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SAIL RIGS AND HYDROFOILS

JACOBS LADDER AT SPEED.

CONTENTS

Swing Wing Rig System By Sunbird Yachts Ltd., - Copyright.
373 Hunts Pond Road, Titchfield,
Fareham, Hants PO14 4PB England.

Developed from the 'Junk' rig the three main improvements claimed are:—

1. Improved windward ability but retaining easy handling.
2. removal of heavy yard spar.
3. More pleasing appearance.

Battens — Sail and Relative Parts

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Sail Rigs and Hydrofoils

by Michael Ellison.

Our past publications from number 3, "Sail Evolution" cover just about every combination of sails possible but still new ideas come forward and we often receive proposals for ideas already tried. We need a book to cover our past work on rigs but in this number we present ideas from various members on kites and sails and some thououghts on matching these to hydrofoil yachts.

On R.A.F. aircraft from 1920 to 1940 the same wings were often used for different 'planes as a matter of practical economy. The Sunderland flying-boat and Lancaster bomber are one example. This illustrates that the same sail rig should be quite satisfactory on different hulls. There are of course different shapes for high speed and high load wings and for marine use we must change the shape of our sails for maximum lift at low, very low or negligable air speed in flying terms.

The bi-plane or tri-plane rigs offer many advantages especially lowering the centre of effort and an easy means of cross bracing for strength as described by James Grogono for "Icarus 11" on page "Crossbow 11" is probably the best known successful user of this rig while the French "Trimama" is a successful 'three in a row' design. "Clifton Flasher" with five 'one way' aerofoil sails put up a measured speed of 22.14 knots in 1974 and won the 'design award' at Portland in 1974. (Nigel Irens). She held the 'C' class record until it went to"NF^2" in U.S.A. but "Flasher" did not use hydrofoils. Against these fast craft there have been some like the 45' "Yo" which started with a 'bi-plane' rig and then sailed faster when one mast was removed and the other put in the usual position. The improvement in performance is difficult to understand - would "Crossbow" also be faster with a single mast ?

This line of ideas is useful and important. "Crossbow" is designed and built for the sole purpose of being fast. That she might be faster racing round the buoys or in light winds with only a single mast is no interest to Tim Coleman and his team. "Eva L" may be the slowest yacht in the world (Pub 96) but this need not mean that a bermudian ketch rig is not satisfactory or extra slow. It must be true that great care is needed to match the rig to the hull having full regard for its intended purpose and use.

The construction and narrow beam of monohull yachts made side-by-side rigs impracticable until recent racing rules and light weight, high strength materials made wide hulls fashionable so that these rigs have only been possible since the foundation of our Society and the development of multihulls over the last 28 years. Perhaps it is to our credit that so many rigs have been tried rather than a surprise that we see so few in regular use. Certainly no one is yet claiming the fastest "kite cloth" in their advertisements.

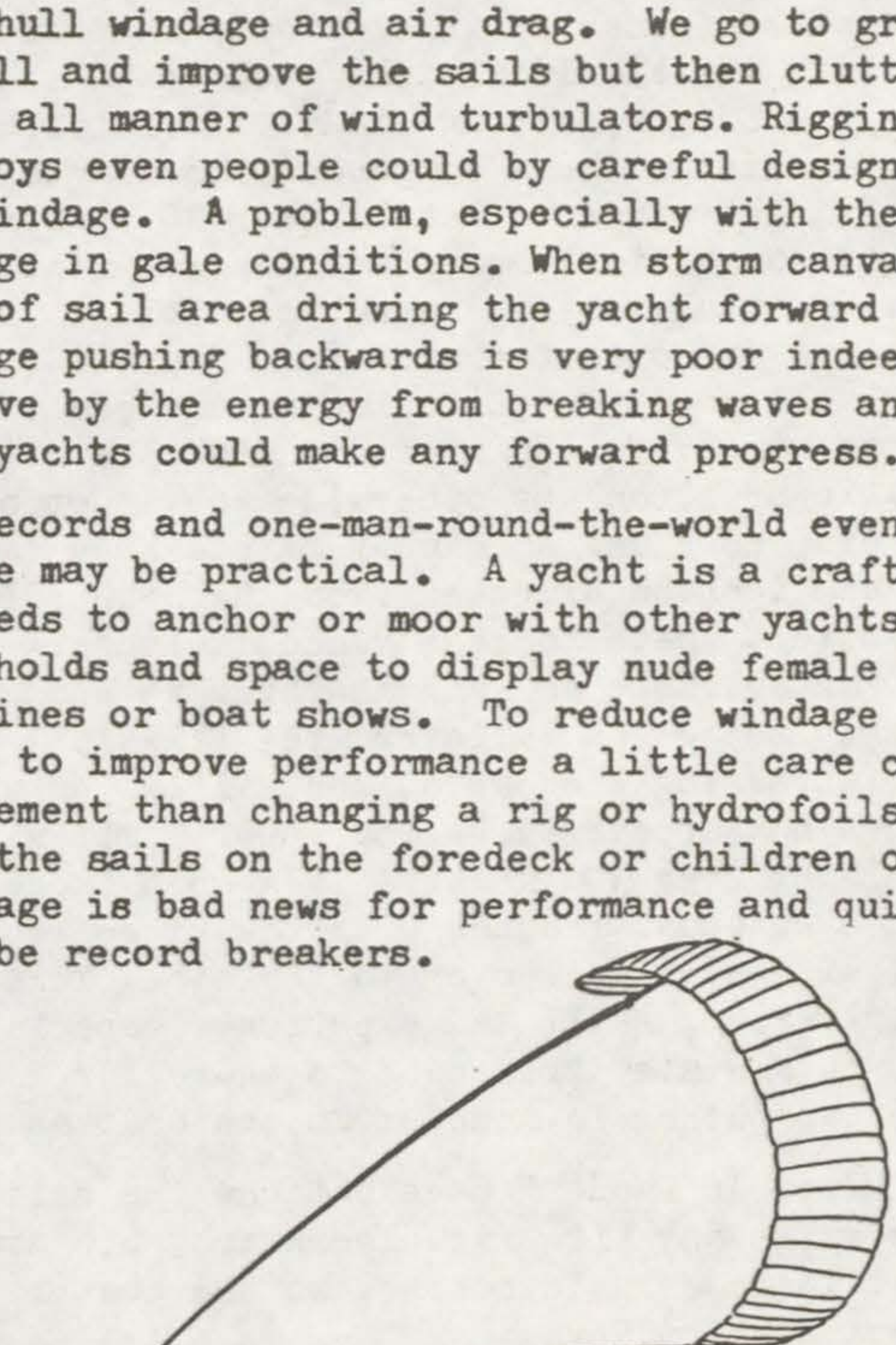
Cover Picture = 'Jacob's Ladder' with neither sail or hydrofoil !

It has been reasonably demonstrated that the bermudian sloop and cutter rigs offer the best windward performance of the arrangements in general use and that the schooner, ketch and yawl are not competitive when racing. It has also been shown that there is a "hump" in sail performance at about 14 knots of wind speed. Above this speed the air flow around the mast alters and results of racing catamarans with single "wing" sails seem to show that from this point the headsail (which fairs the air flow around the mast) is no longer essential if the mast can rotate.

When Christopher Hook and John Walker first presented their hydrofoil and aerofoil inventions it was remarked that there were so many new ideas that it was impossible to know which were good and which failed with the result that the projects foundered. The way forward could be to try the best available rigs on our foilers and then try multi-mast rigs sideways or other forms of lifting rather than heeling sails. Prout Brothers and Jon Montgomery have used practical masts which can be heeled to windward easily and this should be simple with a 'goal post' rig. Ken May warned us that if overpowered such a rig capsizes at an increasing speed as more sail area is presented and lift reduces when the yacht heels. If the rig is inclined to 45 degrees there is no heeling moment but the area for propulsion is greatly reduced.

Through many publications and notes it is suggested that we pay more attention to hull windage and air drag. We go to great lengths to fair the hull and improve the sails but then clutter up the deck and mast with all manner of wind turbulators. Rigging, rails, hatches, lifebuoys even people could by careful design be positioned to reduce windage. A problem, especially with the bermudian rig is windage in gale conditions. When storm canvass only is set the ratio of sail area driving the yacht forward to the rig and hull windage pushing backwards is very poor indeed. Reduce the forward drive by the energy from breaking waves and I wonder if some modern yachts could make any forward progress.

For world speed records and one-man-round-the-world events a fully streamlined shape may be practical. A yacht is a craft used for pleasure and so needs to anchor or moor with other yachts, she must have rails, hand holds and space to display nude female forms when featured in magazines or boat shows. To reduce windage is a problem but if we wish to improve performance a little care could bring a greater improvement than changing a rig or hydrofoils. A net is useful to keep the sails on the foredeck or children out of the water but the windage is bad news for performance and quite out of place on would-be record breakers.



KITE Sailing - A Progress Report

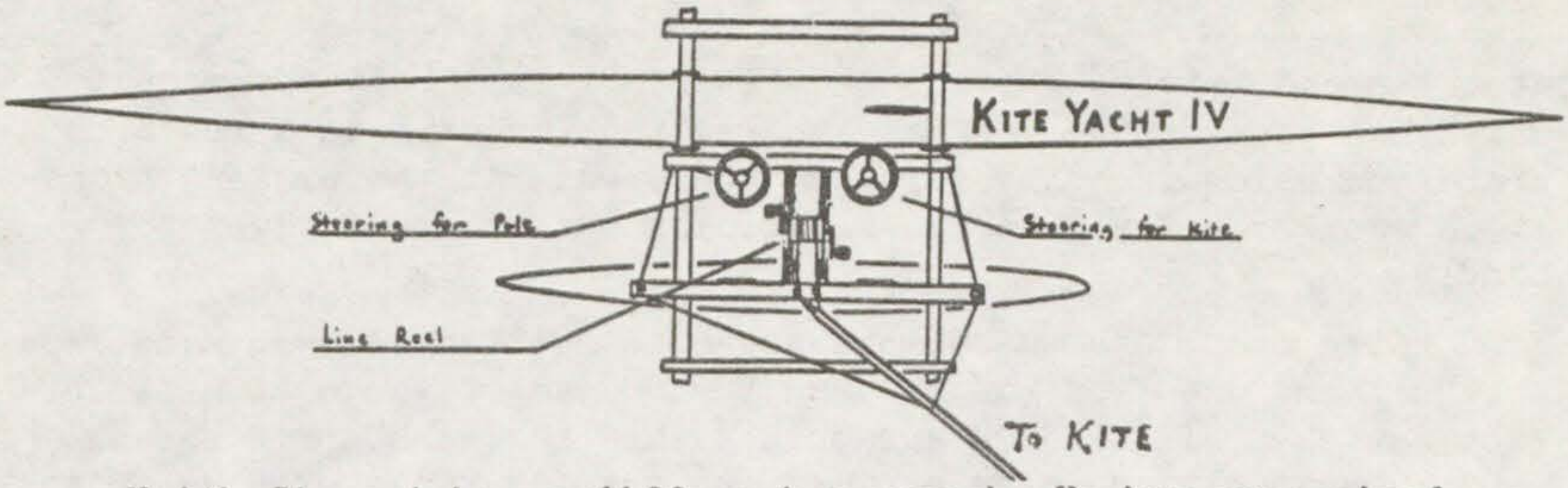
From Theodor Schmidt
C.F. Meyer-Str. 6,
CH - 4059 Basel.

The principles of sailing with kites have been described many times on these pages and will be familiar to most members. The purpose of this article is to show some of the ways these principles have been applied in practice.

Two types of kite propelled craft have been appearing regularly at various European speed sailing events; Keith Stewart's series of Kite Yachts and Ian Day's "Jacob's Ladder" which, helmed by Martin Rayment, currently holds the world sailing speed record in 'C' class at 25.0 knots. (49.1 KpH).(21.85 to 27.88 sq.m. area.)

"Jacob's Ladder" is a modified Tornado catamaran hull powered by a stack of 15 Flexifoils. These are commercially available rectangular stunt kites which are ram-air inflated and are flown stacked one above the other on two lines, looking rather like a ladder to the heavens. These kites have the property of pulling very little when kept stationary with respect to the boat, but if they are steered to swoop quickly around the sky the pull increases tremendously. This is because the force the kites produce is nearly proportional to the square of their apparent wind speed. The ratio between the forces of this dynamic mode and the static mode is very high with the Flexifoils, as much as 30 in light winds but down to perhaps 3 in very strong winds. The ratio between the maximum and minimum driving force components horizontaly downwind can be over 100 in light winds but still over 10 in strong winds. This gives the kiteman a similar degree of power control as with a conventional sail. Unfortunately it is not possible to maintain full power with the kites far over the side from downwind. They are then in a vulnerable position quite low down where there is less wind and room to manoeuvre. In a strong wind the kites can be kept there in a static position but otherwise they must be kept moving or they will drop down and so cannot maintain as large an angle from downwind as might be expected from the high efficiency of the kites themselves. Nevertheless "Jacob's Ladder" goes upwind well and is very manoeuvrable as long as there is enough wind to keep the kites flying. Being ram inflated, the Flexifoil body becomes stiffer with increasing wind speed and will withstand very high winds. Force 10 does not appear to be the upper limit although the kites can be travelling over 100 knots ! "Jacob's Ladder's" best speeds are reached on broad reaches with the kites kept working in large vertical sweeps well over to the side. This requires considerable concentration, skill and experience especially as dunking the kites means an assisted trip back to shore for a relaunch, as the Flexifoils can not be launched from the boat at present.

"Jacob's Ladder" does not use the self steering property inherent in any kite rig. The kites move around so much this would result in an erratic course, so the boat is steered with conventional rudders.



Keith Stewart has a different approach. He has recognized that the proa is probably the type of hull best suited for kite propulsion. A conventional hull driven by kites can easily gybe but can not tack unless able to go backwards briefly. Either way ground is lost when going to windward. A kite powered proa simply shunts by shifting the point of attachment of the kite lines. This is less complicated than on a conventional proa where the sails must be shifted or swung round and the rudders changed over. The kite-proa needs no rudder as its course is determined by the direction of pull of the kite lines and the position of their attachment in relation to the center of lateral resistance.

With the help of David Culp and more recently the author, Keith Stewart has tried many permutations of the relative positions of hull, outrigger float, leeway resisting foil and attachment of kite lines. The present configuration has a centerboard in the main hull and an outrigger with float to leeward. A pole attached to the outrigger beam carries guides for the kite lines and can be moved around for steering. A track could be used instead but would need to be heavier. With this type of configuration Flexifoils would not be very suitable as the boat would follow the movements of the kites, resulting in a weaving course. The float is for stability at rest and is lifted out of the water completely or partially by the vertical component of the kite force when under way. Some attempts were also made to power a Seafly hull (copy of "Mayfly") with kites. This small flying hydrofoil catamaran called "HiFly" has not yet been very successful mainly due to the difficulties of managing both kites and hydrofoils at the same time !

Stewart has tried out many different types of kites, but they all have one thing in common : parts or the whole of the kites are inflatable and they can all take off from the water in some manner. The latest model called the "Parasail" is a totaly inflated type of parafoil and has the same type of shroud and steering lines which are rigged together with a pulley to permit flying on two lines. Unlike the Flexifoils this kite pulls hard all the time it is flying, the static pull being several times that of the former, area for area. It will not fly as fast as these however and the dynamic pull is therefore less. Although not as powerful a rig as the Flexifoil stack, the "Parasail" performs better in the static mode, pulling harder far out to the side and is well suited for going upwind very closely. A unique feature of this kite is that it can be 'parked' upside down on the water and be made to take off at any time. This was demonstrated many times on the water. The "Parasails" can be stacked but this is so complicated that single large ones were used at the speed trials. Whereas the Flexifoil is a refined product which has been around for many years, the Parasail is a research prototype which is being further developed. At the present stage it is easier to fly than the Flexifoils but more difficult to handle.

"Kite Yacht 1V" was also a new construction (though made from the hull and one float of veteran "Sulu") so it was not until the last few days of the 1982 Weymouth trials that the craft began working properly and made a timed run over 11 knots with $7m^2$ kite in a medium to light wind. Using $10m^2$ kite in a slightly stronger wind produced bursts estimated at 15 to 20 knots but not timed.

Many experimenters are having fun sailing more or less downwind using conventional unsteerable kites. These must of necessity be quite small unless a second tripping line is rigged, otherwise it would be impossible to get them down without winching gear. Most people use toy sized Jalbert parafoils as they are ready to use straight out of the bag and give quite a good pull. Last year Baron Arnold de Rosnay crossed parts of the Pacific using such kites to pull his sailboard while he was sleeping at night.

Stewart's best single line kite is a totally inflated delta derivative which is easy to handle and launch off the water. It can also be filled with lifting gas causing it to rise in no wind at all. As it is never completely calm higher up the kite will always provide some pull, this would be the ocean sailor's godsend when becalmed were it not for the difficulty of carrying helium or hydrogen around.

A recent development is a radio remote control unit for the above kite which enables it to remain in a stable position at any angle up to 45° either side of downwind. With an efficient craft this is enough to go upwind somewhat, and it is thus possible for a boat to self-steer upwind without any moving parts, even in very light winds. This has been seen to work from calm to force 5 with the kite inflated with helium. It is hoped the principle can be extended to more efficient kites which might make ocean-going kite pulled craft a practical proposition.

