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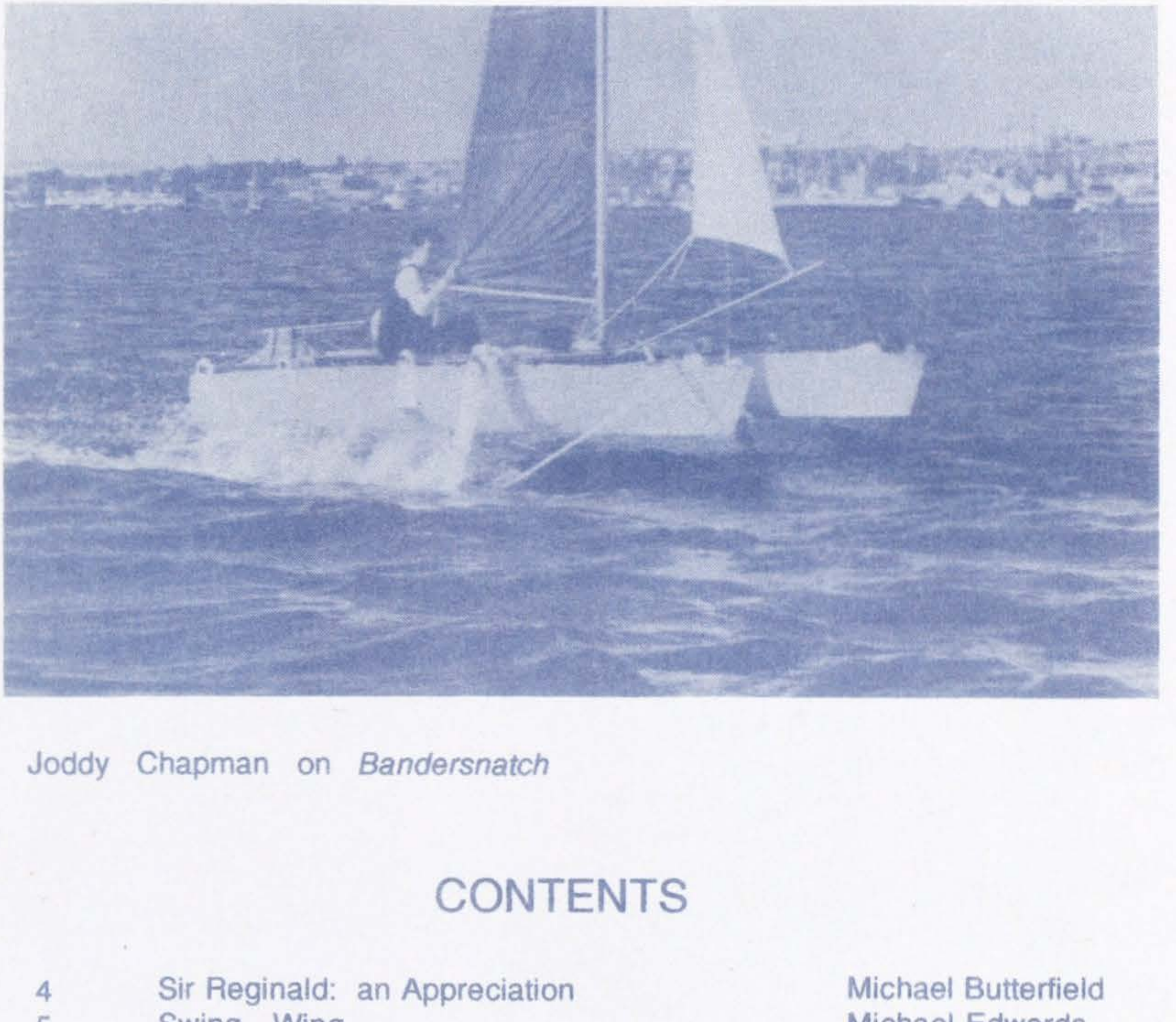
# AYRS 108

MAY 1991

# FOILS & HAPAS



Joddy Chapman on *Bandersnatch*

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Administration and Editorial Address:

Michael Ellison

Pengelly House,
Wilcove, Torpoint,
Cornwall, PL11 2PG.

American Agent:

Michael Badham

RT2, Box 180
ME 04530
USA


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*Scanning by Peter Zeller*

## Editorial

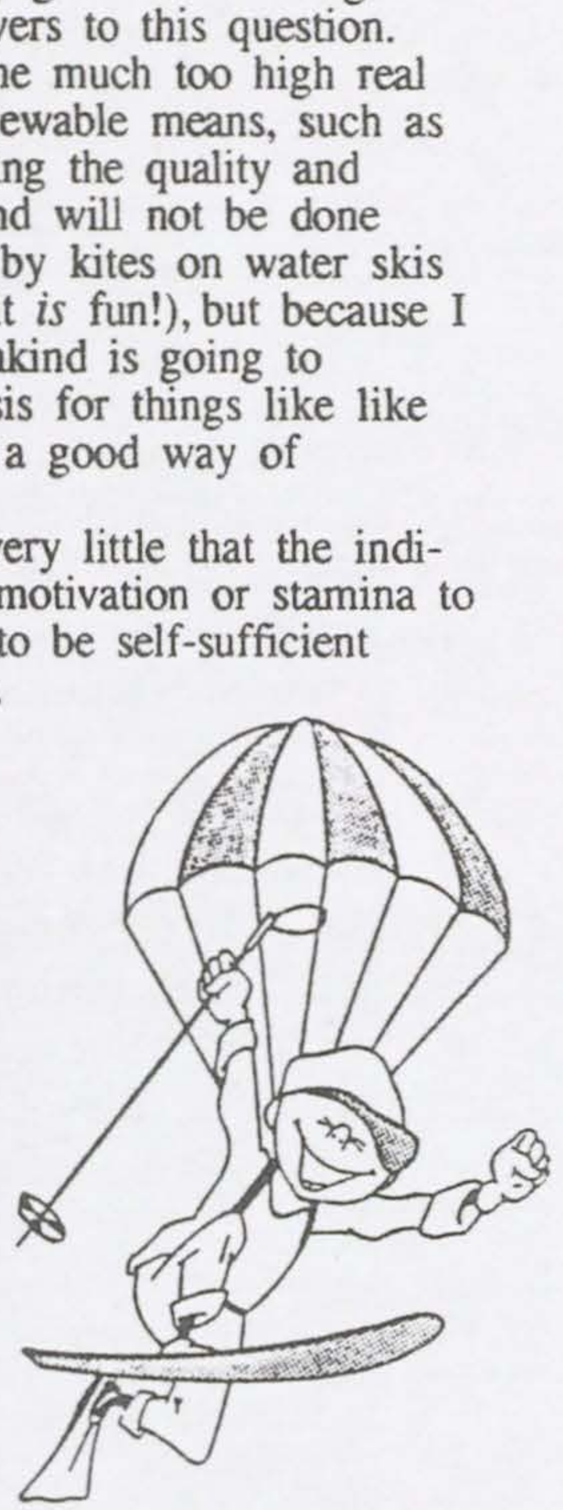
The Gulf War has shown what people will do to each other in order to get each others riches. Although many factors were involved, the basis for the unrest in this region is a satanical fluid called oil. It has enabled dictatorships to grow rich and arm themselves out of all proportion. For its sake, western nations are prepared to kill hundreds of thousands of human beings and let millions of animals perish in oily filth predictably unleashed by mad terrorists. At the same time they are not prepared to seriously seek better solutions for supplying energy.

But we must get away from our dependence on oil, the sooner the better. The solutions are all available: solar and wind energy, renewable biomass, combined heat and power, and most important of all, the saving of energy by increasing efficiency and avoiding useless processes. Little further research is really needed; the technology is there to be used. It is a matter of priorities, of implementing ecological economics and amounts to a simple decision whether to let humanity perish or not.

The future however looks bleak. With all the facts available, governments voted in by short-sighted people continue to do practically nothing. Although atitudes are changing, far too little is being done far too late. The EEC of 1992 promises another vision of horror: Even now, dangerous and polluting lorries cart potatoes from Germany to Italy just to be washed and back to Germany for consumption. Such lunacy will increase once the restrictions of the borders are removed and there is little chance that the EEC will give the environment and peoples' well-being priority over monetary profits.

Viewed in this perspective, are we not playing silly games with things like speed sailing or solar boat racing? There are several answers to this question. The much too low monetary price of oil (in contrast to the much too high real cost of oil) has practically killed off transportation by renewable means, such as sailing ships or widespread cycling. Research into improving the quality and quantity of such transportation is accordingly at an ebb and will not be done except by people like us. I don't engage in being pulled by kites on water skis or solar-powered boating just for the hell of it (although it *is* fun!), but because I believe such knowledge might simply be necessary if mankind is going to survive. Speed sailing and kites, etc, are not only the basis for things like like future wind-ships, but as spectacular sports they are also a good way of increasing public awareness on related subjects.

Another answer to the above question is that there is very little that the individual can do to save the planet. Not all of us have the motivation or stamina to be green activists or politicians, the money or inclination to be self-sufficient regarding energy and food, or the courage to be pacifists.
But we can do our bit. We can insulate our houses and dress warmly, grow vegetables in the garden, recycle and compost our wastes, avoid frequent use of cars and dangerous chemicals, avoid over-population, make lots of money to give to worthy charities and societies (like this one!), and vote for the right people and issues when we have a chance. We can also at least do something sensible in our spare time. And what is more sensible than to go sailing!



In this issue, the main theme is foils, with George Chapman's update of the Bandersnatch File and Roger Glencross's speculation on ultimate sailing using kites and hapas. Michael Edwards presents the sailboarder's answer to the problem of reefing.

Theodor Schmidt, Editor of Nr. 108

*Opinions stated by authors and editors are their own!*

# *Sir Reginald Bennett*
## AYRS Chairman 1972-1990
## An appreciation

When, after the death of Perry Henniker-Heaton, we approached Reggie to ask him to become our Chairman, he was a very active Member of Parliament. He was also the Member responsible for overseeing all the bars and catering arrangements in the House, itself a very time consuming activity. With his usual generosity, however, he immediately agreed to shoulder this extra burden and threw himself whole-heartedly into the task.

We were assured that he had ceased to practice as a psychiatrist. He was then and continues Commodore of a very exclusive club.

Reggie's sailing experience at the time covered the whole gamut from Bembridge Redwing to Twelve metre. He has since proved himself to be both keenly interested in and knowledgeable about a whole variety of sailing craft comprising, inter alia, spidery hydrofoils and kite driven canoes. In the eighteen plus years that he has so ablly steered the Society, he has been a constant source of useful information and amusing anecdote. He has brought us a lot of humour and good cheer. He has been the perfect ambassador for all venues and occasions.

We are all immensely grateful, particularly those of us who have served under him on committee and who know how much work he has done for us, for the time and effort that he has devoted to our enterprise over the years and are sad that he has felt that the time has come to vacate the chair.

The World Speed Sailing Committee, of which he is still chairman, has grown from its humble origin in the Society's early Weirwood "regattas". It continues to reflect well upon its parent and we are also grateful to him for all that he has done and is still doing to enhance the influence and prestige of that committee and our best interest. Long may he continue.

Michael Butterfield

# Swing-Wing

*by Michael Edwards*

**A new variable area wind surfing sail adjustable during sailing.**

The main problem with modern fully battened, highly stressed wind surfing sails is that they are never quite the ideal area for the conditions. The wind changes continually and different sail areas are.required for different points of sailing. Therefore wind surfers are obliged to have a whole series of different size sails (plus masts and wishbones) if they are to get the best out of their boards. A change in wind strength usually means a complete change of rig on shore. Long distance wind surfing can be hazardous unless there is a support vessel carrying a quiver of rigs. A drop in wind strength can mean that very small, fast boards will sink (hence their name sinkers).

**Swing-Wing is a solution to the problem.**

The leach consists of a vertical pocket of double sail material. Inside this pocket is a vertical inner panel which slides in and out like a letter in an envelope. The leach pocket is supported by extra long battens which are double, but joined at their outer ends. The vertical inner panel has its own battens, and slides in and out between the double battens of the leach proper. The vertical inner panel has its own uphaul and outhaul, which are controlled by the sailor down at wishbone level. Tension on the inner panel is provided by a shock cord downhaul. To make space for the inner panel, the double leach has a double uphaul and a double outhaul.

During sailing, the sailor adjusts the combined inner panel uphaul/outhaul to give the desired sail area. There is a simple system of lines, pulleys and jamb cleats to allow this. He pulls or loosens the control lines using toggles on each side of the wishbone. This is easily in reach near the sailor's harness line. The inner sail moves up as well as out, so that there is no need for a longer wishbone to accomodate the extra sail area. This is an advantage in that the double leach is securely fixed to the end of the wishbone to prevent the sail flapping.

In practice, the present 4.3 $m^2$ sail extendable to 5.6 $m^2$ can be sailed in a wind strength ranging from about Force 2 to Force 6. This is about twice the wind range of a standard sail. The sail can be adjusted inside one second so that squalls can be accomodated. In windy conditions, the sail can be put in the reefed state for beating to windward, and then be increased for sailing off the wind. Hauling the sail upright after a fall is made easy by reducing the area.

The sail is only as heavy as many present-day 5.6 $m^2$ sails. It rolls up into a standard sail bag. It looks stylish.

The potential for the principle is very large. The present-day race sail is 7.5 $m^2$ . A Swing-Wing version could be made up to possibly 10 $m^2$ for light winds. Long distance off-shore cruising becomes a reality. Speed sailing may benefit from a sail that can be tweaked during a fast run. Sailing schools might find the versatility most popular with their pupils.

