AMATEUR YACHT RESEARCH SOCIETY

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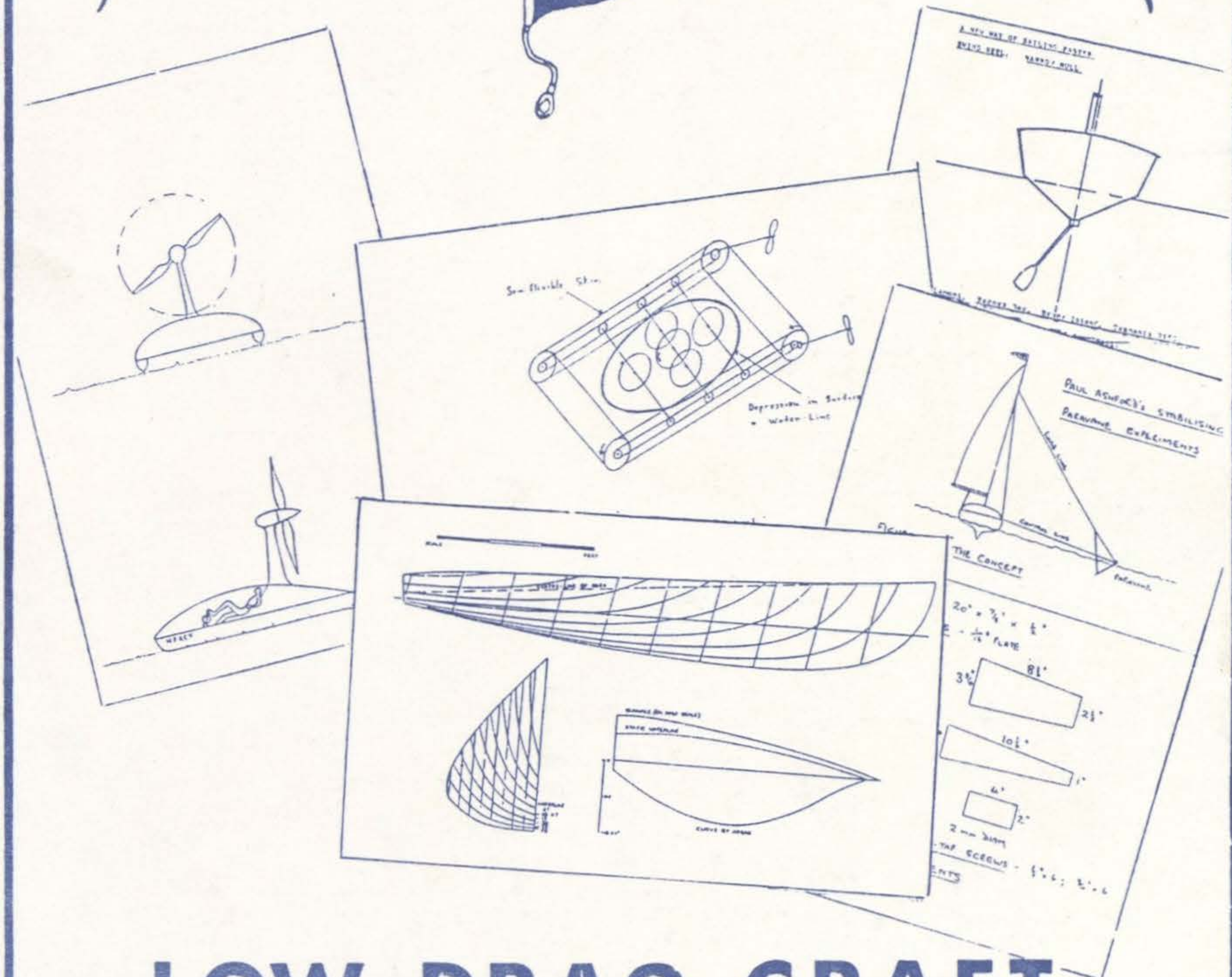

LOW DRAG CRAFT

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AYRS 107 DECEMBER 1990

THE AMATEUR YACHT RESEARCH SOCIETY

Founded 1955 to encourage Amateur and Individual Yacht Research

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Introduction by Roger Glencross

It is my pleasure to edit this publication on a subject which is of importance to all yachtsmen, whether they are interested in high speed craft, low-energy boats or fuel economy, that is the reduction of drag.

Question:

A Tornado catamaran with a standard rig is moored on calm water in clear air on a line attached to a potentiometer. A steady ten knot wind is blowing and the sail is adjusted for the highest pointing, and then for the highest thrust on the line. What were the line's angles with the wind and how much was the force on the line?

Nobody knows.

The same craft is moored in a river flowing at ten knots and there is no wind. The rudder is adjusted for the lowest hull drag angle and then for the highest thrust on the line. What were the line's angles with the water flow and how much was the force on the line?

Nobody knows.

Our Founder, Dr. John Morwood wrote in AYRS 62 (1967) that "the most urgent yacht research was to study hull and sail drag angles to find the minimum. Only this way can the most efficient yacht be evolved. The need to improve the hull drag angle is far greater than the need to improve the sail drag angle because the hull is the worse of the two. So the improvement in overall perforance will be greater. Also, hull drag angles can easily be studied by amateurs in a tidal stream, a fast flowing river or a test tank, whereas model sail testing needs a wind tunnel."