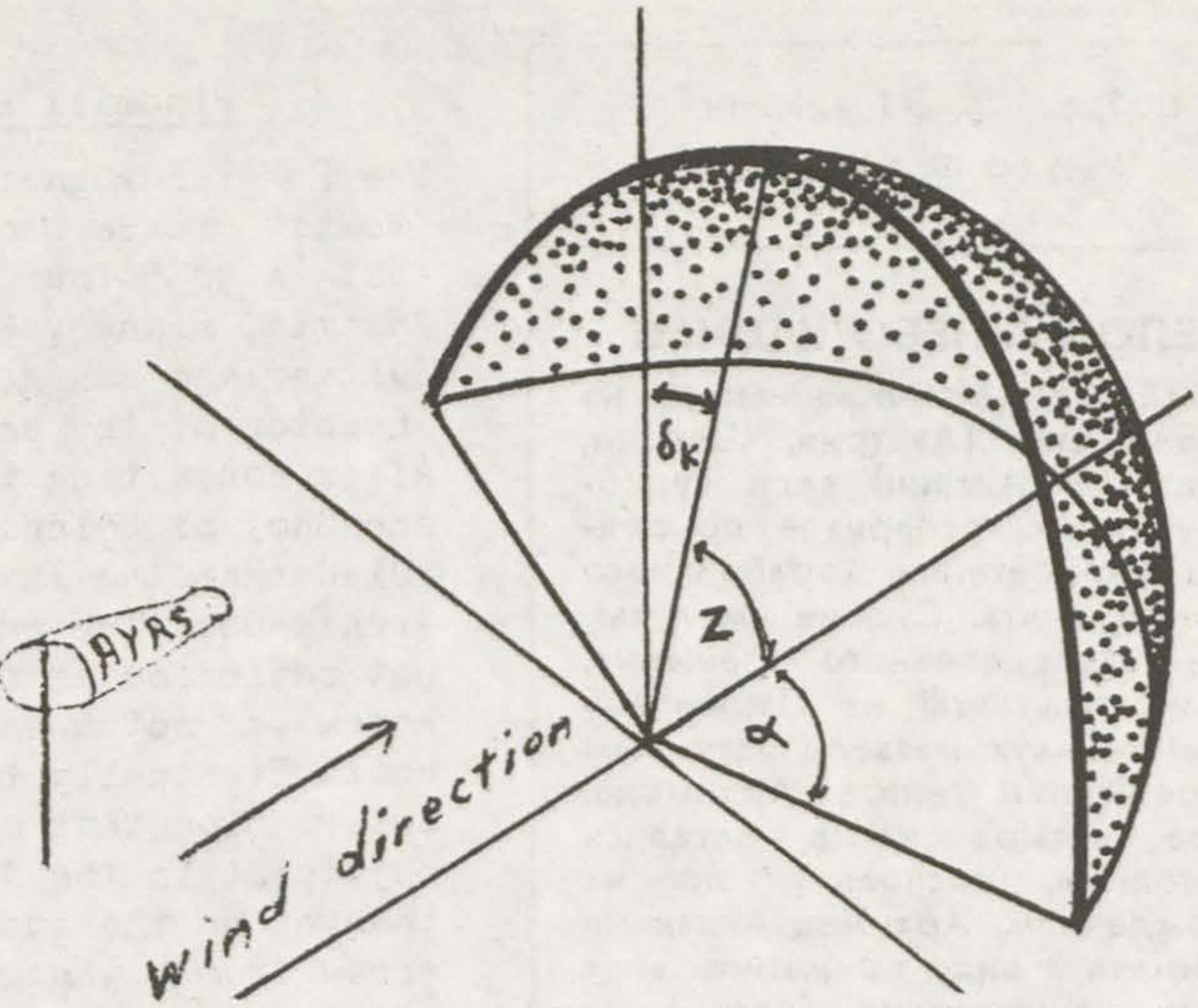
References

"Kite Sailing - A Survey" Theodor Schmidt. Boat Technology International. July 1981. This contains an almost complete list of previous references.

"Jacob's Ladder" Ian Day. Yachts & Yachting. 17 Dec 82.

"The Kites Come Into Their Own" Multihull International, Issue 177 October 1982. p 232 & 233.

A.Y.R.S. index Kite references sometimes refer to a sail mounted on a mast or spar and not free flying as a "kite rig". These are now called "inclined rigs". Thus No.9 p23-26 refers to flying kite propulsion (October 1956) also No 17 p31 & 32. Walter Bloemhard used the term for an inclined rig (No 26 p30) and George Benello with W. Copley followed (No 33 p 46). Number 37 p43 shows O.W.Neumark being towed in the sky on a 200 sq. ft. inflatable wing which he hoped to convert into a kite for towing boats.



<u>Appendix</u>

The figure represents all positions an efficient kite can have with respect to its point of attachment. The maximum elevation angle 'Z' (= $90^o - \delta_K$) is only obtained with the horizontal projection of the kite pointing downwind. δ_K is the kite's aerodynamic drag angle which is arc (D/L). A typical value for Flexifoils and parasails is 20^o. The maximum horizontal angle from downwind α is only obtained with the kite line horizontal and thus with the kite very near the ground. In a steady wind with a weightless kite and an imaginary line α would be equal to 'Z', but in practice α cannot be reached as the weight of the line and kite require it to fly at some altitude. The thick curve shows the static boundry line along which the kite can hover in place. Anywhere else it will be moving in whatever direction it is pointed. The kite's maximum speed is approximately the true wind speed V_T divided by the sine of the drag angle δ_K. The kite can reach this speed near the point directly downwind of the line attachment but will be slower the closer it gets to the static boundary line. This explains why fast kites like Flexifoils can generate such enormous forces in fast downwind sweeps but pull so much less when forced to manoeuvre or even hover in one of the corners to the side. (Also the Flexifoils feather out so much at low speeds they hardly pull at all being hampered by the weight of line necessary to withstand full dynamic force. In contrast Parasails and Parafoils pull with a constant force all along the static line right into the corners but they are not as useful in the dynamic mode due to increased drag at speed because of shape distortion and fluttering. It must also be noted that efficient kites are highly unstable and must be steered constantly although there is a semi-stable position at the zenith. This is where conventional kites sit which are stabilised by gravity. In the dynamic mode gravity forces are very much smaller than aerodynamic forces and cannot be used for stabilization. Controlling dynamic kites automatically will need a computer of some type.

Собрал Д. Эйдельман

Рисунки В. Боковни

ДЕЛО ЗА НЕБОЛЬШИМ!

В 1835 г. четыре инженера из четырех стан (Австрии, Швеции, Франции и Англии) вели судебный процесс, оспаривая приоритет в изобретении корабельного гребного винта. Суд не смог вынести определенного решения, ибо консультанты из Парижской академии наук назвали истинным изобретателем винта Архимеда.

Все четыре истца остались недовольны, поскольку, по их утверждениям, Архимед никак не мог иметь в виду применить винт для движения судна. Тогда мудрые консультанты откопали предложение швейцарского физика и математика Якоба Бернулли (XVII век), который сформулировал идею винтового движителя совершенно четко: «Было бы много удобнее для кораблей, если бы они использовали не силу ветра, а движение мельничных крыльев, опущенных в воду».

Бернулли при этом совершенно серьезно добавил, что для реализации его великолепной идеи необходима самая малость — какой-нибудь двигатель, который вращал бы эти опущенные в воду мельничные крылья...

Windmill Power

The Russian magazine "Katera i Yachti", issue 4 of 1982 reports that in 1835 four engineers from Austria, France, England and Switzerland saught the original inventor of the screw propeller. After consulting the Paris accadamy of Science the court ruled that the inventor was Archemedes. The engineers were not satisfied as they said his screw was not used to drive a boat. Eventually they dug up the information that a Swiss physicist in the 17th centuary thaught up the idea of driving a screw from a windmill.

In May 1983 B.B.C. program 'Tomorrow's World' showed Ken May's model windmill boat that Rob Denny hopes to develop to full size for the 1984 O.S.T.A.R. if he can find a sponsor for the project.

As some people still say the earth is flat so some watch our model on wheels driving up hill against the wind and still do not beleive it. Understanding is a different problem and the full explanation is printed in our publication 91, 'Power From The Wind', for both horizontal and vertical axis windmills.

I assume that soft material which can be reefed is a "sail" and rigid aerofoils usually with variable pit ch are called blades. "Wind Turbine" seems to be a 'smart' name for a "windmill" with rigid blades used to power a boat or generator rather than the traditional water pump or mill stone

I think the artist has the waves going backwards ?

Windmill Project - Notes from R.A. Denney of 7D Queensdown Rd.,
Hackney,
London E 5.

Rob Denney hopes to find a sponsor to back the development and building of a windmill powered craft for the next single handed Atlantic race which starts from Plymouth on 2nd July 1984.

The proposal document has been well prepared and the project has the backing of a number of experts with technical skill in the different fields of knowledge involved. Rod Macalpine-Downie has designed a trimaran hull to support a 28ft diameter, three bladed, controllable-pitch horizontal axis wind turbine driving a 40 inch variable pitch water propeller using hydraulic transmission.

The 'rig' is to be mounted on a tripod two legs of which revolve on a 6ft diameter track so that it always faces the wind. The vertical centre leg houses controls and hydraulic hoses.

'Turbine' blades are made of wood pressure-saturated and coated with epoxy and fibreglass. It has half the strength of steel but only one fifth the weight and has proved very successful both in England and the U.S.A.

The advantages of the turbine rig are:-

1) Its ability to sail directly into the wind.

2) The ease with which it can be controlled (one handle turns the rig, another alters the pitch of the blades, both of which can be done automatically).

3) The minimal strain it imposes on the boat compared with a conventional rig.

4) The additional space as no sail stowage need be provided.

5) The ability to sail the boat from a completely enclosed, weather protected position without exhausting oneself winding winches, changing and trimming sails.

6) It should be possible to generate electricity for general use.

The disatvantages are that :-

1) It may be slower with the wind from behind as it will not be possible to hoist additional downwind sail area, although if time and budget permit we would experiment with kites which have already proven successful in smaller boats. We should then have sufficient down-wind speed to attempt a record breaking passage back from America, for which the 'Sunday Times' paper is offering a substantial cash prize, and associated publicity.

2) The danger of walking into the 'turbine' although it will be feathered, braked and stationary if any work needs to be done on deck.

The Craft

The boat is to be 40ft long, 30ft beam trimaran, of fairly conventional design, with emphasis on keeping everything as light and simple as possible.

She will be built using epoxy saturated, cold moulded wood which is extremely light and strong.

The central hull will contain a bunk, cooking and navigation equipment plus the controls and machinery for the rig, which will be positioned where the mast of a conventional rig would normally be.

The outer hulls are solely for buoyancy and stability and will be connected to the main hull with carbon reinforced wooden beams.

The water propeller will be of controllable-pitch to ensure maximum thrust in all conditions and points of sailing. It will be situated about 14 ft forward of the stern, so that it is always in 'solid' water, undisturbed by the boat's pitching and rolling.

The Team

Robert Denney has ocean racing and cruising experience as well as yacht design and building. He built the catamaran "Jan 11" for the 1982 'Round Britain' and ownes an "Iroquois" catamaran. In view of his past preference for two hulls we asked why three for this project? The answer "The boat has to be light and stable with sufficient internal space, including headroom, to live in and take people sailing, without them going on deck and walking into the turbine. To get this into a catamaran it must be very high or very large, both of which increase weight. "Jan 11" was extremely cramped and a good lesson in weight versus comfort. Support for the rig is more difficult on a cat, as is support for the propeller.

Geoffrey Williams (1968 OSTAR etc.) is currently involved with the design and building of a large wind turbine generator with Windpower Ltd. and he is giving advice on aerogenerators and blade construction.

Rod McAlpine-Downie is designer of the yacht and will look after supervision of the building.

Dr Roger Wootton has many years of experience of designing and appraising windmill rigs for commercial use. He will be project manager, responsible for analysis of turbines and stress, also meteorological data.

Dr Stephen of Moog Controls Ltd will look after hydraulics.

The first phase of the project is proceeding with a review of the problems, assessing expected performance, checking stability and producing a report including accurate costs and timetable.

Mainsail Reefing

Note by Michael Ellison.

Some members have not appreciated that reefing the mainsail down to the boom or forward to the mast using roller reefing gear produces the same change in the centre of effort. Phil Weld, winner of the last O.S.T.A.R. chose to reef his mainsail to the mast. He estimated that the gain due to the ease of setting more sail was greater than the loss of drive due to the absence of sail battens.

Headsail roller reefing gears have proved 99% reliable, they are a real asset to cruisers and a benefit to short-handed racers. It is reasonable therefore to consider roller reefing the mainsail in the same way.

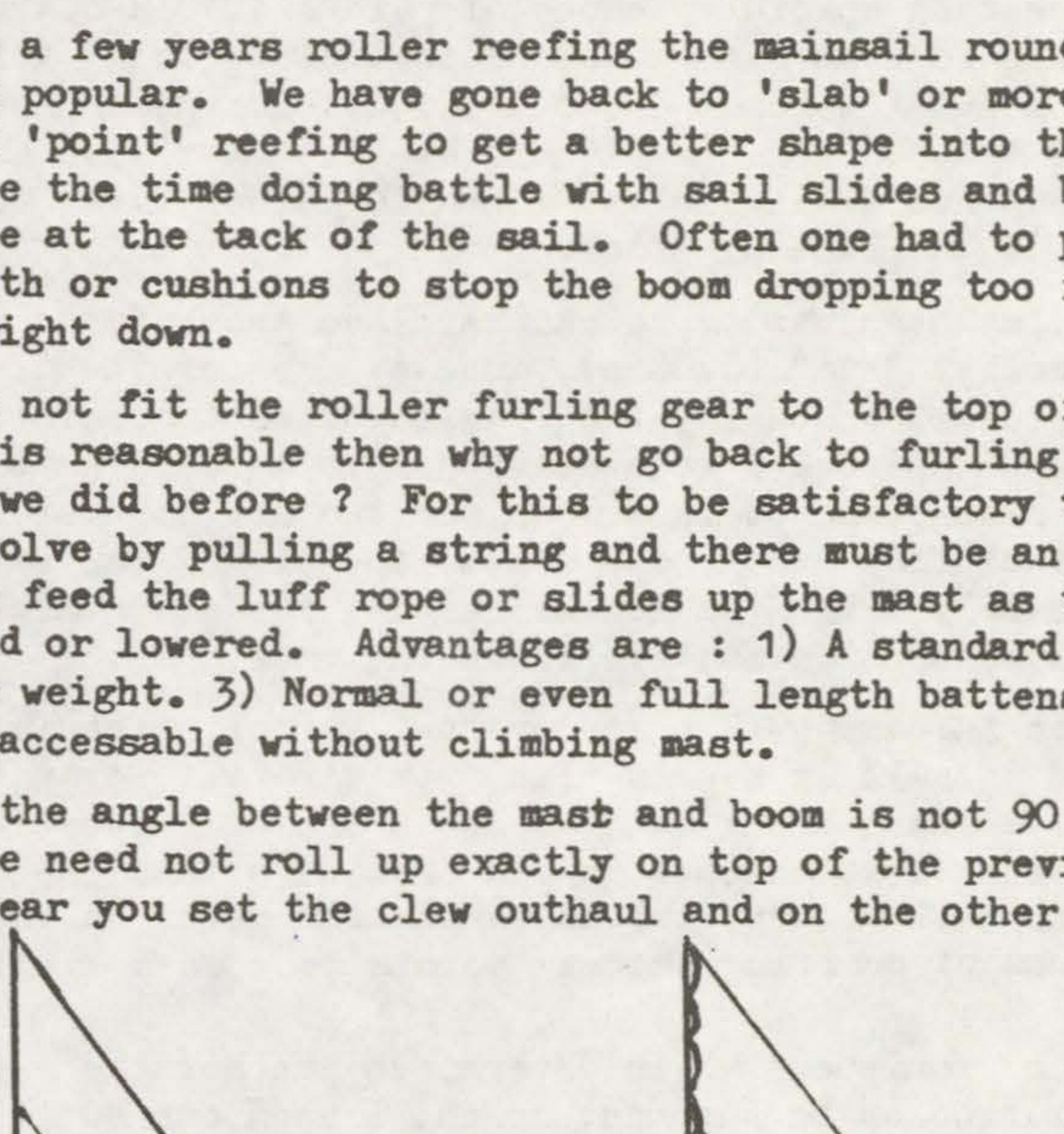
Two types of gear are available. First the special mast which the sail rolls up inside, second are conversions of headsail gears set aft of the mast with a small gap to give space for the furled sail. For both types an extra heavy mast is probably necessary and the weight aloft is increased by the furled sail and top swivel.

As with headsails the sail must be cut flat in order to roll up. With the slot aft of the mast sail performance might improve but the luff should not sag off to leeward as some headsails do. There can be no battens until inflatable ones are developed to keep the hook out of the leach.

For a few years roller reefing the mainsail round the main boom was popular. We have gone back to 'slab' or more convenient forms of 'point' reefing to get a better shape into the sail and to reduce the time doing battle with sail slides and building up luff rope at the tack of the sail. Often one had to pack the clew with cloth or cushions to stop the boom dropping too far when rolled right down.

Why not fit the roller furling gear to the top of the boom ? If that is reasonable then why not go back to furling round the boom as we did before ? For this to be satisfactory the boom must revolve by pulling a string and there must be an automatic guide to feed the luff rope or slides up the mast as the halyard is raised or lowered. Advantages are : 1) A standard mast. 2) Lower weight. 3) Normal or even full length battens can be used. 4) Gear accessable without climbing mast.

If the angle between the mast and boom is not 90 degrees the bolt rope need not roll up exactly on top of the previous round. On one gear you set the clew outhaul and on the other the halyard.



Amateur Builds His First Mast. From Michael Peters,

After I was two years into building a Cross 24ft (7.32m) trimaran sloop in my backyard I needed a mast. The plans called for either a $2\frac{1}{2}$" x $5\frac{1}{4}$" x 30' (6.35cm x 13.34cm x 9.14m) solid spruce spar or aluminium extrusion. Alternatives Douglas fir or Norway pine. (each part of the world has its own most economical spar making timber.) Sparmakers in Chicago quote for a sitka spruce was in the $ 500 range while a bare aluminium extrusion ran to $ 250. Both more than I was willing to pay.

I decided to look into the possibility of making the mast and two booms myself. As I had decided to build a wooden boat I thaught it logical to make the mast of wood rather than aluminium.

The beginning amateur does not know what he is getting himself into when he decides to construct his own mast. The right tools are indispensable to turning out a craftsmanlike job worthy of the boat it will grace. Fortunately, living in a large city, I found a local park craft shop devoted to the amateur boatbuilder. It was set up with mast bench, thickness planer, shaper, and a multitude of odds and ends I would need to do a sound job.