Development is going on all the time. In particular, different shapes of inner panel are being prepared to see whether the centre of effort can be lowered by just pulling

the panel back. Alternatively, just pulling the panel up may be very beneficial in increasing the aspect ratio for beating. Different controls are being tried. For instance, having the panel in its extended position held with shock cord uphauls and outhauls, and pulling the downhaul for adjustment, rather than the reverse described above. There is a slight problem of capillary friction between the layers of sail material when wet. Rigging the sail needs speeding up. The wishbone mounted controls need more attention. Lighter battens would reduce the slight weight penalty.
Overall this new idea has been remarkably easy to bring to a realistic working stage using standard windsurf sail construction methods. Its future appears very bright.
This may be a small break-through applicable to many wind-powered vehicles.(Photos on back cover) ❑

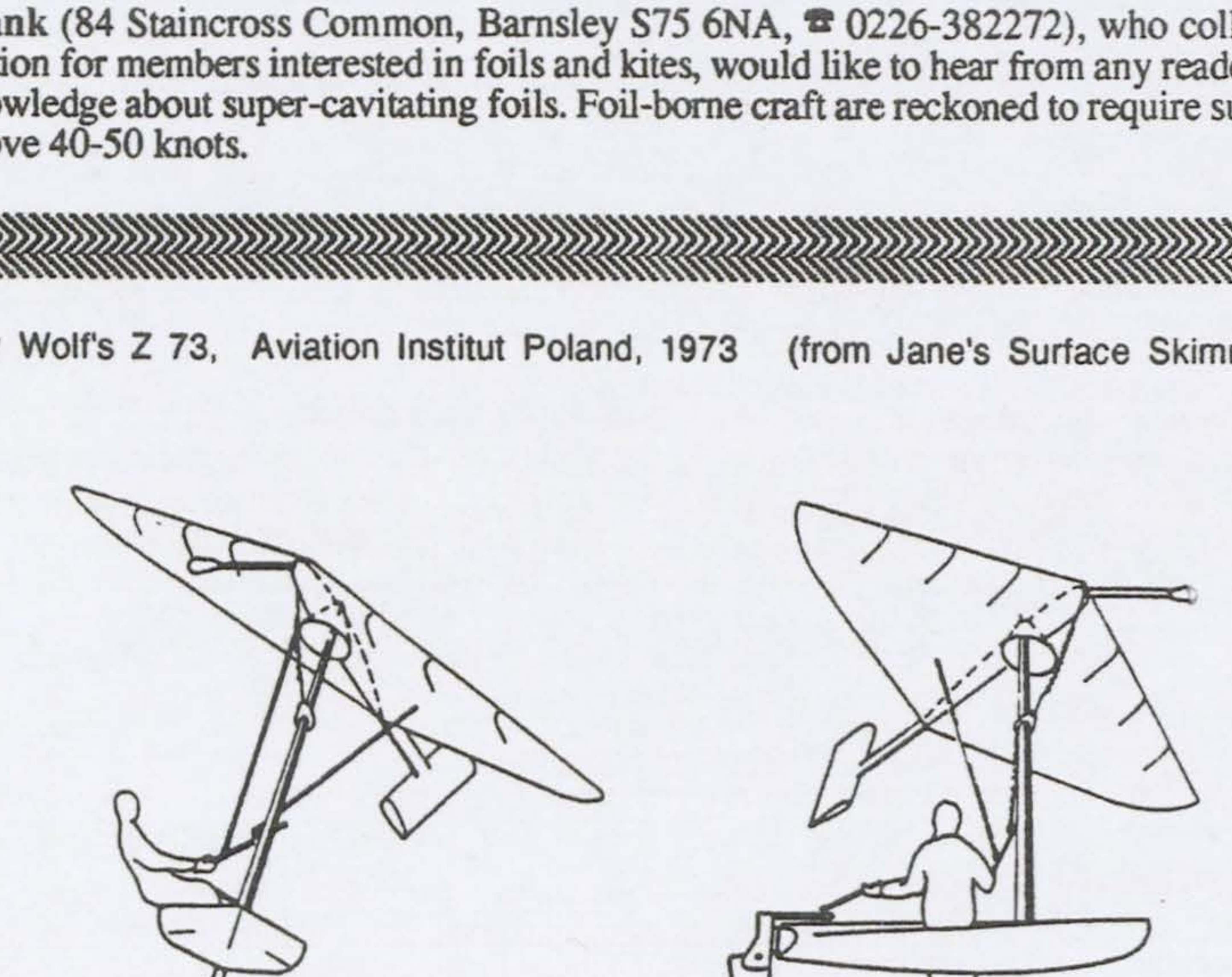
**Note by the editor:** The name *Swing-Wing* should not be confused with the *Swing Wing* sail developed by Alan Boswell and Robin Blain of Sunbird Yachts. This is a type of aerodynamic junk sail which combines the handling advantages of traditional junk sails with the better windward performance of wing-sails.

**W. W. Gillison** has sent in his 3rd Report to the AYRS. This deals with comparisons between different types of sailing craft and in particular submerged hulls. Gillison proposes a "Tri-Sub" concept, which has less drag than other hulls under certain conditions.

This 21 page report could be useful to those interested in sailing submarines but is too long to reproduce here. It is available to members on loan from the society administrator.

**Reg Frank** (84 Staincross Common, Barnsley S75 6NA, ☎ 0226-382272), who collects information for members interested in foils and kites, would like to hear from any readers with knowledge about super-cavitating foils. Foil-borne craft are reckoned to require such foils above 40-50 knots.

Dr Jerzy Wolf's Z 73, Aviation Institut Poland, 1973 (from Jane's Surface Skimmers)



# Stable Sailing on Submerged Hydrofoils

*by G. C. Chapman*

This article is a revised version of the „BANDERSNATCH FILE" which was published in the June 1990 AYRS Newsletter, and brings the story up to date to the end of the 1990 season.

Since retiring from speed sailing after 1979, I continued to develop submerged hydrofoils, initially using the system I devised in 1978 where each complete foil assembly is continually adjusted by a height-feeling sensor in the bows. The only comparable system I have heard of is that used on Greg Ketterman's LONGSHOT, of which more later. My version worked up to a point (see AYRS 101, August 1985, page 12) but I felt the drag of the feelers was excessive, and with only 10 $m^2$ of sail, the boat needed more than 12 knots of wind, preferably 14-15 to get up and fly.

In 1985 Philip Hansford's DOT alias PHILFLY first took to the water and showed that flaps on the main foils, controlled by trailing feelers, work very well. So in 1987 – it can be slow progress – my son and I put afloat a borrowed CATAPULT with flapped foils and an inverted T rudder/foil in the „aeroplane" configuration. This flew that September and is described and illustrated in MULTIHULL INTERNATIONAL 239, December 1987. BANDERSNATCH, my 15 ft catamaran, flew on similar foils the same month using my 10 $m^2$ wingsail. Development using the wingsail, or a conventional sail with a tiny jib, continued in the summers to 1990.

Although after 1979 the aim initially was to achieve dynamic stability and speed, as the years have gone by and sailboard speeds have risen so my aim has changed towards „stability in flight in lower wind speeds". In the UK summer winds – on the south coast – only blow between 12 and 20 knots when the wind is rising or falling. There are plenty of days of 8-10 knots gusting 12, and some of 20 plus: but only minutes of 13, 14, 15, 16 knots. I therefore set a target wind for lift-off of 11 knots, threw away ideas of beating the boards' 40 plus knots and settled for the simple excitement of flying, when a boat speed of 12-15 knots can be quite exciting enough.

I have stuck with the catamaran and aeroplane configuration because they are practical, they allow reasonable performance with foils raised, and I had the cat already. Access to the foils is good, and with foils and rudders all „lifting" and a 5 kg outboard, single-handed off-the-beach operation is satisfactory.

## Choice of feelers and foils

The Pattisons' FORCE 8 has each complete main foil pivotting about a horizontal axis at the bottom of a fixed vertical strut, its incidence set by a Hook-type forward-reaching feeler in conjunction with the pilot's joystick. They had problems with control, partly I suspect from the feelers which periodically dig in, and partly from the indeterminate feathering of the foils, necessitating some shock-cord spring tension. Each bearing has to carry the full load on the foil, and in addition the struts carry the leeway.

I had thought that Christopher Hook's forward-reaching feelers had conditioned many peoples' thinking and that the Guru had never toyed with the idea of trailing feelers. Hugh Barkla kindly sent me a Hook leaflet of 1965 where he describes trailing „whiskers" and glosses over the means of conveying their information to the foils. Maybe the only person to read that was Mark Simmonds who put a single trailing feeler on RAMPAGE in 1976. Hansford's DOT was on the beach at Weymouth in 1984, which shows how conservative we can be!

The flapped foil has the structural advantage of a monolithic construction for the forward 70% or so of foil area, and a reduced loading on the 30% flap for the feeler to control by a simple linkage, against having to move the whole foil. In both types a symmetrical section foil (eg NACA 0015) is appropriate since the foil will have to develop downforce, and to do this using a cambered foil incurs excessive drag. My foils are of wood with GRP sheathing, stiffened with carbon fibres, and using polyester resin.

The trailing feeler has obvious advantages. We have found that the 5 cm (2") triangular plate at the tip rides over wave tops at flying speed, developing enough force to pull the flap down against both the feathering action of the water and the elastic pull needed to pull the flap *up* when the boat tends to fly too high.

Our flaps originally moved from 28° of depression to 7° raised. We found at the Calshot Speed Weekend of April 1990 that the gusty wind which had traversed Kent, Sussex and half Hampshire contained not only gusts but also lulls, of greater intensity than we had experienced when the west wind had only travelled over Cornwall. When a lull strikes, the load on the boat due to sail force diminishes markedly. The momentum of the boat carries it forward and if the lull is large enough the sail goes aback, so that the sail force may actually reverse. At Calshot this caused the boat to rise, heeling to windward, so that the leeward foil broke surface: the boat then crashed back.

The cure was simply to increase the angle that the flaps can be *raised* to 28° by a small modification. We also increased the gain of the system slightly so that movement of the feeler tips between the draft marks on the struts, some 18 cm (7"), moves the flaps from full up to full down.

## Some design details

As the system was improved I found that I had to stiffen the supports for the feelers, and fit metal adjusting links in the wire between the feeler arm and the link-arm at the top of the strut: cord adjusters stretched too much and were imprecise.

When the boat is deeper than the upper „flying WL" the feeler arms are partly submerged. As they trail this is no great hardship. A „lost motion" mechanism is possible but I believe is an unnecessary complication. There is merit in having some part of the linkage, at the top of the strut, act as an indicator to show what the flap is doing.

The choice of foil area is a compromise. Both on CATAPULT and BANDERSNATCH we found that added surface-piercing foil area, higher up, is a help in getting foilborne in lower winds. Once up, the smaller the main foil area the faster you can sail, but equally the more wind you need to keep flying. BANDERSNATCH currently has 1035 $cm^2$ (160.5 sq. inch) main foils, of which 32% is flap, the span of each being 62.7 cm (24.7").

The inverted T rudder foil is simple enough, again a symmetrical section, area 639 $cm^2$ (99 sq.in.). It is essential to know to within 1° or better the incidence of this foil relative to your datum level. Then the rudder foil can be set right from the start to „just positive incidence" and the boat will then fly level in pitch, any small adjustment being made by moving crew weight fore or aft. An adjuster in 1° steps is adequate for tuning.

Conventionally – i.e. ever since MONITOR – it has been convenient to fix the main foils to a cross beam near or under the mast. Ideally the line of action of horizontal effort of the main foils should nearly coincide with the corresponding sail force vector, seen in plan, to give balance in azimuth. The rudder should carry a small amount of the leeway, to give weather helm feel. With the main foils at the ends of a catamaran's main, mast-supporting beam, this criterion is met either with a jib and conventional sail or a wingsail with some area ahead of the mast.

Roll balance depends on the moment due to the sail's heeling force being met by weight distribution and foil forces. I maintain that for minimum foil drag the total of hydrodynamic lift forces must be minimised and that this can be done by inclining the struts & foils. (AYRS 101, page 13 and MULTIHULL INTERNATIONAL 206, March 1985).

Keeping the foils horizontal and the struts vertical incurs separate lifting and leeway loads, greater bending moments in the struts and more ventilation down the struts. The advantage is shorter struts for the same foil immersion. I have been gradually reducing the dihedral angle and having deliberately reduced it further than I might, the experience with the current 20° tends to confirm that I'm right, because more leeway is evident on the struts which need fences to resist ventilation. However adjustment is not so easy!

It is also, in accordance with my theory, necessary to sit amidships to totally eliminate leeway from correctly angled struts and to sail upright. This need is evident, even if not so far achieved; all three of us who have sailed BANDERSNATCH have continued to sit on the weather hull.

Years of trying to test and prove systems in a hurry led me away from the systematic approach. In 1989 I made a determined effort to be systematic, and it paid off, even though imperfectly done. Test flying a sailing hydrofoil is much more difficult than test flying an aircraft, more akin to what the Wright Brothers were doing. So it is essential that everything is accurately set up ashore beforehand and recorded: that adjustments can be made accurately and repeatably: and that as far as possible there are indicators which can be seen and/or photographed. We have boat speed and apparent wind speed indicators, and the crude indicators of flap position. The main assemblies can be set afloat to within 0.5° over a range, and the feelers raised or lowered in 1.5" (3.8 cm) steps, and the gain adjusted. Elastic tension can be preset with a spring balance, and two elastics each side set to different tensions give three choices of tension.

Starting with zero incidence on the main foils and the flaps locked in neutral and the feelers raised, I then increased foil rotation by 1° steps until the boat showed signs of lifting off at 3°. Then by going back to 2.5° with the flaps and feelers working led via some adjustment to a final choice of 2.5°.