This publication does nothing to provide figures to fill this black hole in yacht research. However, it hopes to alert members to the importance of research into drag. Such experiments and measurements are a suitable task for high schools, sea cadets and university research projects, as well as an enjoyably way of passing days of unsuitable or non-existant wind. It is vital that results should be published. The AYRS recirculation test tank is also available on hire and is suitable for models of up to 18 inches long, 6 inches draught and for scale speeds of up to 20 knots.

Reg Frank introduces us to the various types of drag in his article "yacht drag". Theo Schmidt sets out in his first article the need to minimise drag in fast manpowered boats, due to the severe limitations in the power plant. The solutions that he offers include laminar-flow hulls, planing hulls, hydrofoils, air lift devices and moving skin hulls. Theo's second article reviews low-energy boats, including animal powered, manpowered, electric and solar powered boats. The need for low-energy and low-drag craft is accentuated in these days of high oil prices.

Hugh Barkla's approach to the reduction of hull drag is to use three planing floats in triscaph form. Pauls Ashford demonstrates a solution to one of the problems facing low-drag boats - poor stability. He deploys a paravane to windward. Neill Lamont envisages a solution to the same problem with his swing-keel.

In order to reduce wave-making drag, one has the choice of getting the hull above or below the waves. Foil-borne craft have been covered frequently in AYRS publications but not so submerged hull craft. Several members are working on submerged buoyancy and one is building a submerged-hull sculling boat. The difficulty of these tasks may be reflected in my failure to obtain a contribution on this subject. Anyone contemplating work in this area is advised to read David Chinery's experiments in AYRS 90 pages 48 to 51. Another aspect not covered is the reduction of skin friction by the use of polymers (eg. washing up liquid) in the water or the hull. This is effective but pollutes the water. Antifouling is also not covered.

I thank all members who contributed articles to this publication. I apologise to those members whose articles were not included. Hopefully they will be published at a later date.

AYRS COORDINATORS

AYRS have set up subject or area coordinators in order to encourage more interchange of ideas and mutual help between members. Members are urged to communicate with the coordinators covering the subject or area of their interest and the coordinators will be able to put such members in touch with others working in the same field. If you feel that you can help by becoming a coordinator please advise the committee member responsible, Roger Glencross. If your area of interest or expertise is not noted on the membership list, please forward details to Roger. The present coordinators, whose addresses are in the membership list are as follows:-

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YACHT DRAG - By Reg Frank

A sailing vessel needs sufficient stability to carry its sail. Exceptions include craft propelled by kites, gliders, inflated wings and inclined rigs. Their propulsive force can be directed near to the centre of gravity, which keeps heeling and pitching moments small.

Resistances to motion include water and air surface drag, eddy making drag due to separation from surfaces, and also surface making drag. In more detail the drag on a foil-like device, sail, wing, fin, hydrofoil, strut etc, can be split into induced drag (which is essential to generate lift and is connected with deflecting the direction of air or water) and form drag and surface drag. Water-generated drag is much larger that air drag, so cruisers are not yet streamlined above the waterline.

Wave making drag is the main reason for speed limitation in a monohull. Long narrow hulls and floats with less frontal area go faster but there is a need to provide lateral stability. In general, obtaining stability of different sorts usually means more drag.

Turning to areodynamic drag, since water drag is so much more important than air drag, sails are operated near to stall in order to get maximum drive at the expense of large drag. An aeroplane-type wing has its least drag/lift ratio at a coefficient of lift of about 0.4. But then wing area would be too large for normal winds. In stronger winds area becomes small enough, for example, for record sailing speeds. But the apparant wind is swinging all the time so a wing has to be steered relative to the wind. An example is the Walker "Plane Sail", steered by a tailplane controlled by a wind direction sensor.

With regard to tank testing, there is a vast amount of published information, but one problem is in finding out where to enquire and then in obtaining published reports. Two very useful books are "High Speed Sailing" by J.Norwood. 1979 (Adlard Coles) and "Aero-hydrodynamics of Sailing" by C.A. Marchaj. (Adlard Coles). Model testing is needed for new ideas which are not yet included in books, but remain critical of what is published. Authors cannot be experts on everything and they often repeat mistaken explanations. Where drag is concerned, forecasts of maximum multihull speeds included speeds which seem unlikely. The reason is that as a craft goes faster the apparant wind moves forward and that means big increases in the lateral forces needed from keel rudder and hull, which has been under-estimated in computations. The drag due to lateral forces is much increased. To find out about that you have to go back to Edmond Bruce in early AYRS publications.

Edmond set out the principle of scaling as follows: Large boats will behave exactly as do their models at all smaller sizes if: (1) All linear dimensions are accurately scaled. This means that sail area will be proportional to the square of the scaling factor, as will the wetted surface while the displacement will be proportional to the cube of the scaling factor. (2) All speeds and velocities are scaled in proportion to the square root of the scaling factor. This means that the boat speed expected will be proportional to the square root of the scaling factor IF THE WINDSPEED IS SIMILARLY SCALED. This means that large boats are sailing in winds which are relatively lighter than small boats.