I was also fortunate in finding a shop with a stock of spar quality air dried sitka spruce ; an ideal mast making wood which grows in the Pacific Northwest of America and Canada. It is hard to find except in specialty shops. I paid $ 1.10 a board foot for it. The board foot is a measurement equivelent to 1" thick x 12" wide x 12" long. (2.54cm x 30.48 x 30.48). The plans specified a sandwich of two 30' x $1\frac{1}{4}$" x $5\frac{1}{4}$" stock. (3.18cm x 13.34cm x9.14m). This size was not available and I had to accept three 16' and three 14' peices of 1" (2.54cm) stock.

The first step was to thickness plane each of the six pieces to approximatly 13/16" (2.06cm), an easy job for the 12" wide thickness planer. Each layer of laminated mast consists of one 14' and one 16' piece. I made scarf joints at each butt by tapering the end of each plank so that when the two are counter opposed and glued together they become one continious plank. The ratio of scarph is approximately 4 to 1, which means that for a 1" thick plank (2.54) a 4" (10.16cm) section is beveled on the end.

The job is done with a router box, a tool which is very simply constructed in half an hour's time from straight scrap lumber. The end of a given mast plank is clamped in the box, whose sides are beveled. A router attached to a flat board is then pushed alternately down and across the ramp, cutting a similar beval on the plank. The whole process of scarfing the six joints took me a little over an hour.

The peice of equipment which determines whether the mast will be straight or crooked is the mast bench. I used one 40' (12.19m) long, 6" (15.24cm) wide of $\frac{1}{4}$" (6.35mm) steel held onto a brick wall with angleirons from underneath. The bench is perfectly straight and level. Before I found out that such professional devices exist for mast making, I considered using a long flat floor and heavy weights to hold the drying spar together.

I chose urea formaldehyde glue to hold my laminate together. This light brown powder is activated by mixing with water until it has a paint like consistency. After generously brushing the glue onto my planks as I set them up on the bench, I had to use some 60 large jawed C clamps to hold the entire assembly immobile for the two day drying time. Besides holding the planks from slipping relative to one another, the clamps provide the pressure which the urea formaldehyde needs to effect a proper bond.

After the glue had set, the next step was to fashion this timber into the shape of my finished spar. I struck two parallel chalk lines 6" (13.34cm) apart and sawed through with my 7" (17.7cm) circular handsaw. The curved edges of the mast developed after a lot of hand planing followed by sanding with the orbital sander and sanding block in turn.

The varnishing was time consuming mainly because it's necessary to wait for the drying time between the six or seven coats needed.

Seven mast tangs were required for the attachment of the standing rigging. Rather than buy them, I decided to try my hand at fabricating these too. I did this very easily as all the stock called for on the plans was 1/8" (3.18mm) thich stainless steel. I bought 1" wide (2.54cm) wide straps from a sheetmetal shop, hacksawed them to the proper 7" or 8" (17.78 or 20.32cm) lengths and ground the ends round on a bench grinder. With the addition of the proper drilled holes and some polishing, I have tangs every bit as seaworthy as ones from a factory.

Lack of metal working experience decided against my making the halyard sheave. A retired toolmaker friend volunteered to make me two in his basement shop. From a 4" (10.16cm) diameter aluminium cylinder he cut off ½" chunks and cut 3/8" (9.53mm) groove down the middle of each to exactly match the halyard line.

Installing the 26' (7.92m) of 5/8" sail track proved to be a very time consuming procedure. Because the hole spacing for the screws on this track is only 4" (10.16cm) apart, I had to drill some 80 pilot holes. I forced bedding compound into each hole and also on each screw shank before I drove it in. Sitka spruce is reputed to dry rot easily if left unprotected. Thus, the precautions against getting even a drop of water inside the mast.

The only wrong choice of materials was my use of brass instead of stainless steel for the track. The brass developed cracks after only one season. This could have been from my tightening the screws down too far. I replaced a 10' (3.05m) section with stainless steel.

As the booms were so much shorter than the mast, I built them in the basement. The main boom measured basically 1-5/8" (4.13cm) x 3-5/8" (9.21cm) with a taper on each end. The jib boom was a 1-5/8" (4.13cm) square. I laminated each of the booms out of 1" (2.54cm) stock, surface planed to 13/16" (2.06cm). Since I was'nt well equipped with large clamps at home, I made my own out of peices of 1" x 4" x 10" scrap timber with 4" x ¼" bolts and butterfly nuts. Tapering the underside of the main boom was very easy because I was able to feed it through a bandsaw.

It cost me $ 67.20 for timber to build my mast and booms. Five dollars worth of glue was more than enough for the whole project. I'm not counting the cost of hardware, since that figure would be about the same for either a home or professionally built spar. The time required? Two weeks of evenings and weekends.

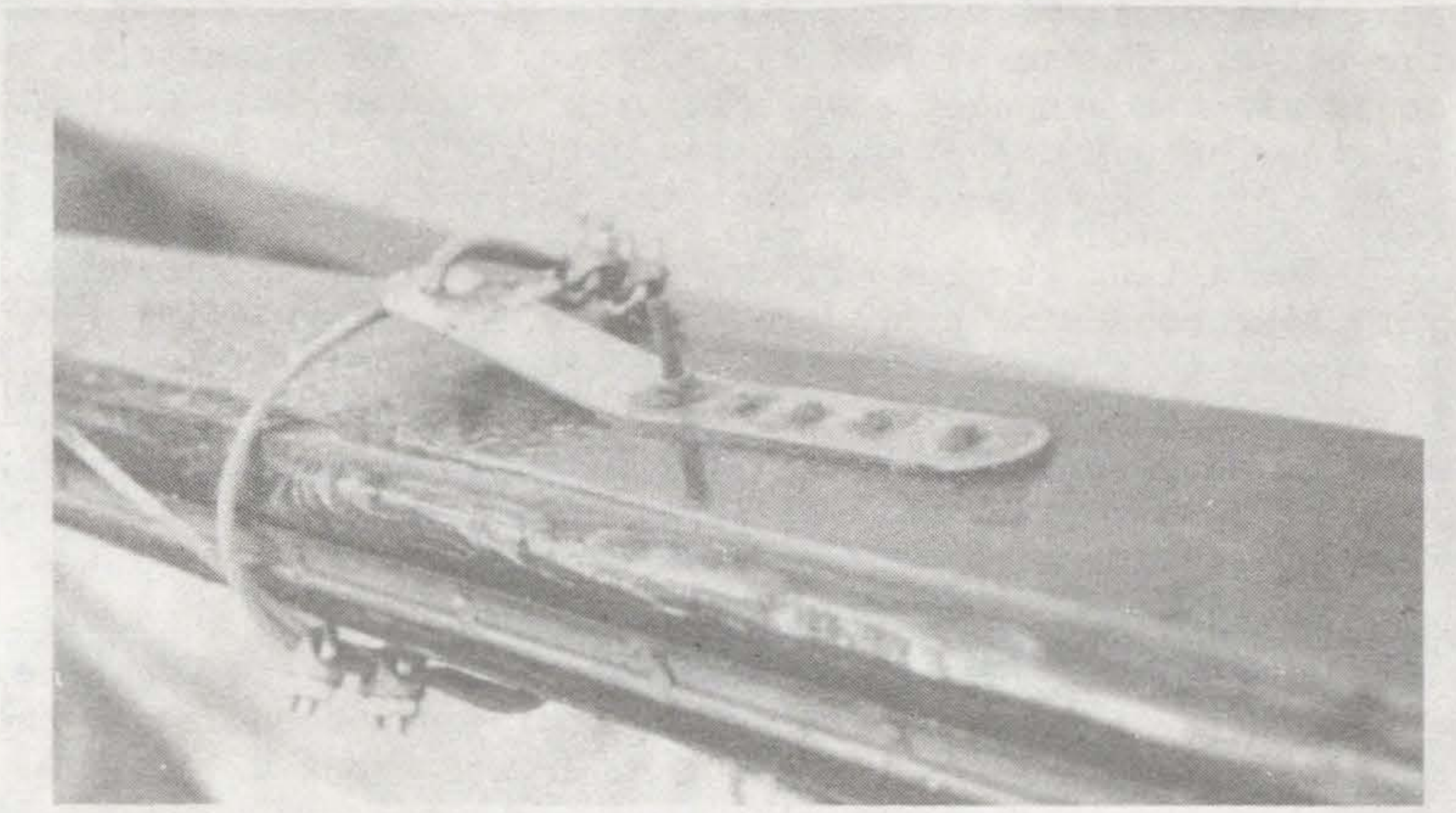


Photo from Michael Peters

A Lesson from 'Sabu' Construction.

Do not listen to people who claim that screws or nails are only needed until the glue sets. Most glue is stronger than the wood but several test samples I have destroyed show that the wood breaks or more usually tears before the glue bond but screws transmit the load through the surface making a much stronger joint. Wood pegs soaked in epoxy as suggested by S.P. Systems to replace 'treenails' seem to be as strong as screws.

'Canard Foil' = Improved Keel Performance ? May 1983

From Javier Soto Acebal, Maure 2126,
Buenos Aires 1426, Argentina.

I have an idea that looks strange but which should be efficient. This is to fit a "canard" foil in front of the keel with two objectives :- to contribute to the lift (required by sails) and to delay seperation over the low pressure side of the keel.

The second point is less clear, I think the vortex rotation produced by the canard will direct higher velocity water close to the keel into the boundary layer (low pressure side) and help keep the flow attached thus delaying stall.

Seperation will be insignificant when Reynolds number is small (absolute values) and so the canard will not be a benefit on calm days. When more lift is required and there is higher pressure on the leeward side of the keel seperation limits the amount of lift available and the canard should delay this point of stall.

From the figures you may note that I chose a "keel canard" configuration of 20 degrees sweep forward in one case. I like this for the beneficial characteristics of forward sweep, it is not important to this idea but note that the weak point of "sweep forward" is "root stall" so here again the canard is beneficial because the vortices of the canard are working in the root zone of the keel.

As it will not be efficient on calm days the canard must be retractable. The section being constant will not leave a gap or slot in the hull. When raised a high aspect ratio keel will remain which will be optimum when limited lift is required. As there will not be an excess of lateral area the leeway will remain optimum giving a high Lift/Drag ratio and improved Vmg. As the wind increases and more lift is requred the canard can be lowered partially or totally.

I think with this canard configuration the boat will have a better distribution of lateral area and will therefore maintain a better course. When sailing free the canard is fully raised reducing wetted area.

For an equal keel area the canard configuration gives more lift and exerts less drag. This implies that the side force of the sails will be balanced with less wetted area leading to improved performance.

The calculations were made with theoretical equations that do not take account of the benefit of the vortex generated by the canard which if well positioned will lead to greater improvements.

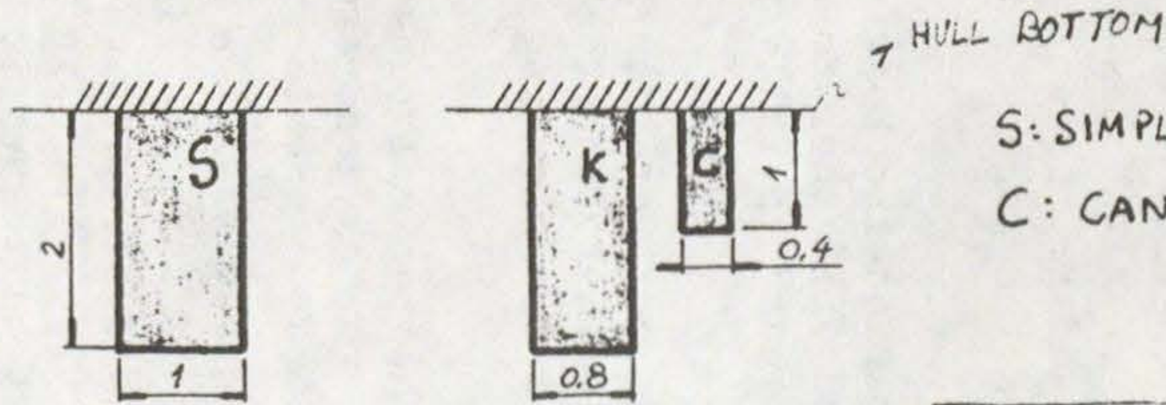
Comparing the two configurations shows that the canard has more keel-hull interaction; the effect of this interference being beneficial. I think the success of the configuration will depend on its location (its fore and aft position). This is very difficult to predict by theory and must be tested in a tank.

Javier Soto Acebal is a 23 year old engineering student interested in yacht design. He would be pleased to hear other opinions.

To illustrate my idea I have compared a simple keel and the canard configuration, for the same boat and with the same lateral areas. I have chosen vertical foils for clarity and speed of calculation.

May 1983

From Javier Soto Acebal, Maure 2126,
Buenos Aires 1426, Argentina.



S: SIMPLE CONFIGURATION ; K: KEEL OF THE CANARD CONFIGURATION

C: CANARD ; CC: CANARD CONFIGURATION

$\boxed{\text{EQUATIONS}}$: <u>LIFT COEFFICIENT</u>: $C_L = \left(\frac{\partial C_L}{\partial \alpha}\right)\alpha + \frac{C_{Dc}}{a}\left(\frac{\alpha}{57{,}3}\right)^2$

$$\left(\frac{\partial C_L}{\partial \alpha}\right) = \frac{0{,}9(2\pi)a}{57{,}3\left[\left(\cos\Lambda\sqrt{\frac{a^2}{\cos^4\Lambda}+4}\right)+1{,}8\right]}$$

WHERE: a = EFFECTIVE ASPECT RATIO; Λ = SWEEP ANGLE;

α = ANGLE OF ATTACK; C_{D_c} = CROSSFLOW DRAG COEFFICIENT

<u>DRAG COEFFICIENT</u>: $C_D = C_{d_0} + \frac{C_L^2}{\pi a e}$

WHERE: C_{d_0} = MINIMUM SECTION DRAG COEFFICIENT; e: "OSWALD EFFICIENCY FACTOR"

USING THESE EQUATIONS I OBTAINED: $\begin{cases} C_{L_S} = 0{,}2538 \; ; \; C_{D_S} = 0{,}01229 \\ C_{L_K} = 0{,}2763 \; ; \; C_{D_K} = 0{,}0119 \\ C_{L_C} = 0{,}2763 \; ; \; C_{D_C} = 0{,}0119 \end{cases}$

<u>FORCES</u>: $L_S = \frac{1}{2}\rho S_s V^2 C_{L_S} = K S_S C_{L_S}$ ⇝ WHERE: $K = \frac{1}{2}\rho V^2$ = CONSTANT FOR THE TWO CONFIGURATIONS

S_S = LATERAL AREA ; IN THESE CASE = 2

THEN: $L_S = K \times 2 \times 0{,}2538 = K\,0{,}5076$

↳ LIFT FORCE OF THE SIMPLE CONFIGURATION

$L_S = K\,0{,}5076$

$$L_{CC} = L_K + L_C = \frac{1}{2}\rho S_K V^2 C_{L_K} + \frac{1}{2}\rho S_C V^2 C_{L_C} = \frac{1}{2}\rho V^2 (S_K C_{L_K} + S_C C_{L_C}) = K C_{L_K}(S_K + S_C) \rightarrow$$

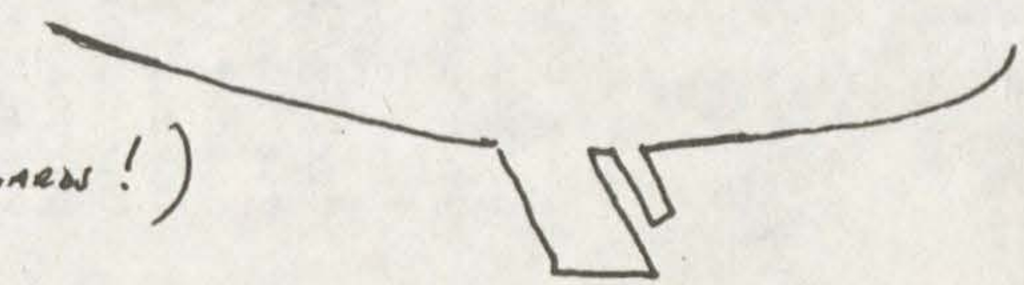
$\rightarrow C_{L_K} = C_{L_C}$; THEN: $L_{CC} = K \times 2 \times 0{,}2763 = K\,0{,}5526$ LIFT GENERATED BY THE C.C.

<u>DRAG FORCES</u>: $D_S = 2 \times K \times C_{D_S} = 0{,}0244\,K$ → DRAG OF THE SIMPLE CONF.

$D_{CC} = K[C_{D_K} S_K + C_{D_C} S_C] = 0{,}0238\,K$ → DRAG OF THE CANARD CONF.

Direction of travel ⟶

$\frac{L_S}{D_S} = 20{,}803$ $\qquad$ $\frac{L_{CC}}{D_{CC}} = 23{,}218$



(ARROW TO INDICATE KEEL SLOPES FORWARDS!)

Hydrofoils on Large Multihulls

From 'High Speed Surface Craft Conference' Paper, Spring 1983.

by Mr James Grogono, The Garden House,
Riverside, Bisham, Marlow, Bucks.

James Grogono is a leading member of the "Icarus" hydrofoil team holding the world sailing speed record for 'B' class. He is presently very interested in encouraging and helping larger offshore yachts to take advantage of hydrofoils to improve performance.

Hydrofoils have been successfully applied to small multihulls during the last 20 years and three of the five world sailing speed records are at present held by these craft. American hydrofoil NF^2, holder of 'C' class record has been overtaken by kite boat "Jacob's Ladder" but she may well have foils fitted in attempts to increase the record during 1983. Hydrofoils have also been used for the purpose of stabilisation of larger multihulls but no attempt has recently been made to produce a "flying hydrofoil" capable of sailing in the open sea. Analysis of the displacement and sail area of a wide variety of sailing craft leads to the conclusion that the modern generation of high speed ocean-going multihulls are suitable for hydrofoil application. It is suggested that the best option is to convert an already established large multihull to hydrofoils and to employ the configuration and retraction mechanisms which have proved successful at a smaller scale.

