rises, or in handling the heavy puffs so characteristic of this part of the country. I have had to come in off the lake on several occasions because the wind was more than I could handle, while the Snipes and other

Don Nigg's hydrofoil at rest

small craft were weathering it fine. This is an area that others can develop—roller reefing on the boom, or something to shorten sail rather than having to carry a heavy luff.

I don't know how fast this boat might have gone had I felt capable of letting it out on several occasions. I have held it to what I estimate to be within the 20 to 30 knot range for which it was designed. At the top of this range it is riding pretty high in the water and the foils are beginning to feel the waves. It is entirely on the cantilevered tips of the rear foils and riding on the bottom half of the small foil in front. This is another area for other experimenters to carry on—those who want to see how fast they can go. This boat would surely destroy itself in seconds if turned loose in a 25 knot wind.

The surface buoyant mode handling characteristics of this boat are also somewhat better than *EXOCOETUS*, but it still leaves a lot to be desired. This is not unique to these two designs, all the other experimenters I have talked with have complained about this. The boats all seem to get into irons quite readily when not on the foils, and they are hard to get out. They will not come about because their light weight and high drag when floating is too adverse to permit them to headreach through the wind. This means that they must be jibed about or boxhauled. Here again is an area for more development. It might be noted that the front steering configuration appears to be less of a weathervane. It is therefore probably less of a problem in irons than are the rear steering types.

I hope others will pick up this development from here, as this is probably the last one I will build. I've had my fun, and after getting the plans drawn up and released, I'll probably turn my attention to other matters.

Don Nigg

Ed.—Plans now available from Don Nigg. $20·00, U.S.A. $21·50, Canada and Australia. £10, U.K. Or from the AYRS, Woodacres, Hythe, Kent, England.

Letter from: David Buirski Suikerbos, The Grange, Camps Bay, S. Africa

Dear Mr. Morwood, October 1966

Please find enclosed copies of photographs taken recently. Since last writing to you I have made and sailed with both high aspect and low aspect foils. I first made a high aspect foil, which I found was adequate in heavy wind, but, as suspected, stalled badly in light winds. It has another severe failing in that it hobby-horsed in a chop.

I then proceeded with making a low aspect foil, as can be seen in the photographs herewith, which was perfect in both heavy and light wind conditions. Incidentally, because the foil is not flat on each face but naturally curved because of its foil shape, and as only the centre is at 46°, it does not hold quite as well as the flatter centreboard type, thereby giving me an additional bonus in that on the runs I am able to get all the board out of the water. Although it was not easy to get the foil out, it comes up very slowly and is perfectly controllable. The same thing applied to a beat in light winds, just allowing tip of foil in water, thereby cutting down drag and wetted surface.

The boat is very fast in both light and heavy wind and drag from the foil seems negligible.

Dave Buirski's buoyant Bruce foil, mostly lifted out

A rig tried out a few days after the photograph was taken, using a much bigger Genoa further forward, which gave me a total sail area of 210 sq ft, was far more satisfactory than that illustrated in the photograph, which indicated that the sail area had to be moved further forward. Unfortunately, this will mean using a heavier mast, as the mast in the photograph will not be able to handle the sail area in a stiff blow.

While sailing solo a friend of mine did actually overturn this craft—a sheet jammed and while he was busy freeing it the boat came up into the wind, stopped, and a sudden gust tipped him over. It proved a simple matter to right it . . . every bit as quickly and easily as a normal dinghy.

Dave Buirski's boat showing low A.R. foil

Someone remarked "It's fast alright—perhaps that's only because it's 21 ft long". "A 21 ft catamaran', he said, "with two hulls like yours, might be just as fast". He overlooked, of course, the weight and wetted surface aspect. Nevertheless, he had a point and I realized that to prove that it is indeed faster I will have to compete against an existing catamaran using an identical single hull fitted with my low aspect foil. The ideal craft to compare with would be a Thai Mark 4, as it has proved to be one of the fastest catamarans of its size in the world, and as there is one in Cape Town and also a mould from which I can have a hull made, I intend doing just this, coupled with your suggestion of using an ice yacht rig. If it is convincingly faster than the Thai, the same comparison can be drawn with a C Class cat, proving, as you think, that it is the fastest craft in the world.

I would therefore be most happy if you could let me have details of the ice yacht rig if they are back from the printers.

David Buirski

CHAPTER XV

CENTREBOARDS

by John Morwood October, 1968

With help from Edmond Bruce. Drawings: Ron Doughty.

The main function of a centreboard is to increase the lateral resistance of the hull of a sailing boat, when required by the course, at the minimum cost in drag due to the increased wetted surface, "induced drag" and drag due to eddies produced by the board shape. The overall difference in the yacht is that, when it has leeway of an angle which Edmond Bruce thinks should be 5°, the "drag angle" or "lift to drag ratio" is decreased or increased respectively, to make the boat sail closer to the wind.

History

Dagger boards were used in the Formosan bamboo sailing rafts and in the South American Jacanda and balsa rafts. The leeboard was invented by the Chinese and (with the spritsail) was taken up by the Dutch. The centreboard, however, was a true invention because it would be against any sailor's instinct to cut a slot through the hull of his boat. Both English and American patents for centreboards appear in the early 19th Century so it must have been more or less unknown before that.

The workboat centreboard

The centreboard had its best development on the American east coast where the water is often shallow. Catboats and the New Haven Sharpie are good examples. The shape finally developed is, when dropped, a triangle about twice as long at the top as on the "drop", an aspect ratio of 1 : 1. This shape gives an excellent performance and might well be used for any cruising boat.

Dinghy centreboards

The modern light racing dinghy appeared on the yachting scene with the high aspect ratio Bermudian rig and the science of aerodynamics rapidly becoming known. The result was that the value of aspect ratio was known and many people tried very high assect ratio boards. For instance, there is a story of Beecher Moore sailing a *Merlin Rocket* with a board 6 ft long and 6 in in chord, an effective aspect ratio of 24 : 1. Apparently, he could sail it and beat others to windward with it but nobody else could. In fact, of course, an increase of aspect ratio for an aeroplane wing above 6 : 1 is almost useless due to high parasitic drag elsewhere in the plane. Because a centreboard has only one "wingtip" we need not think of any ratio above 3 : 1. Greater aspect ratios than 3 : 1 will only improve windward performance by a fractional amount and they will decrease heeling stability. The modern trend is towards even lower aspect ratios, even for catamarans.

Centreboard construction and design

Deeply immersed dinghy and catamaran boards can be made of square strips of wood, glued together to make a plank which may be shaped as follows:

1 The profile should be a semi-ellipse of an aspect ratio span^2/area of 3 : 1.
2 The section should be pointed fore and aft with the maximum thickness at one third of the chord from the leading edge, though some put it at the mid chord line.
3 The thickness to chord ratio should be 1 : 12.

The reasons for all these dimensions are as follows:

1 Making the board of glued square sectioned strips avoids warping. Plywood is a poor material for strength in a long axis and a board made from laminated veneers whose grain runs along the length is unstable and can warp.
2 The profile and aspect ratio given are the result of sub-sonic aeronautical theory backed up by wind tunnel tests and full sized aeroplanes. Whether or no this need hold for a centreboard so near the surface is another matter which will be discussed later.
3 The pointing of the section forward has been found to be useful in actual sailing practice as well as in tank tests of hydrofoils. It eliminates vibration in water.
4 The maximum lift to drag ratio with symmetrical aeroplane wing sections is found with a thickness ratio of 1 in 8. Such sections are, of course, rounded at the leading edge. Because we have found that pointing the leading edge of our centreboard section is valuable, this reduced the thickness to chord ratio to 1 in 12. The position of the maximum thickness of an aeroplane wing is usually about one third of the chord from the leading edge. Yachtsmen can also use this position for the maximum thickness of their centreboards—or, they can put it at the mid-chord point, which seems a more logical place, though it doesn't seem to matter much in practice.

In all the above on dinghy centreboards, the arguments are more or less orthodox and commonplace but, if any member has any criticism or extension of them would he please send a letter for publication.

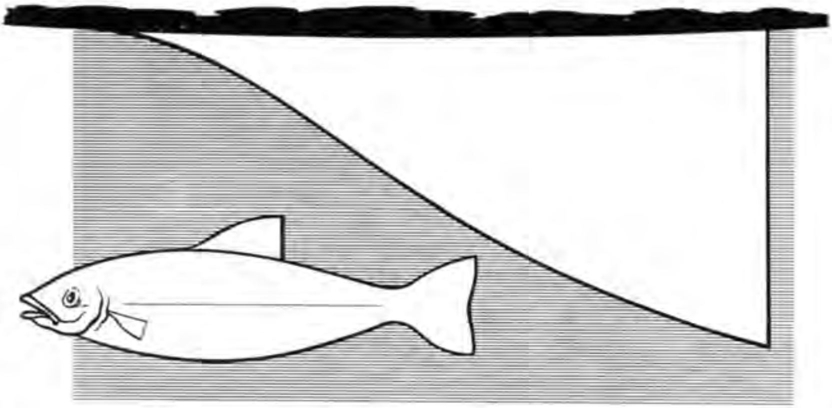
The low aspect ratio centreboard

For boards operating near the water surface, various factors may be taken into account in deriving what may be the best shape. These are:

1 The American workboat centreboard of a triangle twice as long at the slot as in the "drop".
2 The value and use of the quarter circle centreboard as in the International Sharpie and other boats. The term "stable" is frequently used for these boats.
3 Edmond Bruce's tank finding that the lowest drag angle for boats appears when a thin surface-piercing board has an aspect ratio of 1 : 1 though only rectangular shapes have been tested, so far. He also finds that most multihulls have boards which are too small.
4 Centreboards are not completely analagous to aerofoils or hydrofoils deeply immersed in a fluid, which is "incompressible". Being so near the surface, the water acted upon by the board seems "compressible" since it is pushed aside, giving surface waves. Conventional sub-sonic hydrodynamics are not therefore relevant and we must discover the best by trial and error either at full scale or in the tank.

5 The forward upper corner of a low aspect ratio keel should be "faired" into the hull by a concave shape—Smith *Why Sailboats Win and Lose Races*.
6 Hull drag angles get less with increasing "sweepback" angles to the leading edge of fin-keels—Southampton University's study of keel sweepback angles in the 5·5 metre. A sweepback angle of about 25° seems to be about the optimum.
7 A study of the fins of fishes shows that Nature likes a convex curve to a fin behind the concave fairing into the body. A study at the Stevens Institute a few years ago showed that the maximum pressure on the keel of a 12 metre type occurred at the leading edge half way down it. A convexity here seems likely to be of value.
8 The trailing edges of fishes fins can be straight, concave or convex and no fairing into the body is used.

Combining as many of these 8 factors as I can, I have drawn a profile of a fin which seems unlikely to be far off the optimum for a centreboard or rudder and, for good measure have drawn a fish with these kinds of fins which doesn't seem to be too deformed, though what kind of a fish it is, I don't know. Such a fin could be used as a centreboard, salient fin or rudder.



Centreboard size

Harrison Butler (Cruising Yacht Design) gives the total lateral plane area of a yacht below the LWL as between 1/25th to 1/35th of the sail area This seems an odd way to work as sail area is a function of the whim of the designer, the length of the boat and whether or no it is "light displacement". Skene (*Elements of Yacht Design*) is more rational in that he related lateral plane to the immersed "mid-ships" section by a factor of between 4 and 6.

Neither of these authorities is therefore of much good to us and neither helps us with multihulls. Lateral plane does, however, seem to be related to hull displacement in a general way and this angle could be explored. Moreover, multihulls seem to fit in with this rule.

To be precise, the optimum size of centreboard is that which gives the smallest possible drag angle which appear to be in the region of 10° for a multihull. I do not know a figure for a drag angle for a single hulled yacht to which one could aim.

SURFACE-PIERCING HYDROFOILS FOR HEELING PREVENTION AND LIFT

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

Air-ventilation

In Chapter X, the present writer stated the critical dimensions, for the locations of canted hydrofoils, which would achieve dynamic neutralization of heeling. The dinghy, pictured there-in, originally was provided with a foil of high aspect ratio. Above certain speeds to windward, it was troubled with a loss of lateral lift. From observation of the water, it was quite apparent that this was due to 'air-ventilation', from the water surface, down the negative pressure side of the canted hydrofoil.

The dinghy was next equipped with a lower aspect ratio foil of larger area, as best pictured by the model on page 127. As a result, the air-ventilation troubles disappeared, regardless of the boat speed achieved. Evidently, one cannot be guided by the teachings of aeronautical handbooks when designing surface-piercing hydrofoils or even submerged foils which are close enough to the water surface to cause any degree of wave-making or surface turbulence.

To gain more insight into the problems of surface penetrating foils, a series of tests were performed in the author's laminar-flow towing tank. These will now be described.

Test arrangement

When the towing tank was originally built, it employed an over-head towing carriage on a track. When it became evident that towing by means of a single long cord, attached to a point equivalent to the sail's centre of effort, produced more accurate results, the overhead railway was put aside but kept intact. This was fortunate as we shall see.

John Morwood, in *AYRS No.* 62, page 8, suggested an experimental arrangement for quickly measuring hull drag angles at various amounts of leeway, for a stated boat speed. This writer was so impressed with the labour-saving possibilities of this arrangement that he re-activated the former over-head railway and equipped it with the Morwood suggestion. It was arranged so that its pair of arms was attached to both the floating model and the carriage through universal joints located at the height of the centre of effort of the sails, chosen as L/2 for the model. This permitted simulating any heeling which would occur under natural conditions, also any lift.

A constant model speed was obtained since the towing carirage was operated from a properly geared synchronous motor. This produced a violent starting yank on the model but, fortunately, its progress was stabilized by the time it reached the end of the tank where readings were made. Readings were made somewhat difficult by the fact that the scale was moving. The violent means of accelerating the model should be softened for more complete satisfaction. A stationary scale, probably electrical, would also help.

Measurements

We all want to know the optimum for size, aspect ratio and shape for our hydrofoils, whether vertical or canted, for best windward performance. We have learned that the criterion, for best windward performance, is the lowest possible drag angle for the particular hull employed.

The number of experiments required to determine the grand optimum foil would be the *product* of all the variations of size, aspect ratio, canting, curvature, shape, arm length, windward or leeward position, etc. This seemed overwhelming to a lazy individual. Thus, for an initial educational insight, only rectangular, thin, flat foils were studied.

The model hull chosen was a 15-inch long, Model No. 8 with a high metacentre as discussed on page 19 of *AYRS No.* 45. It was connected to a single outrigged foil, without a float. The outrigger arm lengths were initially adjusted to one-quarter of the length of the model. This corresponds to many trimarans when sailing with the windward float out of water. A small rudder and an out-of-water counter-weight for the foil were provided.

Vertical foils were tested and also canted foils. The vertical foils were first positioned to leeward. The best combination was then placed to windward to obtain a comparison. The constant speed of the model was 0·65 feet per second. This is equivalent to the low speed of $V/\sqrt{L} = 0{\cdot}35$ in order to avoid the complications of appreciable wave-making, with its increase in drag angle.

The canted foils were always to leeward so that, in addition to heeling compensation, vertical lift was also provided. A compromise outrigger arm length was studied for comparison with the critical arm length, for heeling neutralization.

Vertical foils

Table A, for vertical foils, concisely presents the measured inter-relations and the overall optima between six variables. These are:

Variable:	*Optimum:*
1 Hull Drag Angle	12°
2 Leeway Angle	5°
3 Foil Width	2½ in
4 Foil Depth	2½ in
5 Foil Area	6·25 sq in
6 Aspect Ratio	1·00

Plotting six variables on two dimensional plotting paper with criss-crossing lines and various labels seems a confusing mess. For this reason, only the tabular form for data will be presented here. The reader may want to plot any pair of variables which may interest him.

The much discussed optimum leeway angle of about 5° has appeared again. An optimum 5° leeway for the model in laminar flow may well be 4° for full size in turbulent flow. The advantage of high aspect ratio for surface piercing foils apparently has been disproved since a unity ratio seems best. Both the width and depth of the vertical foil, for a hull equal to this one's high merit, is about one-sixth of the water-line length. A poorer hull probably would have different values except the tank optimum leeway of about 5° might still prevail.

Model Hull Drag Angles versus Dimensions for Vertical, Flat, Thin, Rectangular Foils. Outrigged to Leeward. Arm Length = L/4. L = 15". Speeds = 0·65 ft per sec.

Leeway Angles	Width = 1¼" Depth =					Width = 2½" Depth =				Width = 5" Depth =		
	1"	2"	3"	* 4"	5"	1"	1½"	2"	** 2½"	¾"	1"	* 1¼"
0°	49°	37°	38°	28°	25°	47°	32°	27°	27°	43°	38°	34°
2½°	40	24	22	18	15	32	21	15	15	35	27	23
**5°	27	16	14	*13	15	22	18	14	**12	23	20	*16
7½°	20	17	16	16	17	18	17	14	14	19	19	17
10°	22	21	19	18	18	22	19	18	18	22	20	19
12½°	24	22	20	20	20	25	21	20	20	23	20	20
15°	29	24	23	22	22	26	24	22	22	23	23	22
Foil Area sq in	1·25	2·50	3·75	*5·00	6·25	2·50	3·75	5·00	**6·25	3·75	5·00	*6·25

* Best of group.
** Best overall.
Note: The drag angle at 0° leeway is not 90° because the single outrigger is asymmetrical.

TABLE A

The question arises as to what the result would be if the best foil of Table A were placed to windward, rather than to leeward. Table A shows the measured data. A foil to windward, rather than to leeward would give greater directional steering stability. This is because the sail force is away from the centre of water resistance, not toward it. However, the table's optimum shows that no appreciable difference would result in their abilities to sail to windward.

Model Hull Drag Angles for Leeward versus Windward Placement of Foil 2½" Wide by 2½" Deep. Arm Length = L/4.

Leeway Angles	0°	2½°	* 5°	7½°	10°	12½°	10°
Foil to Leeward	27°	15°	*12°	14°	18°	20°	22°
Foil to Windward	21°	14°	*12°	14°	16°	—	—

TABLE B

Canted foils

Now we will take up the question as to how a 45° canted foil to leeward, which is used additionally for heeling compensation and also verical lift, would affect the windward performance. The measured data is presented in Table C.

Model Hull Drag Angles versus Dimensions for 45° Canted, Flat, Thin, Rectangular Foils. Outrigged to Leeward. Width 2½" throughout. Arm Length Varied. Speed = 0·65 ft per sec.

Horizontal Leeway Angles	Arm = L/4 Depth = 2½"	3"	3½"		Critical Arm = L/2 Depth = 2½"	3½"	4½"	
0°	38°	33°	31°	Some Heeling	39°	39°	41°	Heeling Dynamically Neutralized
2½°	27	23	20		31	26	32	
5°	19	18	17		17	17	15	
7½°	18	17	*16		14	*12	13	
10°	21	19	18		17	*12	14	
12½°	22	20	19		17	14	14	
15°	22	22	22		17	16	15	
Foil Area sq in	6·25	7·50	8·75		6·25	8·75	11·25	

* Best of group.

TABLE C

Here we find that, for the 45° canted foil, the critical length of the outrigged arm of L/2, producing non-heeling, is far superior to the compromise arm length of L/4. While the best drag angle is the same as the best achieved with the vertical foils, a dynamic lift has been created also. Its advantage at still higher speeds than tested should be outstanding. The vertical lift will greatly reduce the parasitic resistance of the main hull.

Note that the optimum size of the canted foil is now approximately 8·75 sq in rather than 6·25 sq in for the previous vertical foil. The latter is nearly 0·7 times the area of the former. This is precisely what one would expect. The projection, on a vertical plane, of the optimum 45° canted foil area should equal the area of the optimum vertical foil. The sine or cosine of 45° is nearly 0·7, therefore this does occur.

It is interesting to note that the optimum leeway angle of some 7° or more, which was measured in the horizontal plane of the water surface, represents only about a 5° angle of attack to the canted foil. This results because an angle of attack must be measured in a plane perpendicular to the 45° canted foil. This plane must also contain the line of motion. So our convenient "rule of thumb" of a 5° optimum angle of attack has been further supported by the canted foil data in spite of the added complications.

A Curved Canted Foil

While this completes the series of measurements made on thin, flat, rectangular foils, there is no doubt that swept-back shapes and curved foils also should be studied by someone. For curiosity, one "stab in the dark" will be made with one curved thin foil. There is no reason to believe that its curvature is an optimum.

Table D shows the result of a formed circular segment, deflected by 7 per cent of the cord, concave to leeward, for the best canted foil of Table C. It has a 2½ in cord, a span of 3½ in and employs the critical arm length of L/2 to leeward. In a full size boat, a separate foil would be employed for each tack because opposite curvatures are required. The single curved foil in use would always be to leeward. Thus a trimaran-like structure may be called for.

Model Hull Drag Angle Comparison for Flat versus Circular-Segment, Curved Foil of Same Dimensions and Leeward Placement. 2½" Wide by 3½" Span. Arm Length = L/2. Curved Foil Deflection = 7 per cent of Chord.

Leeway Angles	0°	2½°	5°	7½°	10°	12½°	15°
Flat Foil	39°	26°	17°	*12°	*12°	14°	16°
Curved Foil	23°	13°	*10°	*10°	12°	15°	17°

TABLE D

Table D indicates that we still have a lot of scope for improvement. The resulting best drag angle of 10° is greater by only 1° than the best configuration ever measured by the writer. I can highly recommend canted foils which produce heeling compensation and lift, both horizontally and vertically.

SINGLE FOIL STABILIZED SURF BOARD

Designer/Builder: George Bagnall 2, Hester Close, Hightown, Liverpool

LOA	11 ft 6 in	Beam	3 ft 2 in
Depth	11 in	45° Foil	6 ft × 18 in
Sail Area	49 sq ft on unstayed mast.		

Main Hull is ply joined by copper wire, tape and glue at each seam. Hull weight 84 lbs.

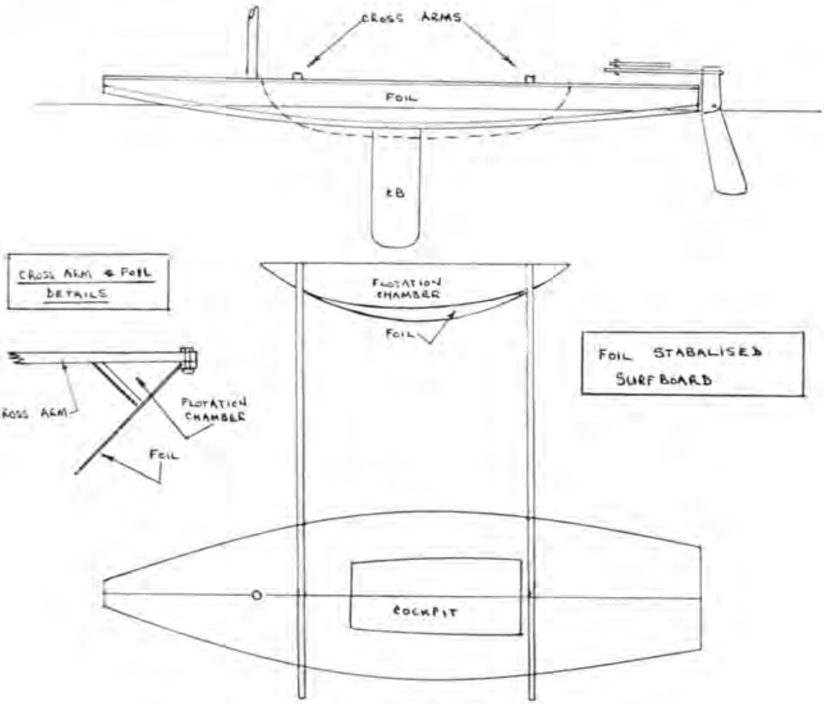
The hull was designed to be sailed as a skimmer and sailed well on all points; but was difficult to handle and needed constant luffing and easing of the sheet to prevent a capsize. The result of adding the foil, as suggested by John Morwood, was a feeling of stability.

George Bagnall's low A.R. Bruce foil

George Bagnall's foil and float

The craft runs and reaches well, but when in a bumpy sea with the foil to lee a certain difficulty in tacking is experienced. With the foil to weather she tacks smartly. At first the foil was used without a floatation chamber but this was added later thus streamlining the foil supporting struts and eliminating any tendency for the foil to submerge. Very little centre board is needed when reaching or running but when beating without the centreboard the boat sags to leeward. Inferences from experience are:

1 The boat does not heel so it does not get the benefit of the long chine to prevent leeway.



Plans of George Bagnall's boat

2 The CLR of the foil should be forward of the CE.

Latest developments have been to build a new main hull, 12 ft 8 in × 2 ft 8 in × 1 ft 2 in without a dagger board but the results with the existing foil were poor, the boat making leeway and being poor at tacking. Foils copied from Edmond Bruce and Paul Ashford's *TRIPLE SEC* (see page 159) were tried but the new hull still made leeway and it is felt that a boat like this will not sail properly without a centreboard of some kind.

CHAPTER XVI

THE FLYING HYDROFOIL YACHT "WILLIWAW"

Designed by: David A. Keiper, Consulting Physicist. October, 1968

2101,-C Bridgeway, Sausalito, California, U.S.A.

LOA	31 ft 4 in	Total displacement	3000 lb
LWL	28 ft	Light weight	2100 lb
Beam:		Sail Area (full working) 380 ft² —sloop rig, loose footed mains'l with camber control.	
Overall hull	15 ft		
Main hull	3 ft		
Hydrofoil	23 ft		
Draft:		Hull material: mostly ¼ in marine plywood, covered with 4½ oz fibre-glass.	
Main hull	16 in		
Hydrofoils	5 ft (zero speed)		

Bow foil: deep-V, 30° dihedral (lower portion), 10° sweep, aspect ratio 26 (at zero speed).

Lateral foils (P & S): four rung ladder, 35° dihedral, 14° sweep, aspect ratio 7·7 (but with full chord struts at blade tips).

Stern foil: four rung ladder, 0° dihedral, aspect ratio 6·2 (but with full chord struts at blade tips), entire assembly pivots for rudder action.

Lift coefficients at design take-off speed of 12 knots: Bow 0·8, Lateral 0·65, Stern 0·3.

Calculated Lift to Drag ratio: 14-15.

Calculated wind velocity required for take-off: 12-13 knots (excess wind increases take-off speed).

Structure: designed to withstand water forces of one ton/ft². All foil units are retractable. Lateral foils may be used with bow and stern foils retracted (Force 2-3 winds).

Accommodation: 2 bunks, one in stern cabin, one in wing (room for 3 or 4 bunks).

Settee, galley table, shelves, bookcases, head. Headroom: 5 ft plus.

See also pages 147 and 152.

LETTERS FROM DAVID A. KEIPER

March 15, 1968.

Dear John,

Please pardon my long silence. Possibly, though, Art Piver has mentioned to you that *WILLIWAW* was undergoing trials with its complete foil system. I enclose a couple of colour photographs (taken by Fergus Quigley) which show the hydrofoils in operating position.

WILLIWAW didn't have hydrofoils until November. By then the westerly winds were pretty dead. The winter winds are too fickle for testing. A good wind has usually turned to pouring rain by the time I got a crew together for sailing. There was one reasonable testing day. Art Piver was crew and ballast. The wind reached Force 4 in several puffs. The craft reached a speed of 13-14 knots (measured with a pitot tube), and was about 90 per cent

Dave Keiper's *WILLIWAW*, showing main and stern foils

foilborne. A poor sail set and a foul bottom were working against that day. The wind dropped before I managed to get the main sheet hauled in, so we didn't get to 'fly'.

Above about 8 knots, the foils add a significant stabilizing effect to the craft, both lateral and longitudinal. At low speed, foil action is mainly a roll and pitch damping. The drag of the foils slows the boat in light winds, but in a chop this is partly compensated by increased sail drive resulting from the greater steadiness of the craft. All in all, this 3000 lb craft has the feel of a 10 ton yacht in light winds, except that when coming into a dock one can put a foot to stop the boat without breaking a leg.