LOW-ENERGY BOATS by Theo Schmidt

Until recently, all boats were "low-energy", but the internal combustion engine has changed this. In a manner which is exactly analogous to the development of cars on land, modern power boats have become a source of noise, pollution, and danger. They cause waste, annoyance, and erosion. Their brash success has killed off traditional boat design and lifestyles, and previously intact eco-systems. Viewed in a long-term perspective, these disadvantages far outweigh the short-term advantages for individuals using such craft.

But the times are changing! Increasing environmental awareness and corresponding legislation are making low-energy philosophies more attractive and helping to reintroduce proven concepts and develop exciting new ones. The following summarizes some old and new "low-energy" technologies:

Sailing boats are a special case. Although designed to require as little energy for propulsion as possible, the powers and forces passing through rigging and hull are considerable.

Some craft are able to move many tons of cargo using very little manpower, for example the large Thames Barges, which were traditionally worked by a man and a boy. Modern designs using wingsails or wind turbines can even be controlled remotely or at the touch of a button.

Animal-powered barges were once in widespread use. Efficiency was mostly gained by operating at very low (walking) speeds, where the resistance in the water is extremely low due to the absence of gradients and mechanical friction and because power increases or decreases with at least the third power of the speed. A single animal can pull a barge weighing a hundred tons or more.

A "high-speed" example of animal-powered efficiency is also available. Over a century ago several "Fast Packet Boats" plied the Lancaster Canal between Kendal and Preston carrying up to 120 passengers at average speeds of nearly 8 knots, with the power from two horses! Although the horses were changed every 4 miles, the passengers in the 75 ft long and 6 ft wide vessels could travel quicker and more comfortably than on the roads of that period. A modern ferry would use perhaps one hundred times the power for the same result.

Human-powered boats are the oldest means of transport known to man. Even today some peoples still use wooden dugouts which they paddle on quiet rivers with remarkable efficiency. Other peoples developed skin boats, kayaks, baidarkas, and canoes, using these for transportation, hunting and waring. Such boats have shaped the history of many American areas, in contrast to the rowing craft and early galleys around Europe, which were probably sailed whenever possible.

In the Orient, too, junks and the like were and still are driven by a long sculling sweep called a yuloh, allowing a sole crew member to propel rather heavy vessels at about walking speed. Other traditional uses include ferries worked by being pulled across rivers along a rope. To this day a three-car ferry crosses the Rio Grande, pulled by six men.

Today many people are rediscovering the joys of human-powered boats, not so much as a means of transportation, but for fun, fitness, and adventure.

Although the steam engine (and even more the steam turbine) is a concentrated source of power, its efficiency is limited and the required boilers are heavy and large. Therefore steamboat hulls have had to evolve to be efficient and their elegant lines bear little resemblance to the pseudo speedboat type hulls so prevalent today.

Electric boats evolved in much the same manner as steam boats. Displacement hulls easily carry the heavy lead batteries. Because of the limited range and the high cost of these batteries, electric boats never became very popular in an age where coal was cheap and electricity a luxury.

Today's electric technology has changed this. Modern electric boats work admirably in all conditions except where sustained high speed is called for, for example offshore rescue boats. They can be rendered partially or totally self-sufficient by fitting smaller or larger areas of solar panels.

Solar boats represent the newest development in the category of low energy boats. They combine many of the advantages and characteristics of both human-powered and sailing boats. They work even in cloudy and windy climates except perhaps in high-latitude winters. The problem that remains is the still high cost of solar cells. Although well-affordable as luxury items, those people in developing countries who could best use such boats are least able to afford them.

All the abovementioned craft have one thing in common. The source of power is limited, not very concentrated, but can be derived from nonpolluting, quiet sources. It is precisely this lack of cheap high power which calls for efficient, elegant solutions in hull design. This renders such craft worthy flagships in our new environmentally conscious age.

HOW TO WIN THE DU PONT PRIZE

By Theodor Schmidt, European Representative of the Du Pont Prize Committee.

Want to make $ 25 000? After the Du Pont Chemical Company's prize for the first Human Powered Vehicle to exceed 65 mph on land has been won, the same company has offered the above sum for the first person to achieve 20 knots with a Human Powered Boat over a stretch of water of at least 100 metres length. A set of rules defines what is allowed (almost everything except cheating!) and describes the conditions under which the record must be set. The present record is about 16 knots, so there is still plenty of scope for winning this prize. The following article gives some recipes but without any guarantee of success. The goal is sufficiently high to require an impeccable standard of fluid dynamic understanding and mechanical engineering, as well as the determination to carry out a very ambitious programme.

Laminar-Flow Hulls

It can be safely stated that 20 knots is out of reach of ordinary single-person displacement hulls. The combination of wetted surface friction drag and wave-making drag is just too much. Wave-making can be reduced by using very long, slim hulls or completely submerged torpedo-like floats. Even here, the friction drag of a turbulent boundary layer is too great.