INTRODUCTION

Hydrofoils are applied to sailing craft for the purpose of reducing drag and thereby generating speed. This will be considered as "Speed Sailing" and other uses, the most important being large offshore races such as Round Britain, Trans Atlantic and Route de Rhum.

"Speed Sailing" has now been an established branch of sailing for ten years, several thousand individual record attempts have been made. Three of the five classes were held by hydrofoils. (now 2)

Class	Holder	Speed (knots)	Date	
Open	"Crossbow 11"	36.0	17.11.80	
'C' Class	NF^2, Hydrofoil	24.4	18.11.78	(Now 25 knots)
'B' Class	"Icarus" "	24.5	4.10.81	
'A' Class	"Mayfly" "	23.0	3.10.77	
10 sq.M.	Pascal Maka	27.8	13.10.82	(Sailboard)

The five classes represent different sail areas and it is curious that the largest and smallest classes are those in which hydrofoils have failed to dominate. Indeed the absolute speed obtained in both these classes is greater than the hydrofoil held records "in the middle". In the smallest class, less than 10 sq.M. sail area, an explanation is provided by the intense development of sailboards for speed sailing. Even for sailboards, hydrofoils might offer theoretical advantage, if small enough, but there are formidable practical problems;- the necessary lift at 12.9 metres/second (=25 knots) requires an immersed foil area of only 0.014 sq. metres. Such foils would require a "negligible" wave height, and all the stability, control, and ventilation problems would be accentuated in comparison with large craft. The author, like several others, has developed a hydrofoil conversion for a sailboard, but without success in terms of speed.

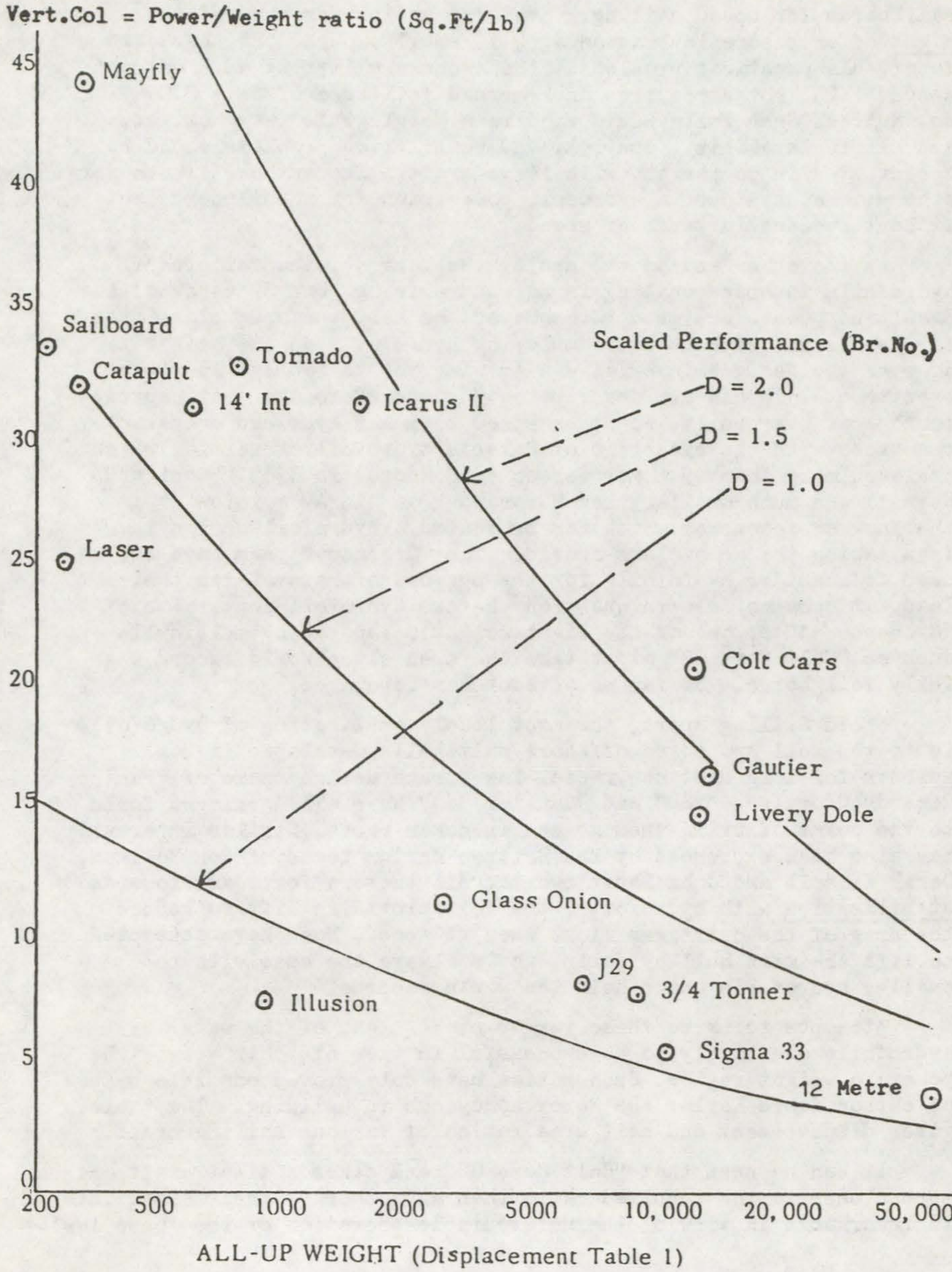
At the other end of the scale, the largest, the failure of hydrofoils in speed sailing is more surprising. One or other of the MacAlpine Downie designed "Crossbows" has held the open class record for ten years, without ever employing hydrofoils on the main hull. However the designer's brief was to win, not to indulge in risky experiments. In his own description "Crossbow" is the most conventional boat ever built. No other speed team has ever had comparable resources with the exception of Baker's hydrofoil "Monitor", which achieved more than 15.5 metres/sec (=30 knots) in 1955. "Monitor" herself was much smaller than "Crossbow" and in my opinion it is the lack of resources which has prevented a hydrofoil design team from taking the open class record. The "Crossbow" team have had no need to consider hydrofoils for the purpose of maintaining their lead. It remains an open question whether hydrofoil conversion of "Crossbow 11" or one of the light weight ocean racing multihulls such as "Colt Cars GB" might take the open class World record when fully foil borne. So far no attempt has been made.

Speed Sailing apart, the most likely application of hydrofoils is to the well sponsored offshore multihulls developed in some numbers for long distance races. The French design teams of "Paul Ricard","Royale", "VSD" and "Gautier 111" have all developed foils to the point of using them at sea in ocean races. Similar interest has also been expressed by the British design teams of Ron Holland, Derek Kelsall and John Shuttleworth. All these efforts are towards stabilisation with hydrofoils, the foil providing lift to reduce the drag of the outrigger float when at speed. None have attempted to lift the main hull by foils, as is always the case with the smaller hydrofoils which hold the world records.

Attempts to raise these larger craft clear of the water by hydrofoils are likely to be successful in view of their very high power to weight ratios. Such ratios have only proved possible by use of carbon fibre Kevlar and Nomex honeycomb in building. The table gives displacement and sail area ratios of various sailing craft.

It can be seen that "Colt Cars GB" and other similar craft are much closer to the required ratio than any other of their size. This is remarkable in view of the unfavourable operation of the 'cube law'.

Power to weight ratio of various craft, plotted against all up displacement.



Yacht	Crew No.	Disp.(lb)	$\sqrt[3]{\text{Disp.}}$	Sq.Ft Sail	$\sqrt[2]{\text{Sail}}$	Sq.Ft/lb	Br.No.
12 Metre	10	60,000	39.1	2,160	46.5	3.6	1.19
Gautier 111	4	13,250	23.7	2,228	47.2	16.6	1.99
Livery Dole	3	12,300	23.1	1,765	42.0	14.9	1.82
Colt Cars GB	3	12,050	22.9	2,500	50.0	20.8	2.18
Sigma 33	4	10,100	21.6	523	22.9	5.2	1.06
1/4 Tonner	4	8,600	20.5	680	26.1	7.9	1.27
Glass Onion	4	2,720	14.0	288	17.0	11.2	1.21
Icarus 11	3	1,500	11.5	470	21.7	31.3	1.89
Illusion	1	854	9.50	64	8.0	7.5	0.84
Icarus	2	722	8.97	235	15.3	32.5	1.70
Int. 14 ft.	2	610	8.50	190	13.8	31.2	1.62
Mayfly	1	340	6.98	150	12.2	44.1	1.75
Catapault	1	320	6.84	107	10.3	32.0	1.51
Laser	1	300	6.70	75	8.7	25.0	1.30
Sailboard	1	200	5.85	67	8.2	33.5	1.40

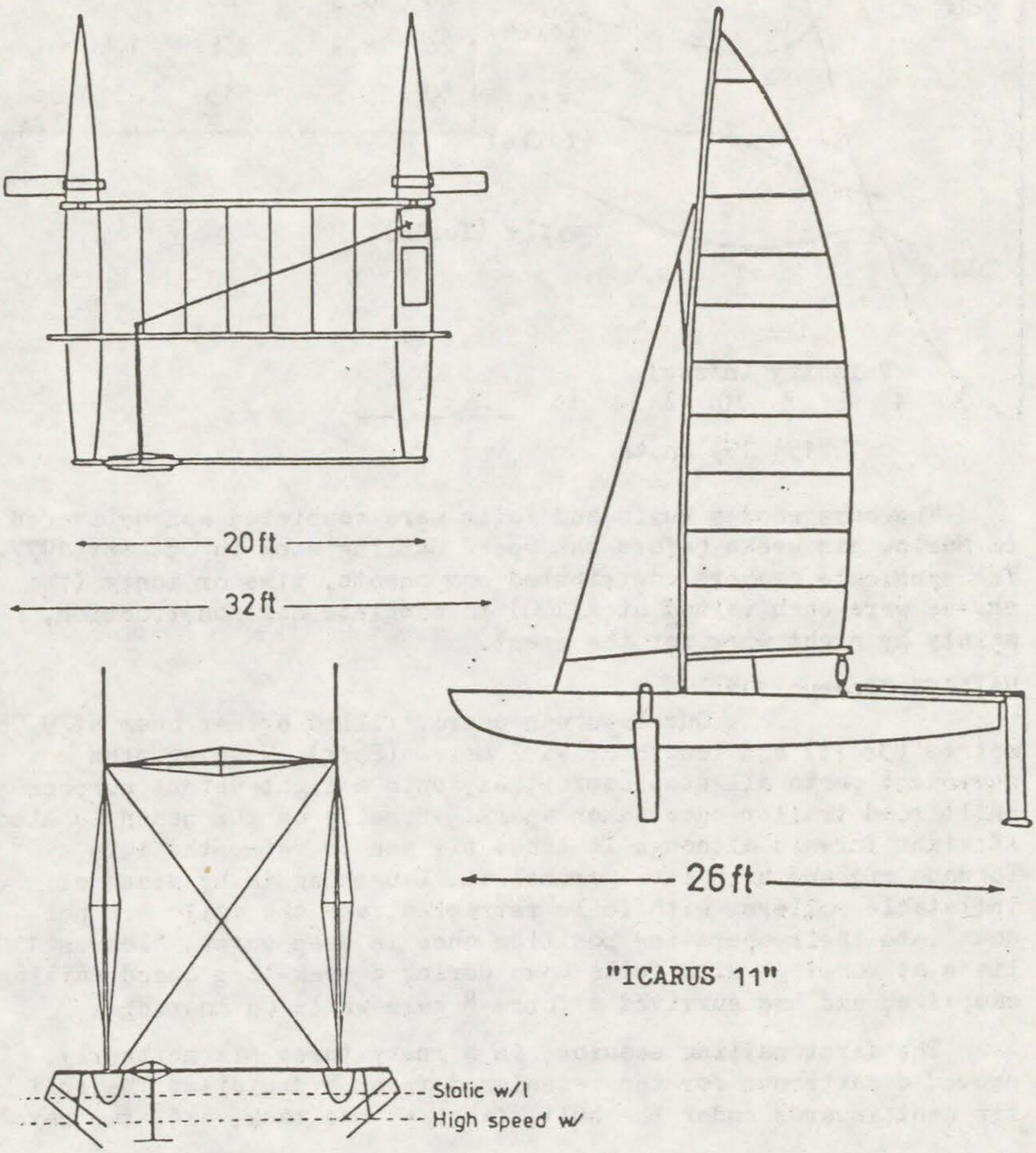
Disp in Lbs = Kg x 2.2 Sail Area Sq.ft = Sq.Metres x 10.8

Bruce Number makes allowance for scale and it is shown that "Colt Cars GB" achieves the best power to weight ratio, and, predictably, the scaled down 12 metre "Illusion" has the worst ratio. This good ratio leaves little doubt that a hydrofoil conversion of "Colt Cars" will indeed 'fly'. However, there are formidable problems in terms of structural strength, especially if the foils are to be made retractable. This is necessary to eliminate unwanted drag in light winds and the foils are only used at speeds above the 'cross over point' in the drag curve. The figure shows the speed necessary for small hydrofoils to come into their own. For larger craft, similar curves apply and the hydrofoils will not be deployed unless the necessary speed is obtainable in the given conditions at sea. For speed sailing attempts will only be made when there is sufficient wind to provide this speed. The other concern when using hydrofoils at sea is their safety, sea worthiness and sea keeping ability.

Design and Construction of "Icarus 11".

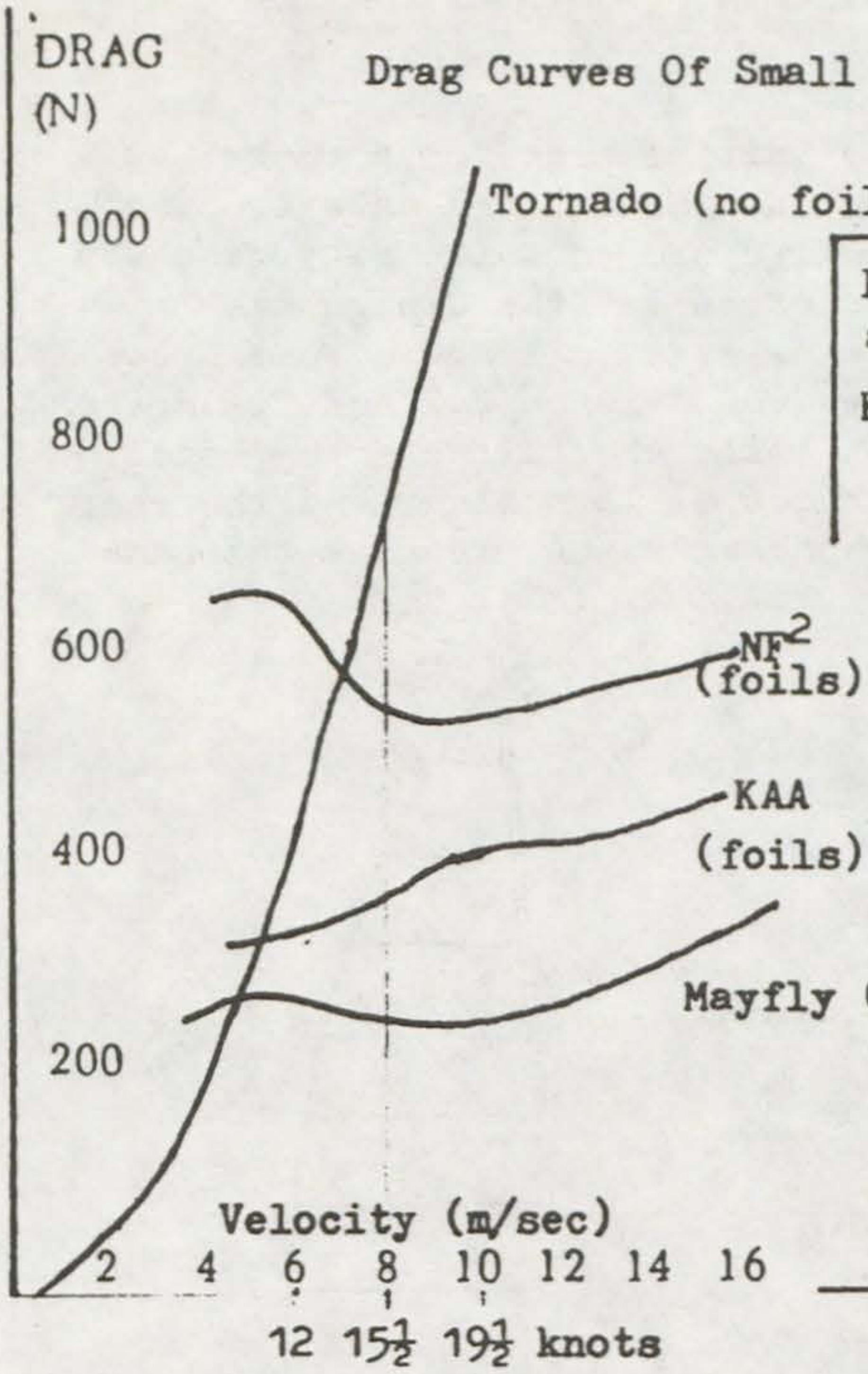
After four years of the R.Y.A. Speed Sailing Competition the records in 'A' and 'B' class were held by the sailing hydrofoils "Mayfly" and "Icarus", both projects with which I had been closely associated. However, the speeds involved ('B' class 20.7 knots,'A' class 21.1knots) were 10 knots slower than the open class record of "Crossbow 11" which was then 31.8 knots. This prompted me to sketch a purpose-built hydrofoil catamaran approximately twice the size of a 'Tornado'. The initial sketches show a scaled down version of "Crossbow 11" with hulls set asymmetrically for the fast tack, with the leeward hull ahead. Further consideration of the narrow apparent wind angle of such craft, along with the convenience of symmetry in enabling the craft to sail in both directions, changed the design to that of a symmetrical catamaran. The rig consists of two Tornado sail plans set one on each hull. No significant alteration was made to the mast, its diamond stays or the boom and sails. A special fitting was necessary to allow "over rotation" of the mast and to'hold the masts apart' high up. This compression strut is a section of IYE M 100 extrusion rigged with its own diamond stays. The fittings at either end which allow the mast to rotate up to 70° each side were designed and structured by Derek Lessware of Sarma UK. He tested and developed the rigging which consists of just three stays for each mast, a fore stay, an "X" arrangement to the foot of the opposite mast, and an oblique back stay to prevent the masts falling forward when the main sheet is not in tension. He also made a model which demonstrated how this arrangement eliminates torsional loads and distorsion from the hulls and crossbeams. The over-rotation of the masts ensured that each Tornado rig performed to its maximum efficiency and we had the benefit of ten years development of the rig when applied to the Tornado itself. The masts are separated by a distance of 5.48 metres and there is no evidence either in theory or in practice, of interference due to "biplane effect".