## Operation

For each outing a „Trials Schedule" was drawn up and adhered to as much as possible, generally accepting that two runs on each tack are enough to validate a conclusion before moving on.

The ideal flying course is between 90° and 120° off the true wind. From hove-to one sheets in and points the boat in the right direction. It helps considerably to have a sail with a boom vang or a wish-boom so that when sheeted right out – beyond the traveller – the sail does not twist. Full drive can then be obtained with the apparent wind 60° off the bow. Our CATAPULT trials were very much more difficult because the Cannon rig suffered from sail twist. We have broken away from the fashion set, I think, by the DART and HOBIE cats and on BLUEY, my other cat, have reverted to a horizontal boom with a powerful „kicking strap“ or vang. The wish-boom rig, as on the original CATAPUT's Comet rig does as well if not better since it has less end-effect under the non-existent boom.

Once under way the weather hull lifts up to its designed height: there is no need to lean backwards because it won't help. Then as speed increases, and maybe you give a jab to the tiller to cause a brief luff, so the boat sings, the lee hull comes up and suddenly the boat accelerates. All goes quiet except for the whistling of the wind in the rigging and the organ-pipe noises if you have a second hand mast. Sheet in that little last bit, shift fore or aft to hold the boat level, if you are practised shift inboard, and explore the limits of flight!

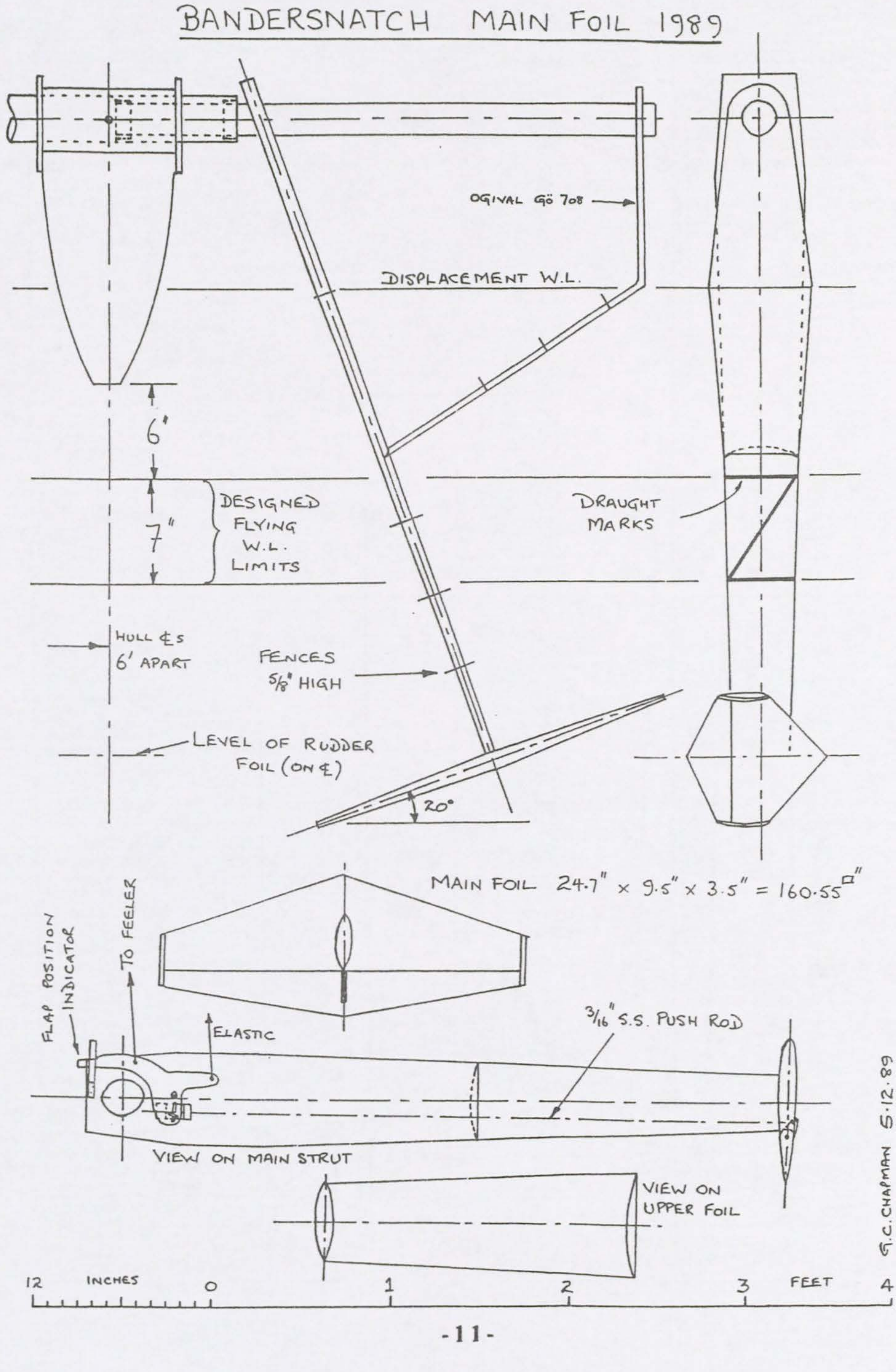
In the case of BANDERSNATCH the total noise due to the somewhat flexible structure is akin to a railway carriage rumbling along. There will be some spray particularly if the struts are carrying leeway but nothing like a planing dinghy's. Three clean and narrow wakes trail astern. Still photos give little idea of speed. The test pilot's problem is in assessing what is going on aboard whilst looking where to go, and keeping an eye open for driftwood. Whereas in other boats you can lie for hours on deck looking up (and admiring, or not) the set of a sail, on a foiler you have seconds only at a time to see what is going on.

Photographs, and an outside observer with radio communication help, provided the pilot can be induced to stop and listen! The temptation to go on flying once conditions are right is enormous!

By the middle of 1990 it was clear that there was not much chance of improvement, and that others could be invited to try their hand. So on 28th July Pete Silcock, an experienced catamaran and tri sailor, who has a THAI cat and a heavily modified TELSTAR brought the latter down to the Hamoaze to act as a camera platform. After waiting for the wind to rise to 10 knots gusting 12 my son gave a demonstration and then he and Pete changed places. After an initial minor crash due to sitting a shade too far aft Pete was quickly flying, the only problem being to get him to stop. Number 28, your time is up!

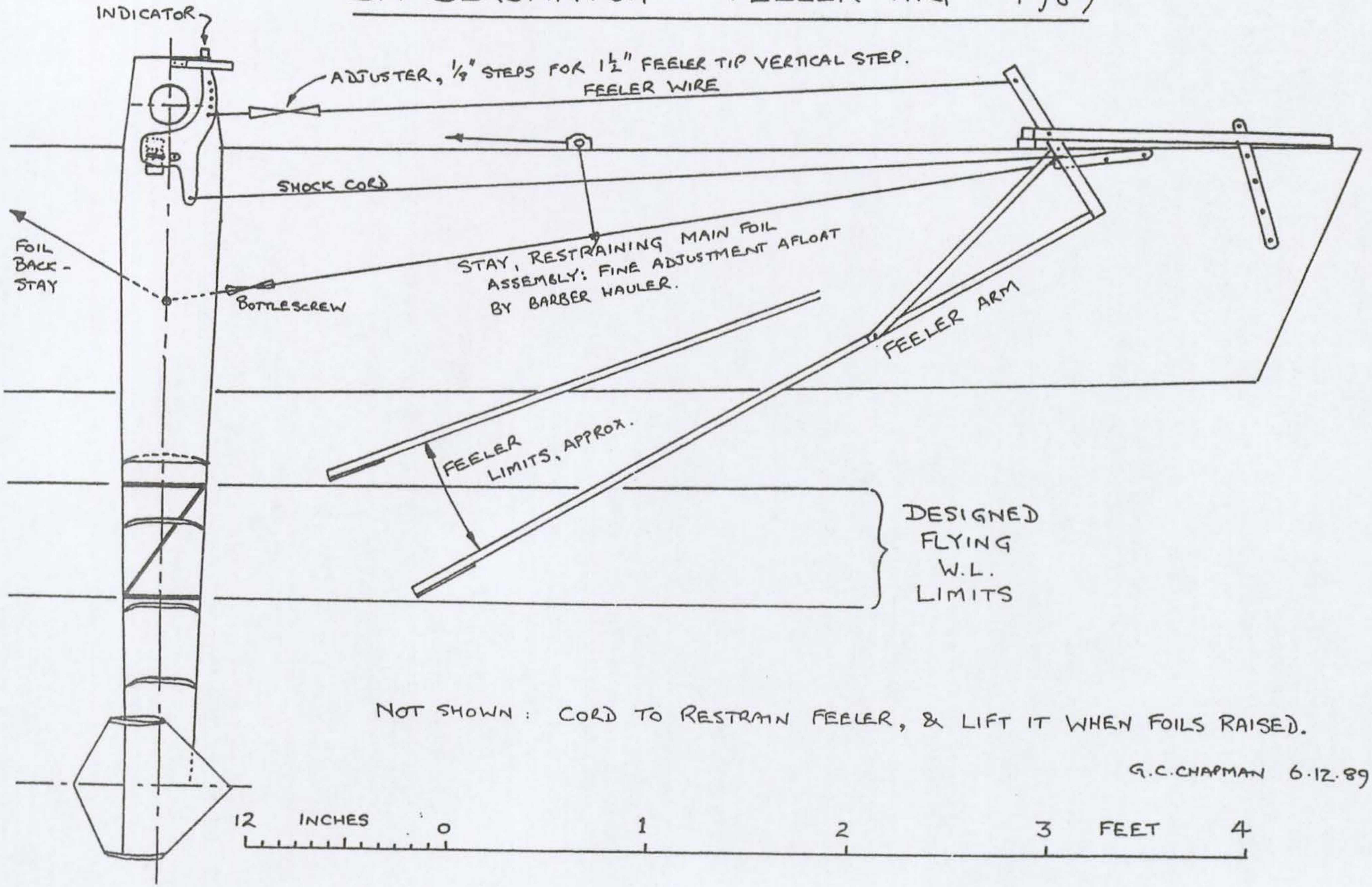
It is fair to conclude that the boat can get up and fly in wind of 12 knots, maybe a shade less. That gives the potential for a lot of flying on the Tamar and in Plymouth Sound. Occasionally wind over tide or wakes gave some relatively rough water. The boat seems to go even better then, even if the flexing between hulls and general rattling increase, probably because the feelers fly the boat to the wave tops so that overall strut immersion is reduced.

I make no claims for high speeds. We found somewhat to our chagrin that my 8 mm cine camera had been running at something like 14 frames per second rather than the 18 f.p.s. set on, so that speeds assessed in the past based on frame counts were far too high. The advent of the electronic SPEEDWATCH device – described in another article – has caused us to rethink our ideas on speed measurement, which afloat is not as easy as we thought. ❑



BANDERSNATCH MAIN FOIL 1989
OGIVAL Gö 708
DISPLACEMENT W.L.
6"
7"
DESIGNED FLYING W.L. LIMITS
DRAUGHT MARKS
HULL ℄S 6' APART
FENCES 5/8" HIGH
LEVEL OF RUDDER FOIL (ON ℄)
20°
MAIN FOIL 24.7" × 9.5" × 3.5" = 160.55□"
FLAP POSITION INDICATOR
TO FEELER
ELASTIC
3/16" S.S. PUSH ROD
VIEW ON MAIN STRUT
VIEW ON UPPER FOIL
G.C. CHAPMAN 5.12.89
12 INCHES 0 1 2 3 FEET 4

# BANDERSNATCH - FEELER RIG - 1989



BANDERSNATCH

1989 General Arrangement.

LOA 16'
Hulls 14' 10"

| | Displ | Foiling |
|---|---|---|
| Boat weight | 155¼ | 186¼ lb |
| Crew + engine | 171 | 171 |
| Total | 326½ | 357½ lb |