I had a couple of hair-raising experiences with the boat earlier—once a capsize with no hydrofoils, and once a wild 60 mile ride with a single lateral stabilizing foil.

Before any of my hydrofoils were fabricated, I was testing the boat and succeeded in capsizing it. The capsize was not planned, but I learned much from it. It occurred in a 20-26 knot gust of wind with 340 sq ft of sail up. At the time, the craft weighed about 1600 lbs. The capsize was gentle, the boat capsizing 'backwards' (bow lifting skywards) because of the rather far-forward pontoons. The mast trapped a column of air, and the boat settled at a 100° heel. The boat was righted easily with assistance from a power cruiser. There was no damage. Then I started making calculations of what the righting moments would be with the hydrofoils installed. Lo and behold, it looks as if the craft should be self-righting with the hydrofoils in operating position and the sails aloft. This results from several factors: (1) the low c.g. and 400 lbs weight of the Aluminium hydrofoils, (2) the small pontoons, and (3) the high and rather buoyant wing section connecting the hulls. At any rate, after a capsize, several factors, one or a combination of them, would certainly right the craft: (1) lowering the sails, (2) windage on the skyward pontoon after the boat swings around, and (3) a crew member hiking out on one of hydrofoil ladders. However, I'm not planning any such experiments in these icy waters.

Last May, I moved the boat to the South end of San Francisco Bay to have it near the company assisting me on hydrofoil fabrication (Aquanautics, Inc. of Sunnyvale, California). At the time, the lateral stabilizing foil on the port side was finished. This was convenient, since the 60 mile trip South would be with westerly winds. However, in the eagerness for tests, I didn't bother to install some planned bracing in the foil ladder. During the first part of the trip, we (an adventurous young lady and I) experienced light winds. A good wind started picking up while between Alcatraz and Treasure Island. The boat came alive, and as wind and speed climbed, the hydrofoil stabilizer began eerie moaning and singing, changing its tune as wind and speed changed. The nearest description of the sound that I can give is that it is like the purring sound heard at sport car rallies, with cars up-shifting and down-shifting. After hauling in the sheets and putting the boat on its fastest heading, we were probably doing 15 knots, with a true wind of probably 15-20 knots. At this speed, the boat had zero heel. The hydrofoil was supplying all of the righting moment, as well as leeway resistance. The main hull was obviously planing on its scow bottom. The craft handled beautifully. Suddenly I felt the boat take a tiny lurch to leeward. On glancing at the hydrofoil, I noticed that the struts were bent slightly. Obviously, sail side force alone had caused the struts to yield. The wind was picking up in force, and so when we got into the lee of one of the towers of the Oakland Bay Bridge, I furled the mainsail. The winds then picked up to near gale force, in the gusts. Steep waves rapidly built up. We started a wild unforgettable twenty mile ride with jib alone. The boat surfed wildly at times. Beam waves smashing on the main hull caused the foil struts to bend much further, but the blading continued to give lift. Surfing at high speed, the craft took on negative heel. Occasionally, my shallow temporary rudder came clear of the water, at which point the boat headed for the nearest wave valley at high speed. The foil always maintained positive lift and steadied the boat from rolling tendencies. Climbing waves, the boat nearly stopped and tended to heel considerably. The trip nearly ended up a disaster when the Southern Pacific Railroad failed to open up one of their swing bridges to allow us to pass.

After this trip, I modified the design of the foil units so that they could withstand the maximum possible water force (which amounts to about 200 lbs per sq ft of surface). Now, with good structure, I feel a bit more confident when taking the boat out for tests.

Letter from David A. Keiper May 1, 1968.

We've been having some good winds here lately. *WILLIWAW* has now flown on its hydrofoils on two separate occasions, doing 15 knots with five persons aboard. The transition between hull buoyancy and foil lift is very smooth, going up and coming down. The speed isn't very startling as yet, but we did leave a cruising trimaran far behind. Now I'm working on the problem of getting the boat to accelerate once it is flying.

Commenting on your letter of March 19:

To make a hydrofoil yacht self-righting doesn't strike me as a difficult problem. With pontoon buoyancy considerably less than craft weight and the weight of metal hydrofoils below the hull, it comes naturally. Sealing the mast is an extra guarantee. Because of the overall light weight of the hydrofoil craft, a knock-down is a distinct possibility. I would regard the self-righting characteristic on a hydrofoil craft as an essential for safety. On a trimaran, it is much more difficult to design self-righting into it, and also design for high performance. Since trimaran capsize is very rare, it doesn't strike me as necessary to have the craft inherently self-righting. With a hollow sealed mast, the trimaran can be prevented from settling at a 180° heel. With provision for filling the underwater pontoon with water, the trimaran could be righted.

Letter from: Clayton A. Feldman San Jose, California, U.S.A.
October 5, 1967.

Dear John,

Disliking long delays in correspondence and having received your letter concerning low aspect ratio foils yesterday, I set about testing your concept of foil design, a few minutes in the workshop last night being productive of half-size models of the 4 foils and a 6 ft pole with a 45° slot sawn into it. The foils made from ⅛ in hardboard snap into this slot.

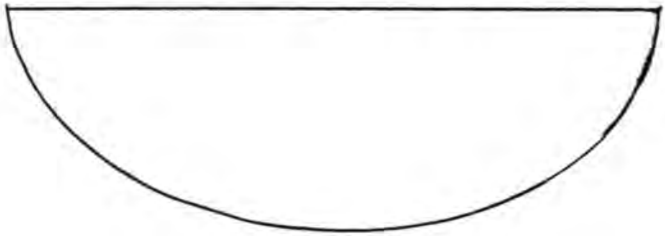
Then to the backyard swimming pool where each foil was fixed in the slot and swung in an arc.

Again Morwood triumphs, for the low aspect ratio with 45° entry and exit clearly cut the water the cleanest, left the narrowest and sharpest wake, and had the least turbulent flow across the foil from entry to exit.

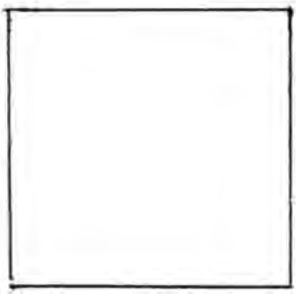
The rounded Bagnall foil (*Ed.*—See page 191) was next best with good entry and exit and little turbulence, the Ashford (See page 159) third with considerable turbulence and a broader wake, and my own rectangular foil clearly the poorest, with turbulence at entry and exit and considerable "piling-up" of water across the face of the foil.

As to which shape would give the most lift, one can only assume that the deciding factors would be the surface area and the aspect ratio, and these being equal, the shape with the least generated turbulence (the Morwood shape) should be the best.

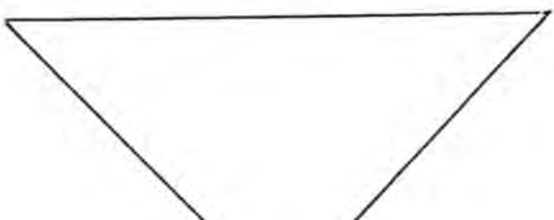
In the next phase of the experiment in which you have entangled me, I think I shall build a crude 4 ft LOA narrow hulled boat and try the foils first in the pool before making a set for my little 8 ft trimaran (See page 156). If I am convinced that the low aspect ratio foils can do more than just stabilize a float, I shall try them on the 8 footer, using some life rings for reserve buoyancy and do away with the floats altogether. This may seem over cautious but I still think that I shall get wet without floats!



BAGNALL TYPE



FELDMAN TYPE



MORWOOD TYPE

May 26, 1968.

My little 8 ft trimaran is semi-retired as I get a devil of a backache from cramming myself into the tiny hull for any length of time.

Earlier this year, however, I did pursue the hydrofoil findings of the last few publications. First I added a small jib on a bowsprit for a bit more speed, then I added longer crossbeams to make an asymmetric trimaran, the centre of the most distant float's foil being the "Bruce Length" of sail centre of effort to perpendicular intercept with the line drawn between foil centre of effort; the other float was left on at the usual distance from the hull for insurance. Well, it sailed well, was extremely stable (annoyingly so!), but came about with all the elegance of a log raft.

Having satisfied myself that the inboard float was not needed, it was promptly left at the dock and I went flying off with the single hydrofoil-float doing the job. The boat was then a good deal faster, quite stable, and much more manoeuvrable. In 15 mph winds, with the float to windward, I had to really lean out to even see the bottom of the float. Once the foil became to weather, it stuck in as though glued unless I suddenly threw my weight to leeward, then it would start to slowly lift out of the water. I never let it break out completely, as happiness is staying dry!

I am starting preliminary sketches of a 15-16 ft hydrofoil stabilized trimaran, designed to AYRS criteria, and hopefully to be constructed of polyester foam which should make a very light transportable boat.

Thanks for your (and AYRS) encouragement and inspiration.

SULU—MOSQUITO TRIMARAN Mk II

Designers and Builders: Derek Norfolk and Rodney Garrett

April, 1969

36a Duke Street, Brighton, BN1 1AG

Hull Displacement	610 lb	Sail Area	178 sq ft
Float Displacement	325 lb	Draught	10 in
Length OA	18 ft	Draught Plate Down	4 ft 3 in
Beam	10 ft	Beam Folded	3 ft 9 in

Trimarans in the cruising classes are available in ever increasing numbers, but for those who prefer the cheaper sporty type of boat, the choice is very limited. For lively performance combined with stability and effortless sailing the trimaran configuration seems to offer one of the best solutions for two sailors (in this case not so young) who like to join in the racing without having to endure the strenuous efforts required for dinghy racing.

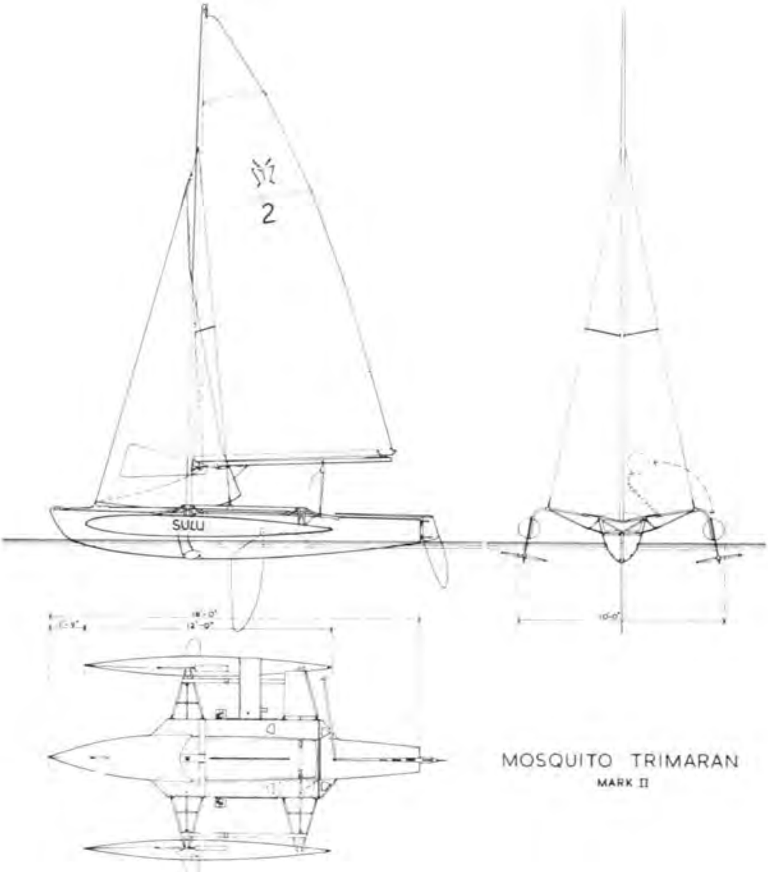
Thus *SULU* was evolved by her joint owners for their enjoyment and ease of operation and also to be capable of a good all-round preformance. Not least among her attributes she has provided an excellent "test bed" for further trials with the fully retractable variable incidence foils which are installed in the floats.

She was not constructed with the intention of being a production prototype, the fabrication being somewhat involved in order to achieve the desired

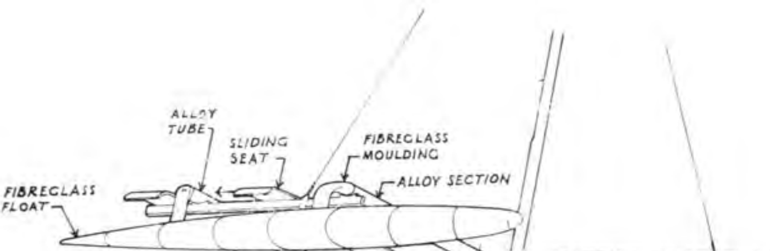
SULU at speed with lee float off the water

hull shape and to effect the special degree of foldability for ease of transportation and at the same time come within the limitations of the home workshop.

However, now that the inevitable problems have been ironed out and an efficient design has been created, simplification of detail and economy of construction employing factory techniques could no doubt be made. The cost of materials including building frames for the hull, plug and mould for the fibreglass floats, spars, rigging and sails complete, worked out at approximately £285. This figure is without the foils which would amount to about an additional £15.



MOSQUITO TRIMARAN
MARK II

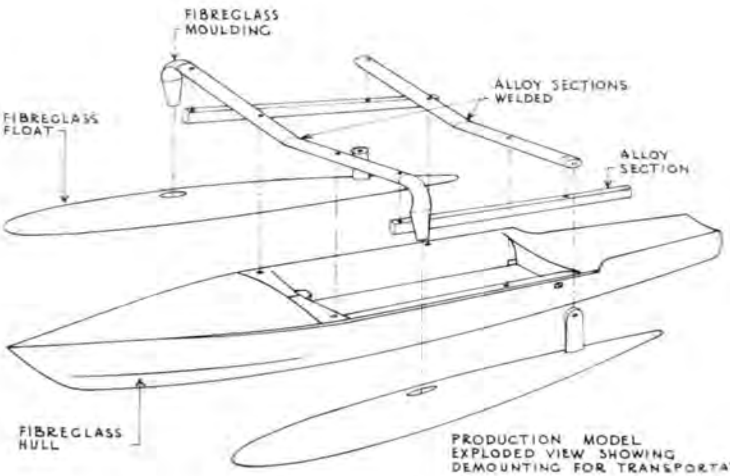


UNDERSIDE VIEW OF SUGGESTED PRODUCTION MODEL

The fore and aft position of the floats relative to the hull have been found in practice to be about right. Under all sorts of weather conditions the hull always lifts bow first. On no occasion has the boat taken any water green over the forward deck even in conditions when an A Class Cat has pitchpoled.

The shape of the floats is circular in section aft and elliptical forward, becoming a pointed ellipse right forward. This arrangement gives a fine entry on the surface of the water reducing wave making, and also prevents the forward end of the float from pounding.

If the conditions are such that the bow of the float digs in, it lifts out very quickly because the water will slide off the elliptical section easily and without disturbance. Each float is fitted with hydrofoil blades which are fully retractable into the body of the float, with an automatic "bomb door" to close the opening on the underside. The foils are raised and lowered by a wire tackle which may also be used to alter the angle of attack as desired. The blades are hinged to enable them to retract into the float and to open automatically when lowered. The hinge arrangement also makes it impossible to get any negative lift which would tend to pull the float lower down into the water.



PRODUCTION MODEL
EXPLODED VIEW SHOWING
DEMOUNTING FOR TRANSPORTATION

When the boat is sailed nearly upright in light and moderate winds there is no advantage in using the foils. If the wind is strong enough to keep the float nearly submerged and the sea is fairly smooth, the use of foils can give quite dramatic speeds, but unfortunately so far not measured. The best that has been recorded to date is a two way race of approximately 11 miles in 65 minutes, leaving Flying Dutchman and Fireballs far behind. When the boat is hard pressed by a heavy gust (without foils) the lee float submerges, the hull will lift a few inches and in this position she seems to stay giving time to ease off the sheets. The heel angle reduces the effectiveness of the sails, the A frame tubes hit the water and the boat slows up. This is, of course, not recommended but if it happens no harm is done.

Photo: Yachting World. Foil working

The boat has not yet capsized, or in fact approached it, and it is not known if it could be righted, without external assistance. The two crew would just about be able to submerge one float in the event of a complete inversion, but from then on it is, up to the present, a matter for conjecture.

For transporting the boat by road trailer, the mast is taken down and the two sets of tubes under the "A" frames are unbolted at their outboard ends; the floats and "A" frames are hinged up over the top of the hull. The unbolted tubes are swung round alongside the hull, reducing the overall width

Photo: Yachting World. Foil retracting to about 3 ft 9 in. The mast is then lowered down between the floats on to the transom and the crutch of the road trailer. The whole operation, either folding or unfolding ready to launch, takes about 30 minutes.

Whatever type of boat is designed there always seems to be some disadvantage in comparison with some other type. The floats of a racing trimaran of necessity have to be of light construction and will not withstand much of a collision with another competing boat nor a heavy bump against a quayside. The floats of this boat are no exception, although for sea conditions, launching and landing on concrete slipways and shingle beaches, the floats and their supporting members are amply robust.

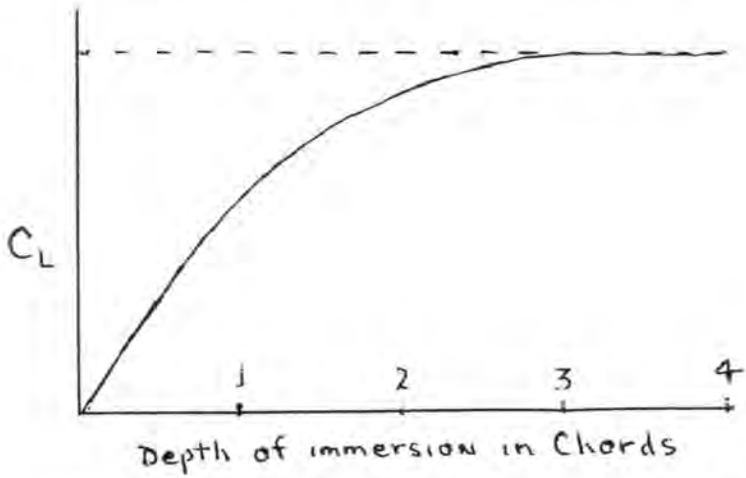
Letter from: Rodney Garrett 36A, Duke Street, Brighton, I.

Dear John,

As regards the surface relation of a fully immersed foil, one can take advantage of the ready made levelling of fully immersed foils to some extent at least, according to the following:—

The lift co-efficient C_L increases with depth of immersion as indicated.

"Fully submerged" condition is reached at about 3 chords depth below the surface.



In practice it is the problem of keeping the T foil type *immersed* which is rather difficult I find, even with the crew manipulating the angle of attack unless he is very much on the ball.

With a trimaran configuration I think that the moment of inertia of the craft is very low. Rather like the tight rope walkers with the balancing pole. When there is a hole in the wind the lee foil or float finds it very easy to pop up.

Obviously the foils are set much too shallow in *SULU*, about 10 in only, and I would increase this to at least 30 in.

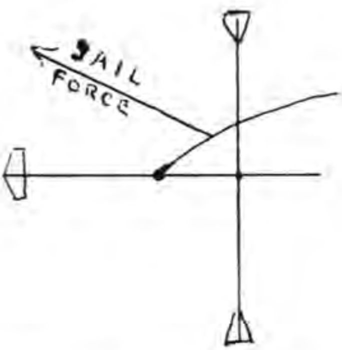
I don't believe that we need to raise the level of the "fliers" as much as some seem to do. After all, the high speed day boats mostly operate in relatively calm water, and they need only to skim over the small waves.

Boats for Atlantic seas are out of my ken, anyway! I find that if *SULU*'s lee float is raised by 25 per cent only, there is quite a release of energy due to the decrease in wetted area.

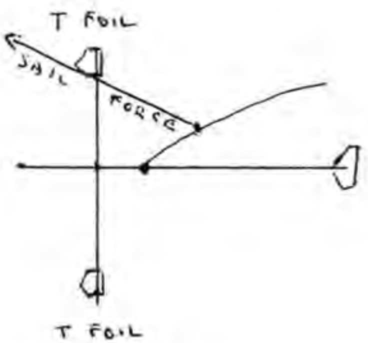
I think I would go one better, (or one less!) than your 4 foil arrangement if possible after the manner depicted on my sketch on page 62 of *AYRS issue No. 66A*, the angle of pitch being controlled from the rear instead of at the front. The tail will be lightly loaded so it would be sensitive and responsive to immediate alteration in the angle of incidence; like the tail ailerons of an aircraft (old fashioned type).

Now *one* lee foil would be mostly doing the lifting job. Even at 19 mph which is about the point where we should be thinking of starting to fly, as most multihulls can do 16 mph plus without much difficulty in standard form, the lift from one of my foils with, say, 2½ sq ft area, is reckoned to be in the order of 455 lbs force, at 2 chords depth only. As you know the lift goes up by the square of the speed, and at 25 mph the lift would be about 810 lbs force at 5° angle of attack and a C_L of ·25.

I think it is essential to have the main foils well forward to resist the sail force, i.e.:



Canard (Don Nigg)



Tridrofoil

I don't understand the arrangement, as in Don Nigg's, which seems to leave a "gap" in support from a foil where you surely need it most?

With my tridrofoil, all 3 foils would be fully retractable for ease of going about or for manoeuvring, etc, etc, and the aft one combines to form a rudder of course in the tail unit which has a modicum of buoyancy.

I call it a TRIDOFOIL which Montgomery (Editor of *Multihull International*) dubbed *SULU*, although it looks like more of a catamaran with a tail, than a tri.

The two hulls or floats would be torpedo shape for submarining efficiently, as I think that there need not be any excess of buoyancy in view of the foils supplying the lift, but enough of course for normal manoeuvring etc. when not foiling.

The arch section bridge deck would keep the crew well off the water to be reasonably dry.

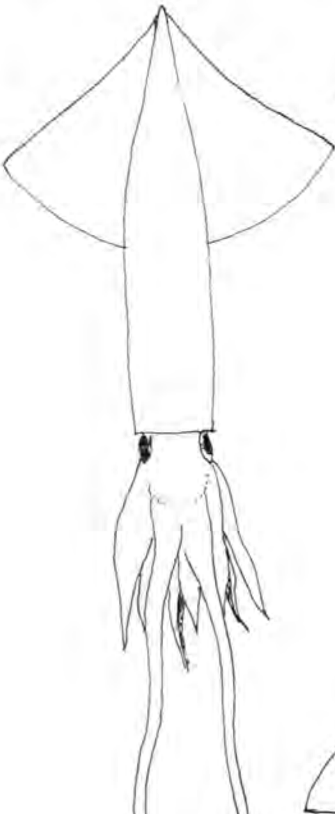
All exciting stuff.

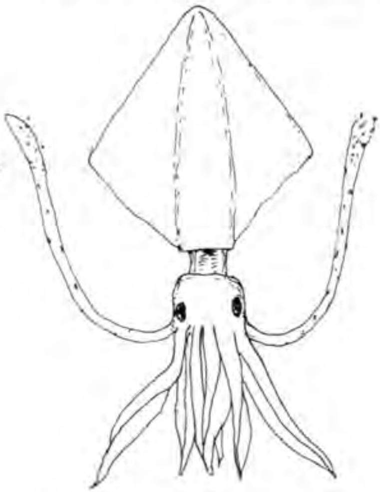
THE SQUID
by John Morwood

This summer (1970), I was reading Nigel Tetley's book, *Trimaran Solo*. Suddenly, I came upon the photograph of two squids which had come aboard, having jumped 5 ft up and 11 ft across the boat. Like Archimedes in his bath, I realized what I was looking at—Nature's hydrofoils.

The Encyclopedia Brittanica was unhelpful under the heading of "Squid" but *Cephalopodia* had what I wanted to know.

The Atlantic squid disperses deeply during the day but comes to the surface at night to feed on plankton. In turn, whales eat squid and cruise along





on the surface, scooping them up. To escape being eaten, the squid, presumably sensing the approach of the whale, jumps out of the water.

The squid's fins are not much used for propulsion and I guess that, when feeding at the surface, it swims with the head end forward by sucking in water from ahead and diverting this water by the tentacles towards the tail end when it is blown out. On the approach of a whale, however, the squid puts out a very powerful jet of water (to which it adds "ink") and jumps wildly from the whale's path at considerable speed, with the tail end, and fins, first.

The fins

When feeding, the fins act as skegs giving a stable course and, because the speed is low, no great hydrodynamic elegance is required from them. They are fixed to the outer shell which is called the "pen". On the other hand, when the squid is doing its escape act, it is going at high speed in the opposite direction. The whole animal retracts into the "pen" to give the greatest force to the jet propulsion and the fin must function with the maximum efficiency.

The placing of the fins of the Atlantic squid near the tail end will make sudden changes of course easier during the squid's leap backwards, though one suspects that the water jet produces a good deal of stability in course. Once up in the air, however, surely the fins will turn the animal so that the head end goes first, the fins acting like the feathers of an arrow.

The shape of the fins

There are two varieties of squid which are of interest to us; the Atlantic and the Mediterranean squids. The fins are thin in section and the profile shapes must surely be those which we could use for hydrofoils. This opinion is seldom that of people trained in aerodynamics or hydrodynamics who always seem to want the highest aspect ratios. However, Edmond Bruce's tank tests prove clearly the value of aspect ratios of 1 : 1. When Nature and tank tests agree, it must surely be a mistake to apply aerodynamic theory.

The drawings by Gerald Holtom show the two types of squid, the Atlantic squid at the left. Both have fins with an aspect ratio of 1 : 1 and those of the Atlantic squid have the leading edge curved which we have shown on other grounds to be desirable. Presumably, the Mediterranean squid is the slower swimmer in the escape act but there is not likely to be much in efficiency between the two. However, the Mediterranean shape is much more suitable for stabilizers than that of the Atlantic type.

We also show a ray of the Indian Ocean which swims at considerable speed by flapping its wings like a bird. Again, the aspect ratio and curved leading edge will be noted.

CHAPTER XVII

AYRS SAILING HYDROFOIL MEETING

Organised by James Grogono — August 1970

38, New Road, London, E.1

On May 30th-31st, 1970 about 50 people gathered in Burnham-on-Crouch for the first ever meeting devoted entirely to sailing hydrofoils. The Royal Corinthian Yacht Club kindly made its facilities available. The boats were provided by the following:

David Chinery	16 ft Unicorn-rigged monohull with cross beam and foils.
Rodney Garrett	High-speed foil stabilized trimaran.
Grogono family	Tornado catamaran on retractable foils.
Phillip Hansford	Model catamaran (full-sized version now complete).
Joe Hood	Light-weight monohull with "DN" land yacht rig, and foils.
Bren Ives	Foil stabilized Hornet.
Christopher Rowe	Foil stabilized "Shark" monohull.

Also present were John Cockburn, whose "Nigg-boat" is performing well on the Isle-of-Wight, and a variety of theoretical experts including Dr. Alan Alexander, Mark Simmonds and John Morwood. The "Chief Dynamicist" of Planesail, Mr. A. Murray, put in an appearance, as did Rodney Macalpine Downie, and throughout the weekend one could find small groups of people arguing one point or another, or quietly absorbing all that was going on.

Saturday morning was devoted to dinghy-park discussions and the process of assembling the various machines, most of which were untried. Rodney Garrett's *SULU* was the best finished, and has an excellent mechanism for retracting the inverted "T" foils, complete with folding "bomb doors". One of the most interesting features in his boat is the function of the crew, who sits with a line attached to the block-and-tackle controlling the angle of attack of the leeward foil. The crew alters the lift to suit the conditions from moment to moment, a surely unique system. David Chiner's *MANTIS*, which had been "flying" well at Weir Wood, was not performing quite so well on this occasion, perhaps because David's present effort is devoted to a larger, lighter monohull, based on one hull of a catamaran, and with a substantial spread of sail. The Grogono-boat *ICARUS* suffered disaster before it had been seen to fly by any of the 35 people sitting shoulder to shoulder on the Committee boat. The supporting strut of the main "tip-over" foil became dislodged from the keel and produced a large hole in the thin plywood skin. Rapid repair enabled the boat to become foil-born in the Burnham anchorage on Saturday evening, and again on Sunday, but in its untuned state, with marginal conditions prevailing, it was outsailed by a brand new Bell-built Tornado sailed by Mike Day.