The hulls and hydrofoils owe their existance to the enthusiasm and support of Colin Douglas, Managing Director of the Training and Safety Company of Swann Hunters ship builders. He allowed the fabrication of hulls and hydrofoils to be "an exercise" for the trainees and their supervisors. Only material costs were charged and he and Brian Sample provided substantial financial support. The hulls are scaled up from the Tornado to 26 feet. Since the hulls are clear of the water when at speed it was deemed safe to keep all structural components to the same strength as the Tornado and there by avoid disproportionate weight increase due to "cube law". The building instructions were aquired from the I.Y.R.U. and the linear diamensions scaled up by 1.3 . The only other modifications were the fitting of a robust "external gunwale" which provided a strong point for attachment of the crossbeams and hydrofoil mountings. Sections of the deck were also left off to allow the crew to operate from inside the hulls. The hydrofoils were initially designed as scaled up versions of "Icarus" and "Mayfly". The main points of difference consisted firstly of bringing the lower end of the main lifting unit in-board to reduce beam; and secondly the positioning of the rear foil close alongside the leeward hull, the only feature preventing complete symmetry. The initial plan for a monoplane each side was modified when Colin Douglas aquired an extrusion of 0.152 metre chord for the "Seafly" project. The extrusion was 10% thickness to chord 'ogival' section and the design was modified to a biplane preserving the same foil area. Foil areas were calculated on a take-off speed of between 6.2 and 7.2 metres/sec. (12 and 14 knots). The front foils are retracted by rotation on a transverse axis, for the purpose of launching, and the rear foil is mounted on a rotating crossbeam which produces the same effect.



"ICARUS 11"

Drag Curves Of Small Sailing Craft



Lift Produced at different speeds by "PRACTICAL HYDROFOILS"

Knots	M/sec	lb/sq.ft	Kg/sq.M
10	5.16	57	279
15	7.74	128	626
20	10.3	228	1115
25	12.9	356	1740
30	15.5	513	2510

The bare wooden hulls and foils were completed and delivered to Marlow six weeks before the Speed Sailing week in October 1977. The syndicate members contributed components, time or money (the shares were each valued at £ 100) to complete her construction, mainly by night work for the event.

SAILING "Icarus 11".

Our lawn was nearly filled by her beam of 9.75 metres (32 ft) and length of 7.92 metres(26ft). However, the component parts all stow comfortably onto a light-weight purpose-built road trailer once taken apart. Assembly on the beach is also straight forward although it takes six men to raise the twin Tornado rig and high level crossbeam. Launching is by means of inflatable rollers, with foils retracted, and the foils are put down into their operating position once in deep water. "Icarus 11" lives at moorings with foils down during a week-long speed sailing campaign, and has survived a force 8 gale while on moorings.

The first sailing session, in a gusty force six northerly, proved disasterous for the redesigned front hydrofoils. The foil tip bent inwards under the hull, first on one tack, and, two days' later, in more stable winds, on the other tack. Thanks to the ingenuity of Derek Lessware and "Granby Precission" of Weymouth the foils were repaired in time for further sailing trials later that week. The foil tips were removed, since initial "flying height" was too far off the water, causing the rudder foil to ventilate and lose all steering effect. With these modifications "Icarus 11" sailed well and in a stable manner. We failed to produce speed on the course above a single and unsatisfactory run of 14.6 knots. Off course she sailed at approximately 25 knots and calculations based on the immersed area of the foils confirm that this speed was reached. Further development included the introduction of an "all-flying tail plane". This enabled the inverted 'T' rear foil to vary its incidence while sailing. The whole rear beam was rotated to achieve this and the tiller became a "horizontal joy stick", allowing the helmsman to control direction by sideways movement and vertical height of the whole craft by vertical movement of the tiller. The load on the tiller was considerable but this system proved successful. After the second years sailing, the author withdrew from the organisation and campaigning of "Icarus 11" and Derek Lessware took over. Further development,with major modifications took place in 1980 but in an unlucky Speed Week no greater speeds were achieved on the course and she foundered on the final day. At the time of writing (Jan 1983) "Icarus 11" is being repaired and put together by Bob Downhill for the purpose of making further attempts at speed records.

LARGE SAILING HYDROFOILS

Hydrofoil application is made more difficult if the craft travels first in one direction and then the other and no further consideration will therefore be given to the proa, although there has been one successful design: Leif Smitt's "Kotaha" which was a 10sq. metre hydrofoil built 10 years ago in Denmark. There is still controversy between the relative merits of trimaran and catamaran configuration for seagoing multihulls. It is likely that hydrofoils could be applied with equal ease to either, but the distribution of the foils would be quite different. For the trimaran there is no benefit in having more than one foil on each float. However the main hull may require more than one lifting unit to achieve stability. For the catamaran the range of options is similar to those tried for smaller catamaran craft like "Mayfly".

Eric Tabarly in his hydrofoil stabilised "Paul Ricard" greatly reduced the size of the floats, allowing the foils to provide the necessary lift. This craft has proved safe at sea and still holds the West to East Trans-Atlantic record. There is no function served by full-sized floats once foils are in effective use, and they constitute a substantial component of parasitic weight and wind drag. Nonetheless, there is a small element of reduced safety, for example produced by a "knock down gust" when the craft is not moving forward at speed and the foil thus not producing its lift. There may also be a greater risk of pitch-pole when travelling down wind in big seas, but this can be reduced by placing the outriggers and their foils well forward.

HYDROFOILS TO WINDWARD

There is no proof that a "flying hydrofoil" is faster upwind than a comparable craft without foils. It is likely that a hydrofoil would need to sail slightly further "off the wind" to generate the necessary speed to become foil borne. The overall drag of a large multihull would be reduced, to windward in waves by being supported in part by buoyancy and in part by its hydrofoils; the waves would produce less drag on crossbeams because the foils would keep them clear above the wave tops. In theory a fully flying hydrofoil would achieve far greater efficiency from its sails by "platforming" over the waves without pitching.

SEA KEEPING; PERFORMANCE IN WAVES.

Powered hydrofoils have been fully evaluated at sea and much of this work is applicable to flying sailing hydrofoils. Although waves reduce speed and may pose stability problems, a flying hydrofoil, if "platforming" will perform far better than a conventional multihull. Our experience with "Icarus" in one metre waves in the English Channel, confirms this. The slender hulls of a high speed multihull are of advantage in producing relatively little extra drag if they touch on wave tops while foil borne. In larger waves where the craft is "contouring" rather than "platforming" a different range of problems arise. The most dangerous conditions are found going down wind where the circular movement of water in the waves reduces hydrofoil lift when it is most needed and the pitch pole effect of the rig will be at its greatest. There would,however, be no need to steer straight down wind to achieve maximum speed to leeward; for many years high speed multihulls have been "tacking downwind" making angles of approximately 45° to the course straight downwind while racing. This skill is combined, in smaller craft and especially surfboards with "staying on the front of a wave" so that the craft is forever sailing downhill, aided by gravity. In hydrofoil application this would involve never "running out" across the trough in front of a large wave. Difficulties would arrive in pursuing this policy at night but they would be no greater than those already experienced going downwind in big seas at night: the foils do not introduce an additional element of instability.

SAFETY AT SEA

It is unlikely that hydrofoils would increase ultimate safety in extreme conditions at sea. Attention must therefore be directed to reducing any elements of unsafety which are introduced by the use of foils. One such is the reduction in size of the floats of a trimaran once reliance is placed on hydrofoil lift. Another concerns the possible damage which foils could do to the main floats should there be any mechanical breakage for example, occasioned by hitting a semi-submerged log. The present range of ultra-lightweight multihulls, designed and developed solely to win long distance ocean races, have introduced an element of hazard in

handling heavy equipment when shorthanded. The competitors and designers have "chosen" to enter the "risk business" to greater or lesser extent and the use of hydrofoils would merely be one more factor in the equation that is put together in the first place. The terms of mechanical strength, ease of capsize and difficulties of handling heavy equipment when shorthanded. The competitors and designers have "chosen" to enter the "risk business" to a greater or lesser extent and the use of hydrofoils would merely be one more factor in the equation that is put together in the first place. The "campaign team" will be looking for a trade off where the benefits derived by greater speed and stability in certain sets of conditions at sea are not overweighed by the disadvantages when the foils are not functioning to good effect. The skill of the hydrofoil designer will be in putting together a convincing "package" necessary to persuade a sponsor that the heavy cost involved in pursuing a development program of an ocean going hydrofoil will be justified by the results obtained.

CONCLUSION

The French offshore multihull designers continue to use hydrofoils on trimaran floats after several years of experiment. Some of these foils must therefore be "successful" in terms of drag reduction and sea-keeping, in accord with the content of this paper. However, the main hull still carries a drag curve similar in form to "Tornado (no foils)" in the figure while the float enjoys a foil-type curve such as that of "NF^2". The potential for high-speed is only a little greater than without the foil on the float, since the main hull drag is unaltered. When conditions favour hydrofoils one can not afford the main hull to be <u>without</u> foils. It is only a lack of technology and resources suitably applied that has so far prevented this advance from taking place. Competitors report speedometers "stuck on 23 knots" in optimum conditions such as those often experienced on the Lerwick to Lowestoft leg of the Round Britain Race. Successful use of hydrofoils would add 5 to 10 knots to this speed, and there is no reason for the speedometer to be "stuck" even at the top end of this new range.

BRUCE NUMBERS - Imperial, Metric & Dimensionless

From 'Multihull International'No. 183, April 1983 by George Chapman.

W.R.Frank has pointed out that the Bruce Number is square root of sail area in square feet divided by displacement in lbs., and has suggested that if instead of weight we take the <u>volume</u> of water displaced, we get a truly 'dimensionless' number which is a criterion of potential performance - and you get the same number whether you measure your boat in imperial, metric, cubits or whatever - provided the <u>water</u> is of the same density.

Sail Area	Imperial	300 sq ft	Metric	= 27.88 sq.m.
Displacement		900 lbs		= 408 kg.
Bruce Number	= 1.8		= 0.712	
Frank Number	= 7.18	$\sqrt[3]{14.05}$	= 7.17	$\sqrt[3]{0.40}$

To convert Bruce Number Imperial to Metric multiply by 0.397. "Bruce Number(Dimensionless)" can be shortened to "Bruce D Number" as distinct from the "Bruce I No." or the "Bruce M No."

<u>Trimarans on Foils</u>   Note by Michael Ellison

In his paper James Grogono states that foil stabilised trimarans can be fitted with lifting foils under the main hull in order to "fly" under suitable conditions and that these craft as used by the French are only reducing the portion of the drag due to the outrigger.

Look at a racing trimaran when "flying" the windward float (as ballast and windage, no water drag). Note that the craft is sailing at a considerable angle of heel. Although this angle moves the point of drive to leeward most of the drag of the outrigger must be compensated by use of the rudder or other control surfaces to maintain a chosen course.

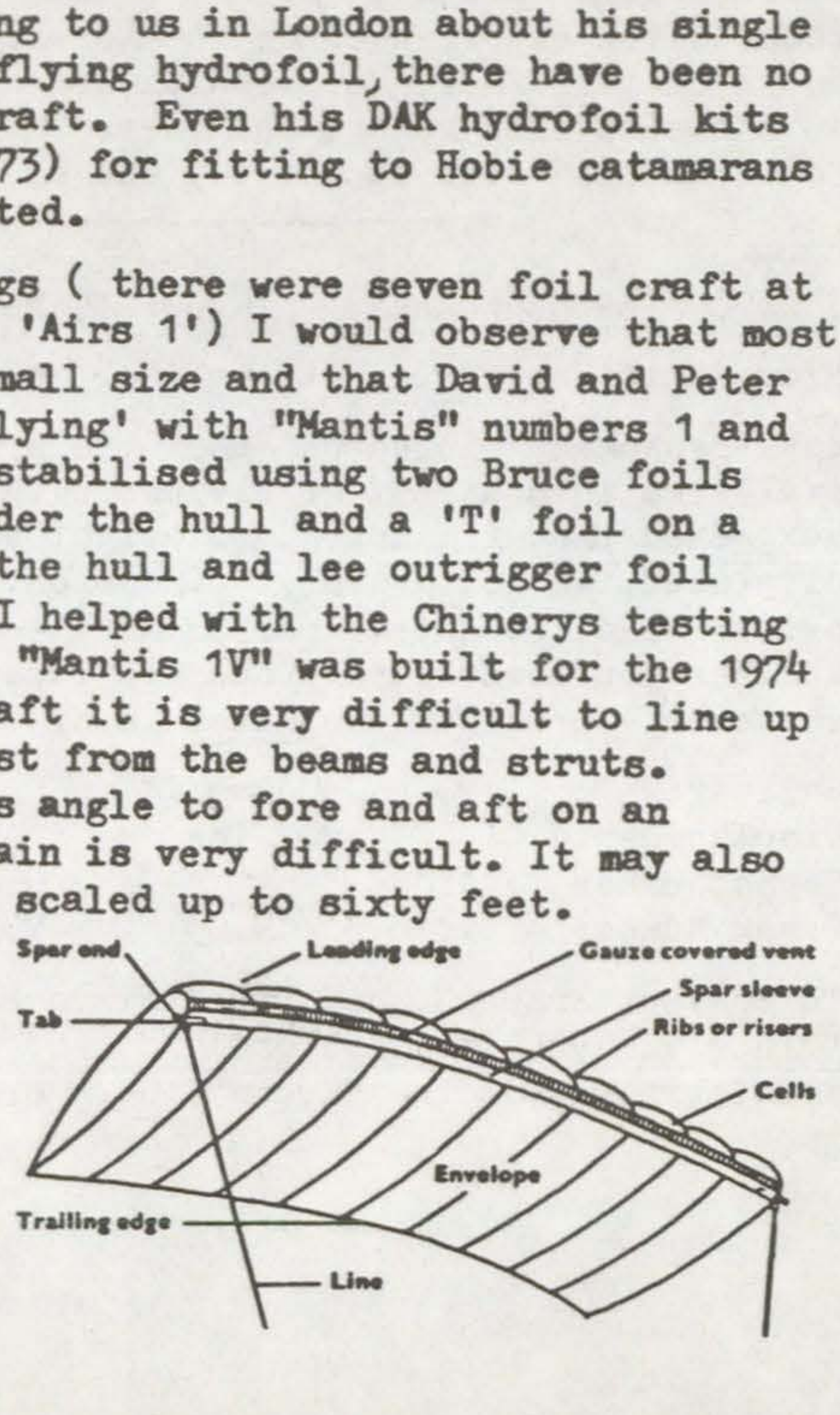
The use of foil lift will reduce the drag of the outrigger as shown by the graph which increases speed by reducing rudder or board drag on the main hull. Reducing the angle of heel should make the sails more efficient (less heeling moment and more drive). Wave drag from the cross beams will also be less.

There is an excellent case for lifting the main hull but to me it seems wise to try to "fly" on an even keel with an immersed foil on the weather side giving four point suspension. The first advantage would be stability with the wind aft; the yacht will not tend to 'flop' from side to side. On windward and reaching courses there will be a downward pull on the weather foil if inclined foils are used. (This is due to leeway angle and does not apply to inverted 'T' foils).

It is strange that after the success of "Williwaw" and of Dave Keiper writing and speaking to us in London about his single handed ocean voyages with his flying hydrofoil, there have been no "Mark 2" versions or similar craft. Even his DAK hydrofoil kits ('Airs 6 pages 5 to 8 August '73) for fitting to Hobie catamarans did not 'catch on' as he expected.

From our Weir Wood meetings (there were seven foil craft at the October 1971 meeting, ref. 'Airs 1') I would observe that most configurations were tried at small size and that David and Peter Chinery developed from 'foil flying' with "Mantis" numbers 1 and 2 to "Mantis 3" which is foil stabilised using two Bruce foils with a forward lifting foil under the hull and a 'T' foil on a rubber blade. Lifting out on the hull and lee outrigger foil never proved easy or fast and I helped with the Chinerys testing of numerous foil shapes before "Mantis 1V" was built for the 1974 'Round Britain'. With small craft it is very difficult to line up the foils and to eliminate twist from the beams and struts. Gauging to 1 or even $2\frac{1}{2}$ degrees angle to fore and aft on an uneven beach in the wind and rain is very difficult. It may also be difficult when the craft is scaled up to sixty feet.

Flexifoil Kite



TREP Analysis: Revised, Revisited, Reaffirmed and Revealed

Introduction

Time Related and Equivelent Performance (TREP) analysis is a mathematical method of analyzing the observed best speeds of a sailing vessel in relation to the periods of time over which the speeds were measured. The result is an equation that can be used to extrapolate and interpolate a vessel's best speed for any time period.

TREP is based on the observation that as sample time increases the average speed of a sailing vessel decreases, i.e. the average speed for a week's sail is always less than the best average for a 24 hour period within that week; likewise, the best one hour average speed within that 24 hours is always greater than the 24 hour average.

I first introduced this concept in an article entitled, "TREP Analysis of'Champion of the Seas' One Day Record Run", in A.Y.R.S. journal 89 (Oct '77) 'Sailing Facts and Figures'. The secondary objective of this article was to lend credence to the claim of 465 n.m./day for the clipper ship.