Only if the boundary layer (the thin layer of water effectively separating the moving hull and the mass of water at rest) can be kept substantially laminar, or otherwise controlled, by chemicals, special surfaces or active devices, is there a chance to sufficiently reduce drag. That it can be done is shown by dolphins, who have a special skin surface and use muscular control to prevent the formation of turbulent eddies, and can thus use far less energy for locomotion than man-made bodies of the same size.

The drag of a body is very dependent on the Reynold's Number Re, which is the product of the speed and a characteristic length of the body, divided by the kinematic viscosity. The boundary layer usually becomes turbulent above a Reynold's Number of 10^6 which is just the range we are interested in. (Reynolds's Number Re in water is about $1 \cdot 10^6$ $V \cdot L$ in SI units).

To carry one person at 20 kts, optimal submerged-buoyancy floats would develop a Re of about $2 \cdot 10^7$, and something like a rowing shell 3 to 4 times this value. Well made surfaces may keep the boundary layer laminar up to a Re of $1\text{-}2 \cdot 10^6$, giving a skin friction drag coefficient of about 0.001. At $Re=2 \cdot 10^7$ the laminar drag coefficient would only be about 0.0003, but this is extremely difficult to achieve in practice and most bodies will have developed a fully turbulent boundary layer at this speed, and a drag coefficient of 0.003. The transition from laminar to turbulent can be delayed by sucking away parts of the boundary layer before it becomes turbulent, eg by making the hull porous and pumping out the water leaking in. Including the power for this pumping,

the total drag reduction is about 2-3 times from turbulent and we are back to a coefficient of about 0.001 in our example. Taking all sources of drag into account, it would take over 1000 W to propel such a craft at 20 kts, only just achievable by a super-athlete for the sprint duration.
So, unless the boundary layer manipulation can be done more efficiently, the chance of success will be marginal with this method and in any case require careful optimisation of all factors.

Planing Hulls

Planing lifts the hull out of the water and thus reduces wetted surface drag and wave-making. A super-athlete might make a specially shaped hull plane briefly (I have seen a four-man kayak pull a water skier), however the efficiency would be less than when proper submerged hydrofoils are used.

Hydrofoils

This is the most promising line to follow at present. The main problem is getting around unfavourable surface interactions, such as the drag of surface-piercing struts and induced wave-making. For information see the writings of the experts in this field.

It may be mentioned at this point that although screw propellers can be designed to work at over 90% efficiency, direct "flapping" hydrofoil propulsion might exceed this, especially if the lifting foil can be used for this work. Many animals of course use flapping propulsion very successfully, both in air and in water.

So far however, most man-made flapping propulsive devices have fallen far short of their expectations. Some which do work well were devised by Cal Gongwer and include the Aequeon, a set of horizontal foils for swimmer propulsion, and sets of vertical foils which propel a kayak more efficiently than paddles.

Air Lift Devices

From catamarans with wing decks, on to sidewall hovercraft and ultimately flying boats and aeroplanes, a multitude of craft is conceivable which are more or less supported by air. In contrast to hydrofoils and submerged buoyancy, which lose efficiency near the surface, airfoils actually work better and surface-effect aeroplanes or flying boats have better Lift/Drag ratios, and thus would be faster, than free-flying human-powered aircraft which can already reach 20 knots.

If we have a craft weighing W with a ground-plane area A, this can be fully supported by a uniform air-cushion of pressure W/A. If the craft moves forward relative to the air with speed V and is shaped to allow air to enter forward below it and not let air leak out the sides or back, the resulting ram air pressure is V^2 times one-half the air density, or about 0.6 V^2 in SI units [Pascals]. Thus the craft will be fully air cushion supported at an air speed above $V \geq 1.3 \sqrt{(W/A)}$, not even yet taking into consideration lifting forces resulting from the upper surface.

For example, a craft weighing 1 000 N (~225 lbf) and 3 m wide and 5 m long would be fully air-cushion supported at 10.6 m/s, provided no air leaks out. In practice this can be accomplished at the sides with knife-edge side walls, just in the water but with little resistance to motion, however the back edge would be difficult to seal off, although this might be done with a roller just touching the surface and moving at water speed.

The back edge could however be left slightly or fully open to allow some or all air to flow through. Although some or most of the "air cushion" lift is lost, a properly shaped upper surface will produce "suction" lift like any airfoil.

Such craft behave like a flying wing with a very high aspect ratio and a corresponding high L/D ratio. There is also some "induced wave drag" resulting from the depression in the water surface caused by the air cushion. Overall L/D might range from 20 to 80, depending on leakage and sidewall drag. Propulsion could be by air propeller, which can work efficiently at these speeds, saving the drag from a water propeller strut or shaft. This has been demonstrated by Steve Ball.

It is only a small step to a fully-fledged flying boat. The aspect ratio of the wing is increased and the side-walls become fences or winglets. Such a craft is outside the scope of the Du Pont Prize.

In any case, the rules require control surfaces (eg rudder) to act on the water, not the air. Also, the craft must be supported by the water at all times. An air-cushion vehicle or surface-effect device can be said to be water supported, as the craft's weight is transferred to the water surface, where it displaces a certain amount of water. A proper flying boat or aeroplane capable of free flight would however be considered to be air-supported and not eligible for the prize, useful though the craft may be. So I am afraid it is not good enough to get out your old human powered aeroplanes and simply dangle a rudder!