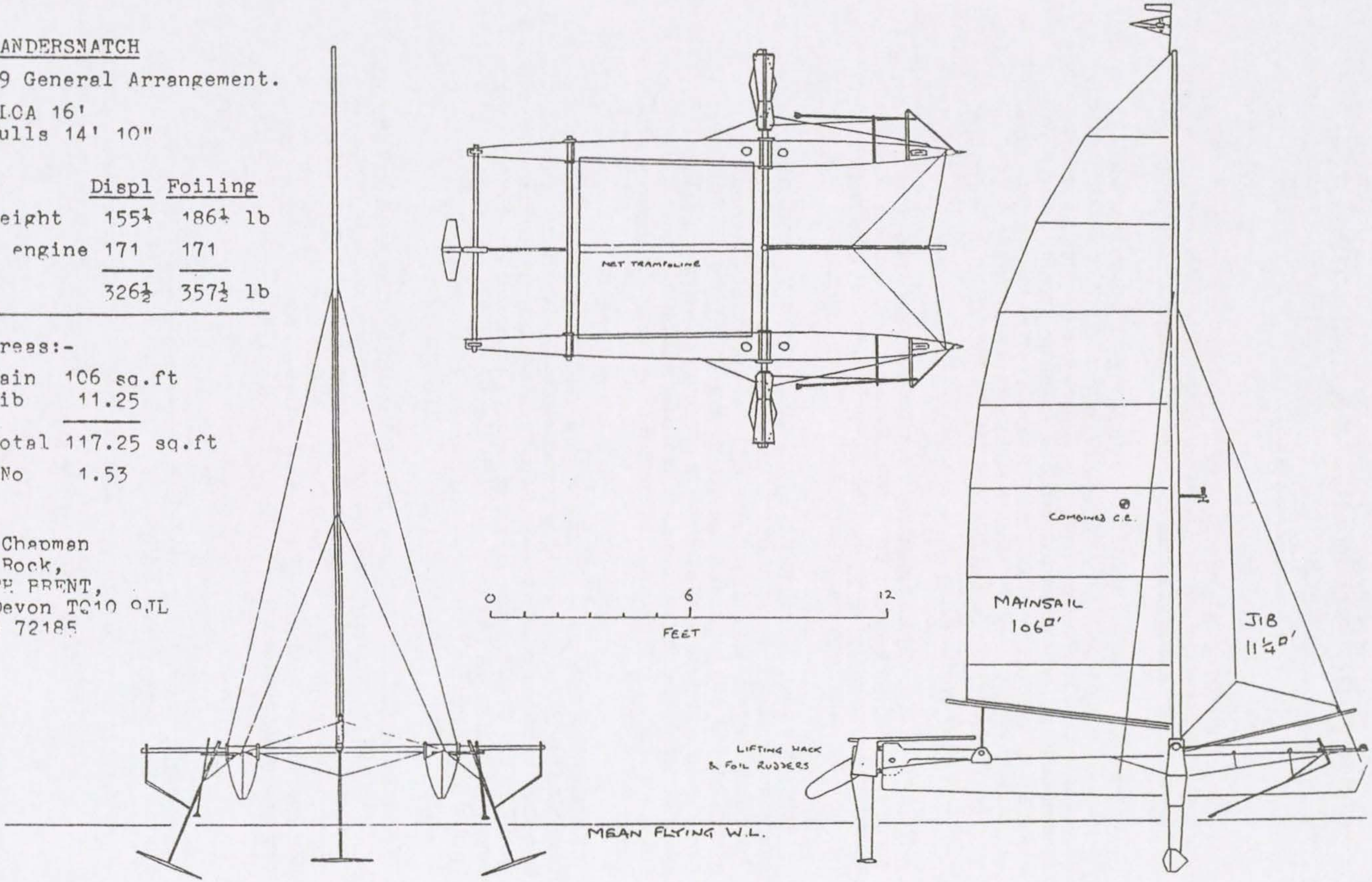
Sail Areas:-

Main 106 sq.ft
Jib 11.25

Total 117.25 sq.ft

Bruce No 1.53

G.C.Chapman
The Rock,
SOUTH BRENT,
S. Devon TQ10 9JL
0364 72185



# After the Sailboard, a Quantum Leap?

*by Roger Glencross*

„Science progresses by a thousand tiny strides, not by a few giant leaps". This is as true in speed sailing as it is in most areas of technology. The speed record has increased steadily but slowly and there are signs that the rate of increase will slow down.

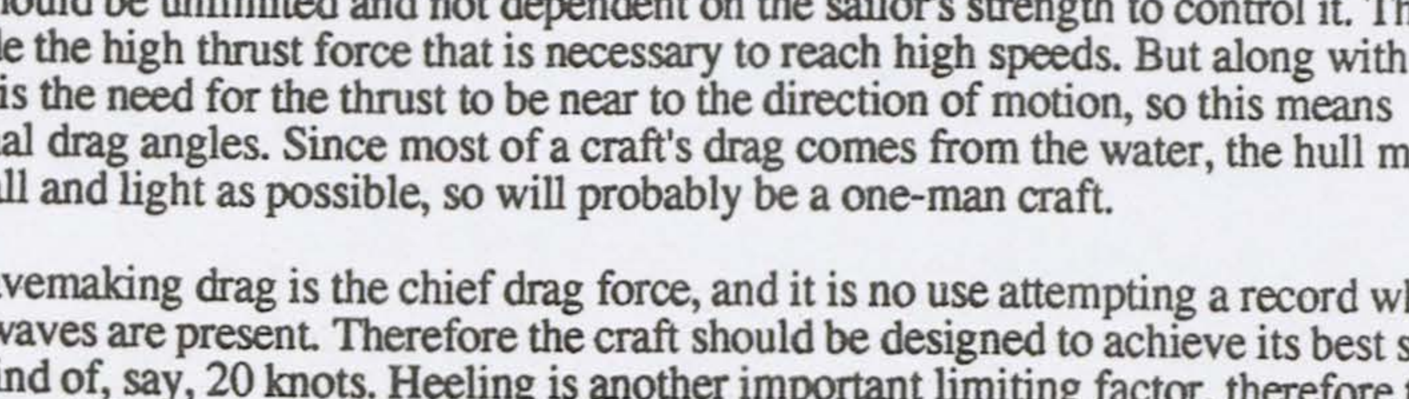
Is it possible for the speed record to be raised to, say, 100 knots, at one attempt? I believe that it is, and sooner than people expect. There are examples of such quantum leaps in science, for example, computers. Their memory capacity, price, compactness and speed of calculation have progressed beyond all recognition since the 1950's. Another example is the speed of flying craft. First a monoplane beat the fastest biplane. Then the jet beat the fastest piston-engined plane. Then the earth satellite travelled at 17'000 mph, many times faster than the swiftest aeroplane. Then the moon rocket reached escape velocity of 25'000 mph.

What can we predict about a quantum leap in speed sailing? Firstly, as in the above examples, it could happen sooner than people expect. Secondly, this ultra-fast sailing machine will be radically different from the sailboards, which are the fastest craft at present, in the same degree that the jet plane differs from the space rocket.

I believe that sailboards will soon be a spent force. One reason for their success is the great professionalism of the board sailor. If you sail seven days a week all year round you will achieve great skill and a complete rapport with your craft. Once you have attained that skill totally, it can only be improved upon slightly. The craft that does not need a high degree of skill and balance yet still possesses a close rapport between craft and sailor, speed of rigging, launching and recovery, the ability to change rig or hull to suit the wind and sea conditions and is inexpensive, could beat the sailboard by a large margin.

There is a limit to the amount of sail area that a board sailor can control. His arms are of a limited length. The ultra fast sailing machine should avoid this limiting factor. Its sail area should be unlimited and not dependent on the sailor's strength to control it. This will provide the high thrust force that is necessary to reach high speeds. But along with high thrust is the need for the thrust to be near to the direction of motion, so this means minimal drag angles. Since most of a craft's drag comes from the water, the hull must be as small and light as possible, so will probably be a one-man craft.

Wavemaking drag is the chief drag force, and it is no use attempting a record when large waves are present. Therefore the craft should be designed to achieve its best speed in a wind of, say, 20 knots. Heeling is another important limiting factor, therefore the craft should be a non-heeling machine. So ignoring heeling, assuming a boat speed of 100 knots and a true wind speed of 20 knots we obtain the triangle of velocities for maximum speed as follows:



So the total drag angle $\beta$ is about 12°. Let us assume 6° is air drag and 6° is water drag. Clearly the craft will have to be very streamlined. A 6° drag angle means a lift/drag ratio of about 10 to 1 (ctg $6° \approx 9.5$). With regard to the aerodynamic part of the craft, a modern high aspect ratio hangglider can achieve an L/D in excess of 30 to 1, but not at 100 knots, where more solid wings may be necessary. If the plane flies banked with one wingtip so close to the sea that the sea acts as a huge wingtip plate this might be achieved. The wingtip vortex on the lower wingtip will be suppressed and the induced drag reduced. An L-shaped wing brings this to its ultimate limit, with the vertical wing providing the horizontal driving force and the horizontal wing flying very close to the sea, taking full advantage of the ground cushion effect to reduce induced drag. The purpose of the horizontal wing is to support the pilot and hull, in whole or in part, and thereby reduce hydrodynamic drag. When flying banked a hangglider would perform both functions. The sail area required at 100 knots would be small, but a larger sail would be required at take-off speed. So variable geometry, tow-up or jettisoning part of the sail may be necessary.

The hull drag angle at 6° is so small that it would be necessary to dispense with a hull and use a foil joined to the hangglider by a line. The buoyancy required to support the pilot and hangglider at low speeds is provided by floats attached to the glider. These are jettisoned after take-off to reduce air drag. The towed foil must operate automatically since the pilot will have his hands full flying the glider. He will hardly be able to see the submerged foil which will be abeam and slightly behind him.

In order to withstand the forces at 100 kts the foil must be small and strong. It must have a surface sensor which keeps it just below the air-water interface. At take-off speed a larger foil is needed, so variable geometry, tow-up or part jettison may be required.

The foil provides mainly horizontal lift and some downward pull. It will have slight positive buoyancy and a lower wingtip weight to give it the right attitude at start-up. Even though dynamic forces completely dominate static forces at speed, a top-heavy foil still seems unstable. A towed foil can run stably if it is curved. The tighter the curve the greater the stability, but the efficiency is reduced. The reasons for this are explained by Professor Hagedoorn in AYRS Airs No 2 page 27. Clearly an aerofoil section should be used, but a simple flat underside and a segment of a circle on the top side may be adequate and would be easy to construct. My experiments show that a rudder fixed at a small positive angle is needed to prevent the foil curving into the towing vessel. Longitudinal stability is ensured by a long pole atop the foil with a float at the front of the pole and the fixed rudder at the back of the pole. Rolling is prevented by a two-leg bridle, and since the bridle and tow-line are the chief sources of drag, the topmost leg of the bridle and the bridle joining point should be above the water. The lower bridle leg should be as thin and short as possible and well faired.

The foil has many problems which the hangglider does not share. The hangglider has already been developed. It does not have to cope with the awkward air/water interface. It benefits from ground effect and does not suffer from surface effects or wave drag which reduce a foil's efficiency. However my initial experiments with a two square feet curved foil weighing seven pounds make me optimistic. The drag angle is so small that I cannot measure it and it is stable up to the speed that I have tested it, i.e. 6 knots.

Can a foil have a drag angle of only 6°, when travelling at 100 knots? I believe so. I reproduce below the table of lift/drag ratios of various foil sections from AYRS No 61 as prepared by Edmond Bruce:

*Aspect Ratio = 6 in all cases. At high Reynold's Numbers*

| Foil | | Max L/D | Angle of attack at Max L/D (deg) | Cl at Max L/D | Max Cl | Angle of attack at Max Cl (deg) |
|---|---|---|---|---|---|---|
| Flat Plate | | 6.7 | 5 | 0.40 | 0.78 | 15 |
| NACA | #0006 | 23.5 | 4 | 0.40 | 0.88 | 16 |
| | #0009 | 22.5 | 5 | 0.40 | 1.27 | 18 |
| | #0012 | 21.6 | 5 | 0.40 | 1.52 | 22 |
| | #0015 | 21.0 | 5 | 0.40 | 1.53 | 22 |
| | #0018 | 19.8 | 6 | 0.40 | 1.50 | 23 |
| | #0021 | 18.5 | 6 | 0.40 | 1.38 | 23 |
| | #0025 | 16.5 | 6 | 0.40 | 1.20 | 23 |

With these NACA sections the first two digits 00 indicate that the section is symmetrical. The second two digits indicate the chord/thickness ratio at the thickest part of the section. The NACA #0012 seems the best overall, but strength considerations may force one to adopt a thicker section. If strength were no problem one could choose the thinner and therefor less draggy #0006 with its unbeatable L/D ratio. The reduction in total lift would be no problem since even a small foil would provide adequate lift at 100 knots. Considerations of strength might also compel an aspect ratio of less than six, reducing the L/D ratio. A lower aspect ratio foil would have a wider range of operation, being less sensitive to stalling.

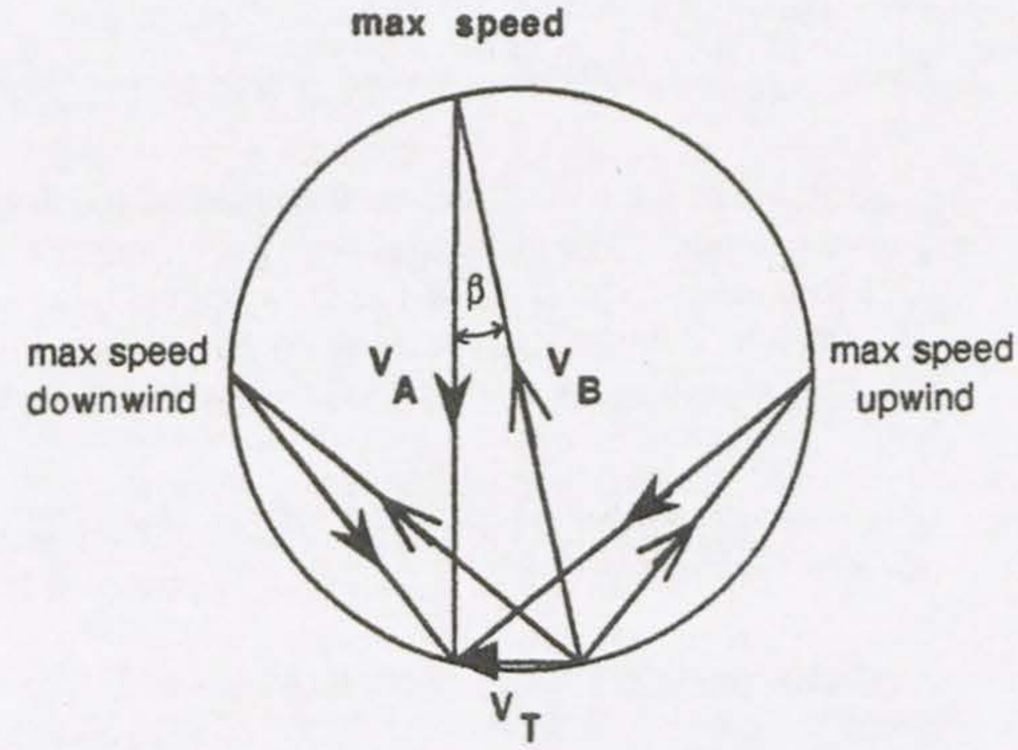
The table of figures is meant for Reynold's numbers of about six million, which would be reached by a foil of 15 cm chord going through the water at 100 knots (Re in water is roughly one million times the chord in m and times the speed in m/s, see also AYRS AIRS Nr. 10 page 44)). At much lower Reynold's numbers the lift/drag ratio is much worse. The craft may not be able to get over this low-speed hump, hence the need to tow up the craft to, say, 30 knots by powerboat.