About three years later, I wrote another article, "TREP Analysis of Williwaw", in journal 94 (April '80), 'Shallow Draft Craft'. This discussed the performance of David Keiper's ocean going hydrofoil trimaran.

Since those articles I have revised some of the details of the analysis, revisited the previous work resulting in new equations, reaffirmed the concept with additional data and revealed a new relationship.

Revisions

My revision involves both the analysis and the data used.

The previous TREP analysis consisted of a geometric regression of the speeds and their respective time periods. In other words the logarithmic value of the speed was related to the logarithmic value of the time period. This implies that neither the speed nor the time can be zero. Whereas this is true for the time period, it is not necessarily true for the speed. Therefore the revised TREP analysis uses a logarithmic regression; the time periods are still logarithmic, but speeds are now left as their original arithmetic values.

The resulting TREP equation now takes the form:

$$S_T = a + (b \times \ln(T))$$

Where S is speed measured in knots for some time period, T, measured in hours. Note that the natural logarithm of the time period is now being used instead of the previously used log with the base of 10.

This revised equation is simpler than the previous one and also contains a very useful coefficient, a. When T = 1 hour, the second part of the equation drops out because ln(T) = 0, leaving us with the speed being the coefficient a. Therefore, I am proposing to call "a" the Hour's Best Speed coefficient or HBS.

The other minor change pertains to the data accepted for analysis. Previously, I had included passages which contained landings somewhere along the way, specifically the circumnavigation figures. Now, I don't believe that these should be used; just the passages between landings.

Having made the above revisions, I think that it is appropriate to take a new look at the old data presented in the two articles.

Revisits

In the previous articles, I presented 4 TREP lines, one each for the best of the clipper ships, Francis Chichester's "Gipsy Moth 1V", Eric Tabarly's and Alan Colas "Manureva" (nee "Pen Duick 1V") and Keiper's "Williwaw. With some changes in the data (Table 1) the updated TREP equations and correlation coefficients are:

Clippers $S_T = 27.37 - (2.46 \times \ln(T))$

C.C. = 0.9964

Manureva $S_T = 18.38 - (1.14 \times \ln(T))$

C.C. = 0.9884

Williwaw $S_T = 10.07 - (0.59 \times \ln(T))$

C.C. = 0.9948

Gipsy Moth $S_T = 9.71 - (0.51 \times \ln(T))$

C.C. = 0.9786

Figures 1 and 2 present plots of the data and TREP lines for the above sailing vessels. Note that the TREP line and the above equation for Williwaw was derived from only the speeds for times above 24 hours, more on this later.

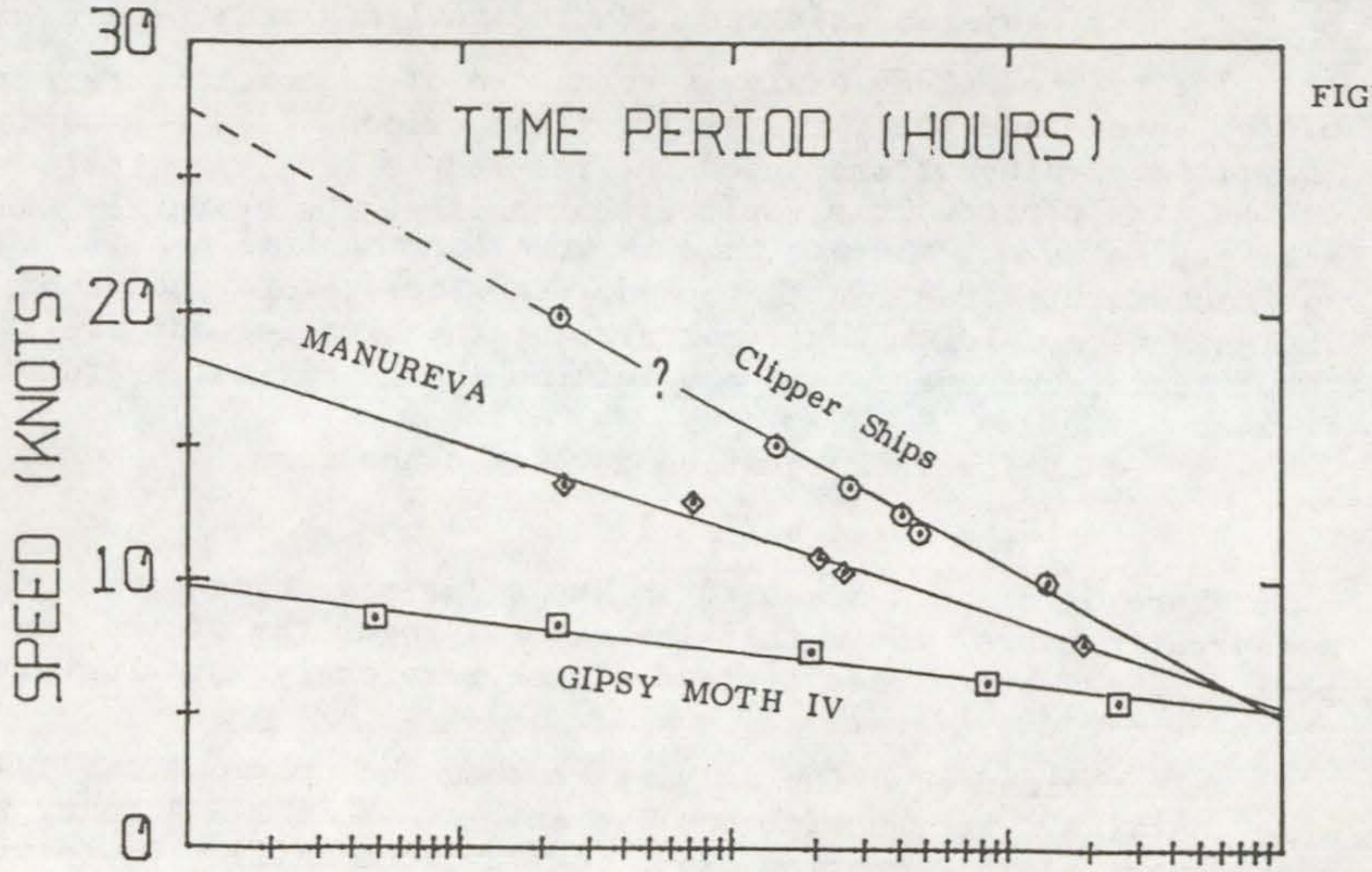


FIGURE 1.

Table 3. Vessel Measurements, Etc.

Name	LWL ft.	S.A. sq.ft.	Disp. lbs.	Hull S. Knots	Br.#	HBS Knots
PREUSSEN	408	60,000	2.5 E7	27.07	0.84	22.44
CHAMP. SEAS	250	56,000	1.6 E7	21.35	0.94	27.37
ATLANTIC	137	18,500	1.0 E6*	15.68	1.36	18.96
G.B. II	68.0	2,800	73,000	11.13	1.27	15.27
MANUREVA	66.5	1,480	14,500	11.00	1.58	18.38
GIPSY MOTH	38.5	852	25,800	8.37	0.99	9.71
JOSHUA	36.0	754	?	8.10	----	9.17
WILLIWAW	28.0	380	3,000	7.14	1.35	10.07

* Estimated from similar boats of her type in the same era.

Reaffirmed

The passages of four more sailing vessels have since been analyzed. They were chosen to complement the above 4 vessels and for having made long and/or significant passages.

The famous "Preussen" was the only five masted ship-rigged vessel ever built. Written in German, reference 5 presents abstracts of her passages.

The 3-masted schooner "Atlantic" set the W - E transatlantic record of 12 days 4 hours 1 minute in 1905 which stood until 1980. The TREP analysis is on the data of the record crossing. Ref 6 & 7.

The 77' ketch "Great Britain 11" has taken line honors in 3 of the 4 round-the-world races that she has entered. The TREP analysis is on the data from the second (1977/1978) Whitbread Race as presented in reference 8.

The first round-the-world race was in 1969, a non-stop race for single-handers. Bernard Moitessier competed in the race sailing his ketch "Joshua", but elected to sail on to Tahiti rather than return up the Atlantic. He presents his story in reference 9 from which the performance data was taken.

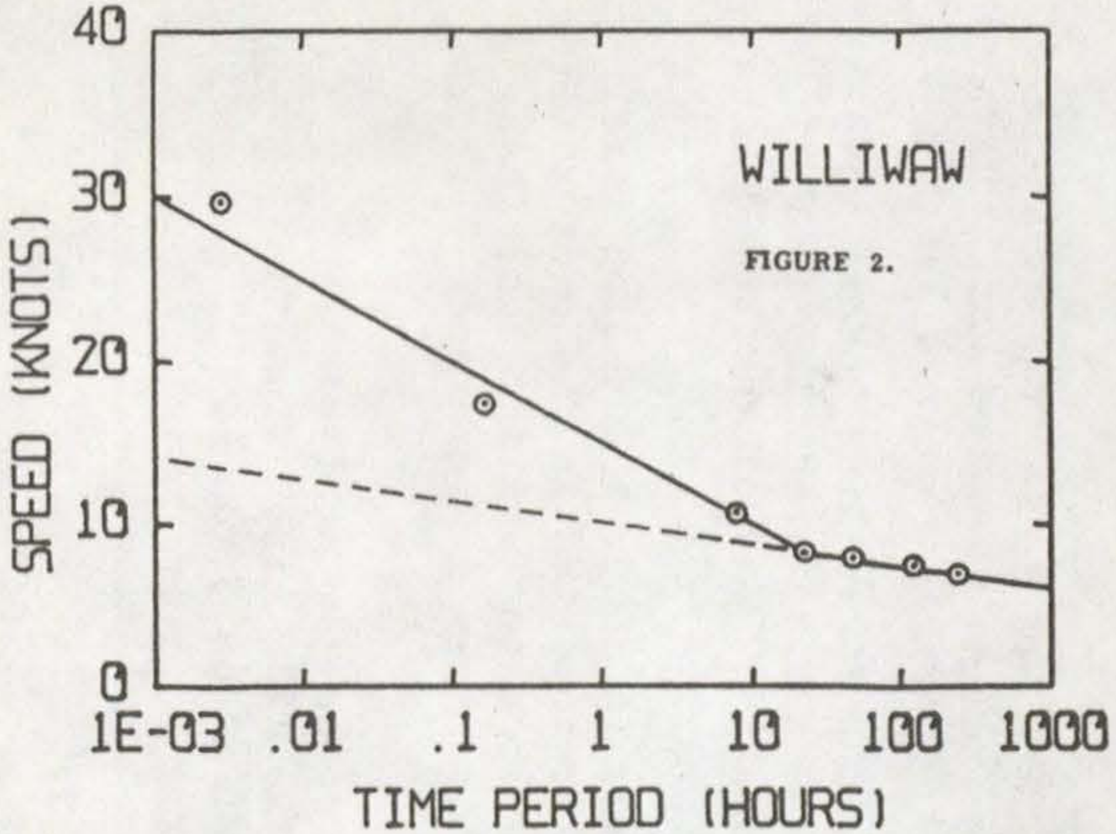
The data culled from these references for analysis is presented in table 2. This data and the TREP lines from the following equations are presented in figures 3 and 4.

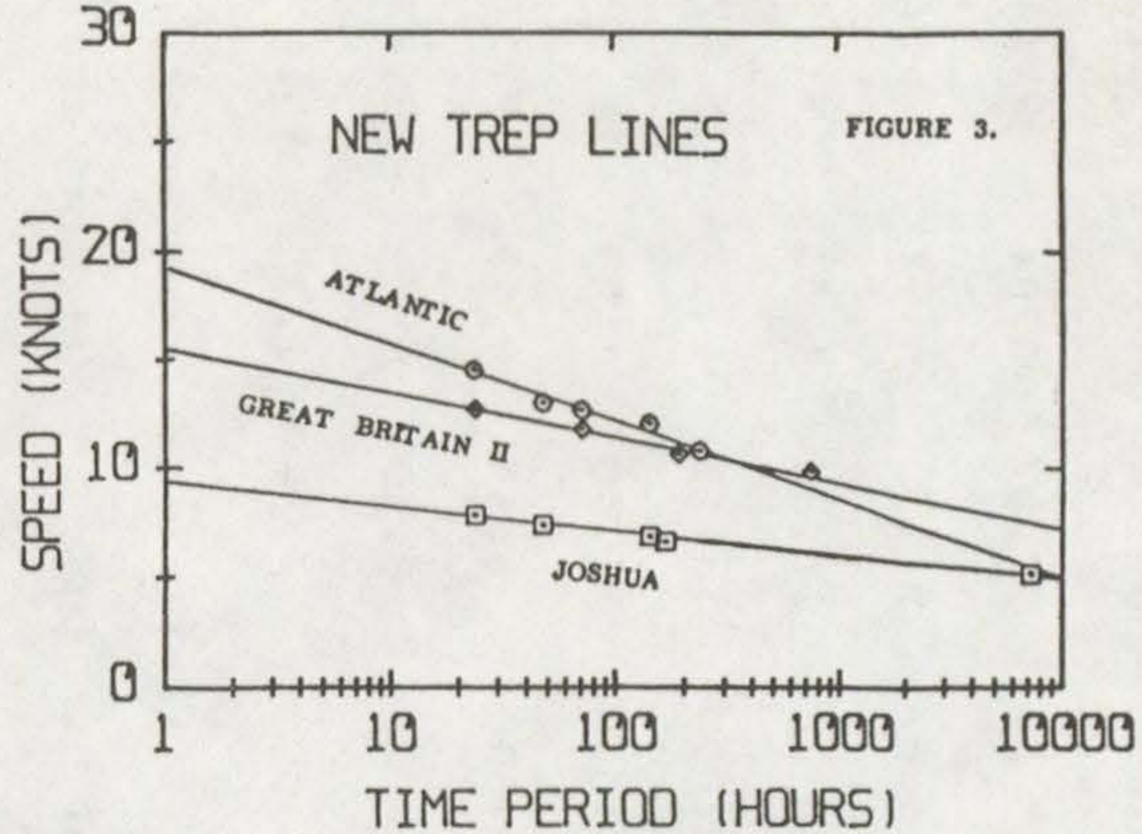
Preussen $S_T = 22.44 - (1.98 \times \ln(T))$

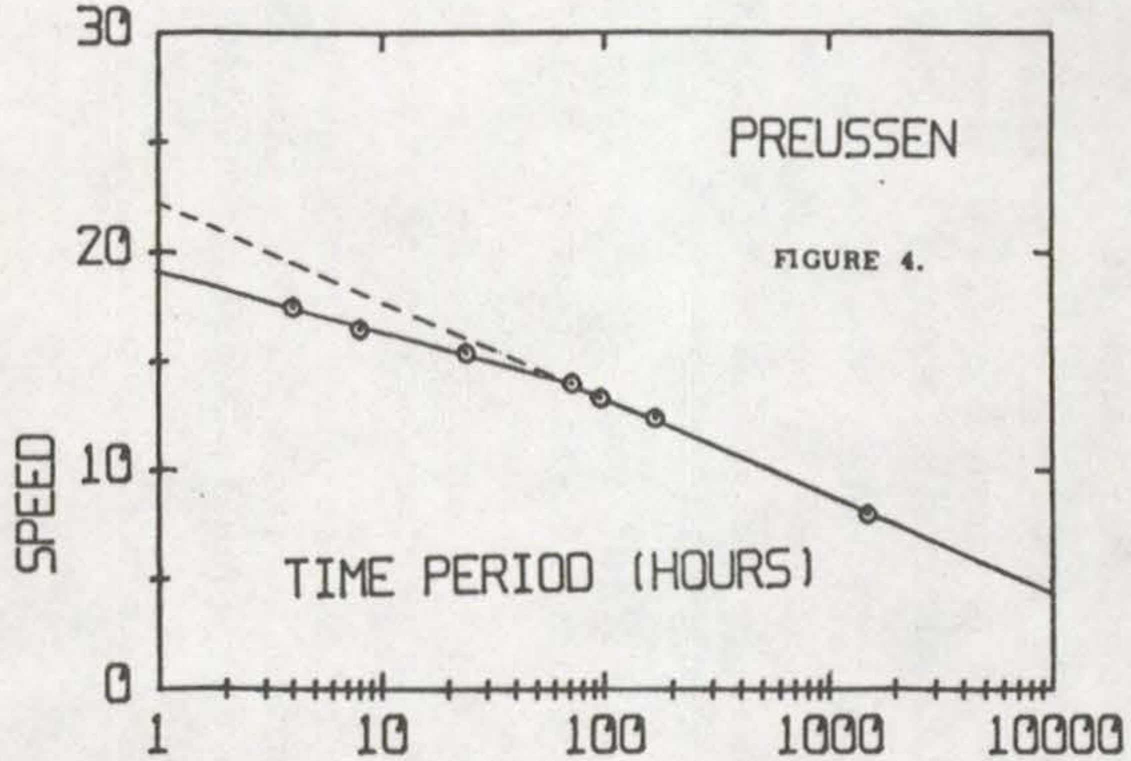
$$C.C. = 0.9996$$

Atlantic $S_T = 18.96 - (1.46 \times \ln(T))$

$$C.C. = 0.9807$$


WILLIWAW
FIGURE 2.
SPEED (KNOTS)
40
30
20
10
0
1E-03
.01
.1
1
10
100
1000
TIME PERIOD (HOURS)


NEW TREP LINES
FIGURE 3.
ATLANTIC
GREAT BRITAIN II
JOSHUA
SPEED (KNOTS)
30
20
10
0
1
10
100
1000
10000
TIME PERIOD (HOURS)