Moving Skin Boat

Wave-making drag can be reduced or eliminated by using extremely long, slender hulls. There is a minimum speed below which water surface waves cannot be generated (~23 cm/s) and it follows that if a hull is so slender that lateral and vertical velocity components of the hull entering and leaving the water are below this figure, no waves will be generated (on smooth water), although in practice there will always be some disturbance giving rise to some waves.

Such low or no wash boats will however have considerable wetted surface and corresponding skin friction and will not reach the magic 20 knots without tricks.

Imagine that the skin of the hull could be spewn out of the bow and gathered in at the stern, while moving at exactly water speed. Such a hull would have practically no skin fricton drag. Inventors have been trying this for over a century by using rolling floats of practically every type imaginable.

Unfortunately small rollers generate enormous form and wave drag while rolling wheels big enough to leave only a shallow depression in the water would have tremendous air resistance and be quite impractical.

Imagine, for example, a sphere of 10 m diameter with a person, running or cycling inside it!

Somehow the skin must be recirculated without making the windage of the boat too big. Various ways are conceivable where a stiff but flexible skin or inflated sausages or rings are guided on roller bearings. Alternatively, floating tracks can be made which resemble certain land vehicles. Remember that as the segments are to move at water speed, they need not be smooth or even flat and indeed might be used for propulsion as a high-efficiency linear paddle.

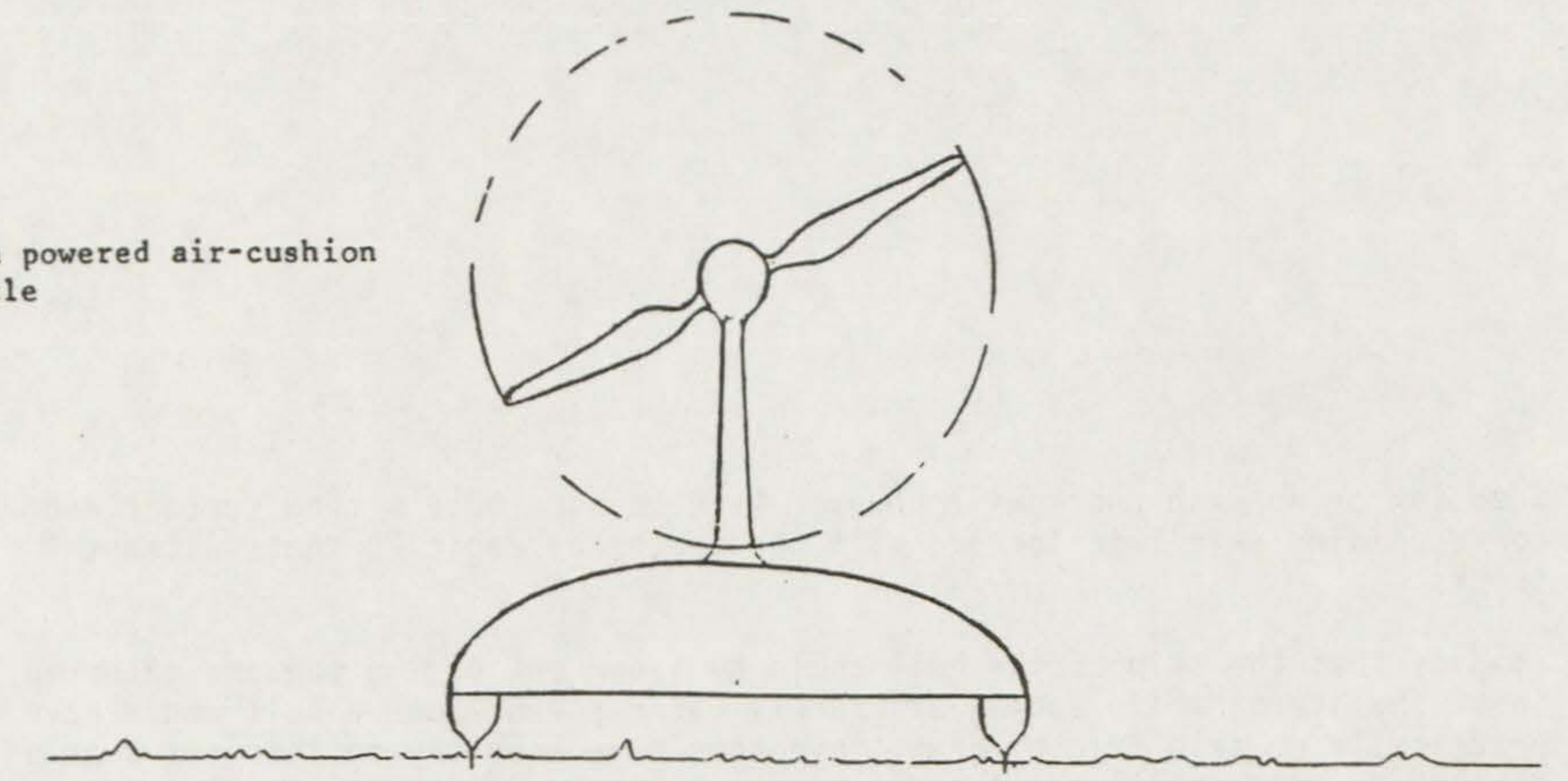
If very well engineered, the mechanical friction of the moving skin or track could be very much less than the same surface area sliding through the water. The speed of such a boat would be mainly limited by its air resistance and would require careful fairing. Remember that the skin or track parts being recirculated are moving forward at twice boat speed. Only a little power would be required to propel the skin at exactly water speed and the rest used to drive a propeller or equivalent, unless the linear paddle scheme mentioned above is used. The way to success is to find the shape and size such that combined air and wave-making resistance is minimal.