The main drag at high speed will not come from the foil but from the bridle, float and rudder. The pole will hopefully ride above the surface. There will also be some loss of lift due to surface effect, i.e. ventilation, and cavitation. I cannot compute this drag accurately, but would hope that a deterioration of L/D from a theoretical figure of 23.5 to 1 down to 10 to 1 would cover it.

In order to encourage the development of such a radical craft the RYA should change its speed event rules by abolishing separate sail area classes, permit motorised tow-ups, jettisoning of parts and crew, no need to start from rest, craft may glide in from nearby clifftops, polymers may be used and no insurance requirements needed! In the meantime perhaps AYRS could sponsor such a competition. There is no need for large cash prizes. The reward for the winner will be immediate world-wide fame! □

# Comments on "Quantum Leap"

*from Didier Costes*

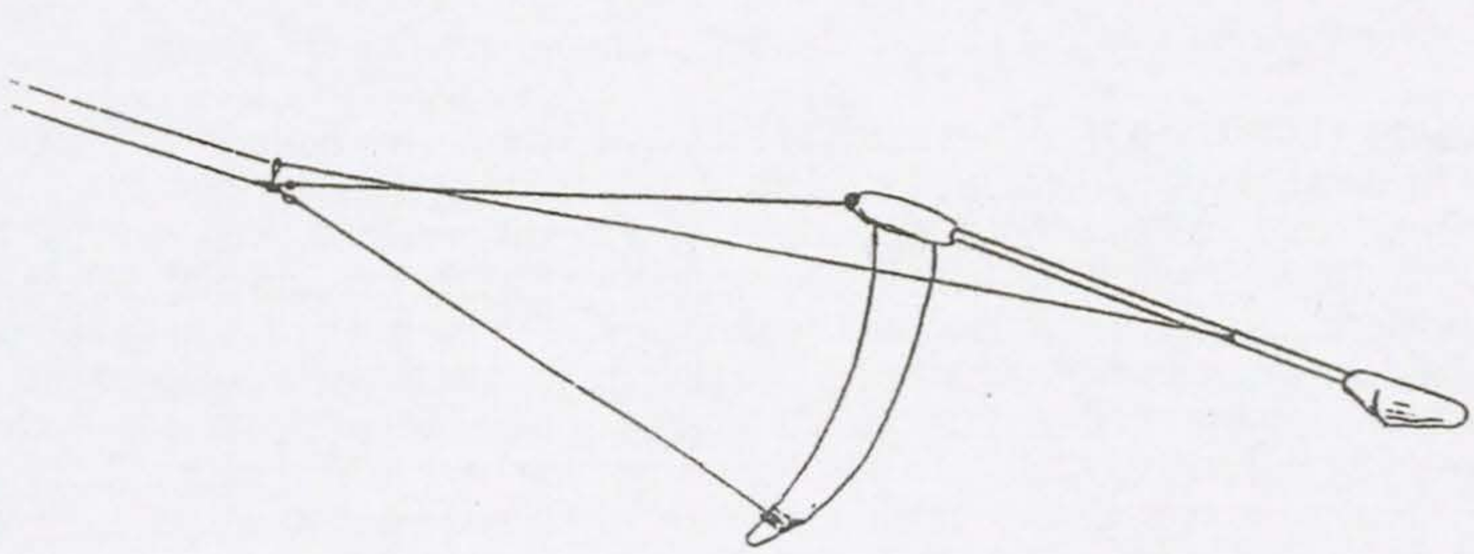



I read with interest your text on fast sailing. I fully agree on the high potential of craft relative to sailboards, if they are designed for self-balance of forces without action of the helmsman. Looking at the enclosed figure, the arc of the circle corresponds to a given constant drag angle $\beta$ and the maximum speed obtainable corresponds to the diameter of this circle.

You know my attempts with the "Exoplanes" to reach self-balance using an inclined sail and upwind foils. This solution could correspond to true "boats" for official records. In my opinion however, "ultimate" sailing consists of connecting by a line a good air glider and a good water glider.

The man may sit in the air glider or below it or stay on a special water glider, with remote control of the air glider which becomes a kite. I prefer not to keep the air glider at a short distance from the water (air cushion effect as you propose) since any instability would precipitate a dangerous crash at high speed. Difficulties concentrate on the water glider. My "Seadog" uses a correct high-aspect wing providing a good lift-to-drag ratio, and the curvature provides stability. However, the immersed line produces at present a dramatic increase in drag at appreciable speeds. I am now developing a new type, of which I cannot at the moment provide details, to be used with a small helium airship. I expect that this Seadog will give an L/D of about 5 at any speed, and a very stable hooking into the water despite waves. When the speed increases, the incidence is automatically reduced in order to limit the forces, keeping the same heading and the same depth of immersion (for stability and for limiting ventilation or cavitation).My first French patent on the Seadog is number 1,494,784, dated 18 May 1966. It describes the Seadog with the curved wing and with an immersed tail, as some speedweek competitors have seen it. Its application with an air glider is noted. I cannot guarantee that this is the real "first" for this type of sailing. I heard that at the beginning of the century the use of a waterboard for airships was contemplated. I would be interested if anyone has any further information about this.

Didier Costes (135 Avenue Victor Hugo, 75116 Paris)



Chien de Mer 1989

Comments . . . (continued):

*from George Chapman (4.3.91):*

Lifting: Using air to lift the craft requires 816 times the area of submerged foil that is required in water. We think that with ground effect to help, you would need less area of wing for the same lift, but that for the same aspect ratio (as a free flight wing) the wingtip drag (my preferred name for what is normally called "induced drag") might be more. On this basis the challenge would be to make an air foil as light as a hydrofoil which lifts the same load.

Wavemaking Drag: Normally refers to the waves made by the craft. The waves made by the wind are different and not so readily susceptible to calculations of drag!

Reynolds Number. Skin friction drag is about 26% of total drag for an AR=6 foil as specified by you, at worst. All types of drag increase with speed. If anything the problem to worry about with a hydrofoil is how to reduce the area as speed increases, alternatively how to support the craft at lower speeds. The drag hump that hydrofoils have to get over normally is that due to the combined drag of hull(s) and foils before becoming foil borne.

Foils The Kite-Ski people said at the last Weymouth Speed Meeting that they think a ski inclined to provide lift and leeway resistance would have less drag than a hydrofoil on a strut - or rather a system of foils on struts, and I am inclined to agree. With good design and very skilled operation the area bearing on the water can be varied and reduced as speed rises, and the ski caters for waves to some extent. The trade-off is skill versus stability.

Leeway, versus Lift. You have to resist leeway. If you provide the lift aerodynamically your hapa has to be on a line to prevent you taking off. Its resolved forces are greater than those for a lifting foil and because the lifting wing is competing with the depressing hapa your drag will be more.

Leeway and Heeling. If you work out for your 100 knot boat the various angles etc, the Drive Force is 10.5% of the (horizontal) sail force. The heeling/leeway force is near enough equal to the sail force. It is a very small Drive Force obtained (if you can do it) at the price of a large leeway/heeling force.

Sail Drag Angle versus Apparent Wind Angle. The hull(s) therefore probably enjoy much the same drag angle over the range of $\beta$, but as the apparent wind moves round from near ahead towards the beam, the area presented by the hull(s) and the shape they present get progressively worse in terms of aero drag. The sailboards get round this by virtually eliminating the hull.If you support the total weight on a wing you may need to consider how effective it is when the wind - at lower speeds - may be coming towards it at an angle, rather than from "straight ahead". Various people have suggested ways to angling the hull(s) to face into the apparent wind but I am not aware that anyone has actually done it.

Practicality. .LONGSHOT shows much of the way forward. The hulls are to some extent shaped to keep aero drag low at higher values of ß. The foil system is "right" for minimising hydro load and drag, and for stability. The sail system has many merits. I do not like the "feelers" which are draggy and potentially risky: they should trail. Possibly at high speeds the two forward foils should become skis? But the rudder foil has to remain a foil to hold the stern down on occasion. Indeed the lee foil must have a "hold-down" capability as must the weather. I favour skis because of the effect of cavitation, which increases drag and damages foils. To avoid cavitation you have to use larger foils than would otherwise be needed. Cavitation is generally reckoned to start to take effect at 40 knots +.

*from Theo Schmidt:*

The ultimate, hull-less kite/water kite type craft has been proposed by a number of people for many years (see following article). Why has noone yet achieved the Quantum Leap? Several answers:

— All kites and hapas (water kites) so far depend on gravity for stabilisation. Most hapas also depend on some form of surface sensing. At high speeds the pulling force becomes many times stronger than gravity forces and the kite or hapa becomes unstable. Although the forces of mechanical surface sensors also increase with speed, so do the magnitude and frequency of disturbing forces caused by waves. At some point the stabiliser cannot react quickly enough and a catastrophic dive or jump is the result. Active stabilisers could be designed, but this requires very clever mechanical and fluidic or electronic engineering. Alternatively skilled and practised human beings can perform astounding feats of control. A two-person concept might work: one flies the kite and one the hapa.

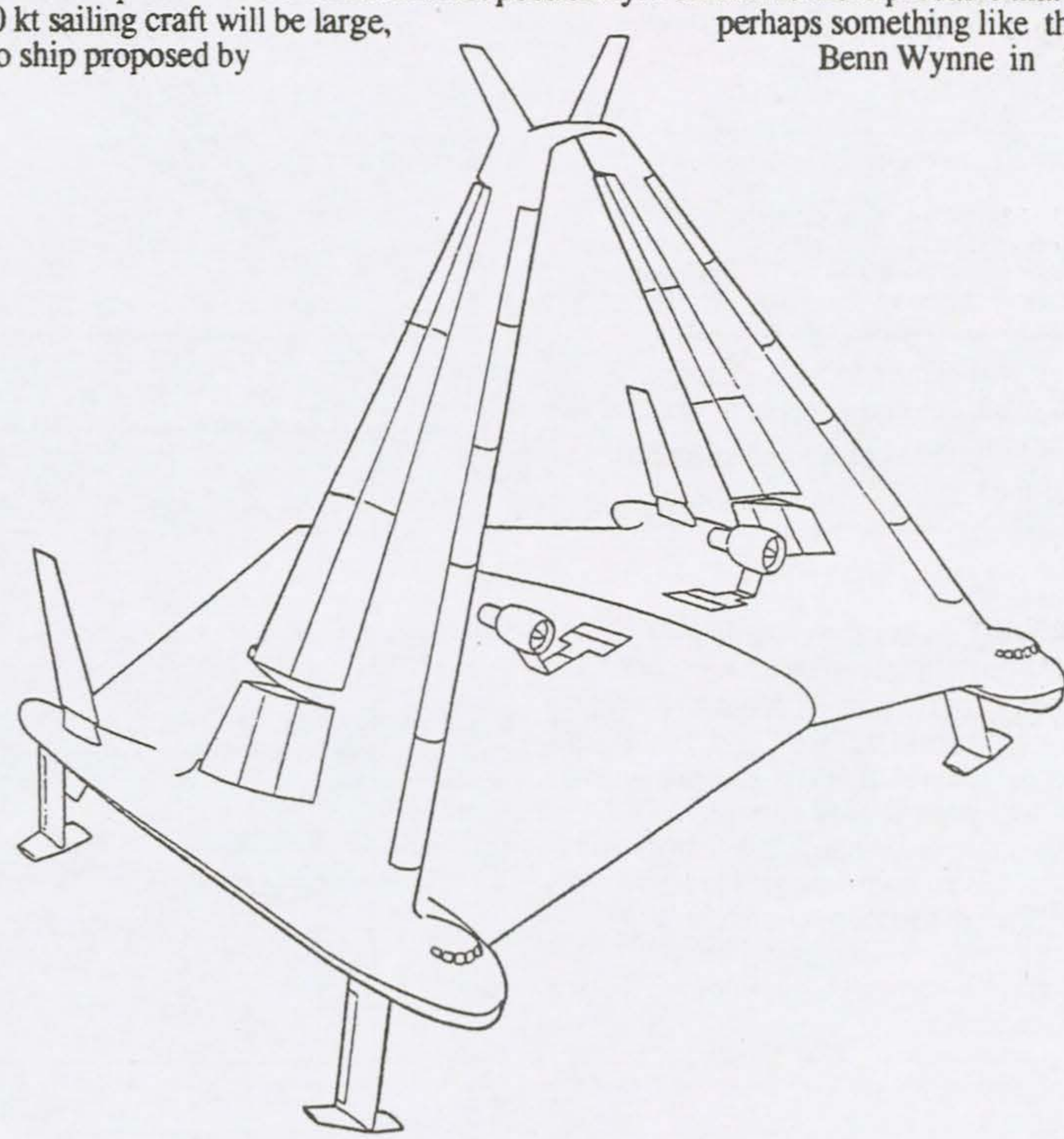
— Most of the hydrodynamic drag comes from wave and spray making at the surface. Although running the hapa deeper will reduce the former and also the onset of cavitation as well as make stabilisation easier, the drag of the connecting line or strut increases and the considerable drag caused by the inevitable piercing of the water surface remains.