PREUSSEN
FIGURE 4.
SPEED
30
20
10
0
TIME PERIOD (HOURS)
1
10
100
1000
10000

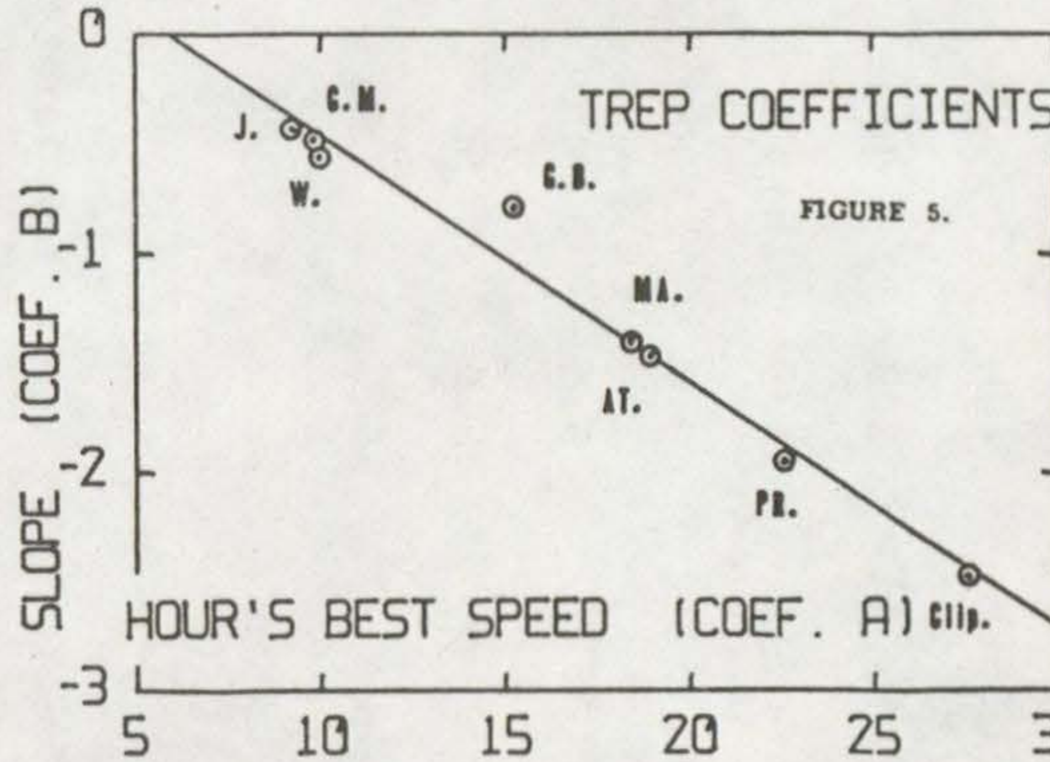

TREP COEFFICIENTS
FIGURE 5.
C.M.
J.
W.
G.B.
MA.
AT.
PR.
Clip.
SLOPE (COEF. B)
0
-1
-2
-3
HOUR'S BEST SPEED (COEF. A)
5
10
15
20
25
30

TABLE 1. Revisited TREP data

Name	Time hours	Speed Knots
GYPSY MOTH	2564.50	5.50
	840.00	6.23
	192.00	7.38
	23.00	8.33
	4.87	8.61
MANUREVA	1896.00	7.14
	252.00	10.32
	205.15	10.85
	72.00	12.92
	24.00	13.58
Clippers	1392.00	9.97
	472.00	11.92
	408.00	12.50
	264.00	13.49
	144.00	15.02
*	23.28	19.84
WILLIWAW	240.00	6.78
	120.00	7.23
	48.00	7.85
	24.00	8.12
	8.00	10.60
	0.16	18.00
	0.003	30.00

Table 2. New TREP Data

Name	Time hours	Speed Knots
PREUSSEN	1512	7.95
	168	12.44
	96	13.32
	72	14.00
	24	15.38
	8	16.50
	4	17.50
ATLANTIC	240	10.80
	144	12.05
	72	12.63
	48	12.99
	23.53	14.52
GREAT BRIT. II	751	9.86
	192	10.65
	72	11.75
	24	12.67
JOSHUA	7296	5.15
	168	6.62
	48	7.40
	24	7.83

* Calculations based on data presented in references 1 & 2 indicate that 'Champion of the Seas' sailed 462 n.m. in 23 hours 17 minutes not 465 n.m. as generally quoted.

$$GB\ 11 \qquad S_T = 15.27 - (0.84 \times \ln(T))$$

$$C.C. = 0.9920$$

$$Joshua \qquad S_T = 9.17 - (0.46 \times \ln(T))$$

$$C.C. = 0.9957$$

Revealed

Having listed the TREP equations by decreasing HBS, I also noticed that the "b" coefficient (slope) also decreases. The strong linear relationship between the coefficients can be seen in Fig.5. The equation for this relationship is:

$$SLOPE = 0.60 - (0.11 \times HBS)$$

$$C.C. = 0.9890$$

Therefore, though more complex, the TREP equation could be rewritten using solely the HBS as :

$$S_T = HBS - (0.11 \times HBS \times \ln(T)) + (0.60 \times \ln(T))$$

Conclusions

Realizing that the average speed cannot increase forever as the sampled time period is made smaller and smaller, I previously set the lower limit for TREP extrapolation at 24 hours. Now, the data seems to suggest otherwise for some cases.

Because the highest ever claimed speed for a clipper ship (Sovereign Of The Seas) is 22 knots, I knew that the clipper's TREP equation could not be applicable for time periods less than 24 hours. There has to be a leveling off. "Preussen" data show this leveling off. For shorter time periods, her speeds lie on a lower line with less slope. Pruessen's speed/time break occurs at about 50 to 60 hours. This observation now raises the question if the break for the clippers is also at some point greater than 24 hours, thereby nullifying the claim for "Champion of the Seas".

Williwaw's data indicate just the opposite; that is, average speeds for shorter time periods are greater than that predicted from TREP analysis of her longer period average speeds. The break here appears to be at 24 hours. Does a foiler's speed continue to increase until she becomes completely airborne or is there a speed plateau before take-off ?

Since we have seen that the speeds of some sailing vessels drop below the extrapolated TREP line and others exceed it, for most perhaps the TREP line is applicable down to a few hours.

Until recently speed data such as that of "Preussen" and "Williwaw" (speeds for periods of less than 24 hours) are extremely rare. Now, we have had yachts tracked with satellites, with their positions recorded on the average of every 2 - 3 hours. TREP analysis of this data should be quite revealing.

References:

1. TREP analysis of "Champion Of The Seas" one day record run, Richard Boehmer. AYRS Pub.89 pp. 36-40.

2. TREP analysis of "Williwaw", Richard Boehmer. AYRS 94, Shallow Draft Craft, pp. 27-29.

References

3. Correspondence from Herbert Dickens in Carl Cutler's files at Mystic Seaport Library, Connecticut, U.S.A.

4. Lloyds Calendar 1956, p.529.

5. Hamecher, H., Konisin de See Funfmast-Vollshiff "Preussen", 1969, pp. 31,47,119,361,369.

6. Loomis, A.F., Ocean Racing 1866-1935, 1967 p. 286.

7. annom., The Log of the "Atlantic". Mystic Seaport Library catalog number CV832L6.

8. Bruce,E., Cape Horn to Port, 1978, pp. 123, 171.

9. Moitessier, B., The Long Way, 1975. pp.13,18,29,56,72,211.

Table 4. Time Conversions to and from Decimal Hours

		Hours	Hours		
1 second	=	0.00028	0.001	=	3.6 seconds
1 minute	=	0.0167	0.01	=	36 seconds
1 hour	=	1	0.1	=	6 minutes
1 day	=	24	1	=	1 hour
1 week	=	168	10	=	10 hours
1 month	=	720	100	=	4.2 days
1 year	=	8,760	1,000	=	1.4 months
			10,000	=	1.14 years

TREP Analysis for durations below 24 hours.

By Cdr.G.C.Chapman R.N. June 1980.

In AYRS 94,p 27, Richard Boehmer uses 3 of Williwaw's data to produce a relationship of speed and its duration which, plotted on log paper, gives a straight line: hence he concludes that Dave Keiper's claim of sailing 195 miles in 24 hours is justified.

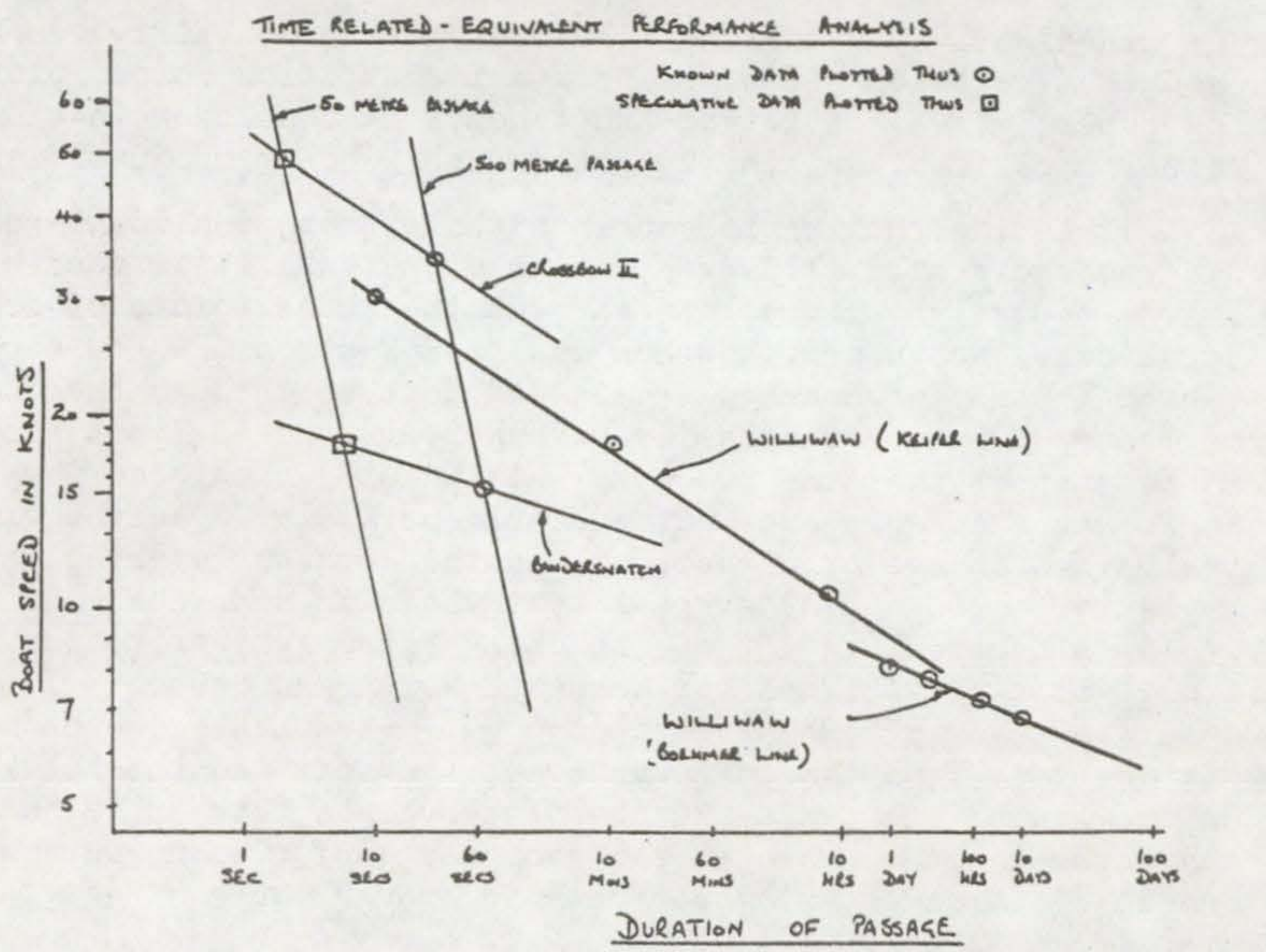
It is instructive to continue the examination downwards. The diagram shows all Williwaw's data plotted, and it is possible to draw two straight lines: one through the three points of greater duration, which nearly touches the 8.12 knot for 24 hours point (which I name the Boehmer Line): and another through the three points of lesser duration (named for Dave Keiper). One's first inclination is to suspect that the two straight lines - which describe the performance of only one boat - should be a single curved line, but the marked change of direction, and the apparent overlap (in the region 10 to 60 hours) suggest that there is some change of mode. It is rather reminiscent of the change from laminar to turbulent flow, and the two lines (of Messrs Blasius and Schoenherr) which describe that in AYRS Airs No 10 p 44. Presumably the change of mode here is from the foil-borne, on the left, to the hull-borne on the right: and the existance of two lines between 10 and 60 hours indicates an area where either mode may apply; when you can get up on the foils and stay there for long enough you can beat the displacement mode.

Speculating further, if Williwaw always sailed <u>without</u> foils, could her Boehmer line legitimately be extended to lower durations ?

Switching to short distance 'Speed Sailing', I have drawn a line, labelled "500 metres", which relates the speed and duration of a passage across a 500 metre course - and similarly for 50 metres. Plotted on the former are the 34.4 knots of "Crossbow 11" - who has claimed that the speedo has touched 50 knots - and a line parallel to Williwaw's: also my own Bandersnatch's 15.2 knots, and the 17 knots my speedo has touched, plotted on the 50 metre line. One can speculate that it is likely that a boat's performance line will form one of a family of lines, but the data I have are insufficient to give any valid indication of the family shape.

A question which this discussion raises is the rightness of the choice of 500 metres for the minimum distance for measuring a World Sailing Speed Record. Why not 50 metres ? Then we could get through many more runs in a day - and appear to go faster ! With some form of radar-assisted speed measurement a computer print-out could draw each boat's performance line from a 60 second (or longer) sail down the "range". I believe the choice of 500 metres relates as much as anything to the practicability of measuring the distance and time with sufficient accuracy to give a computed speed which is not open to doubt, and where a small increase in speed is not liable to be lost in the tolerances - the reason for the 2% "minimum increase to qualify for a new record" rule.

The other question the diagram raises is "Why set a distance and not a time ?" The answer is obviously the need for practicability; but it is no consolation to the owners of smaller boats that the larger boats benefit, relatively, by a course of fixed distance rather than fixed duration.



<u>The Twissar Rig</u>

By Colin Thompson, North House,
17 Gladstone Rd., Burgess Hill,
W. Sussex RH15 0QQ.

Talk at A.Y.R.S./M.O.C.R.A. meeting on 4th January 1983.

A few years ago I came across a reference to "vertical axis windmills". There were no details on configuration, only a mention of their being unaffected by wind direction. Subsequently I doodled a method of working a vertical axis windmill with freely rotating symetrical aerofoil wings, pivoted at the centres and mounted at the end of radial arms. These main wings were orientated by secondary setting fins. This was mounted on and behind the main wing and its angle relative to the main wing was set by a simple cam mechanism sited at the attachment of the main wing to the radial arm. I built a small working version, dubbed it the 'Windyne' and, with a colleague, made it the subject of an inconclusive patent application.

At heart I am a model boater and have built several radio controlled powered craft. Aside from the 'Windyne' I continued construction of my first model sailing yacht, the Marblehead 'Genie' designed by Vic Smeed. I learned that fore-and-aft sails have to be given the correct sheeting angle with respect to the relative wind in order to drive the yacht ahead and that optimum performance is only obtained over a narrow range of sheeting angles for a given relative wind. In practice this means that sheet(s) must be constantly adjusted if peak sailing performance is to be maintained as the wind's apparent direction alters as a result of changes in its speed and direction and the yachts speed. The radio-controlled model yacht sailor standing on the bankside has the additional problem of perceiving the relative wind acting on his boat whilst he is not aboard it!

I wondered therefore if a setting fin system such as I had employed on 'Windyne' could be used on a yacht ? This would ensure that the sail was correctly set at all times with respect to the relative wind. Of course running dead before the wind would (like dead into it) not be possible, but I felt that this limitation might be acceptable. I resolved to complete my model with such an automatic self-setting sail rig and set out to find out about any prototypes, both model and full size, which employed wingsails. I obtained a copy of 'Wingsails' published by AYRS and nearly fell off my chair when I read of the Norwegian Finn Utne's sailing dinghy built in 1940. It employed a symmetrical rigid wing sail controlled by a setting fin angled by means of a cockpit control lever and it was in essence exactly what I had been congratulating myself on inventing ! I was delighted that the basic concept had already been proved, but slightly piqued that the wind that the wind had been taken out of my sails. This only serves to underline the fact that 99% of engineering invention is simply re-invention and that very few developments are truly totally original !

Two limitations of Finn Utne's configuration came to light. Firstly symmetrical aerofoils have a maximum lift co-efficient of only about 60% of that of cambered aerofoils, and secondly light-weight rigid wingsail structures are generally incompatible with the strength and seaworthiness of off-shore yachts. If only the standard soft sail, or doubled-over aerofoil soft sail, such as the 'Freedom' rig employs, could be employed with a setting fin, the result would be a sail system suitable for cruising yachts, sail-assisted merchant ships, or even a new generation of wind-ships suited to Third World needs. The main problem in using a soft sail in this manner is in locating the rotation axis of the rig at its centre of pressure - typically at 30% of the sail chord from its luff. This axis location requires either:-

1) A rotating mast angled forwards above deck, or
2) A rotating wishbone mast, or
3) A balancing headsail sharing a common boom with the main,or
4) A very large mast foil at the luff of the sail.

The more I tried to work out practical layouts for these configurations the less I liked any of them. Rotating mast layouts impose high stresses on the structure and its bearings due to the long lever arm over which the sail's force acts and so I favoured a fixed support mast upon which the rig rotates. Further as head-sails serve only to do the work of the mainsail to windward less efficiently I ruled these out of my projected rig. This statement aroused controversy but the reasoning behind it is as follows. The slot effect of the jib certainly delays flow seperation of the mainsail but only by feeding the main with airflow less upwind than it would if the jib were not there. Thus the mainsails lift vector is angled rearwards by its normal amount PLUS the amount of the airflow offset from the jib. Hence the higher total lift generated is paid for by an increase in induced drag that in practice is greater in proportion than the gain, i.e. the L/D ratio is lowered and with it the yacht's windward performance. These structural and aerodynamic factors left me having to think of something different and it was the biplane that proved the inspiration and this was finally the configuration I decided to build.