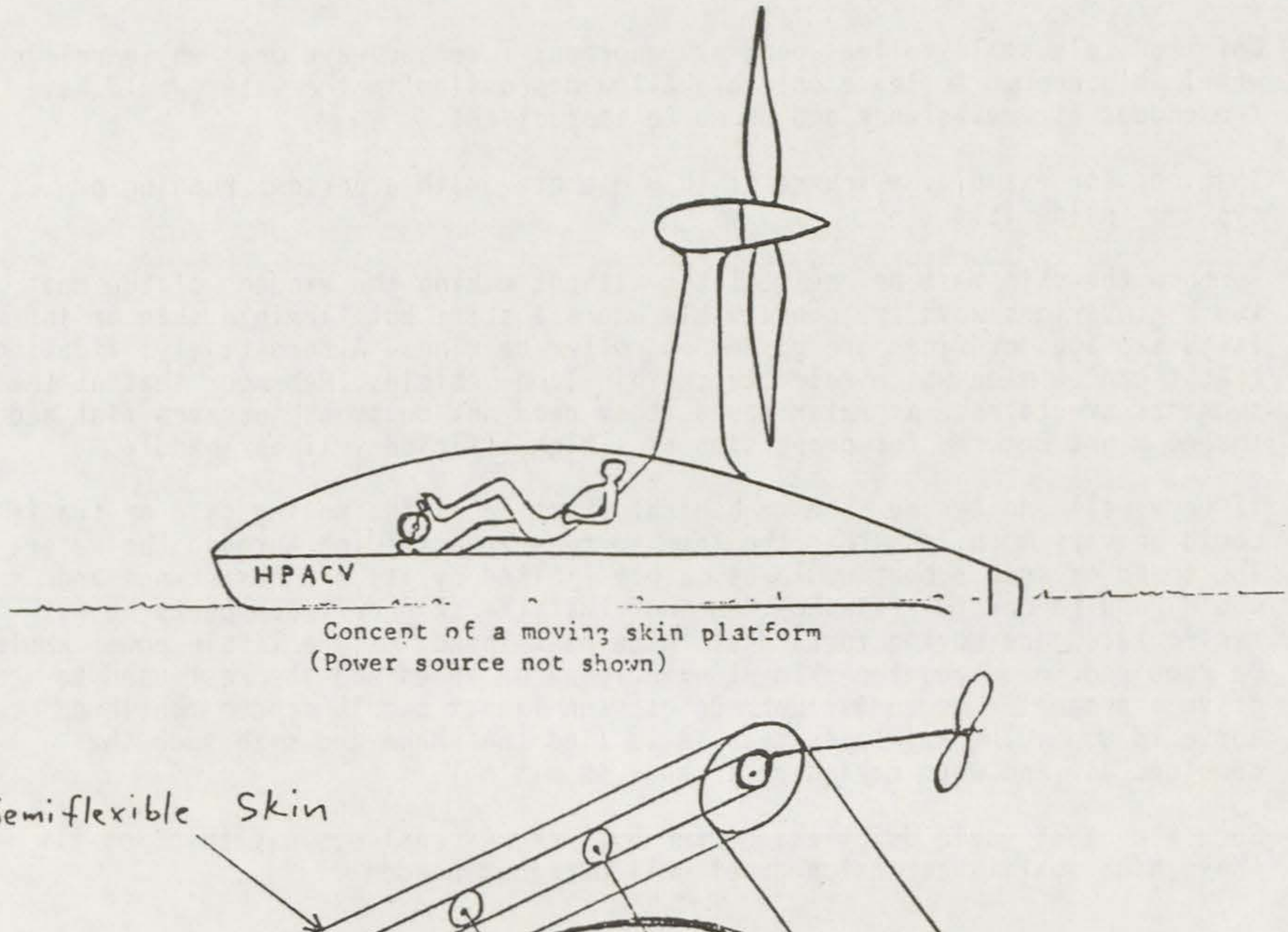
Such a project would doubtless be fun but very expensive. Just think of all those high quality corrosion proof ball bearings needed!