— On the air side, any structure both strong enough to work at 100 kts <u>and</u> having the required small drag angle will be so heavy that it must indeed be towed up.

— In any manned craft of this nature, failures or malfunctions are likely to be dangerous or lethal at these high speeds.

— The effort and cost required to develop sufficiently fast-acting automatic control systems for craft of this nature is so great, that it is unfortunately only likely to happen if such craft are useful for killing people or other military uses.

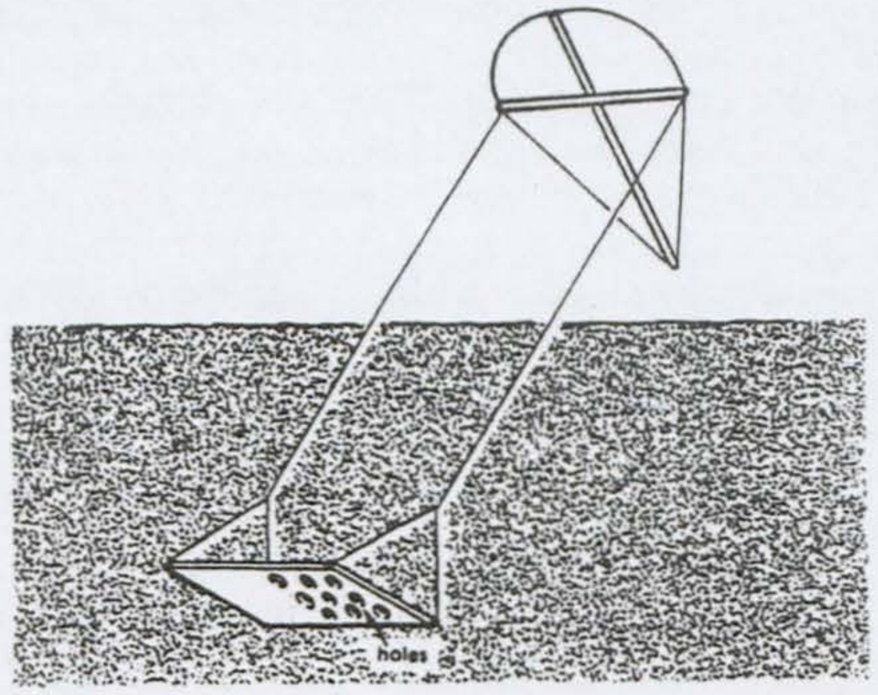
Therefore I don't think we are likely to see any 100 kt kite-hapas for quite a while, although lower speed ones are still a distinct possibility. I think it is more probable that the first 100 kt sailing craft will be large, perhaps something like the 100 kt cargo ship proposed by Benn Wynne in 1978:



# A Short History of Hapas

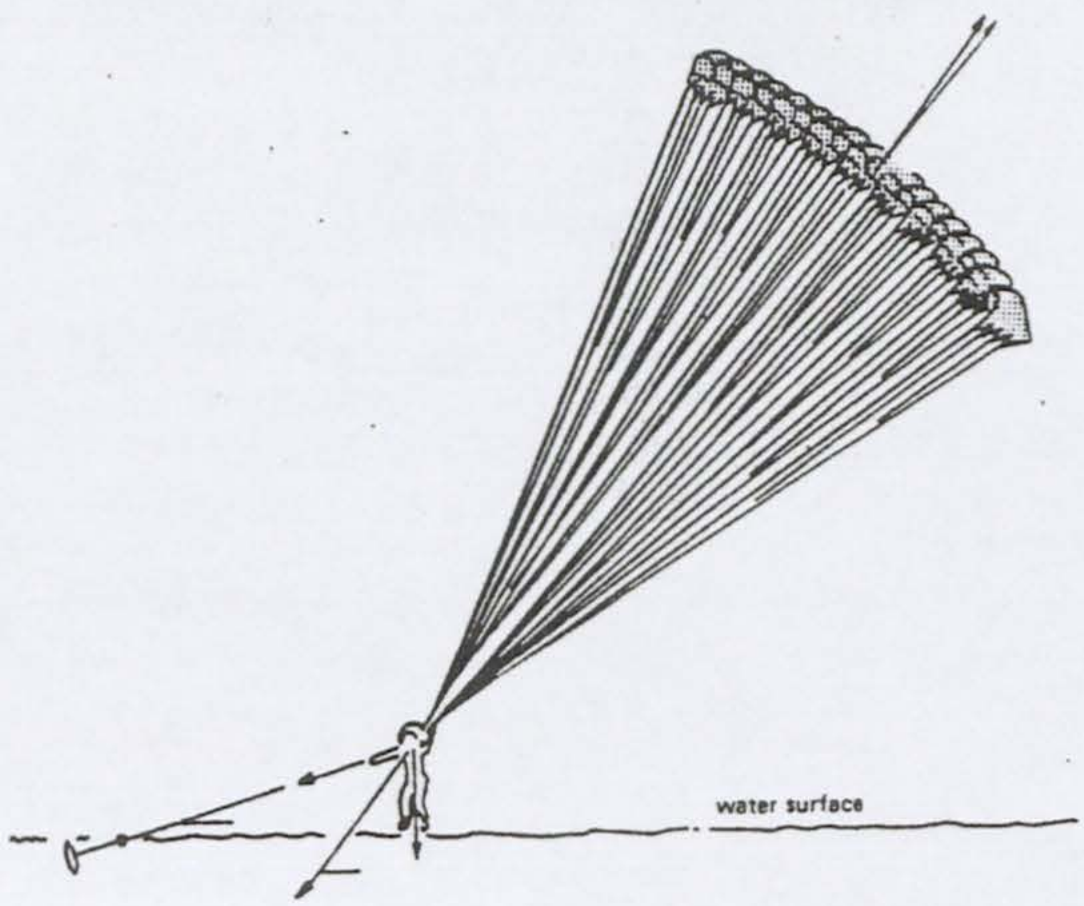
HAPA *Ha-Pa* : A device for providing leeway resistance in the water on a string, used for sailing. Synonyms: Water-Kite, Paravane, Sea-Dog ("Chien de Mer"), Otter-Board.

In 1845 Dr Collodon attached a kite to a specially made board, and the device was apparently capable of crossing Lake Geneva close-hauled.

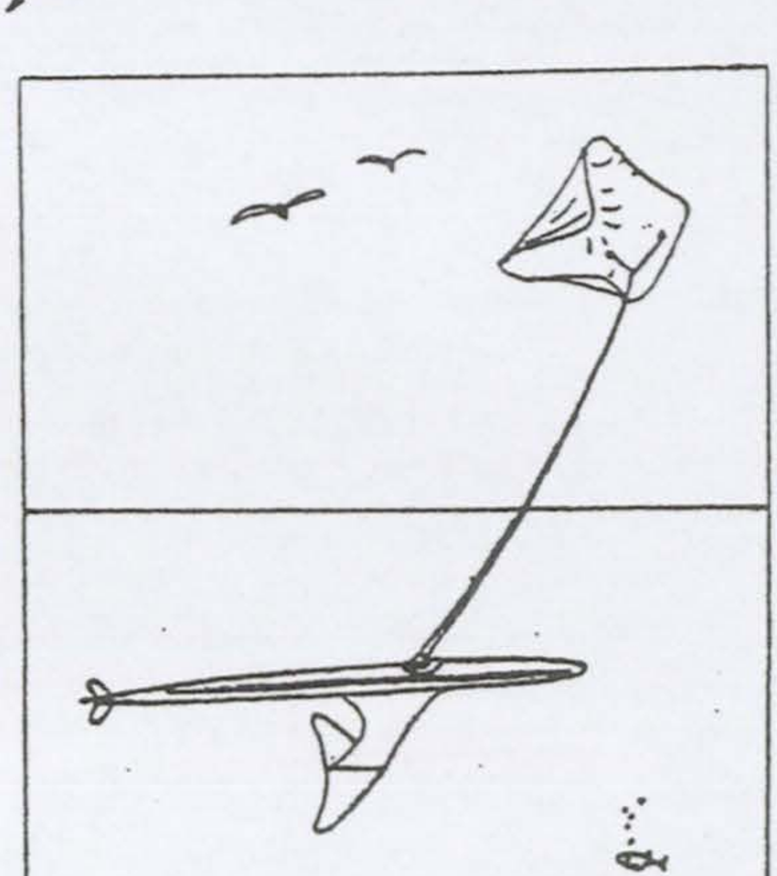



In the 1970s, Prof. J.G. Hagedoorn from the Netherlands devised and tested several hapas (after inventing this word "because it sounds Polynesian"), and proposed using these together with parafoils, suggesting that so equipped aviators could become aquaviators "after being shot down by the enemy". With his publication "Ultimate Sailing", Hagedoorn inspired a whole next generation of "hapa freaks".

One of the first of the present-day experimenters was the frenchman Didier Costes (of Exoplane fame), who devised several hapas from during the 1960s to the present day. His hapas remain the most efficient and the fastest of any built so far, yet Costes is generous and has let others work with his designs.




In the 1980s, Theo Schmidt constructed and used a range of hapas, first testing these in the river Rhein and later in southern England. Starting with Hagedoorn's design, he then made several hoop-type and inverted Π type hapas and modified some of the Costes designs, some of this work being done for Keith Stewart.



In collaboration with Schmidt and Costes, Keith Stewart started an ambitious programme of hapa testing. Using his inflatable kites, his kite-hapas where able to operate automatically, in theory capable of crossing an ocean unaided. Fitting radio controls to both kite and hapa, perhaps the first remote-controlable kite-hapa was built, capable of sailing stablily upwind, downwind, and on reaches.

Inspired by the European activity, Californian Dave Culp started devising all sorts of kite craft, later taking up speed sailing with Flexifoil kites. This set off Toni Rusi and William and Cory Roeseler thinking seriously about kite-water skiing. Cory is the world's most sucessful kite-water skier, having both the skill and the stamina to kite-ski hours on end. Another American who has been experimenting with hapas, or sea-claws, as he calls them, in conjunction with kites, is Harry Morss.

Roger Glencross set out to actually try Hagedoorn's concept in practice. Aquiring a hang-glider and constructing numerous hapas, Roger is often seen in Portland harbour in a motor boat or on a jetty with a line out to side, exercising one of Costes's "chiens de mer" or one of his own. Glencross is prudent enough not to risk his life trying to fly his craft, up to now, anyway. Many others have explored the hapa concept at some time, including Simon Sanderson, James Labouchere, Johnathan Winter and Giles Durand, but mostly didn't specificly persue the concept of the hull-less sailing craft.

Theo Schmidt, May 91

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# Other Research Societies

Under this heading we will occasionally review other associations which may be of interest to members.

## The Electric Boat Association

The EBA was founded in 1982 upon the initiative of well-known AYRS member Lord St Davids. London-based, its present chaiman is Kevin Desmond (122 Olive Road, London NW2 6UU).

The association produces a quarterly journal for members called "Electric Boat News". Aims are to encourage the use and development of electric boats. Regular meetings are held, usually on the Thames. In contrast to the rather freaky and unorganised solar boat scene in mainland Europe, Anglo-Saxon electric boat exponents own or use mainly traditional designs, like the Frolic 21 on display at the last London Boat Show. Such boats owe their excellence to evolutionary design and modern materials, but EBA members are also busy with research and record-breaking, e.g. the construction of the celebrated "An Stradag" for world record holder Lady Arran.

Membership Secretary is Fraser Brown, c/o The Mouse Hole, Abbey Road, Knaresborough HG5 8HX

## The International Human-Powered Vehicle Association

P.O. Box 51255, Indianapolis, IN 46251 USA

Having to do mainly with human-powered land vehicles, there is also a strong involvement with human-powered boats, and human-powered aeroplane feats are also well-reported.As in the early AYRS days, much of the water activity has to do with hydrofoil racing. Today's boats are doing up to 16 kts, still a long way from the 20 kts required to win DuPont's $25000 prize.

The IHPVA is the official body for ratifying both human-powered land speed records and water speed records. The IHPVA was founded in order to recognize the development of innovative vehicles not allowed in cycle racing, a situation not unlike that of early multihulls. Most individual members are Americans, but many other nations are represented by delegates and through their national clubs.