A twin sail layout on rotating transverse frames permits siting of the support mast at the centre of effort of both sails without structural interference with the basically conventional sails themselves. Although there is some loss of aerodynamic efficiency from pressure cancelling in the gap between the sails (the so-called biplane effect in aircraft design) wide spacing and the chordwise stagger which occurs when the rig is angled to the wind reduce this to a very low value. In compensation the layout gives either a lower centre of effort location, or a higher aspect ratio than a single sail of equivelent area. Following the modern fashion for acronyms I coined 'TWISSAR' = Twin Self-Setting Sail Rig.

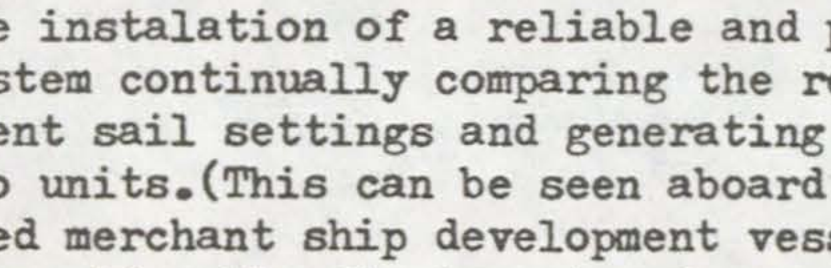
The Mark 2 layout employed two horizontal support frames located one above the other at 25% of the total rig height apart. They turn freely about the fixed central support mast on ball bearings. The upper frame is shaped like the letter 'Y' whilst the lower one is 'T' shaped. The two sail masts are carried at the arm ends of the frames and the single sail-setting fin is carried at the foot ends. Duel cross-braced rigging provides thetorsional stiffness and keeps them aligned. The compression loads arising from this rigging are taken by the lower 25% of the two sail masts and by the tubular centre spar of the sail setting fin. The'T' frame mounts a tubular support arm projecting forwards and carrying a streamlined balance weight to bring the centre of gravity of the whole rig on to the rotation axis. This avoids "steer with heel" effects.

The lower frame mounts a cross beam which carries the two sail clews and their tensioners, thus eliminating kicking straps or booms. Running vertically between the support frames in line with the sail setting fin is a rigging wire which retains the trailing edge of a simple sailcloth mast fairing sleeve. This easy method of streamlining the central support mast permits the use of a large diameter but relatively thin walled plain circular tube to achieve high structural efficiency. I utilized fixed mast head gaffs which allowed the high aspect ratio sail plan to be a plain trapezoid having a taper ratio of 0.4 . This magic figure gives the sail a very close approximation to an elliptic outline which is the preferred shape for least induced drag. This sail plan also substantially reduces the mast interference at the top of a conventional triangular sail where chord is very short compared with mast diameter, (in a full size version sail raising and lowering could be achieved by employing an additional after halyard run in the mast with the main halyard and passing over sheaves to the gaff ends). Both masts are slightly inclined aft so as to bring the centre of effort at each spanwise location on to the rotation axis. This very much reduces the effects of wind gradient and large wave wind shadows which can cause unbalance if the rig has only the <u>sum</u> of its spanwise locations in balance. (Cases 1,3 & 4 in the list earlier).

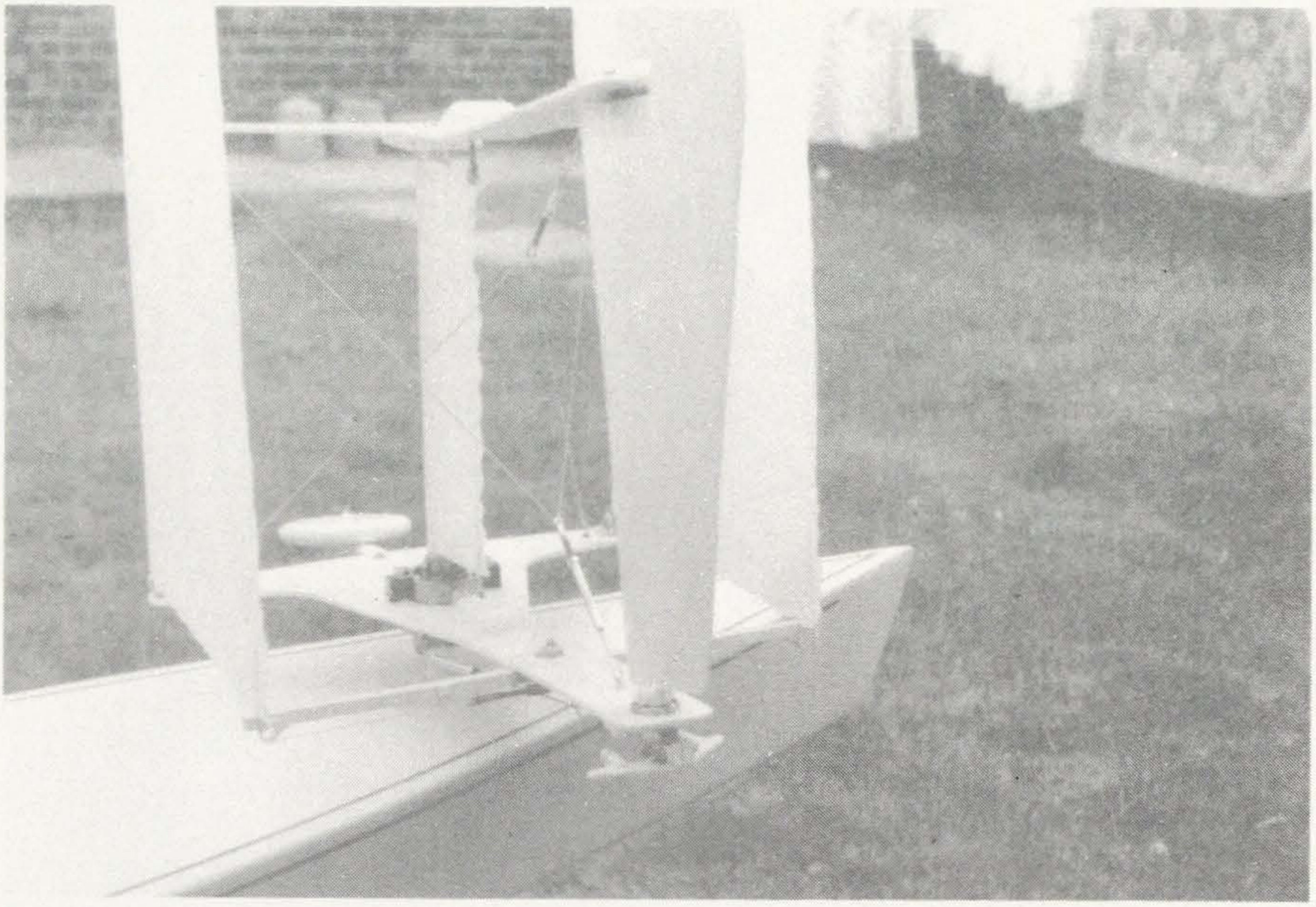
The sail setting fin is a rigid symmetrical-section, double-tapered, aerofoil able to rotate up to 20 degrees either side of the "amidships" position about an axis located on its centre of pressure and inclined forwards at about 15 degrees. The balanced rotation point minimises the loads on the cam control system whilst the inclination optimises its performance at the usual heeling angles. Located at the lower bearing of the fin is a cross tiller arm from which two control wires run forward to the cam control system mounted under the sail rig lower 'T' frame. On my model this is a simple mechanism but in a full size version additional manual or electric motor adjustment of the cam would permit both variation of the setting fin deflection angle to give throttle-like control of speed. Rotation of the cam axis through 180° would change the rigs drive from ahead to astern. Other angles of 90° and 270° would give starboard and port side thrust respectively to assist in berthing. When moored the sails would be dropped after the fin was set to zero deflection and the rig then secured fore and aft. The setting fin could then be released from its control wires and left to rotate freely with the wind by incorporating a clearance slot for the 'Y' frame.

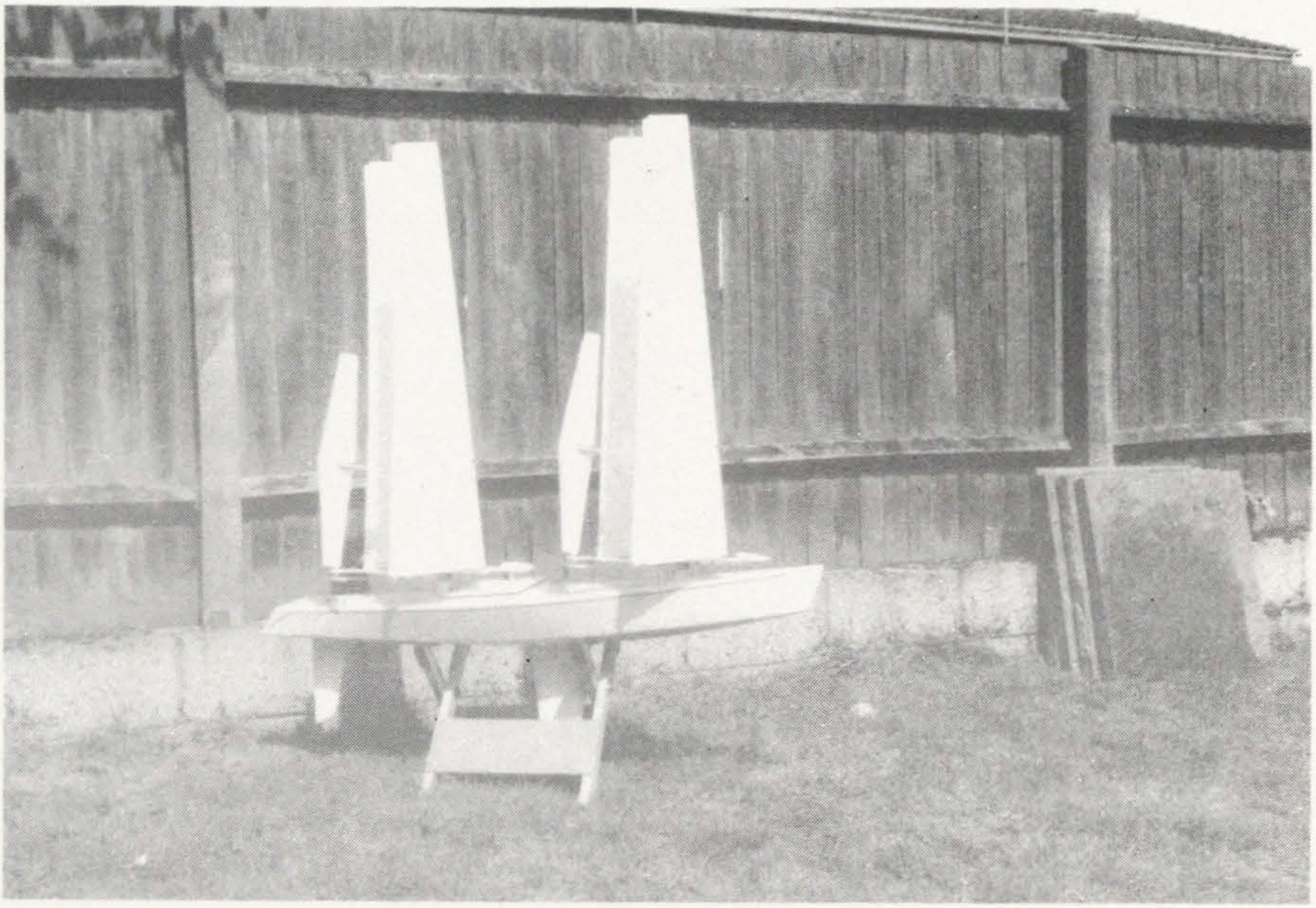
After conceiving the Twissar system I completed the 'Genie' hull with two "plug in" rigs because it was not practical to build only one large rig. The centre of effort of a Twissar rig is always located at the central axis of the support mast so I spaced the two rigs equal distances forward and aft of the original designed centre of effort to retain the original hull balance. Sailing trials have shown that the concept works. However on occasions the rig would oscillate wildly over about 60°, particularly in strong and gusty winds. It was suggested that there was insufficient seperation between the rigs and that masking of the airflow to the setting fin occurred at too small a rig angle of attack. Increasing the separation distance went 90% of the way to curing the problem. The remaining 10% should be removed by the construction of the Mk 3 version. This will be a single Twissar scaled up by 1.5 from the Mk 2 and mounted aboard a trimaran model hull. The switch from a monohull is favoured as the monohull's deep draught is a problem at my sailing site whilst requiring two rigs makes development more laborious by requiring two of all modifications to retain symmetry. The Mk 3 will be "cleaned up" structurally by including all developments to date and will also have a tapered sail foot with a lightweight sail crossbeam structure. The increase in rig size will aid dynamic stability by virtue of the greater angle of attack change - and hence setting fin weather cocking accuracy - resulting from its increased rotation radius.

Compared to the conventional Bermudian Sloop the sail setting fin of the Twissar rig imposes a drag and weight penalty as does the mass balance weight. However the conventional rig also imposes its penalties, especially when one moves away from the thoroughbred racing yacht with its volunteer labour and full deck watches; aboard a commercial vessel low manning levels are nowadays an economic fact of life. The alternative method of controlling the sail forces is by the instalation of a reliable and powerful closed-loop servo system continually comparing the relative wind vector with the current sail settings and generating the correct commands to the servo units.(This can be seen aboard the two Japanese sail-assisted merchant ship development vessels). Such a system has both a considerable first cost and operating energy cost for every hour under way. For the cruising yachtsman or the single-hander the Twissar offers a much greater ease of sailing on a given compass course and, by operating the cam control from the cockpit, straightforward control of the rig including 'stop' and even 'astern' conditions can be obtained.

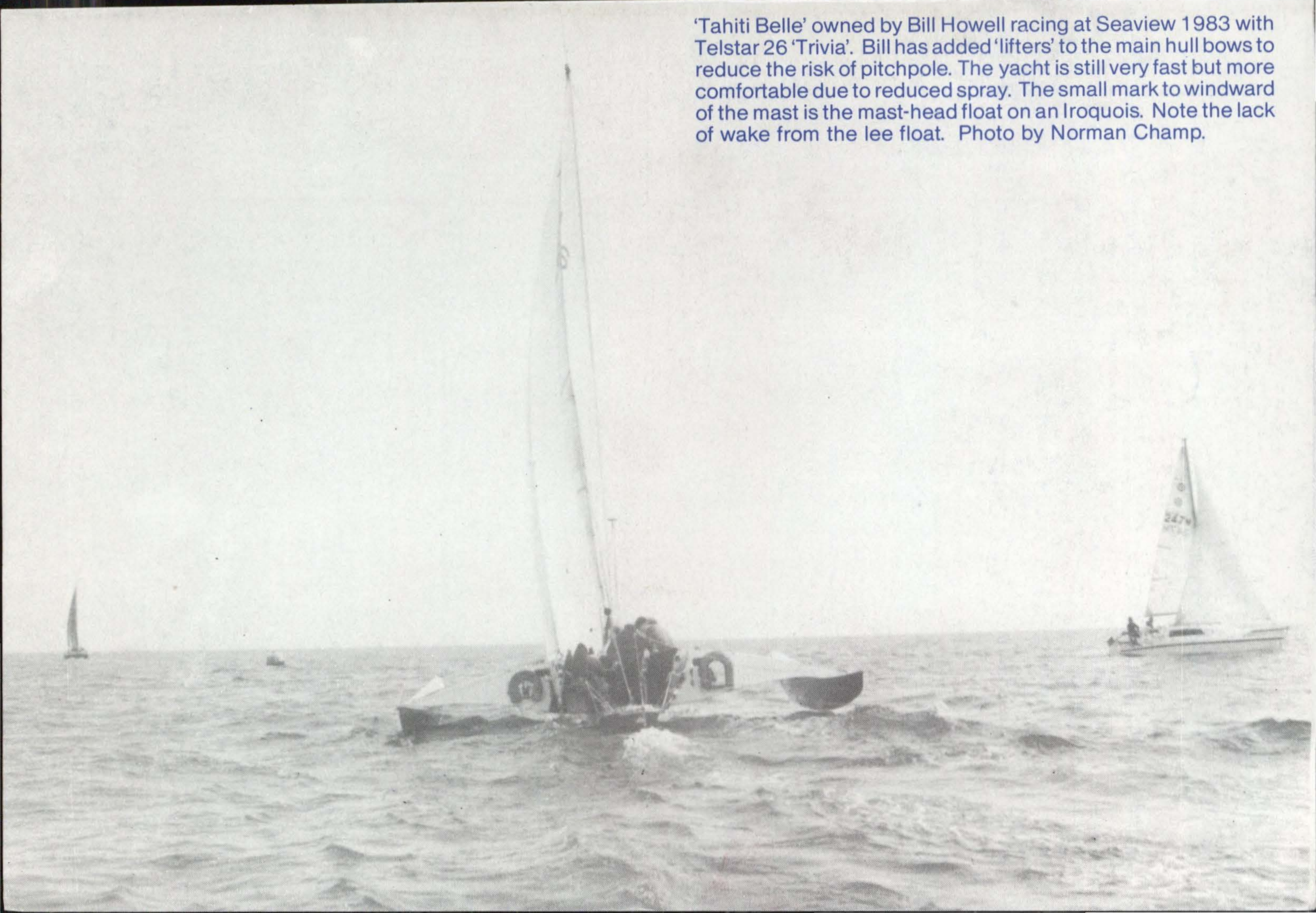


If pull is forward of abeam yacht moves ahead.





Twissar Model by Colin Thompson



'Tahiti Belle' owned by Bill Howell racing at Seaview 1983 with Telstar 26 'Trivia'. Bill has added 'lifters' to the main hull bows to reduce the risk of pitchpole. The yacht is still very fast but more comfortable due to reduced spray. The small mark to windward of the mast is the mast-head float on an Iroquois. Note the lack of wake from the lee float. Photo by Norman Champ.