Joe Hood spent Saturday morning finishing off his very beautiful little monohull, but had the misfortune to damage the hoop-steering front foil whilst ashore. Many of the ideas in his boat, especially those concerning the correct use of light-weight strength, are original and obviously of great potential. He became foil-born for a short spell on Saturday evening and already has various improvements in hand. Bren Ives and Chris Rowe both produced most effective foil-stabilizing systems for their displacement hulls, and there were thus three foil-stabilized and three "flying" versions to show the alternative uses of foils. Last but by no means least, except in size, was Phillip Hansford's model catamaran, which carries the main load on fixed front foils, and has transom-hung steering foils at the stern. This 2-ft model worked superbly, sailing far too fast for the accompanying rowing dinghy, and at the time of writing (August) the full-size 16-ft version is about to have its first trials.

Thanks to Yachting World and Hunting Survey, there was a system of most accurate speed measurement available to all the various boats, but the only fast times recorded (in the light breezes) were by Mike Day in his entirely un-foil-borne Tornado. There is no doubt that this meeting is the first of a series of annual foil-sailing events, and by the speed of present developments it may well be the last in which an "orthodox" boat will be faster than the best "foil-born".

FLYING HYDROFOILS

ICARUS by James Grogono — September 1969

By kind permission of the Editor Yachts & Yachting 38, New Road, London, E.1

The theory of sailing hydrofoils was pioneered in this country, mainly in papers published by the Amateur Yacht Research Society. However, most of the practical development has taken place in the U.S.A., the projects of Don Nigg, William Prior and Mr. Baker being prominent. A search of the literature failed to reveal a successful hydrofoil sailing craft this side of the Atlantic. The purpose of this project was to develop a high-speed hydrofoil craft with the very simplest boat and equipment. Extra stimulus was provided in Hugh Barkla's article a year ago in *Yachts and Yachting* (Nov. 1968, p. 906):

"It should be clear why this is no undertaking for the amateur. The problem requires the intensity of study and the effort and skill in design which only a professional organization of some size could give"!

Sailing on hydrofoils, if successful, certainly leads to very high speed, the characteristics of a foil-born craft being not dissimilar to those of an ice yacht: the total drag increases only marginally as the speed goes up, while the force derived from the sails increases rapidly with the increase in apparent wind. Failure of any development has not been on these theoretical grounds, which are not usually disputed, but on *practical* grounds, the objections being these:

1 The craft may only be foil-borne over a narrow range of sea and wind conditions, and may be sluggish and unmanageable off the foils.
2 Launching and handling are difficult because the foils are deep and fragile.

3 Lack of any certain commercial outlet.

For these reasons a development was planned on a standard one design class, the foils being detachable, constructed in wood, and extremely cheap. The foils should be an optional extra, easily fitted on suitable days, but leaving the boat "in class" on other occasions.

ICARUS, 1970—with front foil steering and "tip-over" rear foils. Transom hung rudders have thus been dispensed with and the boat made much more practical.

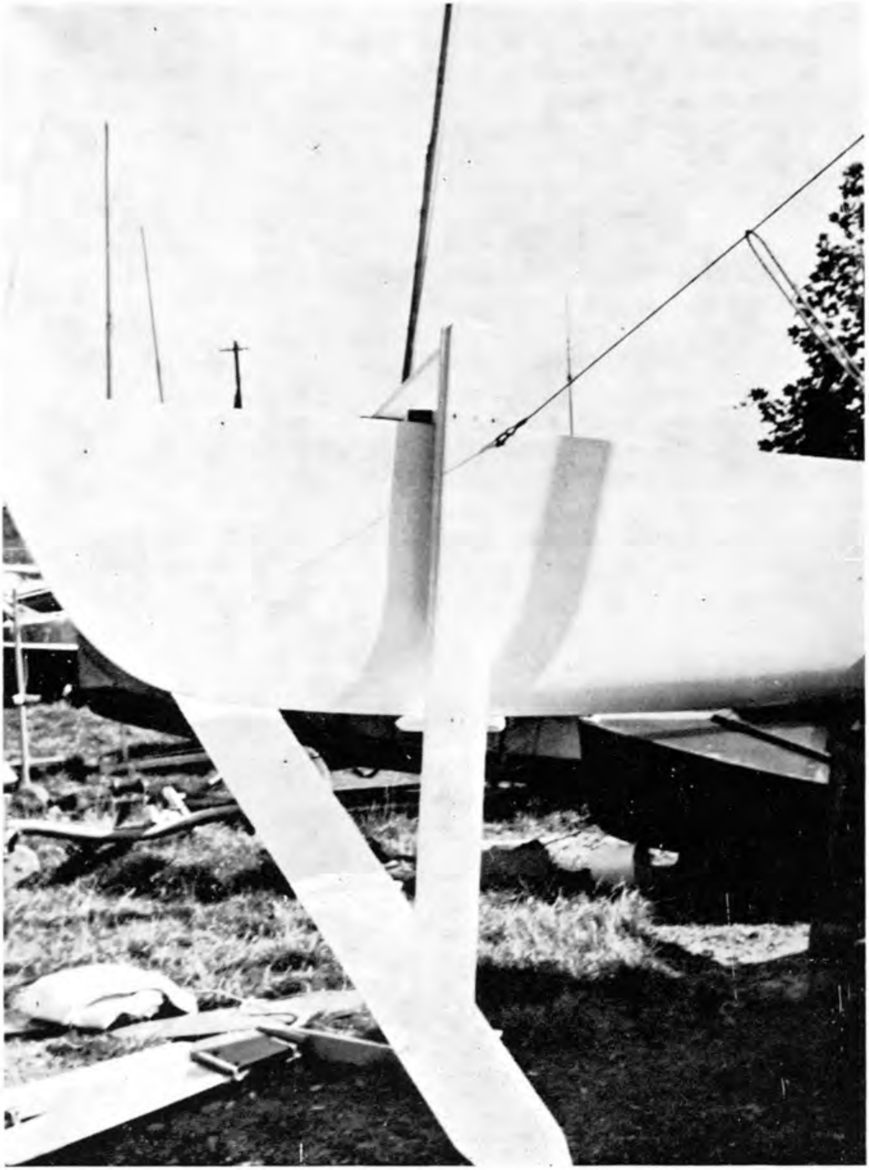


Photo: Yachting World. James Grogono's bow foil

The boat

The boat chosen was a Tornado B class catamaran, simply because of its high power to weight ratio (235 sq ft of sail, 30 ft mast, 300 lb weight), good in the water, performance, and because foils may be attached more easily to a catamaran than a monohull. Since speeds up to 15-20 knots are often reached without foils, the Tornado allows considerable flexibility in foil size and configuration.

The foils

The fluid dynamics involved in hydrofoil design (and aeroplane wings) is complex, but in practical application, gross error can be avoided by use of the following guide lines:

1 Virtually all the lift is produced on the upper surface, and this lift is greatly reduced if air gains access by travelling down the foil from the water surface; fences are necessary to prevent this.

2 All areas of foil within one chord length of the lower end, and within a half length of the water surface should be disregarded in calculating lift. This is a crude but very useful approximation.

3 Foils operate best at low angles of attack. Although the foil section used does not generate its maximum lift until the angle of attack reaches 10° it can be seen that the far more important lift-to-drag ratio is at its maximum between 0° and 3°.

4 Foil cross-section is by no means the most critical factor; the cross section chosen (from the bewildering variety available!) has a simple arc of a circle for its upper surface, and is flat on its lower suface. There is no rounding-off of the edges, and all foils have a thickness to chord ratio of 1 : 11. (The graph in Fig. 2 is actually for a ratio of 1·14 which alters the figures slightly.) This surprisingly simple foil section has proved more than adequate.

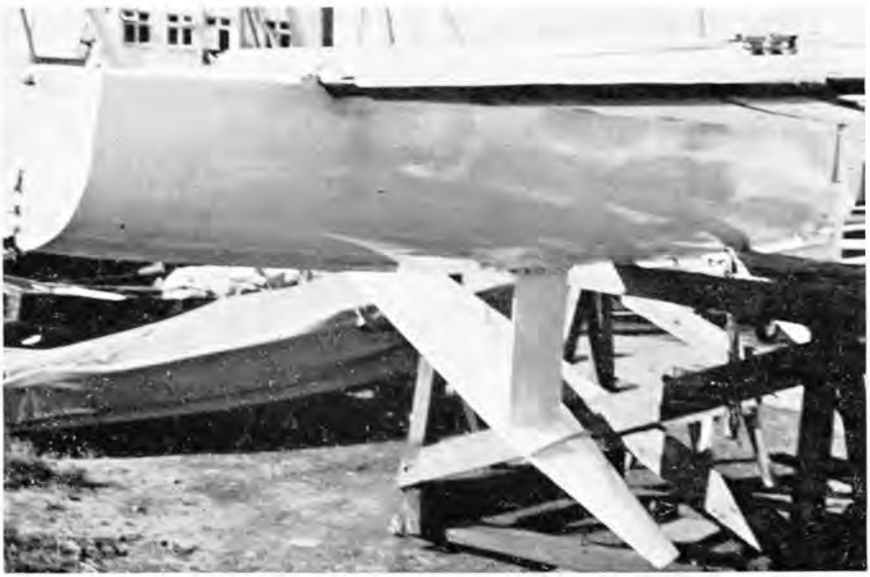


Photo: Yachting World. James Grogono's rear foil

Foil size and disposition

On the basis of the factors considered above, foils were planned as follows:

1 The main weight-bearing foils, designed to carry 80 per cent of the 600 lb all up weight, were required to be 5 ft long and 18 in chord set at a dihedral angle of 38°, and an angle of attack (of its flat surface) of 2° with the horizontal. These foils carry the main load at a very efficient point on

the lift to drag curve, and are easily attached to each hull by means of vertical struts, passing though each centreboard case. The unsupported "deep" end of each main foil is 18 in long. They must be strong enough to carry the weight of the whole boat when ashore.

2 The front foils, relatively lightly constructed, are the same length and angle of dihedral, but the chord is only 10 in, and their angle of attack is 4°.

This greater angle of attack is critical; it has the disadvantage of taking the operating point on the lift-to-drag graph just beyond its optimum, but it provides a readily available reserve lift to combat pitching. Any tendency to

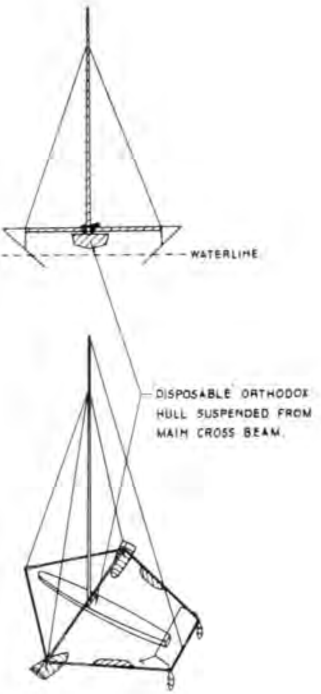


FIG. 1

THE MOST IMPRACTICAL SAILING CRAFT EVER DESIGNED (C. 1958)

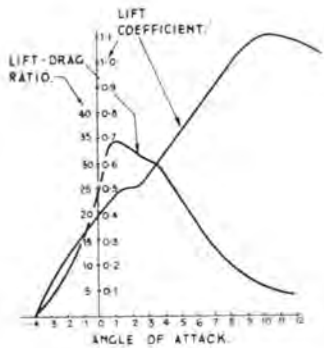


FIG. 2

LIFT-DRAG RATIO & LIFT COEFFICIENT PLOTTED AGAINST ANGLE OF ATTACK

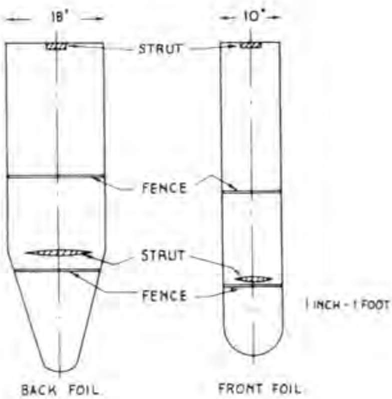


FIG. 3

PLAN VIEW OF FOILS SHOWING SITES OF STRUT AND FENCE ATTACHMENTS pitch is offset by the increased immersion of the front foils as the bow goes down; also, by the difference in the angle of attack between front and back foils, the stern will go down first (in theory!). The well-marked dihedral angle (compared with aeroplane wings) is necessary to let the foil "run deep" away from losses caused by surface effects and air entrainment and it also provides lateral stability. In addition it facilitates the most elegant of all the hydrofoil advantages—the fact that only the minimum required area of foil is immersed at any given moment; the higher the speed, the higher the boat rides. There are two critical speeds for the present arrangement. One is 10 knots, which is "lift out" speed, accidently confirmed to be exactly correct by a motor-boat speedometer during towing trials. The other is 20 knots which is the point at which the vertical struts clear the water, the boat then riding on the unsupported inner ends of the foils. Considerably higher speeds than these are anticipated.

Foil construction

The stimulus to "get off the drawing board" was provided by John James, school friend and subsequent Olympic rowing medallist, who provided half the capital, more than half the man-hours of labour, and prevented numerous blunders by being obstinately unprepared to take any ideas or calculations on trust. The foils and extra long rudder blades were laminated out of 3 in × $\frac{3}{8}$ in strips of Douglas fir, through the expert advice of Brian Saffery Cooper, and their shaping was a pleasant and straightforward task in carpentry. Our inexperience in laminating led to the laying-up of likely looking pieces before the design was complete, and all units went through a "pre-design-construction -stage", with some accidental changes in design as a result. In the later stages we had much help from John Fowler and Dr. E. B. Grogono, especially from the latter's excellent work-shop, and ability to sharpen blunt planes. Extra labour in the rather desperate last few days before the "deadline" included that of a complete stranger, rash enough to walk up the drive with a couple of hours to spare, and promptly employed in painting and making attachment chocks. The total weight of foils and supporting struts is 80 lbs.

Sailing

The completed foils were taken to Burnham and attached to the boat by brass screws and wooden chocks, the whole process taking about three hours. At that time the launching trolley had not been adapted to carry boat plus foils, so launching was accomplished by enlisting the aid of eight strong men, encouraged with a little whisky.

ICARUS sails fairly well while not on the foils, although rather reluctant to alter course quickly or carry her way through the eye of the wind. The bow starts lifting at 5 knots, and it seems best to move the crew weight well forward between this point and "lift out", which occurs at 10 knots. The sensation of lifting out is most exhilarating, and requires a wind speed of only 10-12 knots. (The maximum wind speed recorded on the day on which the photographs were taken was 12 knots). Once foil-born there is a dramatic increase in speed and manoeuvrability. The boat also feels very stable on the foils, especially when sailing to windward, and if corrections of fore and aft or lateral trim are required, there is time enough for the crew to make them. High speeds have been attained, but not accurately measured as yet.

MANTIS

September 1969

Letter from: David Chinery The Cop, Buckland, Betchworth, Surrey
18 September, 1969

Dear John,

This craft was built by my cousin and myself in about 4 months, and first introduced to water some 8 weeks ago. You will notice the influence of Don Nigg, but then I had read every conceivable article that I could lay my hands on.

Before giving my impressions, some brief details:

LOA 16 ft overall, beam 16 ft.

Foil area 10½ sq ft. 20 per cent front, 80 per cent rear. Front foil steering.

All foils retracting. Foil section precisely as described in your journal.

The first (non-retractable) forward foil

Now let me describe the most fascinating experience of my short yachting career, an experience which left me hoarse from shouting with exhilaration.

A superb sunny day in Chichester harbour. Very light breeze. We launched the boat for the second time at the boat yard at Hayling Island, the first was on a local puddle.

Gingerly raised the sail and proceeded, gently running with the wind into the harbour proper. The spectacle raised many comments from those thousands of dinghies buzzing about and I tried to look busy and intelligent as little lads of 8 and 9 buzzed round with insolent ease in their Puffins. It was as much as I could do to hold the brute on a straight course. Then came the Moment of Truth. Eased onto a broad reach with a view to coming into wind to tack. Hopeless. Got in irons immediately and could not get out. Fortunately the escort boat, a *HINA*, which incidentally sails like the clappers, was near at hand so I clambered aboard to have lunch. Then we decided to tow. We removed the 4 hp outboard from the *HINA* and fixed it to the little pram dinghy. We let out some 70 ft of line, got going . . . our speed? Hard to estimate but no more than 3½ knots. Not enough to fly. By now we were all feeling a bit despondent. In some kind of desperation I suddenly heaved on the line and to my joy the hydrofoil very quickly, without any fuss, just lifted out of the water. Imagine my excitement. I then realized that quite suddenly all resistance had gone. Once up on the foils, the craft just slid over the water and I was able easily to haul towards me hand over fist without any effort. All this time the hydrofoils slid grace-

David Chinery's *MANTIS* being towed

fully along getting nearer and nearer as the tow rope got shorter and shorter. When I ran out of rope, I let the whole lot out and repeated the performance. I guess the speed would have been about 4-4½ knots. A very low take off speed but the boat was empty. I had calculated that with the total weight of 390 lbs, take-off speed should be 5½ knots.

Next we removed all the foils, bolted two small floats to the ends of the cross beam and added a normal type rudder. In other words we had converted in a matter of some ¾ hour whilst anchored in the middle of the harbour, our hydrofoil into a trimaran.

We got a sail in that afternoon, of sorts, but because our floats were too small, they tended to depress too easily which made the cross beam drag. The boat was still difficult to get to come about so we resolved to add a centre board.

The boat, when erected on its foils on the back lawn looked (as an interested observer said) like a praying Mantis. In fact this name is very apt as one is always praying for the right weather conditions and this is the drawback with this type of craft. Hydrofoils have to be made first as a displacement boat for light airs and only secondly as a foil stabilized craft in brisk winds and

MANTIS sailing happily as a displacement boat

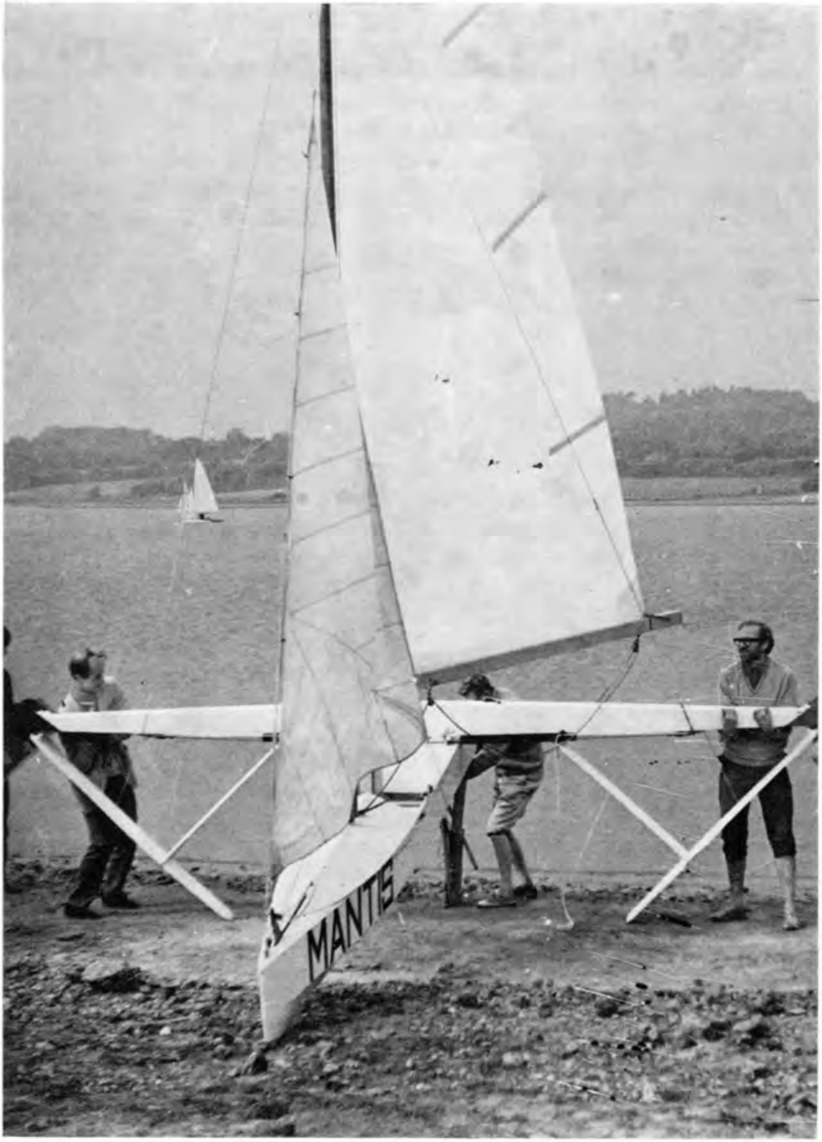
finally as a flying hydrofoil in good stiff breezes. It was very humiliating to sit in the boat, slowly finding yourself drifting backwards in irons, totally unable to get out, waiting for help from the escort dinghy, whilst all the little Mirror dinghies and Cadets made circles round us. I don't want to sound too depressing here, but if members make Don Nigg's boat exactly as he did in the published photographs, then they're in trouble before they start. All foils must be made to retract totally clear of the water in such a way that the boat automatically becomes low drag and displacement craft. If one or more of the foils is used for steering, then alternative methods must be found for steering when the foils are retracted.

On our third outing, the hydrofoil looked very different to the photographs. Now, all our foils can retract clear of the water. The front foil retracts into the hull. The two rear foils retract upwards in a horizontal plane, lying snugly underneath the cross beam. Each foil operates separately and independently. Two floats are fixed permanently to the beam whilst sailing. The design has therefore improved 100 per cent.

We have only to carry two basic units to the water. The hull, with its foil retracted and the beam with its foils retracted.

It is splendid to be able to launch the boat into shallow water. Once under way, the rear foil can be lowered by simply releasing one halyard and pulling another and fixing in a jam cleat. The lift generated is considerable and it is

Front foils—working position



Main foils down—bow foil retracted

fascinating to *lean* to windward. During this particular outing I remember when it was my turn, I somehow came across a Finn dinghy being sailed very energetically, held to 45 degrees, the helmsman sitting out, bottom very wet with spray all over the place. I proceeded to overtake him slowly but surely, I was sitting right down in the cockpit casually steering with my right hand, smoking and holding my pipe with the left and facing forward. Remember all this with only 60 sq ft of sail. The Finn didn't seem amused. The ice yacht sail certainly developes tremendous power. But alas not enough to fly the hydrofoil. We shall need at least another 100 sq ft or so which is necessary to overcome the tremendous initial drag when all foils are lowered. Eventually we repeated the first outing's performance. My cousin climbed into the hydrofoil, my brother and I on the *HINA*, now fitted with a 20 hp outboard. We proceeded to tow. The craft with my cousin aboard came out easily, so at least he has had "THE" experience. All that remains to do to the first prototype is to find more power (sail area) and improve the displacement sailing characteristics, and then . . .

DAVID CHINERY.

Letter from: Peter G. Chinery 54, Carshalton Grove, Sutton, Surrey

MANTIS Mark I

May 1970

Dear Dr. Morwood,

The conception of a car top Sailing Hydrofoil with retracting foils, able to sail on or off the foils equally well, has been with us from the beginning, for the number of days in a season one can "fly" must be limited. Therefore a boat that can sail in light airs, as well as on windy days, is essential.

David Chinery first told me of his idea for a Sailing Flying Hydrofoil in May '69, and offered to finance and design it, if I would convert paper into timber. This I agreed to do, and *MANTIS I* was launched 8 weeks later.

Basically the craft is a monohull fitted with a cross beam with floats at each end; and foils fitted under each side, a foil at the front, and rear steering.

Originally the craft was designed to suit a DN ice yacht rig with front steering, but this was discarded early on, as front steering as a displacement boat did not work. As it got heavier with all the numerous modifications arrived by trial and error, it now has a Unicorn rig, 26 ft mast with 150 sq ft of sail.

Constructed in marine ply and parana pine in my back garden, it took 80 hours to construct and launch, and a further 170 hours work on mods. to get it to come about and "fly". The craft has only visited the water 15 times. The rear foils were made of Japanese oak originally, 9 in wide, thickness to chord ratio 9 : 1. This has all been planed away now leaving 1 in Marine ply which was added to the underside as the foil was modified. The foil width now is 18 in × 6 in long, thickness to chord ratio 13 : 1, top section a true arc. Launching presents no problem for with the foils retracted it slips easily from a launching trolley, or can be assembled at the waters edge.

Sailing without the foils as a normal desplacement boat, it behaves fairly well. Going about is slow but sure. When the wind tends to bury the lee float it is possible to lower the foil and sail "foil-stabilized", when the performance is a great deal better. To go about, we retract the foil and go about in the normal way. With all foils down, going about is impossible for when the craft comes head to wind it stays there, drifting backwards helplessly. With the front foil retracted I have coaxed it round a couple of times with great difficulty. Steering with all foils down could be better, but I think a weathercocking front foil would help this.

Up she comes—*MANTIS*

When sailing a Hydrofoil, one needs several pairs of hands, especially on preparing to go about when the foils are down. Whilst maintaining course, one must retract the front foil, let go one halyard on the windward foil and haul it up with the other halyard. Reach across to lee and do the same. Come about and reverse the process. In a high wind this is exciting. It is impossible to lower the rear foils while moving forward, as the upward pressure is too great to overcome. Procedure would seem to be thus: sail to deep water off the foils, come head to wind, lower rear foils, head off and lower front foil.

By its 13th outing it was beginning to become a family joke, each time we arrived back from a day's sailing they asked "Did it fly today" only to be told "No, but it will when we've done this and that to it". So we were delighted to have some success this time and be able to reply "Yes it did".

I was at the helm on this occasion, trying to "will" it up. The wind was very gusty. It needed coaxing along to get enough speed, for to sheet in hard merely buried the beam on the lee side in a gust and put the brakes on. The wind increased a little, I eased the sheet; then gradually sheeted in. The speed increased. All at once *MANTIS* lifted; just like going up in a lift, sweetly and cleanly. I sheeted in harder, and as the wind dropped back, down she came. This happened several times, the wind dying just when needed. This is the problem of sailing on a lake. The lifting out process is immediate. Once enough lift is generated, out she comes. The front foil rises first, then with a great surge one is airborne. It's a great feeling to be sitting practically on the water one minute, and riding about three feet above it the next. Once "Flying" there is a marked increase in speed, and as the apparent wind moves forward, one sheets in harder. The lee foil is nearly all immersed, whilst riding just on the tip of the other, due to heel. I fitted two seats just behind the beam to get the weight as far back as possible for "flying". This was quite successful in helping to lift the bow.

I have just started work on the *MANTIS Mark II*, a much more sophisticated shapely looking craft, and I hope a much improved performer. David and myself will bring this boat to the next Weir Wood meeting in October.

PETER G. CHINERY.

MANTIS

by David Chinery August 1970

The Cop, Buckland, Betchworth, Surrey

When I look at *MANTIS*—fully rigged, lying on my lawn, it seems absolutely incredible that this machine can actually raise herself from the water like some monster swan, taking off and glide across the surface supported only on three sticks of wood—each shaped with a simple aerofoil section, curved on top, flat underneath. Yet this is the power of a foil.

The boat, fully rigged, without the crew weighs some 350 lbs and when lying at rest in the water the total immersed area of foil is about 20 sq ft—16 sq ft for the two rear foils and 4 sq ft for the front. The rear foils are 6 ft long × 18 in wide. The aspect ratio is 13 : 1 at 0° incidence. The front foil assembly comprises 4 separate foils each 1 sq ft. They are hinged to one another and when retracted lie flush in a special dagger plate box mounted in the bow of the boat.