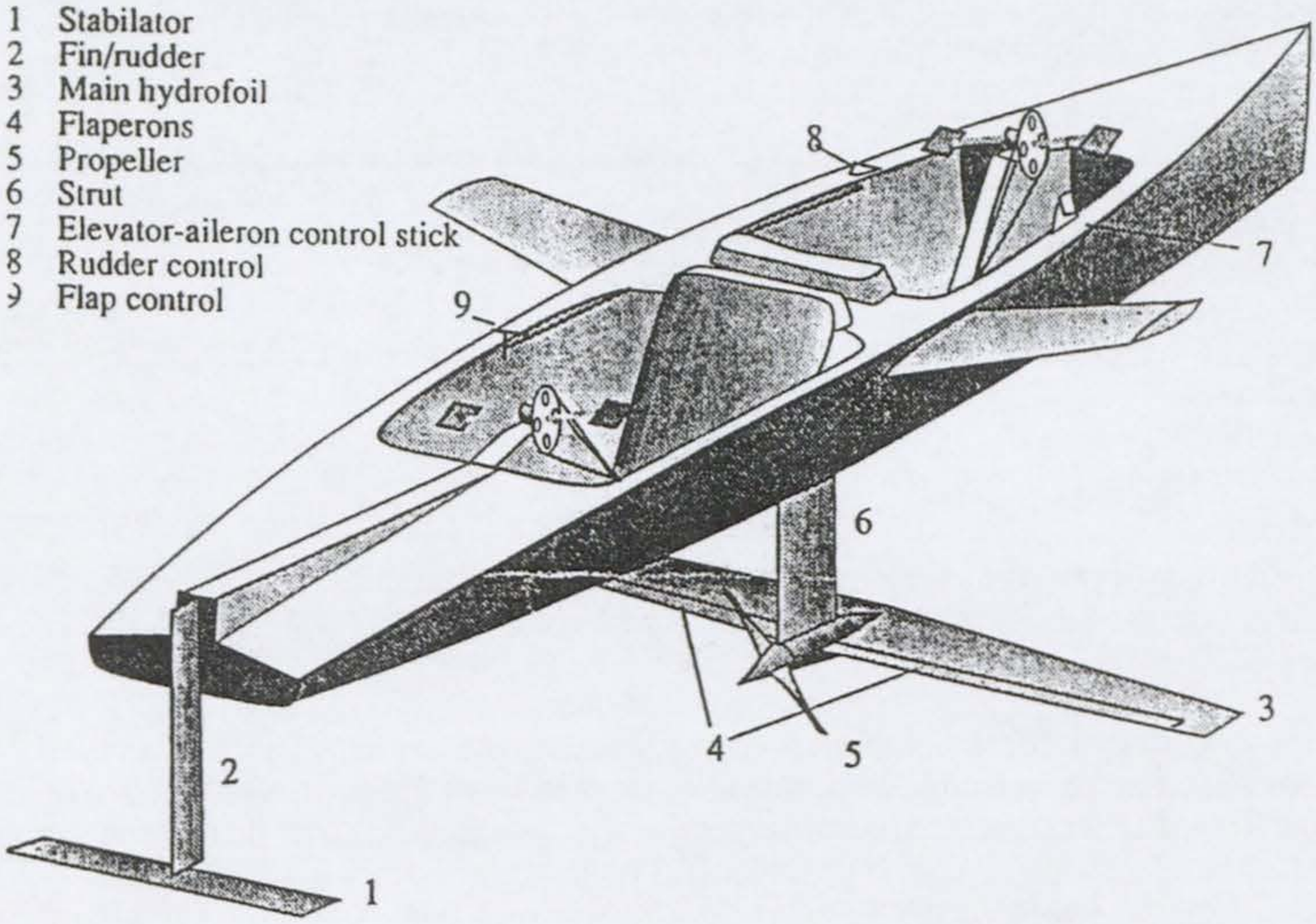
Members get both HPV News and Human Power, 6-8 issues per year for a subscription of $25 ($20 in USA).

**Two human-powered hydrofoil racers:**
The *af Chapman II*, built by students from the Swedish Chalmers University, consistently flies at about 12 kts. Veleau is a Dutch project for 4 riders.

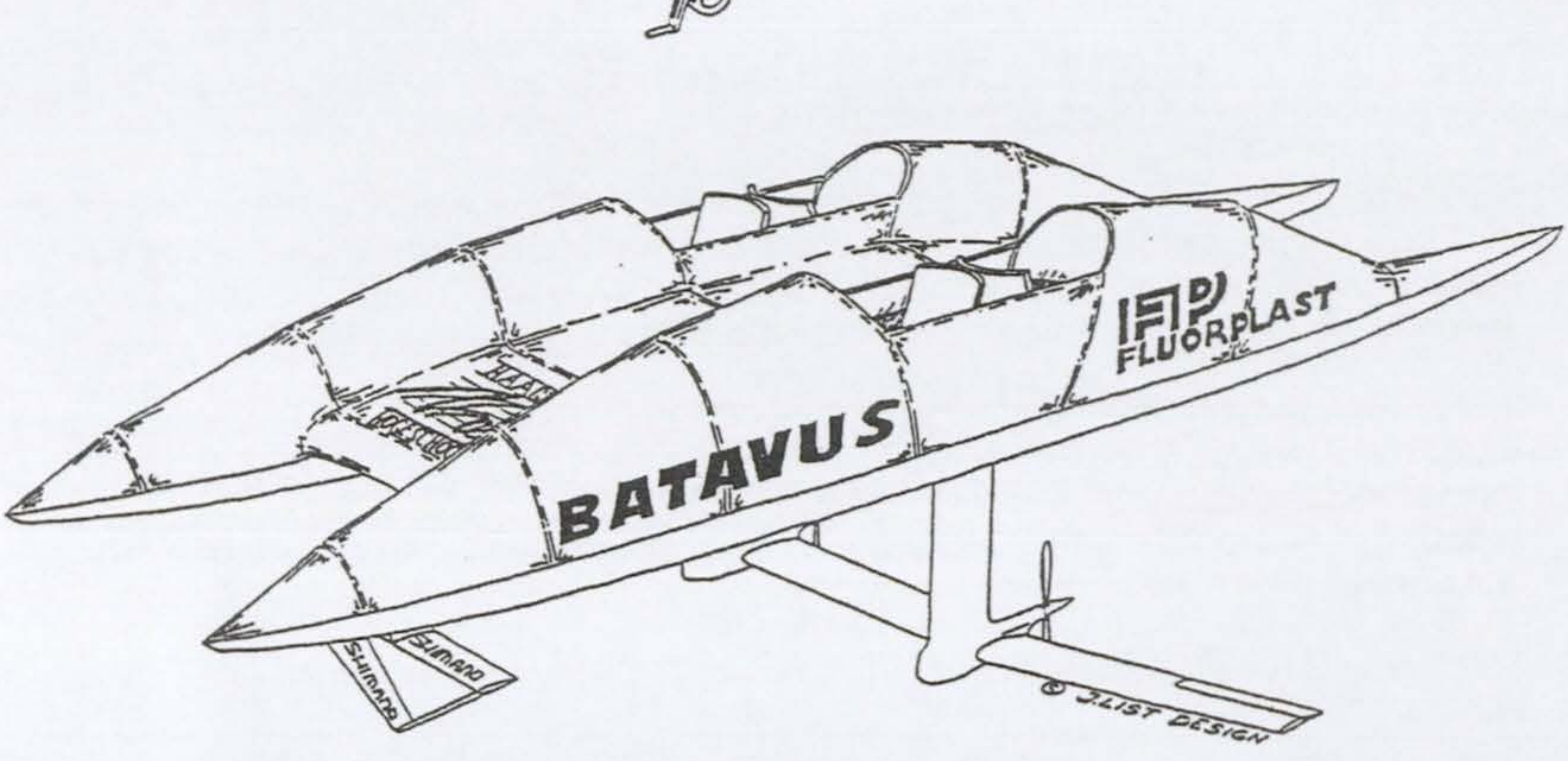
## af Chapman II

| | |
|---|---|
| Weight | 54 kg |
| Length | 6 meter |
| Crew | 2 pers |
| Engine | 2 pers |

1 Stabilator
2 Fin/rudder
3 Main hydrofoil
4 Flaperons
5 Propeller
6 Strut
7 Elevator-aileron control stick
8 Rudder control
9 Flap control




DRAAGVLEUGEL - WATERFIETS PROJEKT
VELEAU



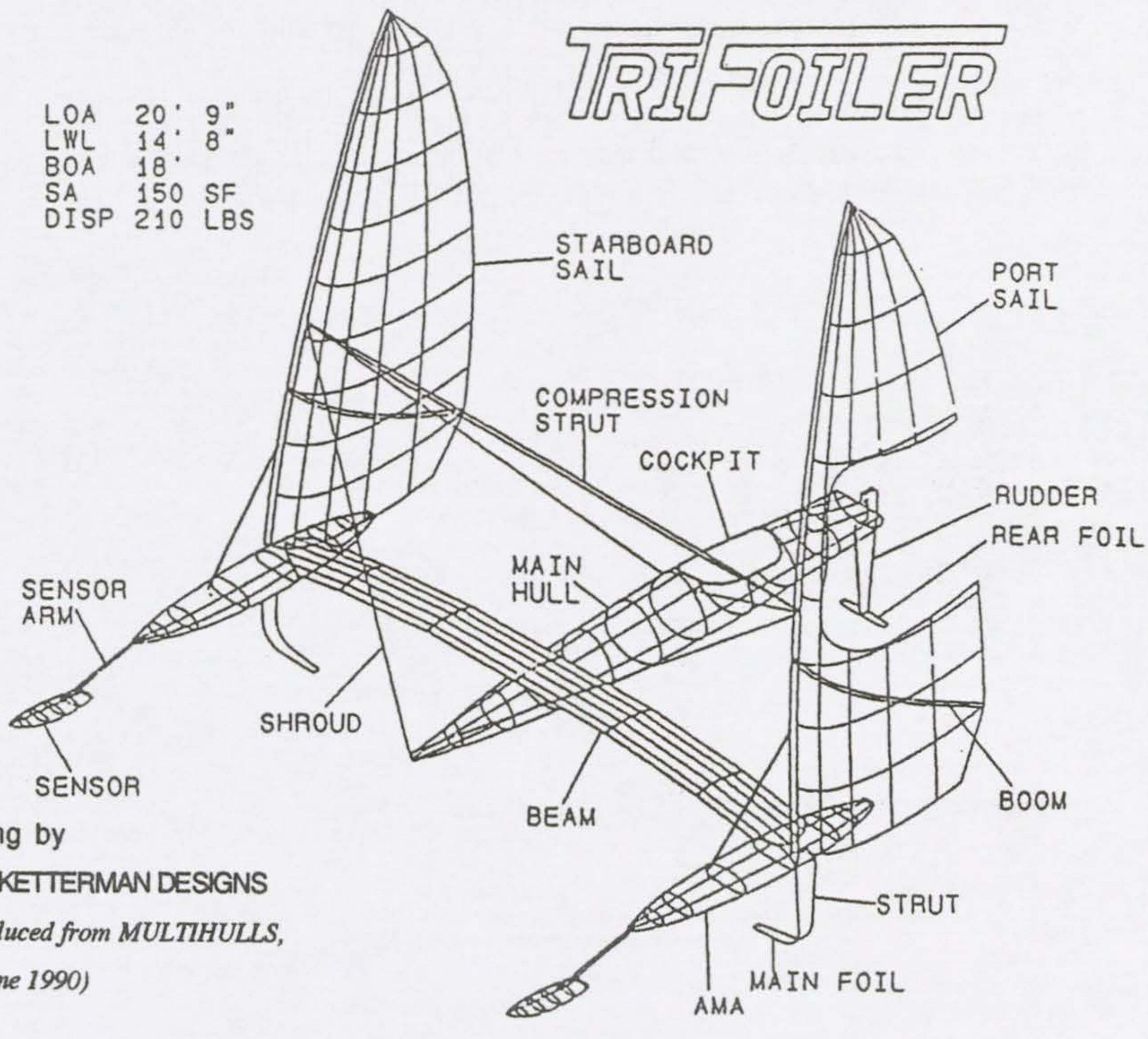
# LONGSHOT: a foiler flys at 37 knots

Reports in the US magazine MULTIHULLS, for May/June 1990, YACHTS AND YACHTING for November 9, 1990, and the US POPULAR SCIENCE for January 1991 (the US ones courtesy of Harry Morss) describe the flying foiler designed and built by Greg Ketterman of Long Beach. The „wire drawing" shows the configuration. According to Y&Y, a speed of 37.18 knots was recorded on a lake in Alberta, Canada, in October 1990, RYA observed and subject to ratification as a World A Class record.

The pilot sits in a cockpit towards the stern of the central hull. There are two sailboard-type sails. The main foils are fixed to the side hulls and reduce their end loss by only having one end each. Their incidence is set by the forward reaching feelers which rotate each side-hull and its foil independently, flexing the main beam in doing so. The latest report shows that there is now a hydraulic buffer/fore-stay to each sail, presumably so that the rapid movements of the feelers are attenuated before reaching the sails. The inverted T rudder completes what is, in foiler terms, an „aeroplane" configuration.

The boat is fast. It does 25 knots on a beam reach in 10-12 knot winds, and needs more like 30 for the 37 knot record, maybe more.In winds up to 15 knots it will foil in true wind angles between 60° and 135° off the wind: at some higher wind speed the boat will tack and gybe on foils.

Bare boat weight is 95 kg (210 lb), LOA 6.3 m (20' 9"), BOA 5.5 m (18'), and sail area 13.9 m$^2$ (150 sq.ft.). Apparently it is a wet boat to sail: goggles are very necessary. This is not surprising seeing that the feeler on the windward side is directly up(apparent)wind of the pilot! The unanswered question is how does one get it off and back onto the beach? Does the early Grogono formula apply: „fill eight strong men with whisky...." ? At last there is more than a glimmer of hope that a proper – well, a reasonably proper – boat will go faster than a sailboard.