Conclusion

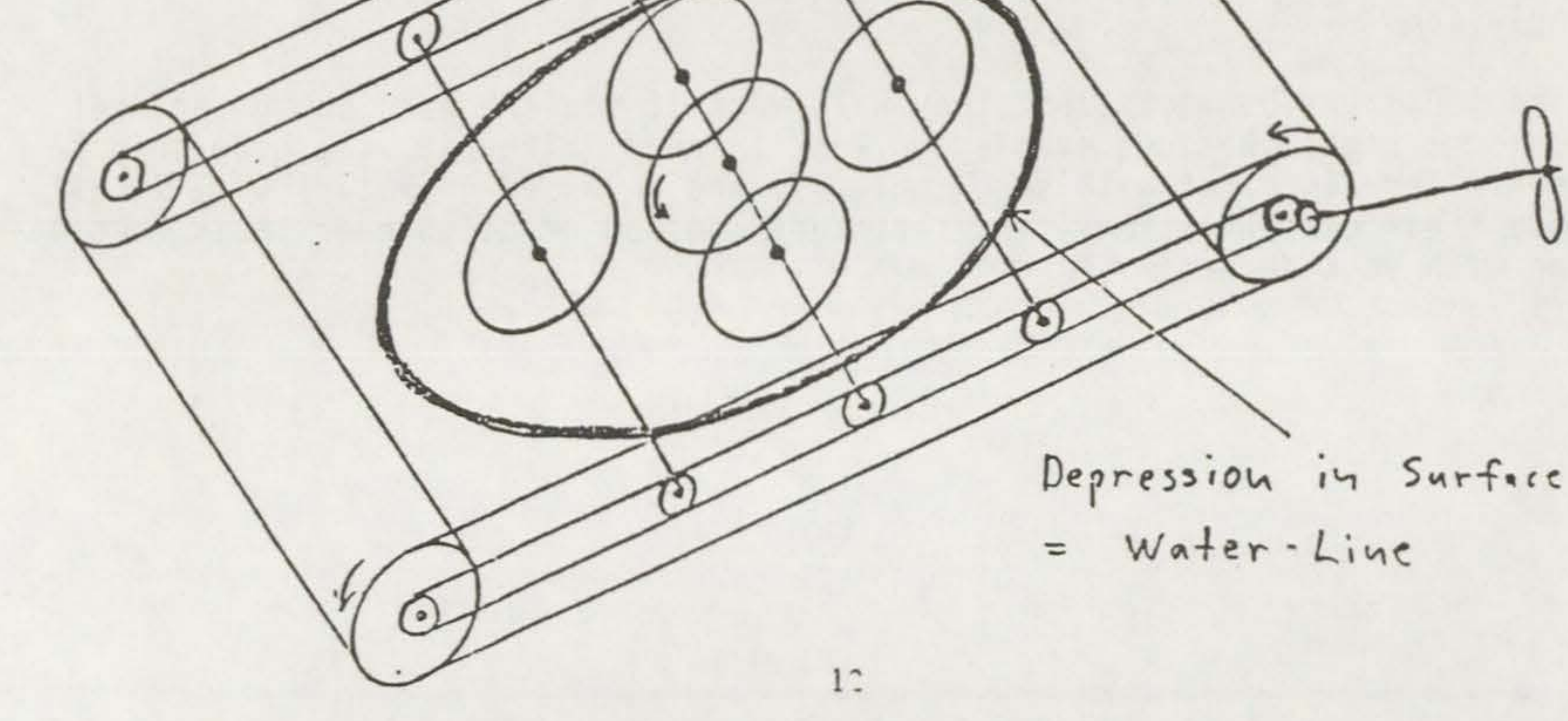
These ideas may be wacky, but they will work if you try hard enough and get your sums right. Besides earning Du Pont's Grand Prize, it will be a snip to win All-Terrain races with some vehicles, and harassed commuters will finally leave their cars when they find that they can hop or climb over their competition with your device!

Human powered air-cushion vehicle





Concept of a moving skin platform
(Power source not shown)



PLANING FLOATS IN MULTIHULL CONFIGURATIONS - By Hugh Barkla

Many of the published measurements on planing forms relate only to the monohulls, in which attitude is not variable at will. The use of three floats in triscaph form allows a favourable angle of incidence to be adopted for planing which would be impossibly high for a monohull. The optimum angle for low resistance might be an unstable attitude for an isolated float. The facility for efficient planing can be combined with a good displacement form for low speeds.

Some brief tests made in the Saunders-Roe seaplane tank thirtyfive years ago are still of value as indicating the potential of this neglected form of vessel.

The writer was invited by the late Mr F G Mitchell to design an entry for the Cowes Speed Trials of 1954, and a configuration was adopted which would give three-point hydroplane form, with the lee float forward so as to meet the thrust from the rig, this being felt to outweigh any disadvantage from unsteady tracking. A form was devised for each of the three 10ft long floats (Figure 1), which could be constructed from three singly-curved sheets of 1/4 inch plywood so that, with no more than a vestigial transom, the structure had a high inherent strength for its weight of 40lb, as well as being quickly and easily built. The float would be trimmed by the bow for the displacement mode, and, when trimmed by the stern, would present a planing surface.