Flying, the boat rides on two square feet at the front and just the tips of the rear foils, say 4 sq ft in total, but this varies according to heel. The angle of attack of the front foil is variable. It can be as little as 5° for a slower lift-off but 8° is safer in that it rides the waves better, and, should the nose become slightly depressed, has more immediate lift to get it up again. The penalty for this, of course, is increased drag, hence a lower potential top speed. In

MANTIS flying

ideal glassy conditions a 5° attack would be suitable and would give us a very good lift drag ratio but has lower recovery characteristics, obviously.

The boat balances just in front of the rear foils, and the crew can balance the boat by moving his weight backwards and forwards from this point. As the rear foils take all the weight of the craft it means that when "flying" they become like a pivot point of a see-saw. The front foil assembly lifts very little of the boat's weight, but rather "feels" the water and guides the main foils angle of attack. If the nose is depressed the rear follows suit due to a negative angle of attack and vice versa, also the front foil counteracts the forward thrust of the sail.

When flying, the boat assumes an angle of heel of about 8° which means the lee foil is fairly deeply immersed—providing great lift whilst the weather foil, barely in the water, just provides the necessary amount of righting movement.

The sheer beauty of 45° angled foils is that the more the boat heels—the more lift the lee foil generates because it becomes more horizontal to the water's surface. At the same time the weather foil assumes a more vertical attitude to the water's surface and loses lift. This simple geometric configuration adjusts automatically to increasing or decreasing side pressures from the wind, and requires NO help from the helmsman who has enough on his hands anyway trying to steer.

Once foil borne, the acceleration of the craft is tremendous, yet Peter, my cousin, the only man to have flown the craft so far, is not all that aware of this acceleration. It was the cine camera that demonstrated this point to us. I was filming from an attending motor boat and got some good shots of the boat gradually lifting out of the water and once foil borne it shot away at a remarkable pace—it must have doubled its speed in as many yards. I would not predict how fast *MANTIS* could fly but I am convinced that breaking the 30 knots barrier is going to be relatively simple. The problems will come when we start doing 40 or 50 knots when cavitation might become a problem—especially with surface-piercing foils. But we must wait and see.

A simple demonstration of the power of water on a curved surface is to hold an ordinary kitchen spoon very gently between your thumb and first finger at the extreme end of the handle, so that the spoon sways like a pendulum. Then turn on the cold water tap and gently offer the curved bowl of the spoon to the water flow. Immediately the vertical flow of water touches the middle a force comes into action and sends the spoon deeper into the water

It is possible to capsize *MANTIS*

stream. Now, by slowly moving your hand away from the water flow you will find the bowl of the spoon will still cling to the water and the harder the tap is turned on the more the spoon will stick. It was this simple phenomenon that encouraged me to design hydrofoils—especially after reading so much about them through the AYRS.

Checking through my records I discovered that a year ago I first put the design of *MANTIS* on paper and three weeks later Peter Chinery started to build it. We obviously learnt a lot during the following 12 months and sometimes our brains ached with thinking of new ideas and trying to solve problems. Designing flying hydrofoils is rather like what cynics have been heard to say about drugs—produce a drug to cure some ailment or other and then produce another drug to cure the side effects of the first and so on. Our main problem was not getting the boat to fly—that was simple, but rather to get the boat to behave itself when not on the foils. The plan shows the craft in its final state but this can be improved upon by making the hull longer, at the front to increase buoyancy and at the rear to obtain a better leverage with the rudder.

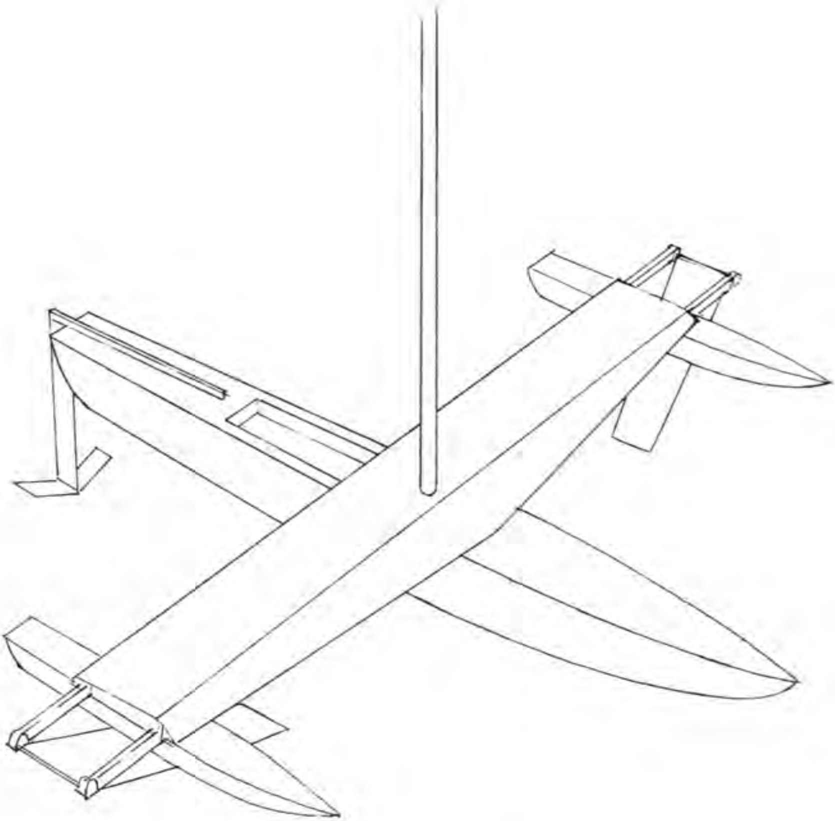
I think we must have moved the dagger box backwards and forwards in the hull about 5 times and the mast backwards and forwards another 10. If we moved it too far forward we could get the boat to come about beautifully as a displacement boat but got too much pressure at the nose whilst trying to fly. Now, at least, it works in both modes and we can improve its characteristics as a displacement craft. In fact, *MANTIS MARK II* is under construction now. When Peter and I were messing about at Weir Wood, people were heard to sympathetically cluck their tongues with a sort of sad amazement—they think we are mad so it's good to have the AYRS close by for support and encouragement.

There's one question that bothers me! When I met John Morwood on the AYRS Stand at the last Boat Show he asked me "What speed do you want to get out of water?" and I replied looking somewhat amazed, "Obviously one wants to get out as quickly as possible." He then asked "Why?" His simple pertinent question set me thinking along completely different lines and, if my thinking is right, *MANTIS MARK II* is already obsolete and what a depressing thought that is. It seems to me that there are two basic foil methods—I don't mean configurations, rather concepts:

a Very large foil areas

b Very small foil areas.

Assuming that there are two identical craft—one fitted with (a) and one with (b). Now, if the craft's foils are immersed and set at the same bearing at precisely the same time: (a) has got a tremendous amount of drag and will be a slow starter but will have a very early lift out (approximately walking speed)—*MANTIS* has lifted out whilst a Mirror dinghy has been overtaking it yet once up on the foils the acceleration is very rapid. (b) has much less drag and therefore will get away much faster than boat (a) but it still means that this craft has to drag its foils through the water up to speeds of 10, 12 or 15 knots before the foils become effective and generate enough lift-off to fly the hull, by which time, theoretically, boat (a) has now been flying much,



MANTIS mark *II*

much longer and, though having a much slower start, is accelerating fast and has, therefore, overtaken boat (b). If one agrees with this premise, it means that the whole concept of flying hydrofoils could change.

We could build a much more stable hull, do away with those vulnerable outriggers and, heigh presto, a non-capsizable boat. The section through the hull will be a sort of flat egg shape with a small retractable bulb keel which winds up like that on the *TEMPEST*. The two rear foils would retract upwards and the geometry would be similar to that of a mechanical road excavator. The front foil will be similar to *MANTIS* but capable of steering and retractable. Now, we add a nice wing sail fully battened, which upon releasing a halyard would collapse into a slit on the top of the hull and give us automatic reefing. Now, we have produced a boat that could very well win the OSTAR.

The crew would sit under a nice aeroplane hatch cockpit cover which could be opened for ventilation, or have some arrangement of venetian blinds to stop the sun, and the sides of the boat could lift down for fine weather sailing or whilst in port—rather like the front of a troop transporter. But it seems to me that safely inside the machine, no matter what the wind conditions, with all the foils retracted upwards and forwards and the little bulb keel lowered, it would right itself from any position automatically without the aid of a crew. Whilst I love the idea of trimarans, somehow the idea of sailing in one terrifies me, but then I am just a coward and must confess that I have never been to sea before anyway.

CHAPTER XVIII

A FLYING HYDROFOIL CRAFT

Designed, Built and Owned by Joe Hood August 1970

11 Deeds Grove, High Wycombe, Bucks, England.

Hull length, overall	16 ft	Cross plank beam	8 ft
Hull length, LWL	15 ft 3 in	Total weight (including crew)	250 lbs
Main Hull beam	18 in	Sail area (DN rig)	6·5 sq metres (65 sq ft)

Main foils retract under plank. Front foil retracts (pivoted) to clear the keel, thus letting the craft run ashore under sail.

This boat has been designed on independant lines from other hydrofoils, being based on land yachts. Joe Hood is a member of Great Gransden Land Yacht Club and he was inspired by the article by Edmond Bruce in Chapter X, (page 121.)

ABOVE: Joe Hood's DN land yacht on water receives a helping hand from a rescue boat. The wings dragged in the water and the bow foil steering broke.

The main aims of the project are:

1 To produce a sailing, flying hydrofoil with a top speed of at least twice the true windspeed and able to be sailed in strong winds, single-handed.
2 To be carried on a car top roof rack.
3 By substituting wheels, to use the craft as a land/sand yacht.

The craft uses the D.N. Class mast, boom and sail.

The construction is mostly in 3 mm birch plywood. The hull is stressed plywood construction, as is the front foil. High stress points are re-inforced with resin and carbon filaments.

After making the first cross plank of 8 ft in length, another cross plank of 16 ft in length was made to give complete "balancing out", if the 8 ft one was found to be too short for easy handling.

The hull weight came out at 30 lbs but was later filled completely with a mixture of expanded polystyrene chipping and a compatible foam in situ mix, increasing the weight by about another 10 lbs.

The foils

The general configuration is that of Don Nigg, with two main surface-piercing side foils and forward steering. The two main foils are similar to those of Don Nigg or James Grogono.

The forward foil is a semicircular shape, attached to a horizontal elliptical cross beam pivoting at the stem. It is made from plywood, reinforced with carbon fibre and resin.

Burnham on Crouch

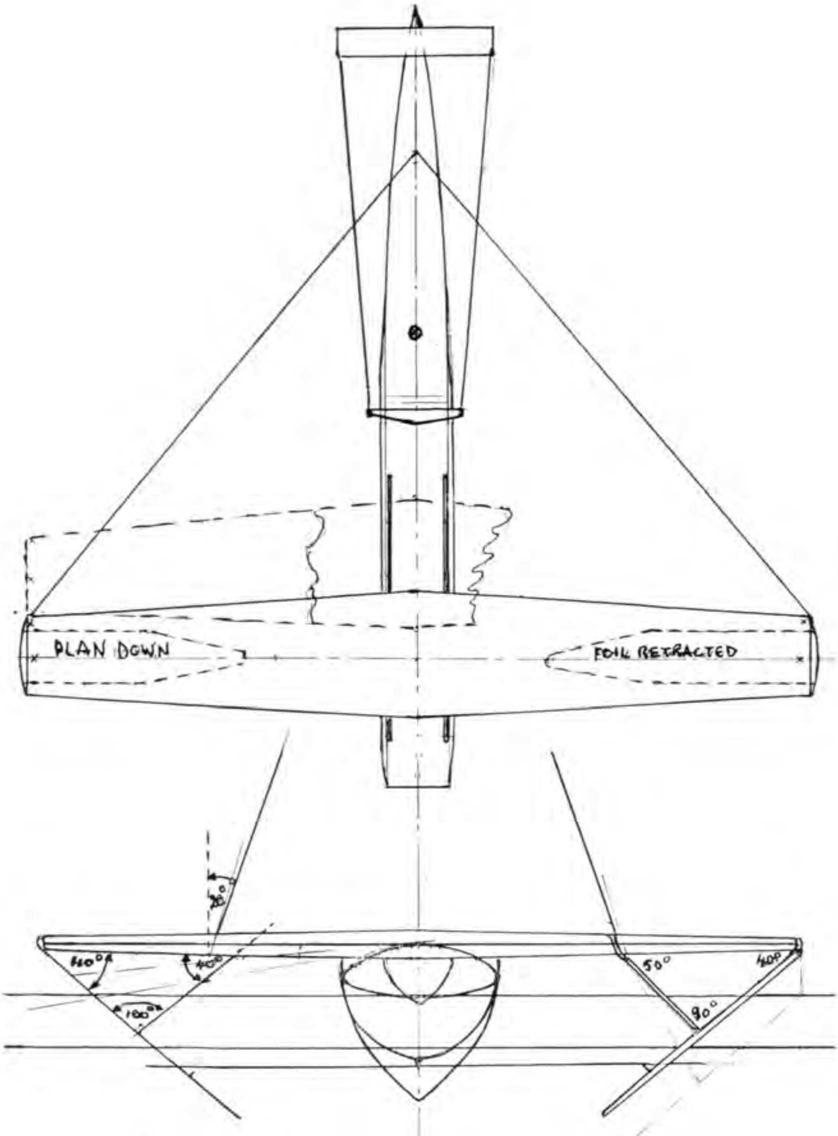
When Joe brought his boat to the AYRS sailing meeting, we were all very much impressed with the loving care and attention to detail. It really was a beautiful job. Unfortunately, the hull was a bit lacking in buoyancy and dragged its transom so that speeds for take-off were only achieved once. Also the forward foil system had the opposite of castor action and steering became difficult. However, the boat sailed well enough as a displacement craft and a limited success was achieved at that stage.

Joe Hood writes:—

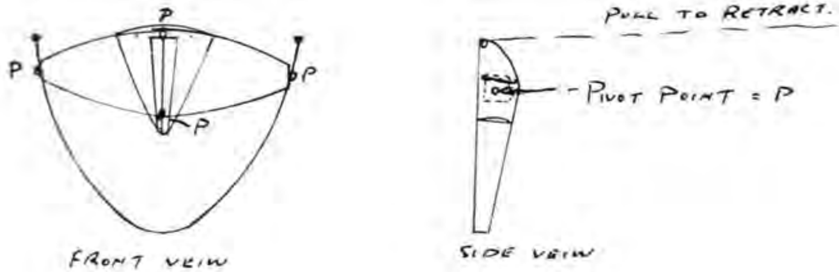
It was of course not intended to attempt to fly the craft at all the first time out, as the crowded moorings at Burnham, together with the fact that the craft was not insured, and with a complete lack of experience in sailing on foils would have made any deliberate attempt to fly foolhardy, to say the least.

When an unexpected puff of wind arrived the craft came unstuck very quickly, and there did not seem to be any transition from displacement to planing, to foil-borne. It was more of a missile launch so to speak.

This was when the steering trouble developed, and as the craft was heading straight for a very solid moored cruiser, things got pretty hectic for a few seconds. Fortunately, the temporary steering lines and tiller attachment stretched sufficiently to take away steering control completely and the craft headed into wind and stopped before any harm was done.



MOSQUITO CLASS



STEERING FOIL

This particular craft in common, it would seem, with other sailing flying foils, was very prone to get into irons, unless a fair speed was built up first. Worse still, she would not boxhaul, and was none too easy to gybe around. Subsequent study of a movie taken from the shore showed clearly that:—

1 There was insufficient rudder (foil) area to provide adequate control at slow speed. There is of course high drag from the outer main foil when tacking (one tends to pivot on the inward foil).
2 The hull is dragged sideways through the water when turning and a deep narrow hull (as was used) naturally resists lateral motion. This latter fact is important if full control is to be achieved at displacement speeds.
3 The cross-plank beam of 16 ft increases the drag moment when turning. This length of plank is not strictly necessary to provide heeling stability. The DN sail is of low aspect ratio, and the centre of effort is probably no more than 6 ft high. A cross-plank of about 12 ft would be sufficient to provide full automatic heeling stability. In any case crew weight in the correct place can compensate for any lack of beam of plank. It would be more correct also to call the cross-plank a wing, for in this particular craft it was designed to produce aerodynamic lift of about 150 lb at a speed of 30 mph.

As Major General Parham pointed out in an AYRS article, use can be made of "ground effect". Lifts of 5 to 6 pounds per square foot can be expected at speeds of 30 mph. The particular wing used had an area of about 30 ft^2. It was set at a positive angle of incidence so as to provide not only aerodynamic lift but also to act in a similar manner to Don Niggs' horizontal foil strut, and prevent the wing tip digging in the water to produce a cartwheel capsize. In an effort to produce buoyancy, the thickness of chord at wing-tip was 4 in, and in practice the high-drag tended to cancel out any benefit of static buoyancy. True, in Don's craft he could walk out to the ends of his cross-plank, but does one need to?

These then are some of the reasons for redesigning some parts of this particular craft. A new wing of 12 ft beam (span) has been constructed, and a new front foil system and hull is being made with a view to solving some of the problems outlined.

A pivoting plank is to be used as an aid to sitting (hiking) out, and the main foils are now knock up, (in a similar manner to a dinghy centreboard). They still can be retracted when sailing, and also the front foil pivots up and forward to retract for easy beaching.

I give many thanks to the enthusiastic AYRS supporters at the Burnham meeting; to Capt Cockburn, and the lads from Liverpool who lost a night's sleep to motor down and then spent all day helping to screw various bits on my craft; even more, supplying cans of liquid refreshment when I would not stop for lunch.

James Grog who, very busy with his own foiled Tornado, nevertheless found time to take us out on his cruiser on the Sunday to watch with interest the time/speed trials. I got some interesting movie film of *SULU, ICARUS,* and *MANTIS* performing.

SUNBIRD I½

(Inverted T stabilisers)

by Chris Rowe

28 Rowhedge Road, Colchester, Essex, England

This hydrofoil boat, though obviously triggered off by some AYRS ideas, is the only one of its kind. An alloy tube is fitted across a single *SHARK* catamaran hull and inside this tube, a tube 8 feet long is placed and it is able to turn inside the shorter tube.

At both ends of the long tube, struts lead down to the water and inverted T foils, whose angle of attack is controlled by turning the inside tube. This is done by block and tackle to another tube which spans the tube attached to the boat and is connected to the long tube by cranks.

Chris Rowe's inverted T stabilizers and cross beam

At rest, the foils' centres are at the LWL and the lee one immerses on heeling and keeps the boat upright. As made for this prototype, the foils were on the thick side and had quite a lot of buoyancy. Each has 3½ sq ft of area and is set at an angle of dihedral of 30°.

The sail area is 90 sq ft and a centreboard is used to prevent leeway.

The first sail took place at the AYRS hydrofoil meeting at Burnham-on-Crouch. In order to prevent a capsize, inflatable buoyancy was used at the ends of the cross beam but the boat was so stable that at no time was the lee foil seen to be driven under by the wind pressure. Obviously, the wind force was being completely "balanced out" by the foils and the difficulty was in too much stability.

Chris Rowe says that the main problem was with the rear steering. He is now building a lighter hull with front steering, using the same foils with more immersion.

There is a possibility that the surface-piercing foils used by most AYRS members have severe losses which would be avoided by inverted T foils. There is thus every chance that Chris has a hydrofoil configuration which may prove, eventually, to be the best possible and we look forward to seeing him again at Weir Wood with his most fascinating craft.

A FOIL STABILIZED HORNET

by Bren Ives and John Potts

7, High Street, Borough Green, Kent

LOA	16 ft	Total beam	13 ft 9 in
Beam (hull)	4 ft 3 in	Sail area	120 sq ft

GOLDCREST, an early Hornet, had two holes in her when I bought her. Otherwise she was sound—and complete with standard Hornet sails—jib and mainsail. This gave me a narrow beam dinghy with 120 sq ft of sail. Never having sailed anything nearer to a Hornet than a Wayfarer, I thought she should be a good craft to test foil stabilization—without using the plank. I was primarily interested in surface piercing foils without floats.

It was largely due to the advice of John Morwood and encouragement of his friend Gerald Holtom that I was persuaded to start. John sent me advice as to the type of foil to use and gave me the chord and proportions to try. He also invited me, together with my friend John Potts, to see a demonstration of Gerald's model yacht. This was fitted with two foils. One was a High Aspect Ratio foil and the other a Low Aspect Ratio foil. Before being fitted with them it had constantly capsized. With either foil it sailed almost upright across the pond.

Gerald was enthused over my idea to try and make full size foils for the Hornet. His enthusiasm and John Morwood's advice persuaded us to try to repair the boat and fit her with foils in time for the AYRS Hydrofoil Meeting at Burnham, at the end of May. As it was Cup Final Day, we had a bare six weeks. John Potts did most of the foil construction. We drew the plan on his garage floor the next morning, and decided on ply construction filled with polystyrene foam. Meanwhile, I persuaded the local blacksmith to weld us a framework to span the boat incorporating a small amount of toe in. Also he made us some steel pipe clamps and a couple of tubular members to raise and lower the foils, and to lock them in position.

We aimed to set the foils at 55° approximately, so that when the boat heeled flat on its bottom, the angle would not come below 45°. We realized that steel pipe was not really suitable for our purpose, but it was cheap. It is much too heavy and we hope to reduce the weight considerably in later versions. Having no idea of the maths involved, I could not even guess at the stresses, but after listening to various suggestions of box girders, and even a 9 ft × 9 in piece of timber, we settled for 1 in pipe. I hope it lasts the season!

A foil and pipe framework

You must appreciate that the foils and their supporting framework and supports were independent of the dinghy. We had minor problems fixing this down to the boat. The framework fitted across either side of the sliding plank—and incidentally prevented us from using the plank even if we had wanted to. This was a measure of our confidence in AYRS ideas! The foils were finished at 2 a.m., exactly four weeks after meeting John Morwood and Gerald Holtom at Hythe.

The following day we took the boat to Eastbourne and, with a bit of friendly help from the members of the Royal Soverign Club, manoeuvred her down to the beach. It took quite a while to fix the framework to the boat with our first method—No. 10 woodscrews and bits of odd wood! The wind was off shore—so we pushed off and drifted down wind with the foils retracted until there was enough depth. Then we got our first shock. John could not move the leeward foil down. He sweated for a minute or two and then gave up. The water pressure was too great. Eventually—still going down wind we realized the answer. I luffed up and they then went down quite easily.

The breeze was almost force 4 gusting to 5. Immediately both foils were down, we hardened the sheets—and she sailed off with negligible heel. She tacked beautifully and the maximum heel we could develop was with the top of the leeward foil just submerged. When you realize that the foils are pivoted 6 in below the framework which spans the gunwales—and when you further realise our total beam was 14 ft—we were not heeling as much as we had expected to. The steering was light with slight weather helm. Subsequently at Burnham we tried lifting the windward foil. This I imagine improved her speed slightly, but gave us the penalty of lee helm. The centreboard made no difference.

The Hornet readily came on to a plane in the gusts and remained just as stable as before. We tried to offset the heeling by sitting out to *leeward* at

Bren Ives and John Potts sitting to leeward

Burnham—and it made no difference. However, the wind was not as strong as on our first test. John Potts even used his toe straps to hang out to leeward, with no effect.

Our thanks to all the people who have encouraged us and shown interest. Not a few were completely uninterested in stability. It seems to us that stability is the first requirement before the quest for speed begins. I am convinced that the method described would enable a racing dinghy to be cruised with safety. Correspondence would be welcome—particularly any practical suggestions on making a lighter framework that will not be too expensive.

LEARNING TO SAIL A HYDROFOIL

by Captain J. C. Cockburn, D.S.C., R.N. (Ret.)

St. Helens, Isle of Wight, Hampshire, England

Fascinated by a picture of Don Nigg doing 20 knots in his *FLYING TRAPEZE* which appeared in the *AYRS journal No. 66A* (shown in Chapter XIV), I bought the design, and built an exactly similar boat last winter.

The construction of this machine is not difficult, even to a ham-handed sailor like myself. The front rudder and foils, however, which control the performance of the entire system, requires very great accuracy. The main, or rear foils, do not.

The boat was launched in May 1970—no one, incidentally, believing that it would work!

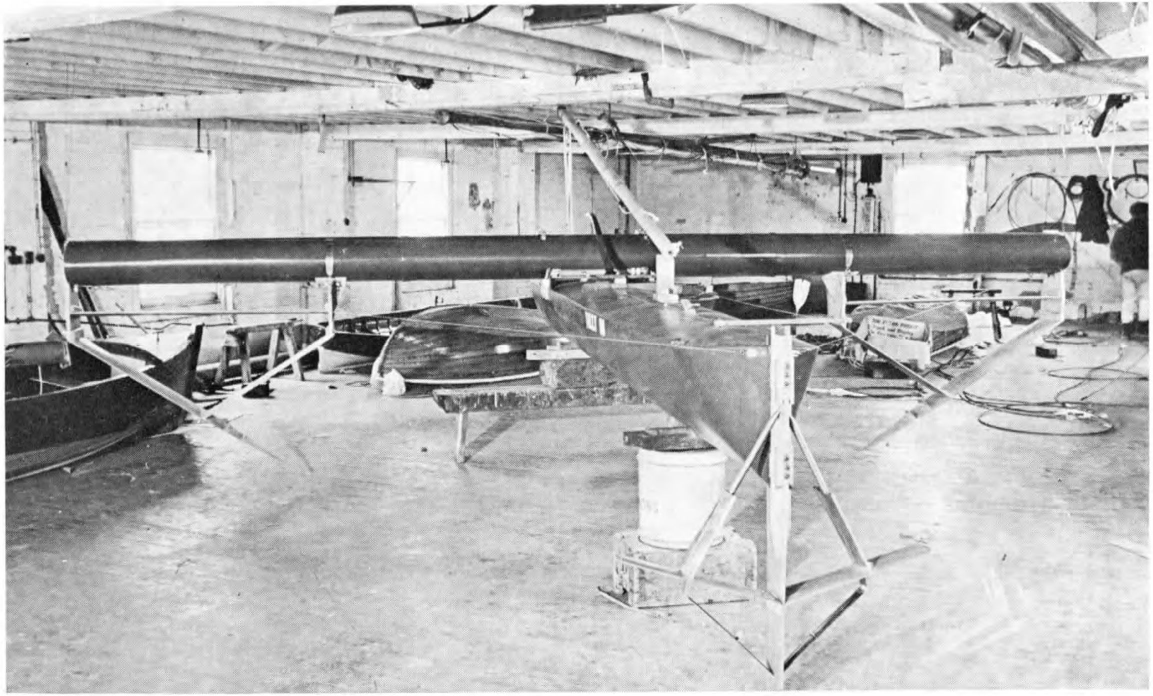
Towing trials were carried out to prove the balance and angle of attack of the foils. To avoid disturbance from the wake of the launch, it is better to push with an outboard powered inflatable. These "push trials" resulted exactly as the designer, Don Nigg, had predicted, namely that at about 5 knots the boat starts to lift out, nose first, followed shortly by a complete lift out.

Now, unless you have a power boat always in attendance, you will spend far more time off the foils, looking for wind, than you do flying. You have to live with the first to enjoy the second.

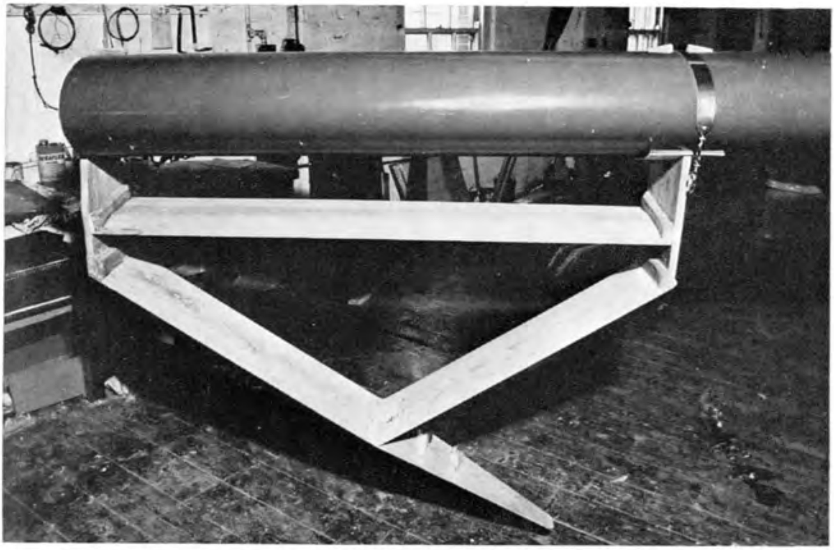
The boat will not come about at "taxi" speeds, owing to foil-drag, and must be either gybed round or boxhauled. Gybing is less sweat, but in either case you lose some ground laboriously gained to windward.