Drawing by

GREG KETTERMAN DESIGNS

*(Reproduced from MULTIHULLS, May/June 1990)*

# Affordable Wind and Water Speed Measurement

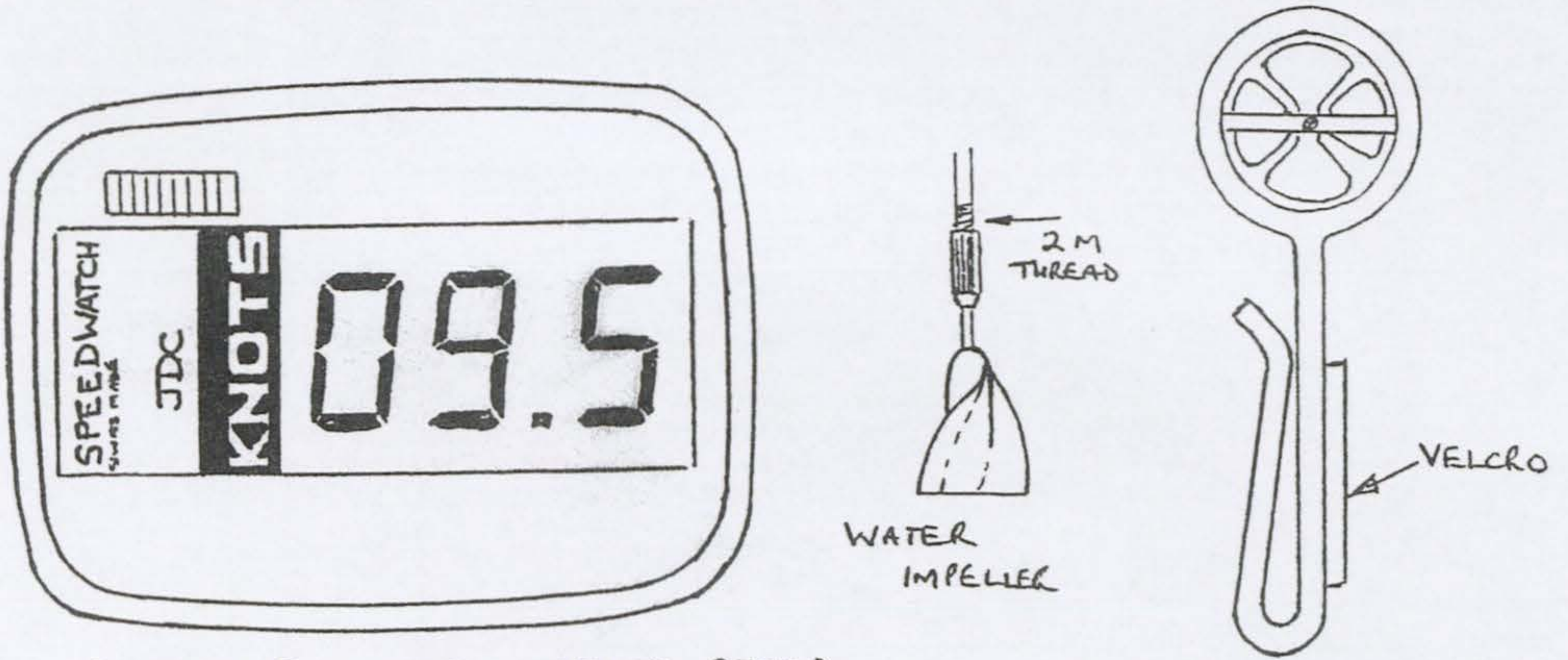
*by G. C. Chapman*

At the April 1990 Calshot Speed Weekend, Torix Bennett the importer of the Swiss-made SPEEDWATCH showed us this device, mainly intended for use in sailboards. Subsequently my son acquired one for use on my sailing hydrofoil BANDERSNATCH and on other of our boats.

A waterproof display unit (see sketch below) contains the solar panel which powers the electronics and the three digit LCD with 18 mm high numerals, reading knots to one decimal place.

Wind or water speeds are detected by small impellers, each containing a permanent magnet. When either (but not both at the same time!) is rotated by its medium the rotating magnetic field is detected by the display unit which updates it's indication at regular and accurate one second intervals. To be effective the rotating impeller must have it's axis at approximately right angles to the line to the display, and according to the instructions must be within 50 cm. We found that the waterspeed must be at least 6 knots to give a reliable indication at 50 cm: the inverse square law applies so for lower speeds the distance must be less. The wind sensor is normally attached to the display unit when the device is hand-held, and then it indicates down to about 1.5 knots.

For „proper" boats a remote sensor is available, comprising an encapsulated coil on a magnetic core, 10 mm diameter by 52 mm long, showing a resistance of 4.2 kΩ, with some 2.5 m of twin cable which plugs into the display. The coil must be within 12 cm of the waterspeed impeller to read at 1.5 knots. We also used a coil of 12 kΩ (from a relay) which would give greater sensitivity, so that the impeller (on the rudder) could be some 70 cm below the coil (on the rudder stock) when it would read at 7 knots plus. A larger coil, 6.5 kΩ from a PO relay reads at 3.5 knots plus at 70 cm.



We have concluded that the instrument works by counting the number of revolutions of the impeller in each second and converting that to the three digit (tens, units, tenths) display, which is updated every second. We find that when holding the display unit near a 50 Hz mains transformer it shows 3.9 knots. Remove the display far enough away to show random numbers. Then as soon as the number has changed move it rapidly to the transformer and 3.9 is only shown at the *second* refresher; some random number is shown at the first. This suggests that the mechanism is one of counting, so that the speed indicated is the average over the second of time rather than the instantaneous speed at the end of the second.

As an aside, conducting the above test led to the observation that in a particular location near the transformer (but outside it's 3.9 knot influence) the random numbers displayed were in the tens; a few inches either side and the numbers are in units. Three of us could demonstrate this effect. Using a torch instead of the mains lamp had no different effect. Placed in a particular spot on my desk the display favours 2.5 as it's random display and will hold it for seconds at a time. It remains to be seen whether this device can detect ESP or be of use to diviners. John Morwood would have been fascinated – and would have suggested the next line of research.

I have found the display somewhat disconcerting because I am used to analogue meters with needles. It takes a conscious effort to discount the continually changing „tenths“ which, because the digits are all the same size, have disproportionate publicity. The corresponding movement of a needle on a meter where the knot graductions are between 2 and 5 mm apart is much less noticeable.

Over the season we have tried to check whether the accuracy is indeed the 1% claimed, between 2 & 40 knots in water, 2 - 80 in wind.

The first trial involved mounting the water impeller on a trolley which can be pushed along the side of the swimming pool. Wheels with vertical axes keep the trolley correctly located relative to the pool edge. One person pushes the trolley at a fast walk/slow run and attempts to keep the indicated speed constant. The assistant takes the time over a measured distance. The scatter of results was considerable and we rejected them.

At Calshot my Smith's water speed meter (really a pressure gauge appropriately calibrated) using a pitot hole in the leading edge of the rudder read low compared with the timed measurements. I corrected this by fitting a short tube projecting forward of the leading edge and indications then seemed to recover. At Weymouth in the '70s the meter had given good correspondence with the RYA figures, with another rudder, so we now believe the Smith's meter is about right.

Photographs taken aboard BANDERSNATCH when flying at between 11 and maybe 15.5 knots (by Smith's) show that on 7 out of 8 occasions the SPEEDWATCH indicated less than the Smith's by an average over the 8 photos of around 9%. The SPEEDWATCH speeds jumped about by ± 1 knot and more each second. We suspect this is because the impeller is mounted behind the rudder which carries some leeway. It is reasonable to assume that the rudder drags some turbulent wake behind it and this could account for the low indication as well as for part of the considerable variations from second to second, since smaller variations are shown on the Smith's meter, whose pitot tube is in undisturbed water. So it seems that the boats speed varies continuously and by more than the helmsman might think from the nature of the „ride“.

By contrast, on my son's electrically propelled canoe in calm water with the impeller on a 12 mm chord strut, indicated speed at 4.9 knots was steady, varying only by a tenth of a knot; but we did no timed runs so accuracy per se was not checked. Holding the impeller under a tap with a smooth flow can also give a steady reading.

A device used by the water authorities to measure flow in rivers – down to very low speeds – has it's impeller on the upstream side of the strut, i.e. facing rather than trailing. Reputedly propellors are also more efficient when forward of their skeg; but both are then vulnerable to debris, and on practical grounds it is probably better to have the SPEEDWATCH impeller trailing behind a sailboard skeg or a boat's keel or rudder.

But we suggest it should be in a position to avoid turbulence as much as possible, and in any case be mounted flexibly, as indicated in the instructions.

The mains 50 Hz induced indication of 3.9 knots taken with the outside diameter of the impeller (12.5 mm) indicates that the pitch angle should be 44.7° at the outer edge for no slip. As far as we can see this is so. but if there is any slip then the impeller will rotate slower and give a lower indication.

We tested the wind speed device holding it out of a car window at up to 35 knots, on a flat calm day, and the indications agreed well; again, the car's speedo was unchecked by stopwatch and distance.

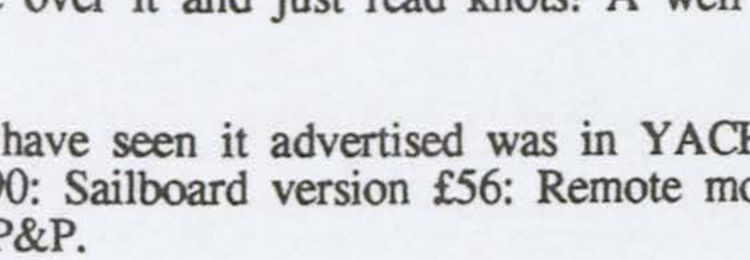
Comparison with a Dwyer WIND METER, in which a 2 mm pith ball moves up a glass tube showed that the excursions – gusts and lulls – appear greater with the SPEEDWATCH presumably because the inertia of the pith ball and the damping action inside the tube slow down the Dwyer's response.

Sound studios use a Peak Programme Meter (PPM) to indicate the sound level. This analogue meter has differential damping so that the needle responds rapidly to peaks but falls back slowly. This apparently gives studio staff a happier indication of whether they have set the microphones and the volume controls satisfactorily, and is less tiring to monitor than a domestic „VU“ meter which responds equally quickly either way. Perhaps if we were to use such meters to indicate wind and boat speed our claims of high speeds would be even greater than they already are!

So we have no grounds for doubting the device's accuracy. With the water speed impeller mounted in a suitable turbulence-free location the device will tell you a lot about your boat's speed that you didn't know before. It is a matter of mental discipline to disregard the „tenths“ if they jump about too much – or put a piece of sticky tape over it and just read knots! A well made device and worth the money.

The first time we have seen it advertised was in YACHTS AND YACHTING for 28 September 1990: Sailboard version £56: Remote model £69: anemometer only £48. Add 95p P&P.

*Technical Exponents Ltd, 74 Waterford Road, LONDON SW6 (071 736 86 15)*



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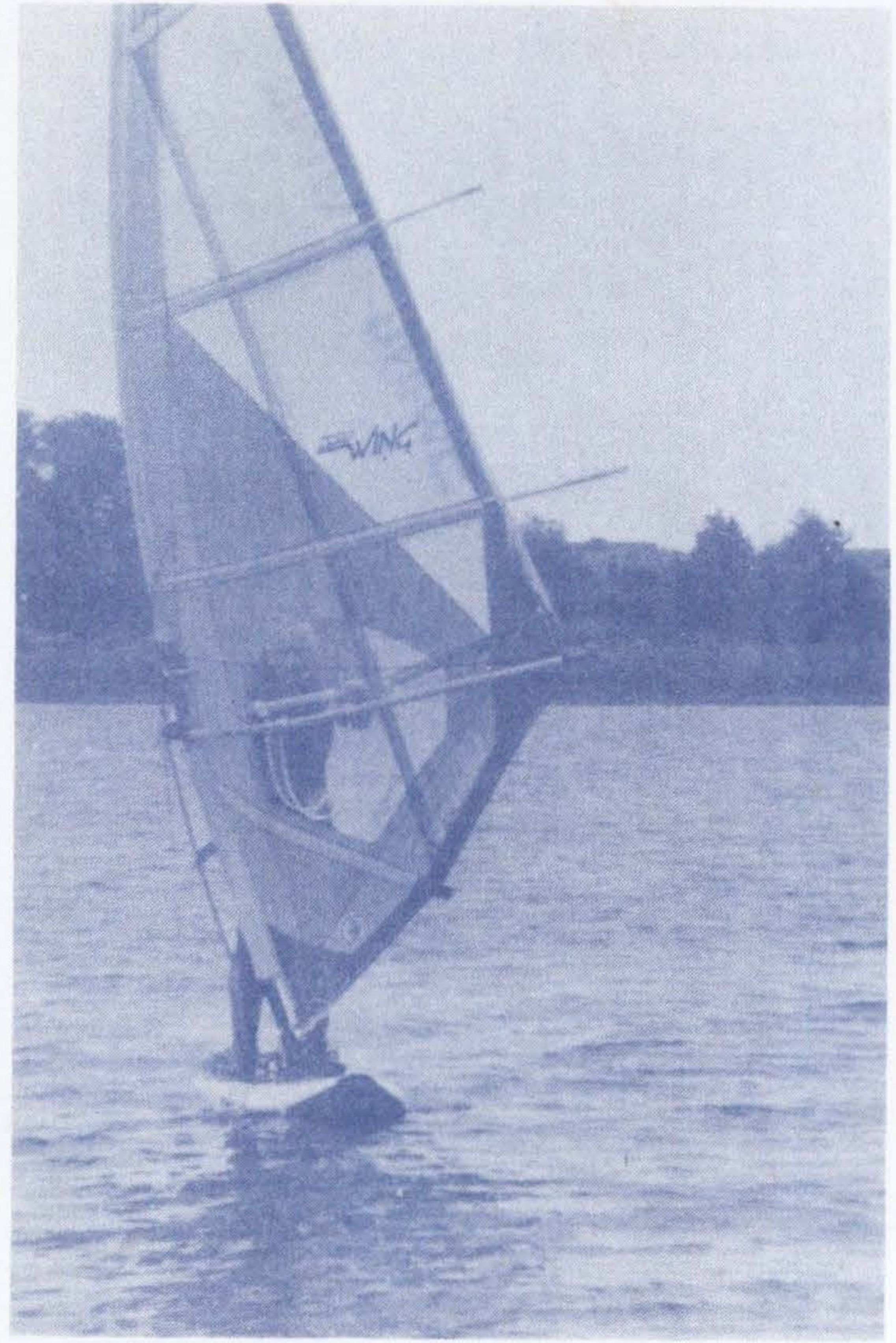


Reefable Sailboard Sail SWING - WING by Michael Edwards