I found out quite early that, in winds when a "lift-out" was possible and at taxi speed, i.e. making to windward off the foils, the end of the beam dug in so far that the boat would come to an embarrassing halt. To cure this, I have added an inflated car inner tube to each end of the beam. With this additional buoyancy, and by sitting astride the beam well out (the seat is only for flying), I can now operate in much higher winds, and get back to my mooring.

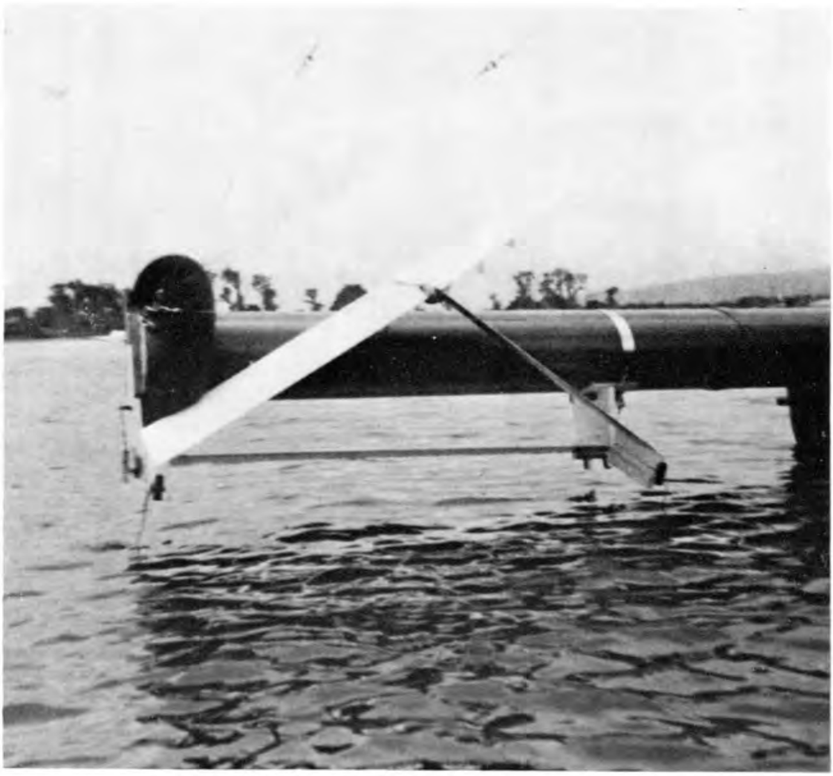
Another early snag was the fitting of the rear foils. These are of oak and very heavy (surely there must be a lighter material?). Carrying them down the beach, rowing them off against the wind in a rubber dinghy, struggling in the waves to button them on, and, later, the whole thing in reverse, took all the fun out of the game. I have now hinged them on the leading edge,



Captain Cockburn's Don Nigg boat, just finished



Captain Cockburn's main foil and cross beam



Foil retraction and wing tip buoyancy

below the Safety Foil, so that they retract forwards and upwards into the triangle formed by the hull and the beam, where they are protected by the stem to beam-end stay. (Will they warp? I don't know). Some small accuracy in angle of attack may have been lost by doing this, but at the speeds achieved so far it does not appear to have made any difference.

You soon get the knack of sailing at taxi speeds, but you must become really proficient in this role before you attempt to fly the boat.

There are no "Handling Instructions", no "Pilot's Notes" to tell you how to set about flying this machine. Like the Wright Brothers, you can only advance as you learn.

Now, much loving care and time goes into building a craft like this one, and it would be a great pity to break it up, or hit someone else's boat, through ignorance or bravado. I therefore recommend a "Softly, Softly, catchee monkey" approach to flying, with attempts on successful short flights in the lower wind bracket.

First you discover the best conditions for lift out. This appears to be a reach with the sail well off. You steam up and down waiting for the wind, gybing round at each end. Wind comes and the bow lifts out onto the small lower Vee foil. Hold everything, and a good puff comes. The sail takes hold, and the whole boat leaps forward as the tail end comes out. Once up, the speed is such that you will run quite a way up on the foils even after the puff has left you. Once on the foils, the ride is extremely smooth and silent. There is great stability and, so far, no inclination to bury the lee foil. The steering becomes finger light, and it is very easy to over-control and zig-zag.

When clear of the water, you can haul in the sheet, and, although it is early to say so, I think she will make to windward.

When building, I thought that Nigg's design was too "engineered", and unnecessarily strong and heavy. Now, having flown quite a lot of times for short distances, I realize that I was entirely wrong (Grogono take note!).

The stresses on the craft are enormous. Not the "Drag" stresses for, with a lift/drag ratio of 30 : 1, these are comparatively small. It's the "Lift" stresses on the main foils, which carry nearly all the weight of the boat and driver, and, in particular the twist stress applied by the front foil system to the hull.

In conclusion, these are very early days in the experiment, and many of my theories may prove to be quite wrong. But, of one thing I am absolutely convinced, namely, that this is a most thrilling and rewarding sport.

A FLYING HYDROFOIL CATAMARAN
by Philip Hansford

53 Sandy Ridge, Chislehurst, Kent

The boat was only launched in August, 1970 and, at the time of writing, only brief trials have been carried out. In the first trials, the wind was strong and the craft lifted out easily. Once on the foils, there was good stability, but it was necessary to move one's weight as far aft as possible to prevent a bow down attitude when broad reaching.

At present, a good breeze is needed to become foil-borne but it is hoped to improve the light wind performance with a more suitable mast and sail.

Construction

The cat has 15 ft hulls, produced by the "tortured ply" method. The cross beams are mast section extrusions. The fore beam carries the main foils

Philip Hansford's flying hydrofoil catamaran which are outboard of the hulls. The rear foils are mounted on inverted pintles and are used for steering.

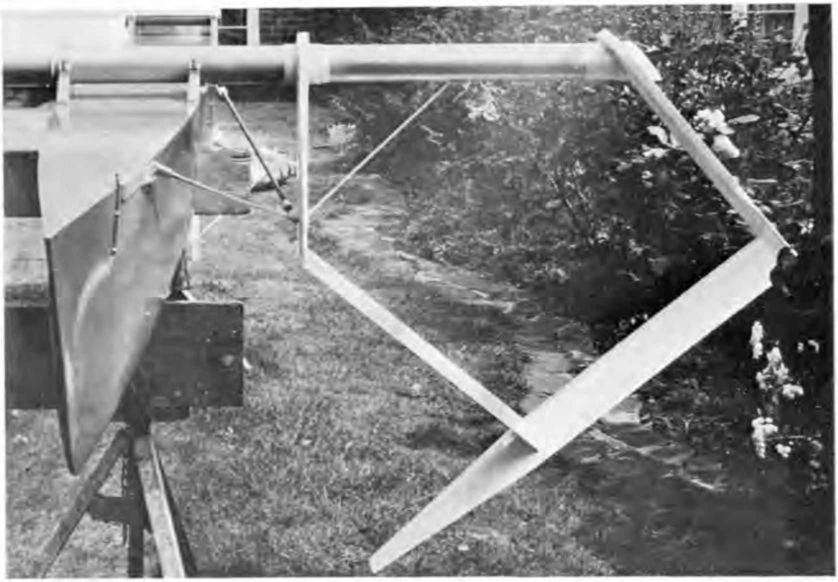
The foils are all of circular arc upper surface with a flat lower side, made of mahogany. The rig is a "Fireball" mainsail, set on a non-standard mast, which is too flexible.

Editorial Comments

This looks like a very light but very workmanlike and rugged boat.

The Main Foils

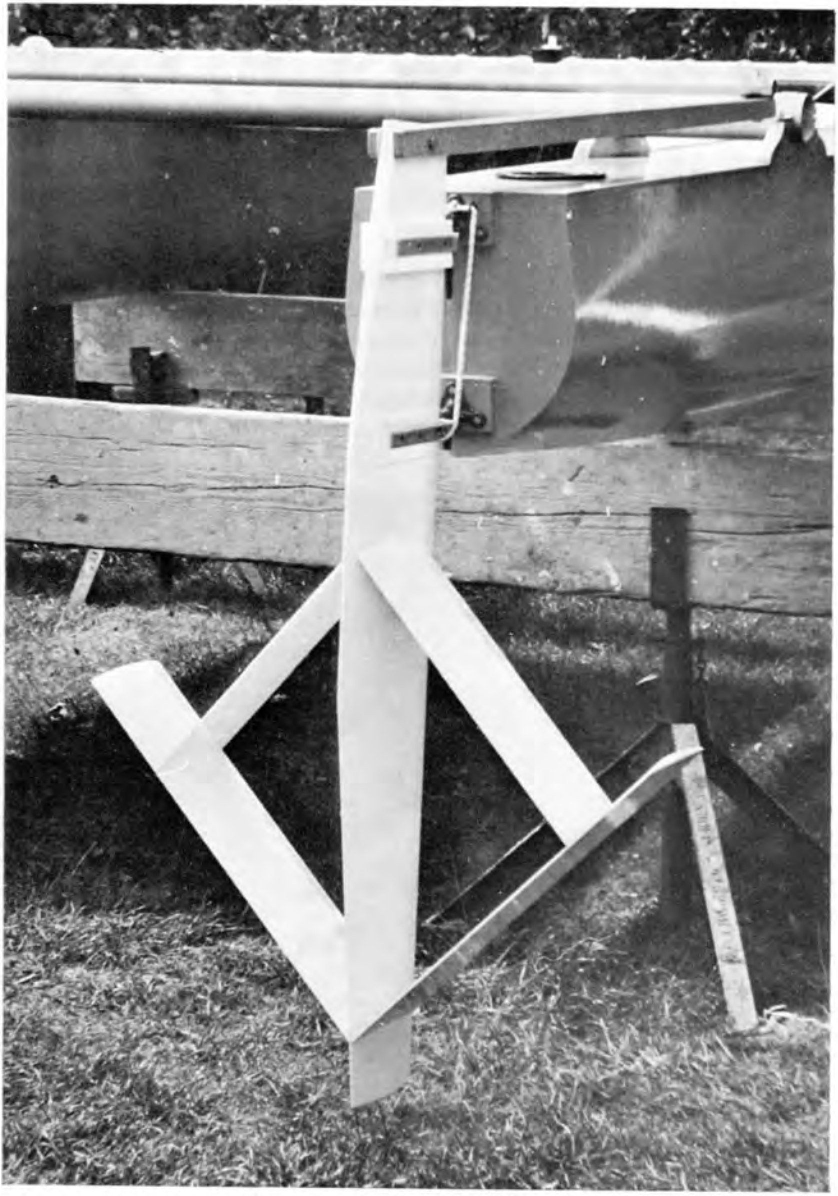
These are set at an angle of dihedral of 40°, as are also the struts. Both are used for lift-off, after which the main load must be taken by the foils. Each foil has an aluminium tube bonded to the upper end of its struts. This slides onto a wooden plug at the end of the main beam, thus transferring the foil lift forces to the beam. A rod led obliquely from near the bow to the inner strut takes the foil drag forces and maintains the set angle of attack.



Philip Hansford's forward foil

The Stern Foils

These are strong-looking and ingenious area-reducing foils which steer the boat on inverted rudder pintles. In my own models of this configuration, I used inverted T foils aft and found they worked well. It would be interesting to see how they would work at full size.



Pnilip Hansford's stern foil (steers)

CHAPTER XIX

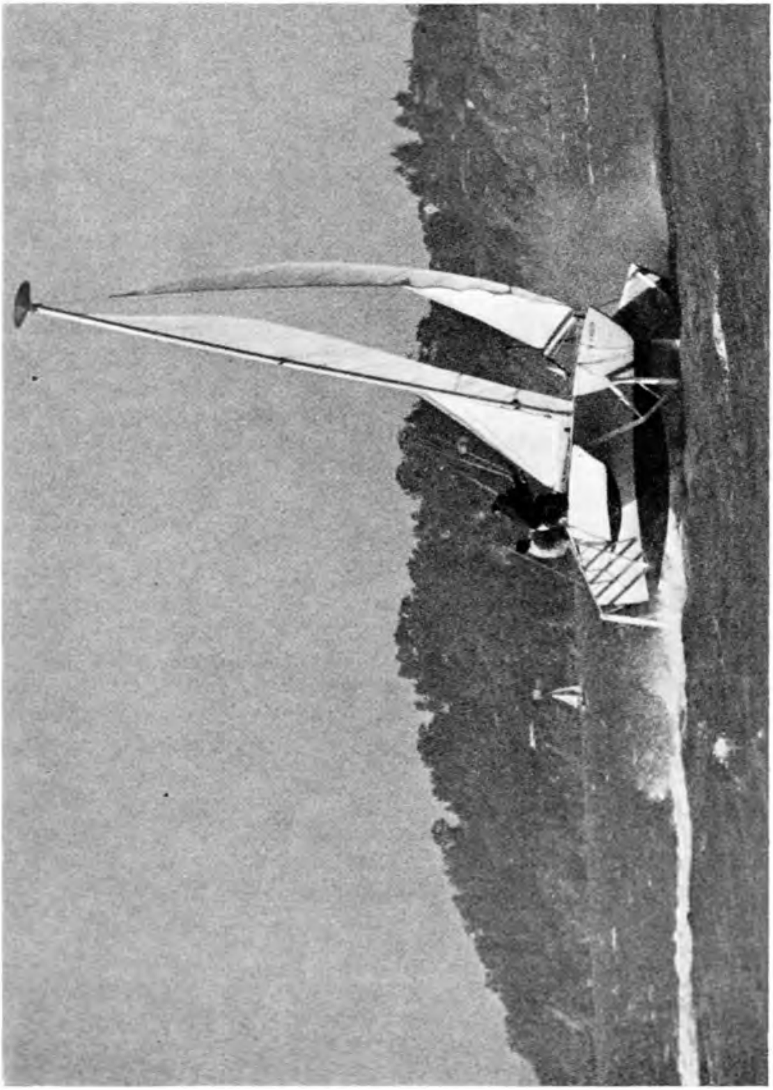
Letters from: Dave Keiper to John Morwood

P.O. Box 71, Sausalito, California, 94965

July 23, 1969

Dear John,

The enclosed photograph shows the present state of *WILLIWAW*. Changes from last year: (1) larger pontoons, (2) a masthead float, (3) a protective coating on the Aluminium foils. In this photograph, *WILLIWAW* is doing 20 knots with five people aboard, plus a couple of hundred pounds of water and food. I've flown the craft with as many as seven, and as few as two,



WILLIWAW

aboard. The wind required for flying (about 12 knots) appears to be fairly independent of load. With a heavy load of people, I increase the lift coefficients on the bow and stern foils and place the people on the windward deck. With two persons aboard, in the cockpit, the craft handles well with reduced bow and stern angles of attack.

A few days ago, we raced a reputedly fast 30 ft trimaran across San Francisco Bay and back. The wind was blowing Force 4 on the beam. They were almost lost to view astern after a short time. We met them again when we were half way back, when they were only about halfway across the Bay.

Last month, we met Eric Tabarly's 65 ft *PEN DUICK IV* trimaran on the Bay. Unfortunately, I had set my foils for a light load, but a whole raft of people showed up to go sailing with me at the last moment. I was unable to get total lift-off in the winds we had. At one point, when the wind picked up to Force 5, we managed to hold even with *PEN DUICK IV*, doing about 16 knots.

A couple of months ago, a friend and I cruised up the coast to Drake's Bay. Winds were mostly light. The best speeds were in close-reaching to beam winds. Downwind, the boat seemed to self-steer, probably because of the tremendous directional stability of the foils. The boat was extremely comfortable at sea. When we came back inside the Golden Gate again, we were struck by Force 7 gusts of wind. The first struck while we were moving about 8 knots with sheets quite close-hauled. The craft began making 20° of leeway, churning the water white, but without heeling. When I turned further off the wind, the craft lifted its nose high and took off like a jet aircraft. We accelerated to about 25 knots inside a couple of boat lengths.

The 31 ft long *WILLIWAW* is about as fast as the average conventional yacht in light airs with its foils set, but begins passing them all in about 8 knots of wind.

DAVE.

August 5, 1969.

Dear John,

I did a "capsize" test by heaving the mast down, using 4 men with a 2 : 1 mechanical advantage on the line. The masthead float was slightly less than halfway in the water at rest. It required about a 75 lb lift to get the boat back upright. Since it would be impossible to lift the masthead in a rough sea without a dinghy, I will figure on lashing the main boom against the rather sturdy rudder gudgeons, and having two crew members climb out on it to lever the craft up.

On the *Mark II* design, I can expect to get the boat to be fully self-righting but I will still use a masthead float to guard against a dynamic situation in which the craft could get thrown upside-down.

DAVE.

August 20, 1969.

Dear John,

Here are a few figures on foil areas, which you request. Floating foil area projected on the water surface is about 18 sq ft. Actual foil area is about

15 per cent greater, because of dihedral. If you want combined foil and strut areas, you will have to tack on an additional 50 per cent. The take-off area, considered with the craft heeling at 8° and the bow lifted 2°, projected onto the water surface, is 12 sq ft. To get actual areas, tack on the same percentage. At high speed, foil area will decrease as the square of the speed, except that all blading within one chord length of the surface will be rather ineffective. My lift coefficients decrease with speed because the bow comes back down to normal trim.

Some more geometry may be of interest: Separation between bow and stern foils is 26 ft. Lateral foil lift is roughly lateral from the sail centre of effort, a distance of 9 ft. The lateral foil is 9 ft aft of the bow foil. I would caution anyone from using these dimensions unless they can get an overall foil lift to drag ratio of at least 13. With lower lift/drag, all spacings should be increased. I've noticed that, if my foils are rough, or I've hooked a lot of grass, that *WILLIWAW* handles poorly. When everything is right, and the wind is non-turbulent, she takes off relatively quietly, like a beautiful bird. In strong turbulent winds, she will labour in taking off, as when you took a ride. Probably, much of the foil vibration results from the non-standard strut sections.

Since *AYRS No.* 58 (Chapter XII), I've gone to more buoyant pontoons. The initial extra stability assists take-off in marginal winds. Essentially, you generate your own wind by close-reaching, which then allows you to surmount the drag hump just below take-off speed. After take-off, you can head further off the wind and still stay up.

The secret of the success of my fixed 4 foil configuration is that it separates the problems of lateral and longitudinal stability. The bow and stern foil combination handles the problems of sail pitching moment and of changes in water incidence due to wave encounter. The leeward lateral foil opposes the sail heeling moment and the leeway force. The windward lateral foil is normally out of the water but, if the bow foil gets negative incidence, it re-enters the water and helps the other foils to prevent the craft from re-entering the water at a steep angle. At high speed, the leeward lateral foil carries much of the craft weight, while the bow and stern foil combination acts like a "sensor" to maintain proper angles on the heavily loaded lateral foil.

DAVE.

October 23, 1969.

Dear John,

I expect to set sail for Hawaii a month from now. If I run into difficulties with the foils, I would head into the Coast. At this point, I can't say how ambitious a cruise I will take. I expect to stay out of areas where gales are frequent, since this prototype yacht is not suitable for an "Ultimate Test"—or perhaps I'm not suitable!

DAVE.

December 17, 1969.

Dear John,

After a series of frustrating delays, I set sail for Hawaii on December 9th. The departure date coincided exactly with the arrival of this winter's first southerly winds and storms. We had light SW winds and lumpy seas as we sailed South along the Coast. Around Half Moon Bay, about 25 miles South, the winds started heading us, making our only possible course WNW. Not wanting to sail to the Aleutians, that centre of storms, and getting a weather forecast of 3 days of southerly winds and rain (southerly winds have now gone on for 8 days), we turned around and headed back. We were now headed North, the South winds picked up and 20 foot combers came in from the West. As the swells lifted us, we caught enough South wind to get foilborne, but it died as we descended into the troughs. Amazingly, the boat held a good downwind course for extended periods of time without assistance from the helmsman. We had also had had self-steering upwind earlier on. All in all, the boat was extremely comfortable, at least considering the mean seas.

I enclose another photograph, this one taken in the feeble Fall winds. *WILLIWAW* is doing about 15 knots, and the true wind didn't get over 10 or 12 knots.

Dave.

Letter from: John Morwood to Dave Keiper

December 23, 1969.

Dear Dave,

What a lovely photograph of your boat. Looking back over your letters, I see that you clearly told me in your letter of August 20th that the weather

WILLIWAW at speed. Note weather foil is out of the water foil came out of the water when flying. Somehow, I had missed this point but now see the devilish cunning of the matter in that the weather foil does not produce a force to leeward, which all other sailing hydrofoils have done to date. Undoubtedly, it is this single feature which must make your configuration the best possible.

It was bad luck about your trip towards Hawaii but I think you did right by coming back.

JOHN.

Letters from: Dave Keiper

Dear John, January 5, 1970.

So now you've caught on to my automatic leeway eliminating mechanism, which has no moving parts. *WILLIWAW's* leeway is usually 5° or less. I expended great effort in figuring that one out, so that I could go out and be a lazy sailor. To get the windward foil out of the water requires an 8° heel on *WILLIWAW*. An 8° heel only costs 2 per cent in sail efficiency. Can I now consider you a convert to the "heeled hydrofoil"? From *AYRS No.* 70, I gather that you are already converted to the "flying hydrofoil".

Next thing you know, I'll be trying to convert you to the idea of high aspect ratio hydrofoils! I've been studying over Edmond Bruce's work published in *AYRS*. I don't question his data at all, but I haven't noticed any data for equivalent speeds of 10 knots or more. It is only above 10 knots that lifting hydrofoils are a benefit to a sailing craft. Certainly, Edmond Bruce's data shows that low aspect ratio vertical foils are optimum as centreboards at low speeds. At these low speeds, a lifting foil is much less efficient than hull buoyancy, so there is no need to erase a small amount of heeling with foils.

The one use for a canted foil at low speed (and it is a very worthwhile one) is to make the craft stand up to strong gusts of wind. My own high aspect ratio foils "stall out" in wind gusts when I'm only moving at a few knots. An aspect ratio 1 : 1 foil laterally would allow the boat to slide sideways in a gust (rather than "Rotate") even when the water flow makes an angle of attack of 45° on the foil. To get efficient lift at high speed in choppy waters requires foils running at a depth of 2 or more chord lengths below the surface. I don't think it is just coincidence that the two most successful flying hydrofoils, *EXOCETUS* (Don Nigg) and *WILLIWAW*, use fairly short chord, high aspect ratio blading.

I've encountered no problems with sternway on my hydrofoils. Putting the boat in irons in a good breeze only results in a couple of knots of sternway —just enough for backing the rudder and getting out of it handily. In similar situations, *NIMBLE No.* 1's backwards speed got to 4 or 5 knots, and I once broke the rudder off this way.

I have just designed a 18 ft pocket cruiser which can be built as a trimaran with foil stabilizer fins. But, with a set of Aluminium hydrofoils added (Price $550) it becomes a flying hydrofoil trimaran. It will be a solo cruiser, a weekend cruiser for two, or a family daysailer. Foils will be retractable for sailing in light airs. Price of plans $20 (Available from Dave Keiper, P.O. Box 71, Sausalito, California 94965, U.S.A.).

DAVE.

Dear John, May 18, 1970.

I wish I could be at your flying sailing hydrofoil meeting at Burnham on Crouch this month. Hopefully, I'll be on my way to Hawaii about then. Now that the storm season is over, I've got all kinds of crew members applying.

WILLIWAW has been loaded with food and water supplies all winter long. Quite a few times, I've been sailing with no crew members on the windward deck, and the boat has done well. One time, beating to windward slowly, I got laid over to a 70° heel, but she came back as I eased the sheets. This was in near gale gusts, some of the turbulent Spring winds. With the mast-head float up top, I don't much worry.

You may hear from me next in Hawaii.

DAVE.

Sausalito, June 17, 1970.

Dear John,

As it turned out, I had a 500 mile "shake-down" cruise in *WILLIWAW*, instead of a trip to Hawaii. In the first 24 hours, we made 175 miles SSW. Then we headed East to Morro Bay, and tacked back and forth to windward up the coast, anchoring at Pt. Piedras Blancas, Santa Cruz, and Half Moon Bay. Very rough conditions on the first day out led only to a strong desire for the nearest snug harbour to leeward.

We had a few problems, but not with the hydrofoils. The worst was the forward ventilator. It is supposed to let in some air and keep rain and spray out. I never noticed air coming in, and it does keep fine spray out, but it collected heavy spray. When closed, it dribbled in previously collected spray. When open, it let it in more quickly. I got a bit seasick, pumping it out below. The chronometer fell into one of the puddles and later stopped.

I made the mistake of not setting the windward lateral foil on the first day, since we would be on the same tack for four days. This was an unsuccessful experiment, for on beam reaches in the rough stuff, the windward lateral foil serves a very useful purpose (I later found out) in that it lifts up the windward side when an angry wave comes in to break on the side. Not having this foil set, we took a lot of heavy spray on board, and had a couple of frames popped out of place by breakers. It was very worthwhile to find out that a couple of my frames were vulnerable, and that the windward foil does serve a good purpose.

THE FIRST 24 HOURS. We tacked for a couple of hours to get out of the Golden Gate with light headwinds. We then met WSW winds, which later picked up in the gusts to 25 to 30 knots, with steep, often confused, breaking seas. We took the wind on the beam, and later more aft as conditions worsened. We reefed the mainsail at 2 p.m. For 10 hours, we averaged better than 10 knots. We were flying occasionally at 18 knots to 20 knots across lumpy sea platforms, but wallowed a bit too long in the troughs, trying to take off. (I later discovered that my bottom was not smooth, which, along with the heavy load, would explain take-off difficulties.)

At dusk, we dropped the mainsail completely, and got the boat self-steering at reduced speed. Through the night, we checked occasionally for freighter traffic. At times, I think it must have been blowing a gale. About dawn, we were awakened by clattering pots and dishes. *WILLIWAW* was laid over to an 80° heel by a monstrous wave. I hung from my bunk with hands and feet. She restored herself quickly as we heard the thunder of the wave breaking . . . We covered as many miles that day as I ever did in *NIMBLE I*, yet on *WILLIWAW*, I was carrying much less sail area, and had the boat self-steering for 12 of those hours. We could have done better with moderate conditions. Only a huge heavy yacht would have done better than *WILLIWAW* in comfort.

THE SECOND DAY. Heading East, we saw the jib leech rip out, which we repaired. Some of the foil fastening bolts loosened up but I cured the problem later by installing washers. On the bow foil, some Aluminium shear bolts failed from fatigue, and we were treated to the spine-chilling experience of having the bow foil forcefully retract while we were doing 20 knots. My crew member witnessed it, but I was down below and didn't realize what had happened, since *WILLIWAW* only nosed down a few degrees and re-entered the water like a decorous lady.

At the moment, I'm redesigning the foil hardware for easier handling and better fastening. Of course, on this prototype, I couldn't spend much time with such matters, it being most important to test the overall configuration and basic structures. I'm very satisfied with my foil configuration, and we didn't suffer any sort of cracks in the welds of the Aluminium foils, in spite of the heavy conditions. Most of the time, we were self-steering, and doing it without vane gear.

DAVE.

Letter from: John Morwood

June 24, 1970.

Dear Dave,

You certainly had a very interesting cruise, and it is nice to know that *WILLIWAW* is so seaworthy.

I do wonder if the expense and multiplicity of your hydrofoils could be avoided by some simplification.

John.

Letter from Dave Keiper

Dear John,

July 11, 1970.

I put *WILLIWAW* up on the ways July 1, to carry out all the changes that I decided were advisable from the shakedown cruise data. The most extensive change is in the pontoons. I'm building up the buoyancy to a bit over 2,000 lbs, extending the present pontoons fore, aft and laterally (mostly aft). It's taken a bit of figuring to do it in such a way that I don't have to change my foil fastenings. I've slit the port pontoon in a vertical plane fore and aft and already have all the new framing in. The old outer side is remounted 8 in further laterally and 2 in lower. This way, my deck remains a single surface.

I need more buoyancy so that I don't have to reef down quite so soon. It will improve progress tight on the wind (semi-flying), and in strong, gusty winds. Unfortunately, when we were reefed down for the gusts, we didn't have enough power to fly during the lulls. My old pontoons were adequate for moderate steady winds, with 1,200 lbs of buoyancy. (When you saw the boat, I had only 600 lbs buoyancy).

I enclose a gull's eye view of *WILLIWAW* (before changes). I don't think you saw the boat with all its foils retracted. A pair of struts go into the water to form rudder blades when the stern foil is retracted, for light wind sailing.

WILLIWAW with all foils retracted

To answer your questions of June 24. Definitely 4 foil units are needed, so there is no simplification possible there. Of course, the foils take care of rudder and centreboard action, so no centreboard trunk will detract from the accommodation, and the amateur wouldn't need to build centreboard and rudder. There are numerous reasons for the metal hydrofoils, which unfortunately are not for amateur construction. Among these are strength, high aspect ratio (relatively speaking), ballasting effect and impact resistance. The blading extrusion used on *WILLIWAW* has only moderate yield strength, but with higher strength Aluminium on later craft, it is possible to cut down on the number of struts (reducing cutting and welding to one half) and get higher lift to drag ratios.

I could design a good semi-hydrofoil (semi-flying) trimaran that would have foils suitable for amateur construction. It would be very wide, and have fairly low aspect ratio foils growing out of the pontoon bottoms at a 45° dihedral. These lateral foils would be lateral to the centre of effort of the sails and ahead of the centre of gravity of the craft. Angle of attack would give $C_L = 0{\cdot}3$ at zero leeway. At 5° of leeway, the leeward foil would have $C_L = 0{\cdot}6$ and the windward foil $C_L = 0{\cdot}0$. There won't be any ventilation problem if the leeward pontoon keeps its bottom in the water. The rudder would be oversize and would have a small fin down to set for a low C_L. It could all be done with plywood and fibreglass construction.

Of course, I think that it is much more fun to lift out completely, and think that it is well worth the trouble (expense).

DAVE.

CHAPTER XX

THE FORTY-KNOT SAILBOAT

by Bernard Smith — Written 1970

Book Review by John A. Heying.

This book is not only highly informative on the subject, but beautifully bound. It belongs on every AYRS member's bookshelf. It is full of nautical history before it gets down to the point in issue, the "Aerohydrofoil", a flying foil borne craft, of a pattern not described by the AYRS in full.

Some months ago, I met a German friend. He took me to a near-by lake about two or three hundred feet in diameter and set loose his 6 ft model of the "Bernard Smith" type Aerohydrofoil. Although I had read Smith's book with a little scepticism, I lost every ounce of scepticism when I saw the true Aerohydrofoil literally leap upon the bare tips of its three foils, trying to take off.

No one could possibly run on foot and catch up with it. It is almost unbelievable that a boat in water can do what this machine can do. It nearly frightens me to think of what a large man-carrying sized version would sail like; and how dangerous it could be if all the control factors were not fully understood beforehand.

My friend then took me to his home and, as his lovely wife poured German beer, he proceeded to show me other fantastic models of foil type craft that nobody else has ever dreamed of, to my knowledge.

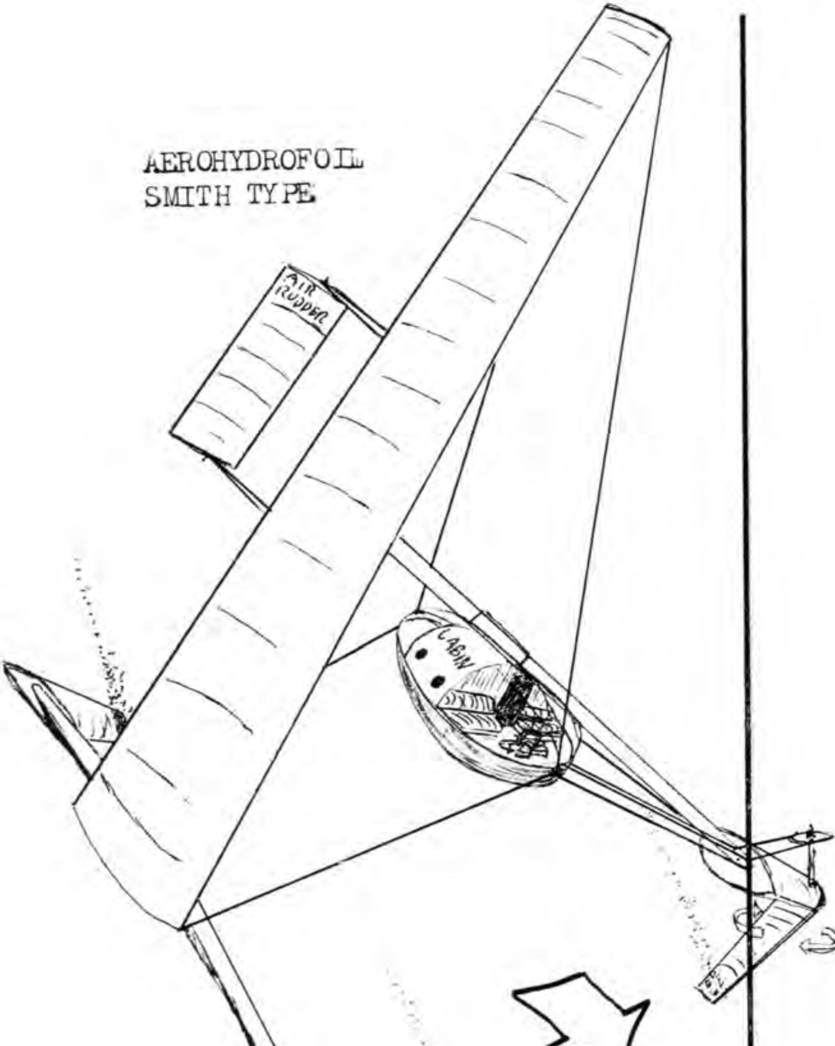
THE FORTY KNOT SAILBOAT describes Bernard Smith's disappointments and trials with various configurations. It wasn't until he began to borrow from the Proa and use Asymmetry that his success began to unfold. He then independently developed or used a "Bruce foil" to weather as an anti-capsize device. All steering is done by an overhead "Air rudder".

The size of the foils are dictated by the rule that any two of the three foils, which are buoyant must be able to support the entire craft. Three foils, therefore, give ample support. The tapering of the foils from their thick, above water sections to their underwater tips is such that the drag from their thick sections above is lost as the boat rises upon the thinner sections, causing less and less drag, and increased speed. I have seen this work, so there is no doubt in my mind, no matter how many mathematicians may argue to the contrary.

Ed.—Unfortunately, Bernard Smith's full sized version failed to perform in the same way as his models, probably due to:

1 Increased wetted surface of full sized buoyant foils.
2 Drag of thick foil sections, preventing "take-off".
3 Lower "scale" windspeeds.
4 The fact that drive varies with the SQUARE of the cosine of angle of slope of the sails.
5 Solid sails were not used on the full sized version but, if they had been, there would have been an extra inefficiency.

AEROHYDROFOIL
SMITH TYPE



There is, of course, nothing essentially wrong with Bernard Smith's Aero-hydrofoil concept. As so many of the AYRS members have shown, a long, light, narrow hull to windward, provided with a "Bruce foil" and two angled hydrofoils to leeward surmounted with an orthodox sail or better a semi-elliptical "squaresail" could be produced which would function perfectly well. My own opinion is that Dave Keiper achieves asymmetry much more elegantly but at a cost in weight.

Letter from: S. Wayne Wells 2895, N. Sterling Pl., Altadena, Calif., 91001

Dear John,

My conception of a hydrofoil sailboat is not of a boat to which hydrofoils are attached but hydrofoils to which floatation is attached. In other words, I would propose a craft which could decently sail one home in the lightest air, but would never win a race in, say, a 5 knot breeze.

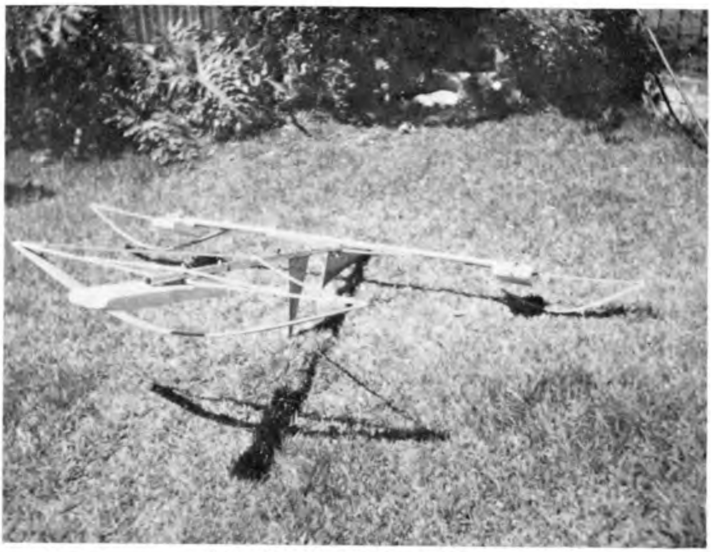
From my experience with some 25 models, my greatest fear in a high speed sailboat is of pitchpoling. I am in favour of surface-penetrating foils which gradually run out of area as they lift, which has proved successful in my models.

3V Canard Model—S. Wayne Wells

I agree with the 12 : 1 thickness to chord ratio, although, with suitable materials, I would go even thinner on the final surfaces which are in the water. Also, the triangular plan form must be best to maintain aspect ratio.

Each hydrofoil should be twisted along its length so that the upper portion has more angle of attack than the lower part. Assuming enough wind power, the foils will produce a great deal of lift at low speeds due to the upper, high incidence, surfaces being in the water, gradually yielding to a cleaner foil at higher speeds. This same twist will also lift the bow if it should happen to pitch too far.

Sliding foil *CANARD*—S. Wayne Wells



3V *CANARD*—S. Wayne Wells

Anotner S. Wayne Wells model

There must be more positive incidence on the forward foil(s) than the aft foil(s). The aft foil will then have a negative angle of attack before the bow foil(s) does.

From my models, I'm now becoming rather settled on the iceboat (Canard) configuration or its reverse. With a single forward foil, I prefer to mount the sail as far aft as possible to help decrease the tendency to drive the bow under.

In my latest boats, I am using the well tried sail and centreboard because I think it is too much to ask foils to lift the boat and resist leeway at the same time. The foils can then be very nearly horizontal, except at the surface.

S. Wayne Wells.

Letter from: W. Morton 61, Mead Road, Chandler's Ford, Nr. Eastleigh, Hants.

Dear Dr. Morwood,

I am interested in hydrofoils and have found a great deal of useful material in the AYRS publications. As your knowledge on the subject is extensive, I wonder if I may ask your opinion on an idea of mine.

I think you will agree that for such a craft to be of any practical use some form of positive control over the lifting force is required. The only two solutions I have seen to this problem are the Hook system and that used on the Boeing boat. The latter would appear to be little more than a floating computer and is therefore somewhat impractical on the grounds of expense. The Hook system has the advantage of mechanical simplicity but the idea of two feelers "sticking out in front" fills me with horror.

A possible alternative solution would be to use a fixed foil and vary the lift by what I would call dynamic fluid control. I don't know if this is the

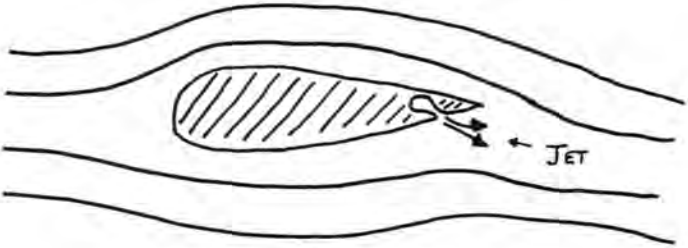


FIG. 1

accepted jargon but what I mean by this is to alter the lift by forcing a jet of water through a slot situated in the lower side of the foil and close to the trailing edge Fig. 1 should make this clearer. The jet acts in the same way as the flap on the trailing edge of an aerofoil and has in fact been used to control a guided missile. As with the conventional flap a high degree of amplification is achieved; that is the lift force generated is far in excess of the force required to move the flap or in this case the pressure required to produce the jet. Although a pump could be used to produce the pressure, a more interesting solution, and one that can be applied to a sailing hydrofoil, would be to generate it by the ram effect caused by the forward motion of the boat in a submerged orifice.

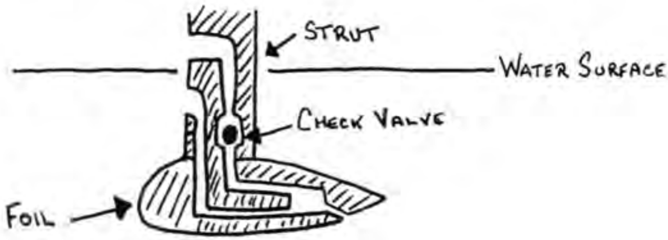


FIG 2

If two such orifices are incorporated into the strut connecting the foil to the hull as shown in Fig. 2, the depth of the foil would be automatically adjusted. This is because if both orifices are below the surface the resulting pressure in the jet is a maximum, as is the lift force. This causes the foil to rise until the top orifice becomes uncovered and the pressure is reduced.

By cunning adjustment of the angle of incidence of the foil it should be possible to produce sufficient lifting force to balance the weight of the boat with only one orifice submerged. Should the foil rise nearer the surface the lower orifice becomes exposed, the jet pressure and hence the lift force falls, and the foil subsides again. Thus the depth of the foil is optimised such that the water surface is positioned between the two orifices. Obviously a simple check valve would have to be incorporated in the upper orifice to prevent the water from taking the easy way out when it is uncovered.

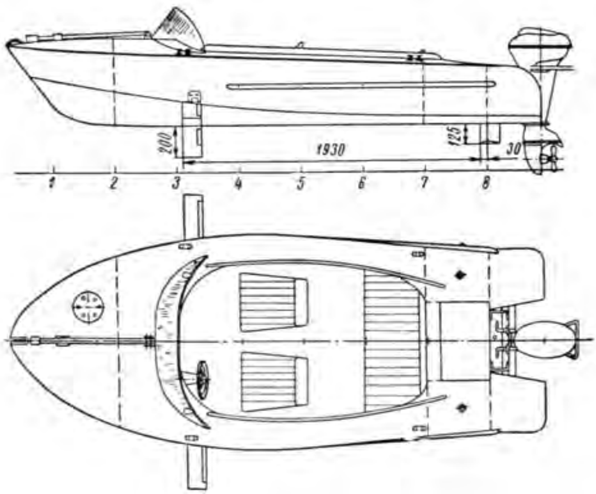
It seems to me that a number of variations can be wrung on this theme.

W. MORTON.

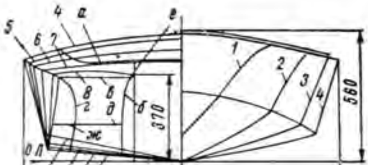
THE RUSSIAN HYDROFOILS 1970

by John Morwood

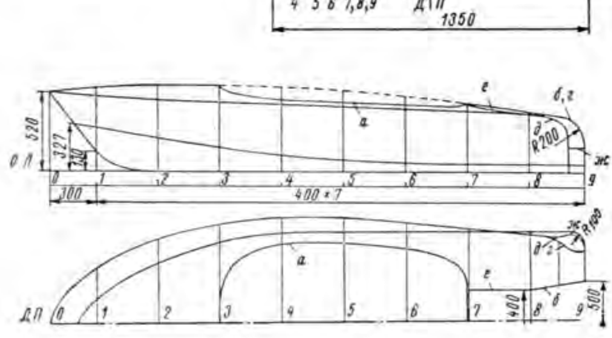
Some years ago, there were allegedly some 1,000 hydrofoil motor boats of all sizes on the Russian rivers, many of them very large passenger-carrying boats. The larger craft, I have been told, keep their relationship to the surface

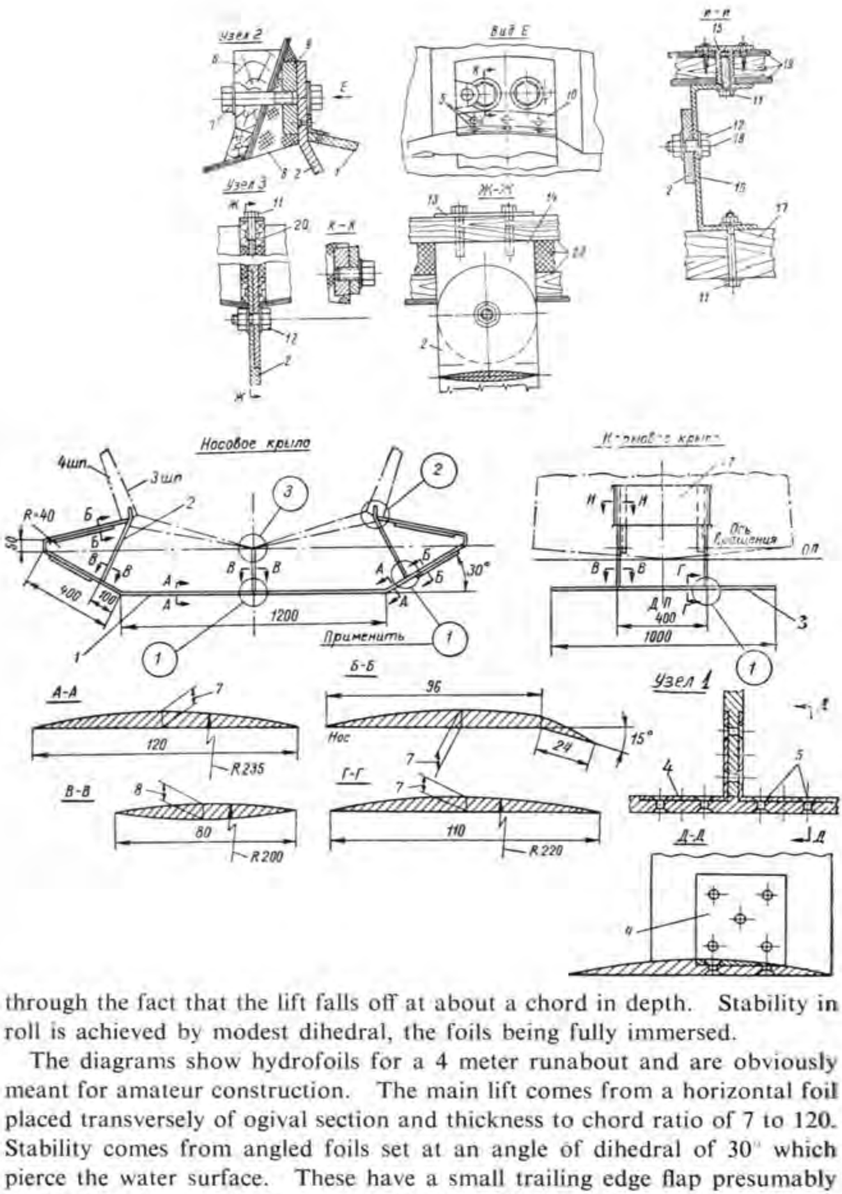


Общий вид лодки.



Теоретический чертеж.





through the fact that the lift falls off at about a chord in depth. Stability in roll is achieved by modest dihedral, the foils being fully immersed.

The diagrams show hydrofoils for a 4 meter runabout and are obviously meant for amateur construction. The main lift comes from a horizontal foil placed transversely of ogival section and thickness to chord ratio of 7 to 120. Stability comes from angled foils set at an angle of dihedral of 30° which pierce the water surface. These have a small trailing edge flap presumably to give instant response to an upset in roll. The struts are symmetrical foils of 8 to 80 thickness chord ratio.

The stern foil is placed just ahead of the outboard and has a 7 mm × 110 mm section. The length appears to be 1 meter.

The drawings seem quite adequate for the foils to be built. All dimensions appear to be in millimeters.

Owing to the design, too much power should not be used. Otherwise, the main lifting foil will come too near the surface.

CHAPTER XXI

HYDROFOIL STABILIZED YACHTS "COQUI" 1969

by Henry A. Morss, Jr.

6, Ballast Lane, Marblehead, Mass., 01945, U.S.A.

LOA	24 ft	Rig	Sloop
LWL	19 ft 4 in	Sail Area	235 sq ft
Beam	14 ft	Est. weight (sailing, crew of two)	1,600 lbs

Designer: Robert L. Taber
Builder: Warren Products, Inc., Warren, Rhode Island, U.S.A.

AYRS publication No. 70 reported the description and performance of the *COQUI* as measured in the summer of 1968 and in preceding years.

Qualitatively, the behaviour of the boat fell far short of what one might desire. Sailing to windward was always an effort, presumably because she carried a substantial lee helm (even with the small forward board added to the regular one) and rather high leeway angle. Clearly, board area was too small and too far aft.

For the 1969 season, this was all changed.

Design

After much thought, the decision was made to mount 45°-canted boards on the two outer hulls. The decision proved to be much easier to make than to carry out. The shape and construction of the outer hulls did not permit a slot or box at 45°. There was worry about getting adequate strength with a fixed, cantilever structure.

Finally, a compromise was adopted. The boards were fastened to the bottoms of the outer hulls by improvised piano-type hinges of fibreglass with

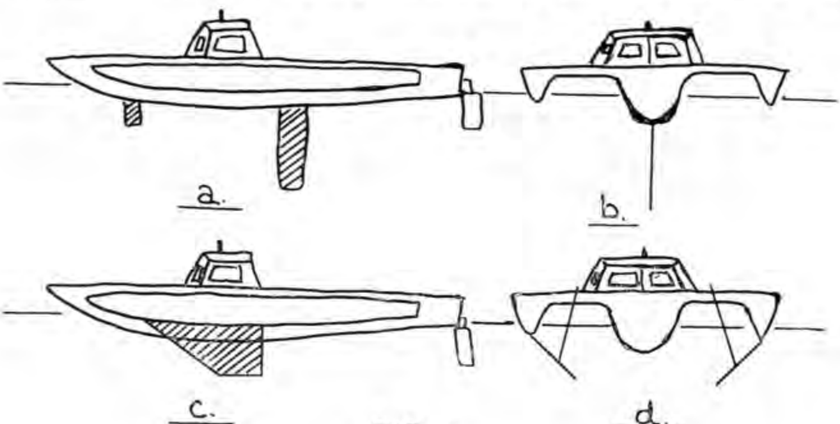


FIG. 1.

metal "pins". The angle of the boards thus became adjustable. Each board was controlled by two bars of streamlined section which came through holes in the deck (see Fig. 1d). Bolts could be moved to different holes in the bars above the deck to achieve the desired setting, including fully "raised".

The area of each board was nearly 13 sq ft (see Fig. 1c), about double the combined area of the two boards used in previous years (see Figs. 1a and 1c). A fair comparison of sloping board to vertical one is best made by noting the area of the sloping board as projected on the vertical plane. Thus for one of these boards at 45° we should compare

$$\frac{1}{\sqrt{2}} \times \text{area or } \frac{1}{\sqrt{2}} \times 13 = 9$$

to the area of the two previous vertical boards, 6·5.

This choice gave an increase of area of a third or so when just one of the boards was used and to nearly three times the old area when both boards were used.

The hinges and especially the bars introduced significant extra resistance. Thus, we could not look for much speed. The result in this respect was somewhat worse than originally seemed likely, partly because hinges and bars seemed to have a great affinity for weed. Much of the time clumps of weed were being dragged along.

It had to be expected also that this extra resistance would increase the leeway angle over what it would have been for the equivalent structure with "fair" connections at the hulls, no bars, and no weed.

Behaviour

The *COQUI* was a different boat. She was close-winded, sailed to windward nicely, tacked with assurance—a real pleasure to handle.

This qualitative observation in itself is looked on as being highly significant. Many trimaran sailors (far too many, indeed!) have boats which don't sail to windward decently at all, which carry lee helm, and which are not easy to sail. Here is the proof that there is no need for such performance.

This author assumes that the point lies in adequate board area located at the right place, fore and aft, rather than in the fact that these boards were "canted". Very likely that assumption will be checked next summer.

During sailing, it was usually hard to see that there was any effect from the slope of the boards. The impression was that the boat stood up to increasing wind somewhat better. That is what was expected, the reason for chooisng the sloping boards. But the amount of improvement in this respect did not seem large. Obviously these boards are not far enough out from the centre-line to do much toward offsetting the heeling effect. (see page 123).

These boards were attached well forward of the position of the main board in the original design of the boat. The estimated position of the centre of lateral resistance of these new boards was just about as far forward as the centre of effort of the rig. The boat sailed with rudder very nearly amidships and with pressure on the rudder which tended to put the bow into the wind.

Perhaps this can be described as a slight weather helm.

As expected, the *COQUI's* speed was reduced somewhat by the parasitic resistance of bars, hinges, and weed. This effect seemed more pronounced as the breeze picked up in strength.

Measured performance

The instruments previously described (*AYRS* 70) were put to work to get some quantitative data on the performance. Since real performance was not, and was not expected to be, particularly good, the major effort was devoted to comparisons made possible by the fact that the angle of the boards could be adjusted, rather than to getting full polar curves at various wind speeds.

Even this modest programme was not completed satisfactorily. The proper combination of smooth water, steady wind, reasonable freedom from instrumental troubles, and suitable crew were not realized as many times as would have been wished. Nonetheless, lots of readings were taken on several days. From these, the following conclusions seem warranted:—

1 Compared to the results obtained with the use of both boards at 45°, when only the starboard board was used,
   a on starboard tack, windward ability was significantly improved and leeway angle was unchanged;
   b on port tack, windward ability was only slightly improved, leeway angle was a degree or more greater (increasing more at higher heading), and the boat would not head so high;
   c on both tacks, balance was changed only slightly.

2 On one day of trials, the starboard board, used alone, at 35° below the horizontal was compared to the same in the usual 45° position. The windward ability was about the same. The boat did not behave as well. Steering was especially difficult on the starboard tack. The breeze was too light on this day to permit any appraisal of the stabilizing effect of the board at that relatively high position.

Why?

The better performance with one board was probably due primarily to the lower wetted surface and parasitic resistance. Perhaps it is appropriate to conclude that the area of one board was enough, or nearly so.

The better performance on starboard tack when only the starboard board was used seemed to contradict expectation. The sloping board produced a force with a vertical component. When the board is to leeward, the vertical component has the effect of reducing the displacement of the boat (and vice versa). With reduced displacement reduced drag and increased speed may be expected. In this case, this should have occurred on port tack, not starboard.

Another reason to expect the opposite to what was observed was that on port tack the working foil (under the starboard hull) was completely immersed while on starboard it was "surface-piercing". The fully immersed foil would be expected to be more efficient than the surface-piercing one. (Possibly little such effect should be anticipated with a foil of such low aspect ratio).

Can the better performance on starboard tack be explained by the angular position of the board? On starboard tack, with better performance, the board was farther from the horizontal (45° plus angle of heel). On port tack, with poorer performance, it was nearer the horizontal (45° minus angle of heel). There is a hint in the previous section of poorer performance when the board was deliberately set closer to the horizontal (35°).

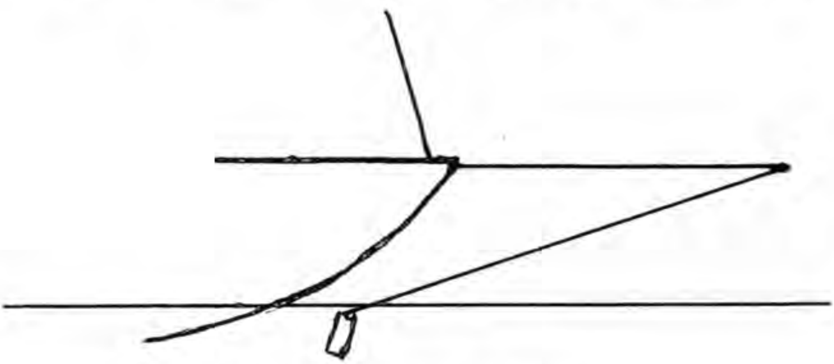
Balance was nearly as good on both tacks with one board as it was with two—another surprise. At least this is consistent with Edmond Bruce's reports (partly oral) that problems of achieving reasonable balance on both tacks in a boat of the non-heeling type are less with a foil of low aspect ratio than they are with one of high aspect ratio.

Instrumental problems

a Inconsistent data. In earlier years a wide scattering of data points was reported. The same occurred again.

As data accumulated, this problem became increasingly bothersome. Observations made within a single day tended to be more consistent than those of several days.

As the only thing I could think to do about this, I moved the wind sensors from masthead to the height of the centre of effort of the rig, in order to reduce errors due to variable wind shear (speed changing with height).



LEEWAY GAUGE

FIG. 2

Nuisance as it was, this was done with a demountable mast at the bow sloping out from the headstay to assure that the instruments would be in air unaffected by the rig, or nearly so.

b Leeway Gauge. A vane at the bow continues to be preferred. The problem is to get steady readings when the water is not perfectly smooth. The situation was improved by moving the pivot farther out beyond the bow and extending the arm (see Fig. 2). With a long arm above water and only the vane itself immersed, the drag of the unit was reduced.

c Wind Vane. This author continues to be impressed that a very sensitive and precise wind vane is needed. This has been achieved, down to apparent wind speeds of 5 knots and perhaps slightly less, with a small, nicely-made, wire-wound potentiometer and a relatively large vane on a long arm. The problem of locating the zero (fore and aft centre line) is not inconsiderable, especially when the vane is taken down at the end of each day's sail and set up again for the next one. The safest procedure is to make complete performance measurements at several values of apparent wind angle on both tacks and plot the reduced data carefully to find the mid-point.

Overall conclusions

1 Adequate area and proper position of underwater profile can make an enormous difference in the behaviour of a boat. Unfortunately most trimarans are deficient in both respects.

2 The configuration of boards under the two outer hulls sloping in 45°, as suggested by Edmond Bruce, has some advantages in sailing but is mechanically very difficult to manage. My present thought is that the gains are not great enough to make this arrangement attractive. On *COQUI* the sloping boards are not far enough out to the side.

3 When the boat is sailed with just one of the canted boards, slightly better performance would be expected with the board to leeward. In these tests, the behaviour was opposite to the prediction. (Most of these tests were made in relatively light winds. Thus the magnitude of the effect should have been small. Perhaps if tests had been made in stronger winds the prediction would have been borne out.)

4 All in all, this has been a thoroughly worthwhile experiment.

THE 10 SQUARE METRE "OPEN CANOE" 1970

by Bruce E. Clark

115, McGavock Pike, Nashville, Tenn., 37214, U.S.A.

I have been experimenting with hydrofoils since 1964, and reports have appeared in AYRS Journals on my earlier models of stabilizing hydrofoils. Due, perhaps, to sailing my first model hydrofoil-stabilized canoe in the clear shallow water of the Florida Keys, with ugly looking coral heads (looking shallower than they really were) menacing anything projecting to any depth, I devoted considerable thought and study to the problem of making hydrofoils less vulnerable to damage when they ground or strike an obstruction. I finally hit on the ridiculously simple idea of "hydrofoil-leeboards". A patent search did not turn up any prior use of this idea (though a basic "toed in" style hydrofoil patent was found, dated 1921!) so I have a patent pending on this idea.

Hydrofoil-leeboards are just ordinary leeboards that are spread apart and at 40 or 45° dihedral. A few refinements are added, or course, such as a proper hydrofoil section, a supporting bracket faired into the foil blade, and a hydrofoil section on the outer end of the supporting arm or crossbeam.

Bruce Clark hydrofoil stabilizer

The first thorough trial of the hydrofoil-leeboards was on a 13 ft × 39 in canoe using 60 sq ft of sail on a 20 ft mast. Performance was quite decent, but it was obvious that the canoe was too short and tubby, the sail area too small. An 18 ft × 36 in canoe was therefore obtained, a prototype rig was designed and built to more fully exploit the hydrofoil-leeboards. The result is the 10 Square Meter (107 sq ft) *OPEN CANOE,* which has amazed everyone who has seen it in action when it is at all windy. Not because it is fast, which is only to be expected with that much sail on an 18 ft 80 lb boat, but because of its ability to take strong gusts without a capsize (yet!) even when a number of other small boats were capsizing. However, the foils have about 5 sq ft of effective lifting area in a knockdown, which would generate about 70 lb of righting force at 5 mph, 280 lb at 10 mph, with 5 ft of leverage on the centreline of the boat. Meanwhile, the skipper will be hiking out on the weather foil supporting arm, so it is not really too surprising that the canoe

Hydrofoil retraction

is easy to keep rightside up, as the half dozen or so who have sailed it so far will all testify.

The sail is a lateen, loose-footed and un-battened like a genoa jib, and has a "luff-pocket" which slips over the yard; the halliard attaches through a "button hole" like opening. This turned out to be a very convenient way to mount a lateen sail, being less trouble than clasps, track or luff groove.

Performance of the *OPEN CANOE* has been most gratifying, as the prototype has outsailed most the conventional boats it has been near, up to those costing 3 or more times what the *OPEN CANOE* could be made to sell for (about $550, which is what "board boats" sell for in the U.S.). The present canoe, a Sawyer *SAFARI* (18 ft × 36 in, 80 lb, and flat on the bottom) does not have nearly as good lines as the same manufacturers *CRUISER* model (17 ft 9 in × 33 in, 61 lb, with moderate dead-rise) and it is felt that the *CRUISER* will prove to be about the best boat possible for this class. The Sawyer Canoe Co. (Oscoda, Mich., 48750, U.S.A.) are planning to produce these rigs by the spring of 1970. Complete plans and instruction are available from me for $6·00 in the U.S., Canada or Mexico, $8·00 elsewhere; there is an $8·00 royalty due upon completion of a rig. I also sell plans and instructions for $8·00 for making a cedar (or redwood) strip-fibreglass *CRUISER* canoe similar to the Sawyer *CRUISER*, which is moulded fibreglass construction.

A 10 Square Meter *OPEN CANOE* class association is planned, when there are enough of these boats to justify it. Proposed restrictions would be: hull, similar to those for U.S. *Cruising* class single bladed paddling canoe races—length not to exceed 18 ft; hull essentially symmetrical end to end, except square sterns permitted; width at least 31½ in at a point 4 in above the keel. A forward spray deck not over 6 ft long to be permitted. Rig to conform to plans, an unstayed lateen, with aluminium tubing spars. Variations in width, angle and location of hydrofoil-leeboards to be permitted.

Bruce Clark stabilizers

Letter from: Peter Westerberg Kungsholms, Hamnpl. Z. Stockholme

Dear John,

I have met with problems when building my hydrofoil and therefore wanted to inform my hydrofoil-brothers about these problems so that they could avoid making the same mistakes.

On the other hand, I was not too keen to tell about the performance of the hydrofoil as this was rather poor. It goes slower than a *SHARK* catamaran on all courses but a broad reach in moderate wind strength.

It can fly, but since I have not fitted the front foil yet I have to sit in the stern so that the hydrofoils get enough angle of attack. The hull is then lifted out of the water partly and the major part of the weight is supported by the hydrofoils. The balance of the boat is not very good then and it feels like making little jumps all the time.

Peter Westerberg's hydrofoil

Peter Westerberg's foil stabilized catamaran hull

I have been out "half flying" a couple of times and last time one of the foils broke loose when she was rather high on her toes.

Since my experiences are so negative depending upon the boat not being ready, I thought the best thing to do was to theoreticise a little in order to be spared from all details and excuse the bad performance of the boat with circumstantial reasoning.

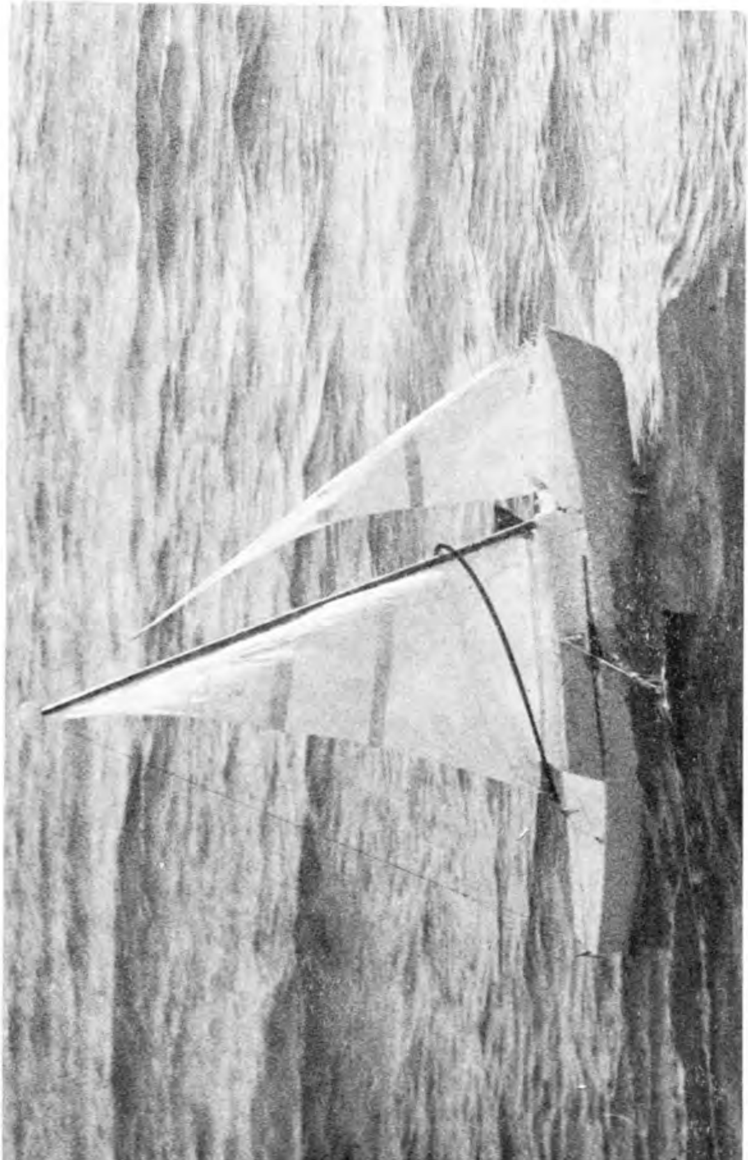
Until I can report better results, I felt it my duty to give some information in exchange for all the things I have read in the *AYRS*.

THE FOILER

August 1970

by Gerald Holtom, 5 Hillside Street, Hythe, Kent.

For 2 years now, I have been doing experiments, trying different hydrofoil stabilizers on a 30 in hull as a design study for a boat which I intend to build for myself.



Gerald Holtom's *FOILER*. Note planing, position of bow wave and foil waves at $4\frac{1}{2}$ knots

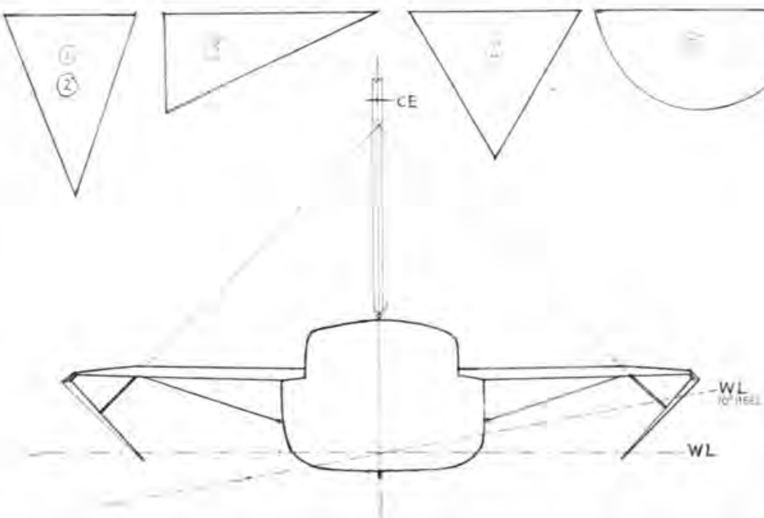
The full size concept is of an unsinkable, non-heelihg, self-righting from the upside down position, fast, family sailing, cruising yacht. All these features, without exception, have been achieved in the model. As the result is quite different from the ballasted keel yacht, the catamaran, the trimaran and the Proa, a new name is needed for this type of boat. I therefore propose the name *FOILER* for this absolutely new type of yacht.

The dimensions of the full sized yacht, as scaled up from the model are as follows:

LOA	31 ft 6 in	Sail area	275 sq ft
LWL	29 ft 0 in	Mainsail	175 sq ft
Beam (WL)	7 ft 0 in	Foresail	100 sq ft
Draught	8 in	Centre of effort	11 ft 8 in (above LWL)

Maximum beam with foils in position 21 ft 0 in
Weight 5184 lbs

The hull lines of the model are similar to those of the Uffa Fox 18 ft *JOLLYBOAT* and I chose this hull for the good reason that I possess just such a hull built of light alloy, the weight of which, when fully rigged and provisioned for cruising will be less than 2,000 lbs. Note that the model, when scaled up is very much heavier than the prospective boat so that it would be unlikely as a displacement yacht to exceed a speed of 2 knots (7 knots at full size).



The photograph and diagrams show the configuration. Various hydrofoils were tried as follows:

1 *Isoceles triangle*, 4½ in at the top, 6¾ in in span. Ogival section. Thickness to chord ratio 1 to 12. This worked but the fols kicked up a good deal of "fuss".

2 *Isoceles triangle* similar to No. 1 but thickness chord of 1 to 24. Less "fuss".

3 90° *triangle* with right angle at the top and aft, 7½ in along the top. 3¾ in in span, a 1/16 in thick metal foil. This worked but, owing to the move forward of the centre of area on heeling, the model was not self steering without a vane gear.

4 *Equilateral triangle* of 6 in sides, thickness to chord ratio 1 to 24. This again worked and it worked equally well when the lower point was cut off.

5 *A semi-circular foil*, of 7½ in in diameter, thickness to chord ratio 1 to 24.

The progression of these foils will be noted from high to low aspect ratio, the final shape closely approximating to a 1 : 1 aspect ratio, when sailing. The area of each was approximately 12½ sq in for the 275 sq in of sail area or a ratio of 1 : 22. The thinner foils seem to work better than thicker ones.

Various angles of "toe-in" and dihedral were tried. The final conclusions were that no "toe-in" should be used and that the best dihedral angle was 45°. The amazing thing was that all the foils tried worked, no matter how they were set (within reason), the difference between them merely being one of the speed achieved. Self steering was achieved with all without any vane gear, with the exception of the right angle triangle foil. The reason for this self steering is obscure but it is noted that Dave Keiper also achieves self steering with his boat.

Balancing out

This is the term we use to imply the relationship of the line of action of the foil force and the centre of effort of the sail. A "Foiler" is "balanced out" if the foil line of action passes through the centre of effort. It is "under-balanced-out" if the line passes below the centre of effort and "over-balanced-out" if it passes above it.

All my models were "under-balanced-out" and all have been capsized in very strong scale winds, though this is surprisingly rare. This feature, which was produced by guess, is believed to be necessary to immerse the lee foil with a hull which has some stability. At full scale, the sails could be reefed and the fully "balanced-out" condition achieved when capsize would be impossible.

Immersion of the lee foil

At first, trials were made with the tips of both foils immersed and leeway angles were large. When, however, the foils were raised so that only the lee foil was immersed, the leeway angle became negligible, close hauled. The weather foil is now always kept free of the water.

The lee foil can be immersed (1) by under-balancing out", (2) by having little or no stability in the main hull, (3) by using water or other ballast to heel the boat or (4) by having a cross beam which can be rocked in relation to the hull.

Capsizing

Owing to the gusty nature of the wind in ponds as well as scale effect, the model was often hit by hurricane scale winds when moving slowly. All the models have been capsized thus. However, as a rule, the model bears the blow, picks up speed and sails on. The puff heels the boat, almost immersing the lee foil completely but it then picks up speed and shoots ahead, the foil becoming less immersed as it does so.

Fore and aft position of the foils

This is fairly critical but not unduly so. It was found by trial and error to be approximately that where the centre of area of the foils is directly athwartships of the centre of area of the sails or slightly aft of this. My hull would luff when heeled.

Good windward performance with self steering was achieved using only the foresail simply by moving the foils forward. Similarly, by moving the foils aft, the model would sail well with only the mainsail.

Foil struts

These are aligned with the water flow so as to present the minimum of turbulence when the foils are totally immersed.

Handling qualities

As stated, only the lee foil is used when sailing, the windward foil being out of the water. Close hauled, the model heeled to about 10° and there it stays with about ¾ of the lee foil immersed. At 20° of heel, the lee foil is entirely immersed and the speed increases to over 3 knots (about 10 knots, full scale).

Last Easter (1970), the model was sailed in a gravel pit in wind conditions which were too strong for dinghy racing. Waves were about 6 in high from crest to trough. The sail area was reduced to 25 sq in and it was felt necessary at the time to keep both foils immersed for stability though this might not have been essential. The model sailed 200 yards on a straight course apparently unaffected directionally by the waves with both wind and sea a little forward of the beam, on an even keel and at about 2½ knots.

Principles of foiler design

1 High and low aspect ratio foils both work. No difference in the speed obtained has been noticed.
2 Low aspect ratio foils reduce overall beam. They also reduce the draught at rest to that of the main hull, allowing stable boats to be built of only a few inches of draught.
3 It may be preferable to have a main hull with some buoyant stability. The foils can then be set higher or lower or be tilted at will.
4 Full "balancing out" is probably best for a model but some "under-balancing out" is acceptable both for models and at full scale, more so with the latter.
5 With a hull with some stability, the cross arm may be rocked or the boat heeled with water ballast. A less stable hull may, however, be used.
6 "Under-balancing" may give too much foil area in strong wind; "over-balancing may give too little foil area.

The design requirements

My wish, as stated at the beginning of this article was for an unsinkable, non-heeling, self-righting from the upside down position, fast, family sailing cruising yacht. All these have been met and I have achieved self steering without gears, as a bonus.

The model is unballasted and therefore unsinkable. Ordinary heeling is not more than 10°, though 20° can occur in gusts of hurricane strength. The model has achieved speeds of 4 knots, which represent 14 knots at full scale and, though this scaling is not strictly valid because of the frequency of very strong winds, the hull displacement lessens at speed which should be an advantage. Accommodation should be good in a boat 31 ft 6 in long × 7 ft of beam, especially with our "high coach roof" design which is the shape of the sail foot and contributes to driving force. The shallow draught makes it an ideal cruising yacht, able to take the ground in the shallowest of waters. The only thing left out of this is the ability to right itself from the upside down position.

Self righting

I believe that any yacht, if placed upside down should right itself by its distribution of weight and buoyancy. This can be done by surprisingly little attention to the centre of gravity and the shape of the topsides and deck. Our "high coach roof" contributed here by adding buoyancy high up to the deck.

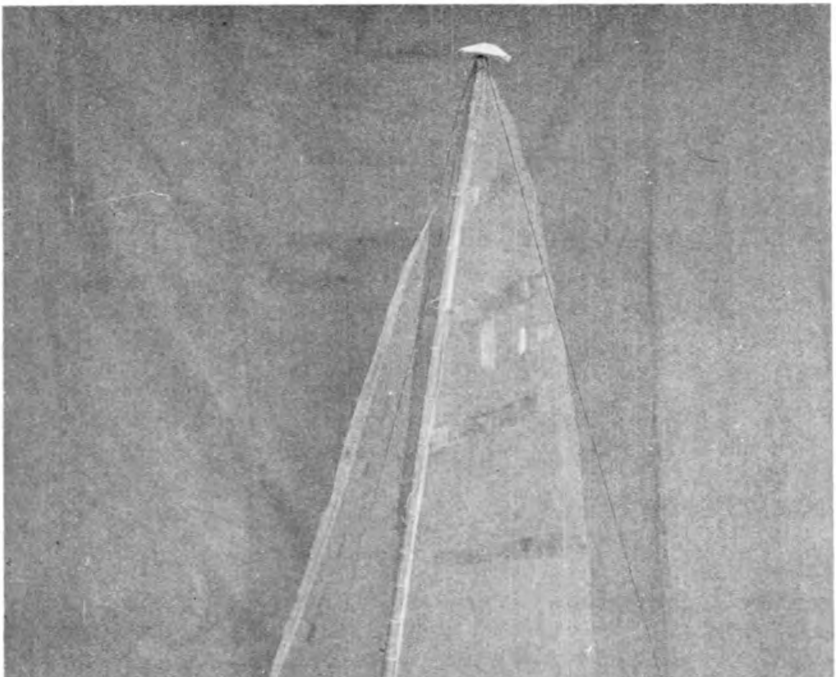
However, my models have the property of dynamically righting themselves as follows. When sailing in wind strong enough to overwhelm them in their "under-balanced out" state, they can capsize in a strong gust. The mast enters the water and the craft is soon upside down. But the heave of the waves soon causes the foil which is then to windward to rise from the water, the wind catches it and the boat slowly rights itself and sails on. Given enough wind, the model can cross a whole pond, capsizing itself, rolling its mast underneath it and coming up again, several times.

The outlook for foilers

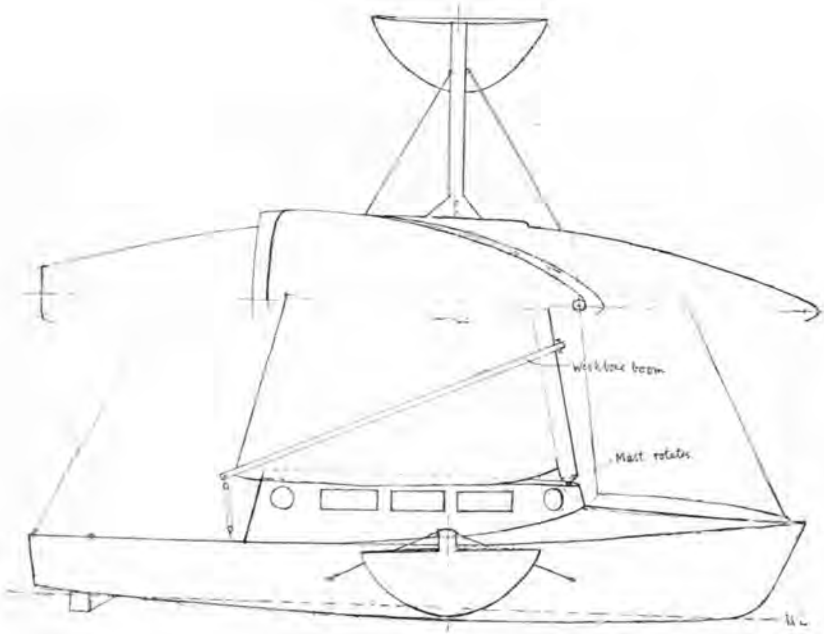
The basic advantage of the Foiler is that it makes possible an entirely new conception of yacht design and yachting. This basic approach to yacht design appears to me to have been the axis around which the thought and experiment of AYRS Members have turned full circle, in the past 15 years, via multihulls to the present. This new way of thinking offers greater scope for design development than any other type of yacht. It is astonishing to me that, after *AYRS Publications Nos.* 1, 2, 3 and 4 in 1955, one has not been able to purchase such a yacht off the peg, nor can one even buy a scale model.

Human nature being what it is, Foiler sailors will be certain to carry more sail area than they should for safety. They will be flattened, pitchpoled and capsized just as all other craft are subjected to extreme conditions. It follows that a Foiler should be designed to have all the virtues of my models. The only thing which we have not yet solved is a method of retraction of the cross arms for moorings but this is a problem which should not be insuperable.

Design problems are engendered in the mind of the skipper who equates safety, comfort and windward performance with keels and ballast. The habit of carrying a "millstone" under one's boat dies hard. "Why can't I fix



Gerald Holtom's model. Note shape of coachroof



stabilizers to my Folkboat", I was asked. You could, of course, but they would be of no benefit unless you removed the keel. It is easier to convert yachts which are designed with keels as separate appendages, bolted to the hull. Much can be learned by fixing foils, removing keel and ballast and sailing with half the canvas.

The replacement of centreboards by foils on dinghies is also a good way to learn the wrinkles of Foiler design and handling. Present gymnastic dinghy enthusiasts will find ample scope for their talents by racing foil-stabilized dinghies in weather too heavy for the present centreplate trapeze artists.

Conclusion

I suggest that the Foiler is the logical first step towards flying hydrofoil sailing. I also think that it is more likely to promote adventurous sailing than the traditional, slow, combersome, expensive and uncomfortable "old man's keel yacht", which various exceptionally adventurous old men and some young ones have popularized in recent times.

The lightweight, stable, buoyant monohull, known as "The Foiler" can be designed to survive pitchpoling, to be self-righting and of greater practicability than the life raft. The Foiler's structural strength in relation to weight would be greater than that of a catamaran or trimaran and it can be fitted with extra foils for "flight".

It is better to be held steady by the winds than to have one's keel rocked by the waves. The Foiler is kindly to the flow of air across her sails and I, for my part, prefer a little yacht which responds with so much life to wind and sea without fuss or bother.

AUTOMATIC INCIDENCE CONTROL OF HYDROFOIL STABILIZERS FOR SAILING CRAFT

by Norman Riggs

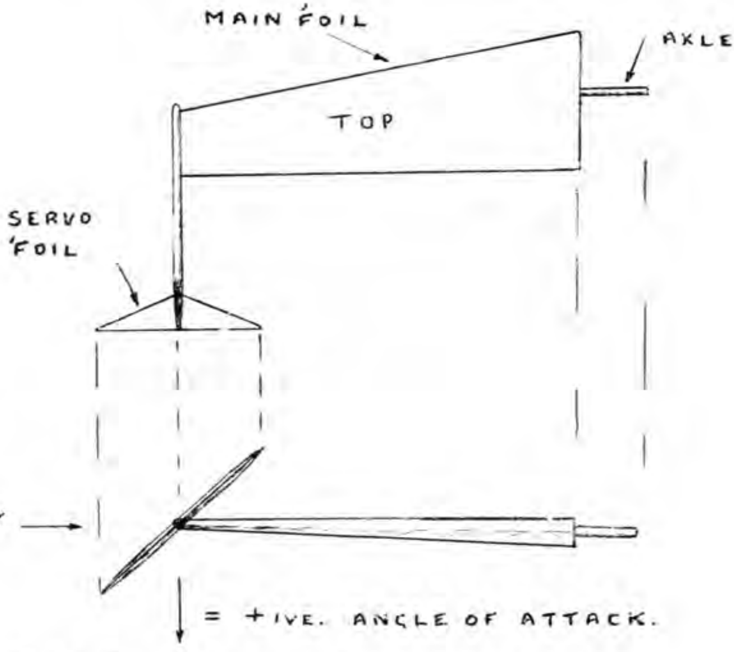
13, Russell Road, London, N.13

The Servo-fin and Servo-strut are two proposed hydrofoil stabilizer systems. These two designs are the result of the writer's attempt to evolve a safe, efficient and practical method of automatically stabilizing a monohulled sailing craft against the heeling moment of the sails.

PART I—THE SERVO-FIN SYSTEM

The illustration shows the basic configuration of this type of stabilizer. Each stabilizer of a pair, consists of two main areas.

The main foil, connected to the hull by a suitable lateral axle, at or ahead of the centre of pressure.



PORT STABILISER (NOT TO SCALE)

The servo-foil, rigidly attached to the main foil, set well behind the pivot point (rather like an aeroplane's tailplane). This foil having an anhedral angle.

Leeway results in a hydrodynamic force, with a component perpendicular to the main foil axis, being produced by the anhedralled servo foil. The leeward servo foil drops and the windward servo foil rises, the leeward main foil giving positive lift and the windward main foil giving negative lift.

The sensitivity of this type of stabilizer, is governed, primarily, by the choice of anhedral angle. The angle of attack of a balanced main foil is equal to the tangent of the component of leeway, acting parallel to the main foil axis. This is true for small angles.

e.g. with the main foil balanced, and horizontal, when the servo fin anhedral is 45°, the angle of attack of the main foil will be equal to the leeway angle.

Where the main foil is balanced, there is no angle of attack on the servo fin, thus losses are minimal. It may be desirable in practice to make the lift proportional to leeway, which implies, in this case, unbalance of the main foil.

When the main foil is unbalanced, care must be taken to avoid excessive loss of efficiency and sensitivity. The servo foil should be kept small relative to the main foil and the ratio of the distances between centres of pressure and the stabilizer axle, high. The main foil may be given dihedral as required.

One alternative to pivoting foils might be to have servo foils operating flaps attached to fixed main foils.

In its simplest form, this stabilizer could possibly be an almost balanced tapering fin, with a pronounced sweepback. The sweepback providing the leverage necessary for servo action. The servo foil in this case, being the fin tip, bent down to provide the necessary anhedral angle. Where small fins are employed to "stiffen up" an otherwise conventional monohulled yacht, the fact that these fins do not work when going astern may not be a serious defect.

PART II—THE SERVO-STRUT STABILIZER SYSTEM

Fig. 1 shows the essential features of a port-side stabilizer. The entire foil assembly rotates freely in a bearing mounted on the hull above the water line. The axis of rotation running down the leading edge of an unbalanced strut cum servo-foil and through the centre of pressure of the practically balanced main lifting foil. The servo foil has anhedral while the lifting foil has dihedral, both having symmertical cross sections. The angle between the two foil surfaces is equal to the sum of the anhedral and dihedral angles, being less than 90°.

The action of the stabilizer is two-fold. The dihedral of the main foil results in lift being produced in the presence of leeway. Additional lift is produced since leeway turns the unbalanced servo-strut, which, having anhedral, further increases the angle of attack of the main foil.

All stabilizing lift is produced by the leeward stabilizer. The windward stabilizer being normally clear of the water (Fig. 2). Negative lift to windward does not seem to be highly desirable, especially as there is a likelihood of the foil coming out of the water or causing disturbance when near the surface. On the other hand, working with only a leeward stabilizer offers positive advantages which will become apparent.

Apart from lift, the leeward stabilizer generates a windward force. Assuming the lateral resistance of the hull to be comparatively small, this windward force has three important functions:

a counteraction of leeway,

b relation of stabilizing lift to side force, making it independent of craft velocity,

FIG.1.

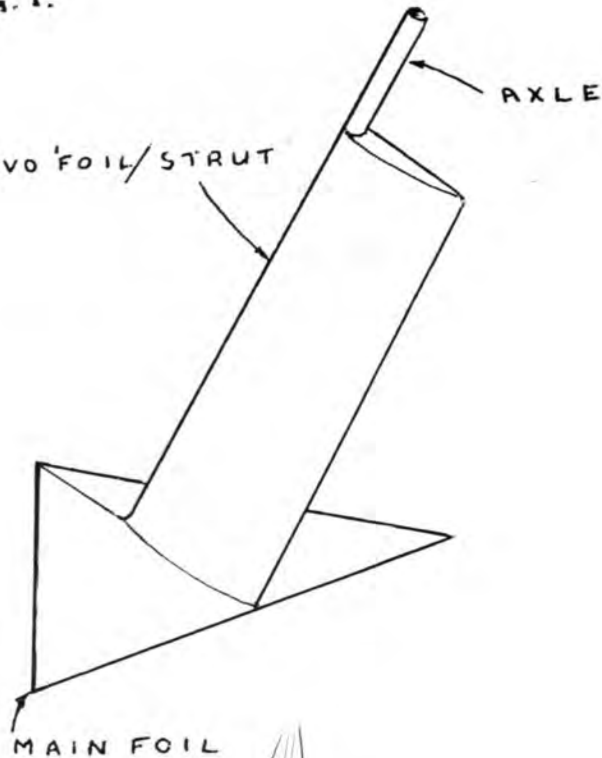
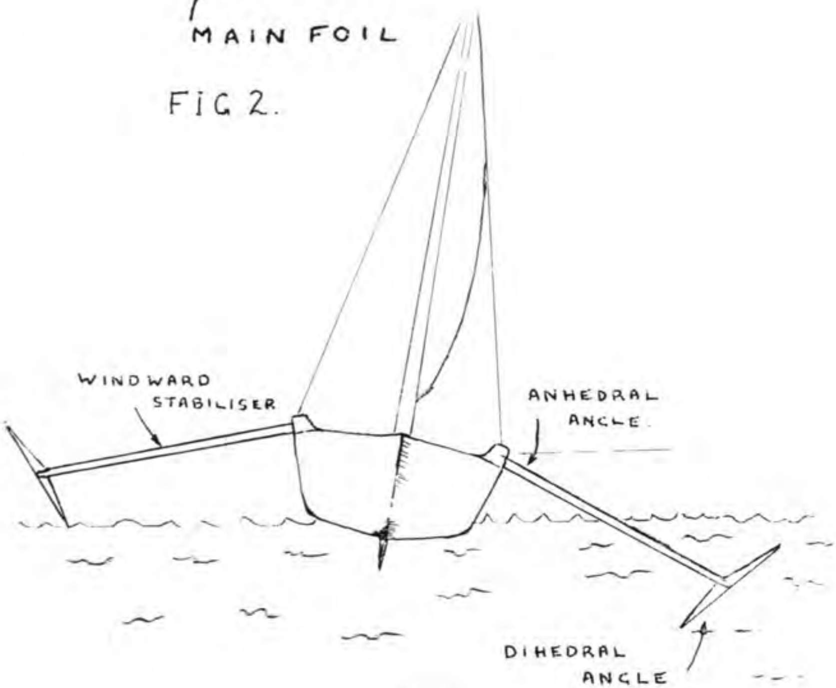

AXLE
SERVO FOIL/STRUT
MAIN FOIL

FIG 2.


WINDWARD
STABILISER
ANHEDRAL
ANGLE
DIHEDRAL
ANGLE

c ensures a constant running depth of the main foil, with respect to the hull, which acts as a surface reference.

When running, stabilizers will not be necessary and may be retracted. In any case if there is no leewyy, the main foil will have no angle of attack. Since the main foil is balanced, the high aspect ratio servo strut will align always with the flow, causing little disturbance of the water surface and having a low value of drag.

Servo strut action reduces the roll damping action of this stabilizer, depending on the effective anhedral angle. This may in fact be of some advantage in so far as sudden and possibly destructive changes in foil loading are avoided. Variations in foil lift, due to pitching movements, are likewise reduced. This is definitely advantageous since changes in lift due to pitching will induce rolling.

FIG. 3.

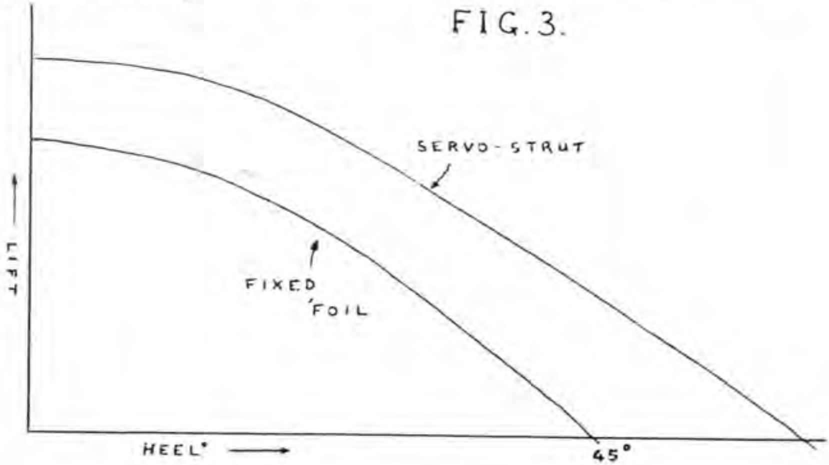
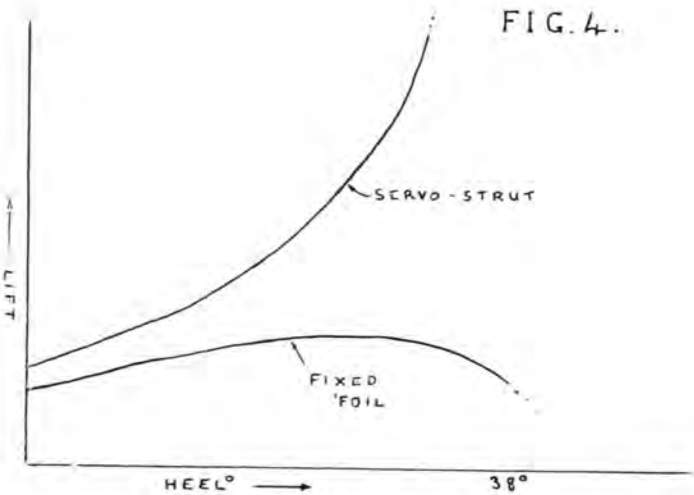


FIG. 4.



The curves of Fig. 3 compare the ideal performances of a leeward servo strut stabilizer and a fixed stabilizer of similar dimensions, for a constant small leeway angle. The anhedral angle of the servo strut and dihedral angle of the main foil are approximately 30° and 38° respectively, while the fixed foil has a dihedral of 45°. These angles were chosen because, assuming constant leeway, the lateral resistance of both types of stabilizer is nearly the same and both are producing maximum lift when not heeled. This was felt to give the fairest possible comparison.

As the hydrofoil stabilized craft heels, lateral resistance is reduced and increasing leeway causes the lift to rise to a value greater than it was initially. This ensures recovery of the original attitude and stability of foil running depth. Fig. 4 shows how lift increases with increasing leeway for the servo strut and fixed stabilizers of our example, for constant side force.

Note that the comparative performance curves take no account of the lateral resistance of the hull but are otherwise sufficiently accurate for a fair comparison. The superior performance of the servo strut stabilizer is clearly illustrated, as are the shortcomings of the fixed stabilizer.

The choice of anhedral and dihedral angles is influenced by several different factors. However, of over-riding importance is the effect of the choice on the operation of the foils when the craft moves astern. As the craft begins to move astern, the foils will rotate through 180°. The anhedral angle of course remains the same but there will be a considerable change in the angle of the main foil.

Consider now our example where the anhedral angle is 30° and the dihedral angle 38°. When going astern, the anhedral angle remains unchanged at 30° but the dihedral angle of the main foil is now 82°. This 82° of dihedral should be sufficiently low to ensure that a line, perpendicular to the surface of the main foil, passes through, or slightly above, the centre of lateral resistance of the hull. Satisfying this condition, the stabilizer of our example although rendered largely ineffective is completely SAFE. Generally, provided that twice the anhedral angle plus the dihedral angle is greater than 90°, the main foils will always have a dihedral angle, rather than an anhedral angle, when going astern.

Summary

1 Fully automatic stabilizing action at all speeds and points of sailing.
2 Potential performance at least as great if not greater than alternative systems.
3 Mechanically simple and reliable, with no hinges or joints below the water line.
4 Used as suggested, could easily be retracted, removed or replaced.
5 The craft, although unstabilized, may otherwise go safely astern.

CHAPTER XXIII

THE OVERALL CONCLUSIONS

by John Morwood AUGUST 1970

The conclusions of this book are a little difficult to see and anything said here may be proved wrong by future developments. The main contentions at the moment lie between high and low aspect ratio and whether or not to "fly" for best speed. I can only do my best to pick trends from a conflicting mass of evidence, and give my opinions.

1 Large "Foilers" are better than small ones.

2 The greatest all round speeds are likely to be got from a long, lean, hydrofoil-stabilized boat. I believe that the foils should have an aspect ratio of 1.4:1 in the form of a triangle twice as long at the top as in the span and curved with the concavity outside (Bruce)—a thin foil.

3 A "Fully ballanced-out" foiler is far too beamy. Reduction of beam can be got from (a) under-balancing, (b) main hull stability, (c) floats above the foils and (d) low aspect ratio foils and sails.

4 Flying hydrofoils are the best fun and suitable for the smaller boats. They are likely to do the best top speeds in the course of time and may be capable of 40 to 45 knots.

5 Dave Keiper has produced the best configuration of hydrofoil "flyer" to date because no foil acts to leeward. Essentially, he has added fore and aft foils to a hydrofoil stabilized trimaran, with floats large enough to reduce the beam to a reasonable size. The fore and aft foils lift the weather foil out of the water.

Hydrofoil experimenting

One must agree with David Chinery and others that one must have a boat which sails well in light winds, as a displacement boat. This necessitates a Foiler type of hydrofoil-stabilization and this configuration should be developed first with stern steering. Only when this stage has been accomplished should extra foils be used for flying and, of course, these must be retractable. Indeed, it is very desirable for the main, side foils to be retractable, as well, and members are urged to work out means to achieve this.

A final thought

The lift to drag ratio of a single catamaran hull is better than hydrofoils up to a speed of 4½ times the square root of the waterline length. A 50 ft foiler will therefore do up to a speed of 31 knots before needing to fly for extra speed.

Letter from: Ken Berkeley, 70, Ross St., Glebe, N.S.W. Australia.

Dear John, September 15, 1970.

I built a C-class Cat., with four Hook hydrofoils and a wing mast, which, with some modifications to the angle, we managed to get flying at about 12 mph of wind, but unfortunately before we could do full trials on her, she was wrecked in a gale, on the moorings.

For the brief time I had her, I was convinced that she would not be practical in a seaway, as the moment she came up on the foils, the heeling moment lifted the two weather foils out of the water, (and it was travelling at some 30 knots on the leeward foils, so this was very nerve-racking), and as the rear foil, which had a small skeg on, was also the rudder, we had some trouble in alternating direction, and getting the boat to descend.

I am now planning to build a lightweight 50 ft Cat., on which we hope to place two stabilizing foils, and I will keep you posted on progress.

KEN.

Letter from Dave Keiper, Hawaian Islands

Dear John, September 29, 1970.

We had a 16 day passage in *WILLIWAW* (Sept. 4–Sept. 20) from Sausalito to Kahului Harbour on the island of Maui, the shortest distance between the two being 2,040 miles. The daily direct distance average thus is 127½ per day.

Overall, it was the easiest passage I've ever had, though we had pretty rough weather for the first day out of San Francisco. The hydrofoils contributed significantly to it being an easy passage, assisting in maintaining control in heavy weather, contributing to self steering (we self-steered almost all the way), contributing to comfort (the motion was more like that of gliding than the usual roll, pitch and yaw).

The foils contributed to speed the first few days of the voyage where we had consistent strong and moderate winds. After that, we had variable winds, a day or two of calm and a week of very weak Trade Winds. The last few days, we had light to moderate Trade Winds, strong during rain squalls. When the wind died on us, we pulled up the foils but the chop was so bad, I almost got thrown off the deck a couple of times. We re-set the foils for comfort, even though we lost speed that way. When the seas flattened, we retracted the foils again.

At dusk on the first day, we sighted heavy floating debris and so cut the sail area way down the first night. On the second night, we struck something solid with the windward (starboard) lateral foil. Next morning, we found the main struts buckled so that it had very little lift. Later, we straightened it out with a hammer, restoring full lift.

For quartering and downwind sailing in light and gentle winds, we usually had the bow and lateral foils retracted and the stern foil set, but adjusted for zero lift. *WILLIWAW* self-steered perfectly this way, even with sails wing and wing. With all foils set, she self-steered in stronger winds, usually for a few hours at a time, maintaining course reasonably even when she started "hydrofoil surfing".

To have made a record passage, we would have needed the moderate beam winds (N.E.) with well developed waves which occur during part of the summer. Potentially, I think *WILLIWAW* could make it in 8 or 9 days. My next design could cut a couple of days off that.

More important than the speed potential is the potential for comfort, control and self-steering. The fantastic light air performance of the trimaran is preserved by retracting the foils, but in the moderate and heavy stuff, the foils get rid of the pounding, tunnel interference, quick motion and broaching of the trimaran.

DAVE.

EPILOGUE

LOA	27 ft	Displacement	1½ tons (approx.)
LWL	24 ft	Sail area	216 sq ft
Sailing beam	26 ft	Headroom	5 ft 6 in
Beam (foils retracted)	6 ft		

Designer: David Chinery, The Cop, Buckland, Betchworth, Surrey, England.

David Chinery, having designed *MANTIS*, his successful flying hydrofoil which we saw at Burnham-on-Crouch and a second flying hydrofoil which is now being built, has produced the design shown here. It makes a fitting epilogue to this book.

David has no hesitation in attributing the sources of his design. At least, he sets out the main sources as they have impressed him but a reference to the foregoing pages will show other influences, some direct, others as oblique sources. David's list is as follows:

1 Greer Ellis, for his writings on the Ice Yacht rigs.
2 Edmond Bruce, for publishing his bible on foils, and showing us how to harness the energy of the water dynamically to stabilize sailing craft.
3 Rodney Garrett, for the development of the floats of *SULU* and its retracting system.
4 Gerald Holtom, whose models convinced us that unballasted craft with side foils are extremely fast and, it seems, can survive almost any condition of wind and yet NOT capsize.
5 Don Nigg, "The Lone Pioneer" who told the world about front foil steering.
6 Arthur Piver, because he demonstrated that unballasted boats built like aeroplanes are light, fast and strong.
7 Dave Keiper for the "Flying" configuration.
8 And, of course, the AYRS, for forcing the concept of foils—encouraging people to produce ideas and bringing these people together (physically where possible) to communicate and exchange their knowledge.

Hull

Built of PVC foam and Fibreglass sandwich (Kelsall method).

Rodney Garrett's *SULU* float bow to go through waves, with a Garrett retractable foil which can align to the water flow.

Large window(s) for sailing the boat in the dry (Gerald Holtom).

Cabin top is the shape of the sail foot (John Morwood)—this is not drawn in the sectional plan.

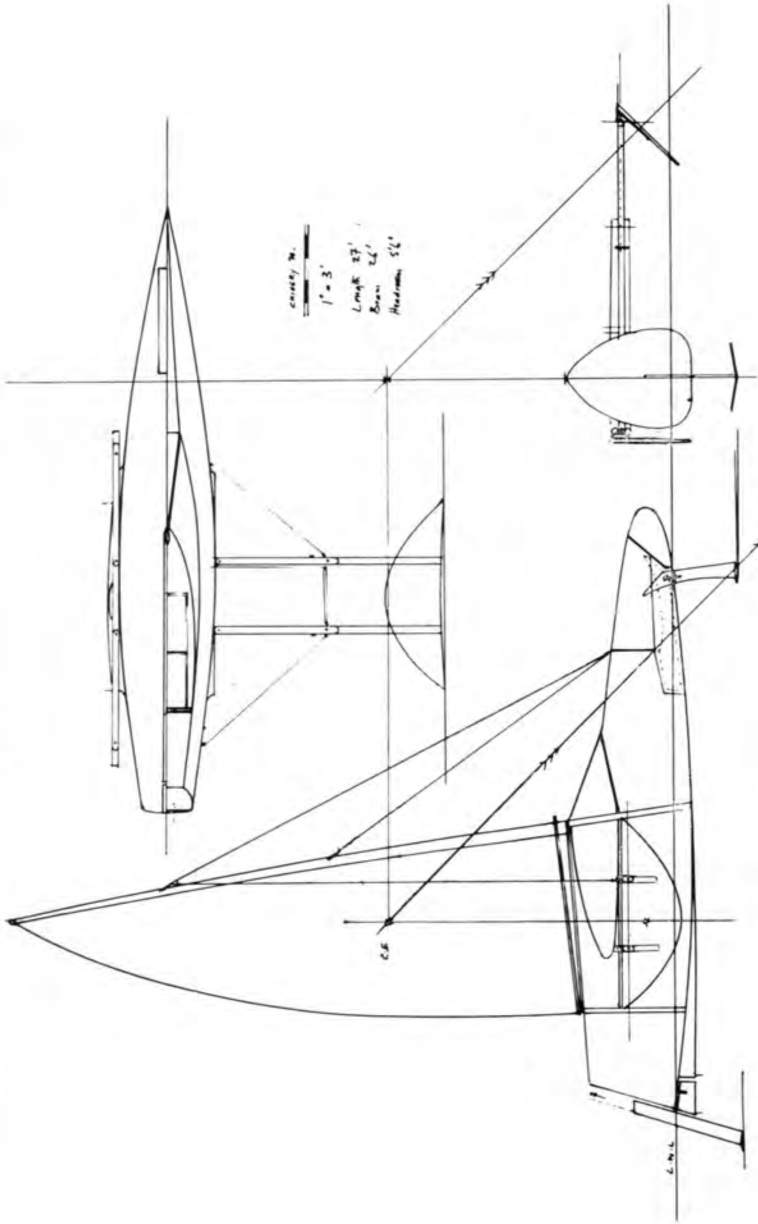
Skeg and rudder for sailing the boat as a "Foiler". A retractable stern foil for flying.

Side Foils

45° dihedral, "fully balanced out" (Edmond Bruce). Low aspect ratio (Bruce). Curved lower edge (Holtom).

Full retraction to the side of the boat, bringing the foil vertical. Method devised by David Chinery, resembling pulling in the foil with the arms, the elbows going out.

Pantographing foil cross arms. As shown by Gerald Holtom and Dave Keiper, the boat should be self-steering without gears. Fore and aft adjustment of the foil's position will give the course to be steered.


1" = 3'

Sail

This is an E Class Ice Yacht sail (Greer Ellis), with the boom eddy abolished. Andy Anderson (Andersons Aerosails) tells us that Holt Allen make a plank-like extrusion for catamarans' masts and this might be suitable for the mast. It would of course be allowed to bow with the concavity to windward (Gen. Jack Parham).

Designer's Comments

At the moment, I feel quite satisfied with the design, although it will obviously be capable of change and development.

Regarding foil aspect ratio, I have a very open mind because, quite simply, I do not know which is better, high or low. I tend to think that *deep* foils (high AR) are excellent for lifting, whilst low aspect ratio is better for stabilizing because the compensating factor is quicker. With the low aspect ratio foil out to lee and just touching the water when upright, when the boat heels a degree or two, more area is immersed quickly.

I know from *MANTIS I* experience that, with the rear foil down, i.e. 6 ft × 1 ft under water, the boat didn't heel ½ in but it was then rather slow, thus defeating the object of the exercise. It was much better to retract the foil and "sit the boat upright". This again makes me think that for stabilizing, an aspect ratio of 1 : 1 seems right.

Summary

David Chinery has produced a design of a "Flying foiler", embodying all the relevant features of hydrofoils, as produced by AYRS members over the years. He described it as "like doing a jig-saw puzzle" but the main thing is that the design "looks right" to us. Certain things, such as the side foils' plan shape, aspect ratio and section and the method of height control while flying will doubtless undergo some development but there can be little doubt that, when the first "all round" successful hydrofoil sailer takes to the water, it will bear a strong resemblance to this design. It is truly a fitting finish to what we think is a really remarkable book.

THE CURRAGH

(A method for modern amateur hydrofoil boatbuilding)

by John Morwood

LOA	25 ft	Beam OA	4 ft 6 in
Weight	140 lb	Cost (1970)	£75

Since at least 1,000 B.C., Curraghs have been made in the Birtish Isles. Julius Caesar had some made while warring in Spain in 49 B.C. to cross a river, having previously seen them on the south coast of England in his campaigns there. The curragh of the Ancient Britons was probably made from hazel withies covered with hides from oxen or horses and Hornell states that its form is modelled upon ancient plank built boats.

Curraghs are still being made on the West Coast of Ireland and this summer I was lucky enough to meet John Goodwin and see the completed hull of a modern curragh in his building shed in the Magharees, Castlegregory, Co. Kerry.

Construction

The curragh is made from 1$\frac{3}{8}$ in lathes, about $\frac{1}{4}$ in thick stretched fore and aft over some 43 bent ribs, of about the same size. Where the lathes and ribs overlap, a single clenched nail holds them together. The lathes are close together (about $\frac{1}{2}$ in apart) near the 4 in plank $\frac{1}{4}$ in thick which is in the middle of the boat and could be called the keelson but separate to a gap of about 2 in near the lower gunwale.

There are two gunwales one above the other and separated about 6$\frac{1}{2}$ in by round rods about 1$\frac{1}{2}$ in in diameter. Each gunwale is from 2$\frac{1}{2}$ in to 3 in wide by 2 in in depth. The ribs' ends pass through rectangular holes in the lower gunwale cut somewhat obliquely.

When the shape is complete, the curragh is covered by canvas coated with boiled tar without any pitch.

Mast and Sails

All Kerry curraghs have a sail. The mast is 10-11 ft long and a lugsail is set on a 9 ft yard. Leeboards are carried but, as there is no keel whatever, the curragh cannot beat to windward.

Use

The curragh is an inshore and longshore fishing and rowing boat with sail for free winds. It can carry a cow or horse (upon a bed of seaweed and suitably trussed) a load of potatoes or anything else needed by people within reason. It can also be an excellent seaboat if caught out in the Atlantic. It has survived when plank built boats have been lost.

The Modern Application

The main advantages of the curragh method of construction are as follows:

1 It is cheap.
2 It is flexible but strong.
3 Absolute latitude of design is freely available.
4 If glass cloth and resin are used for the skin, "one off" fibreglass hulls become simple.
5 Extreme light weight becomes easily possible.
6 The method lends itself exceptionally well to keel-less round-bilge hulls such as are desirable for foil-stabilized sailing boats.

Reference

The Curraghs of Ireland Part 3 by James Hornell. Price 3s 6d. Published by the Society for Nautical Research, National Maritime Museum, Greenwich, London, S.E.10.

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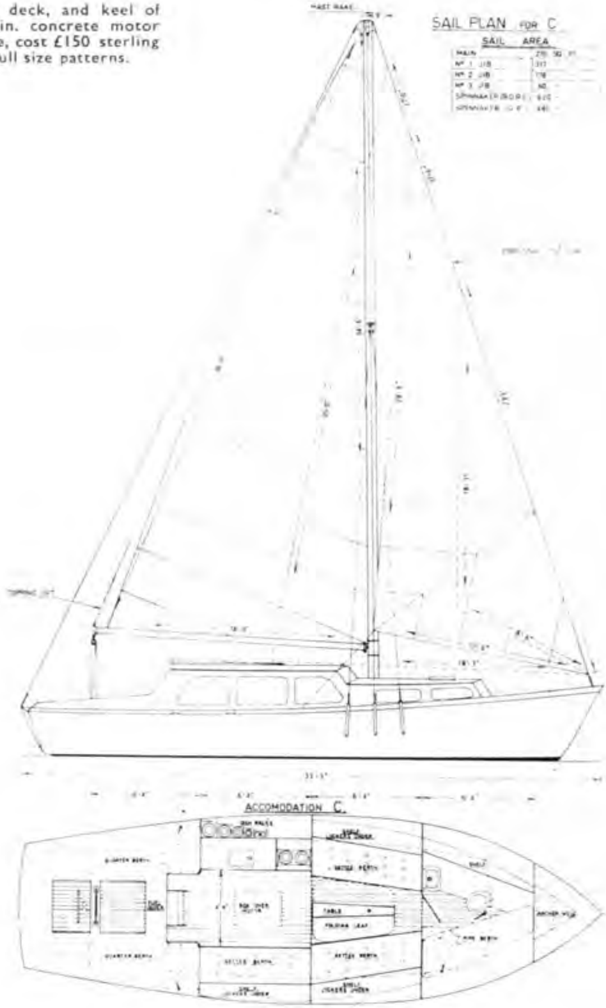

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