It was the behaviour of the latter that was the greatest suprise. The predicted full-size resistance, at optimum trim, proved to be less than one tenth of the load throughout the range of speeds from 17 to 43 knots (Figures 2 and 3). This is good by any standards. The familar doctrine that warped surfaces with their curved buttocks are unsuitable for planing, would indicate inferior performance. The irrelevance of the doctrine to this case is clear from the level of the water surface at planing speeds, as observed in the tank-tests. The wetted length decreased from 25% of the float-length at 20 knots to 15% at 30 knots and 10% at 40 knots. The degree to which the actual planing surface is warped is therefore negligible. Those wetted lengths are measured with the float at the attitude shown in Figure 1, in which the sections are drawn at 72.5 degrees to the centreline of the deck, and are seen in the form of a projection of the hull onto a vertical plane when the deck line is at 17.5 degrees to the horizontal, which is close to the optimum throughout the planing regime (Figure 2). There is clearly no likelehood of negative lift being developed as long as the float is maintained at such an angle of incidence. Apart from use in a multihull, the only possibility of exploiting this capacity for high performance is on a windsurfer, expertly handled. Most boards ride at much lower incidence, well below optimum.

In the experimental sailing triscaph "Trion" of 1954, the floats were coupled to the main structure by a passive link system which gave them freedom to pitch independently when in the displacement mode, and was expected to provide the required increase in incidence as resistance built up. Experience showed however that it would be better to design for positive control of incidence, and several mechanisms could be devised to do this.

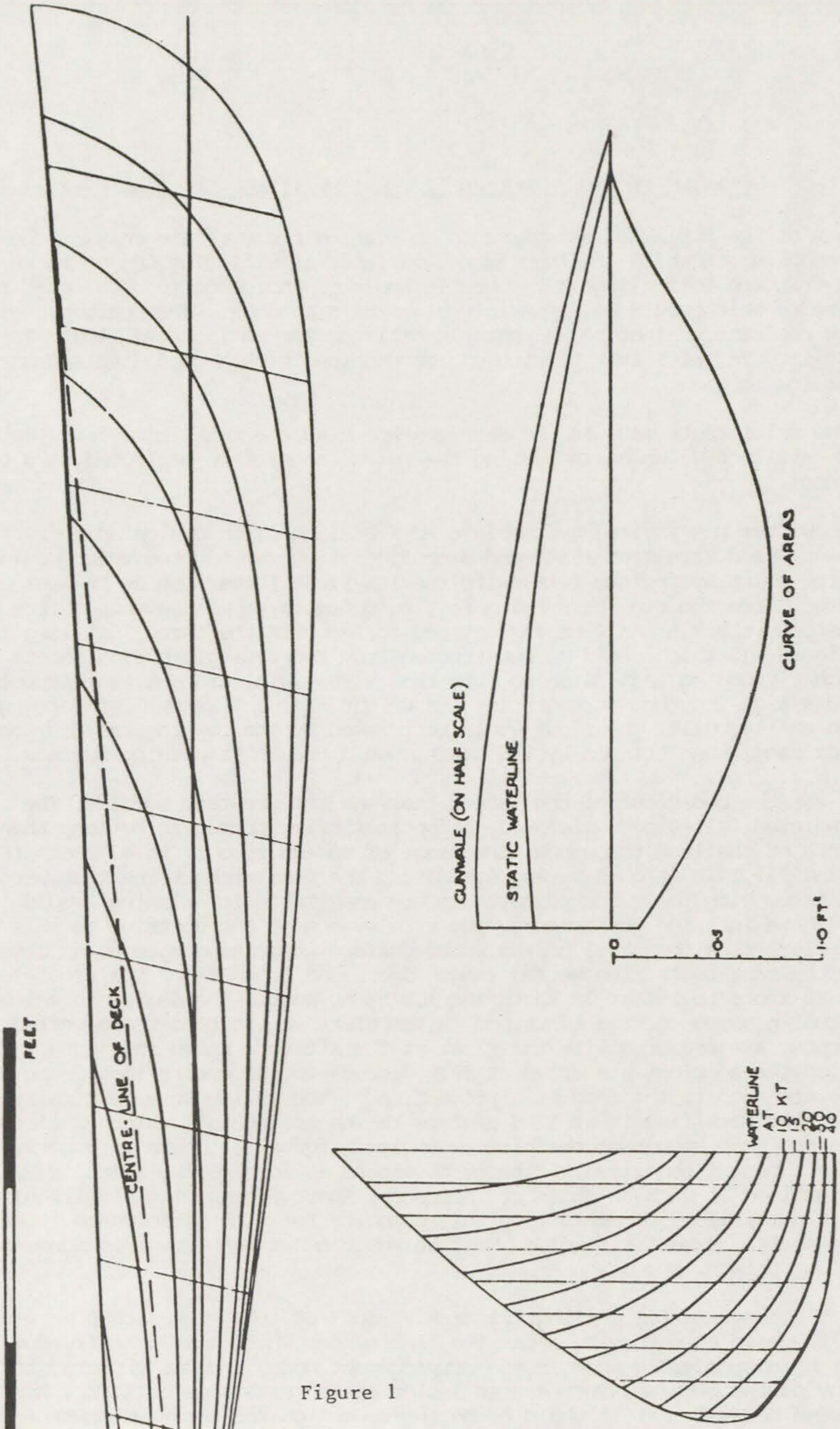
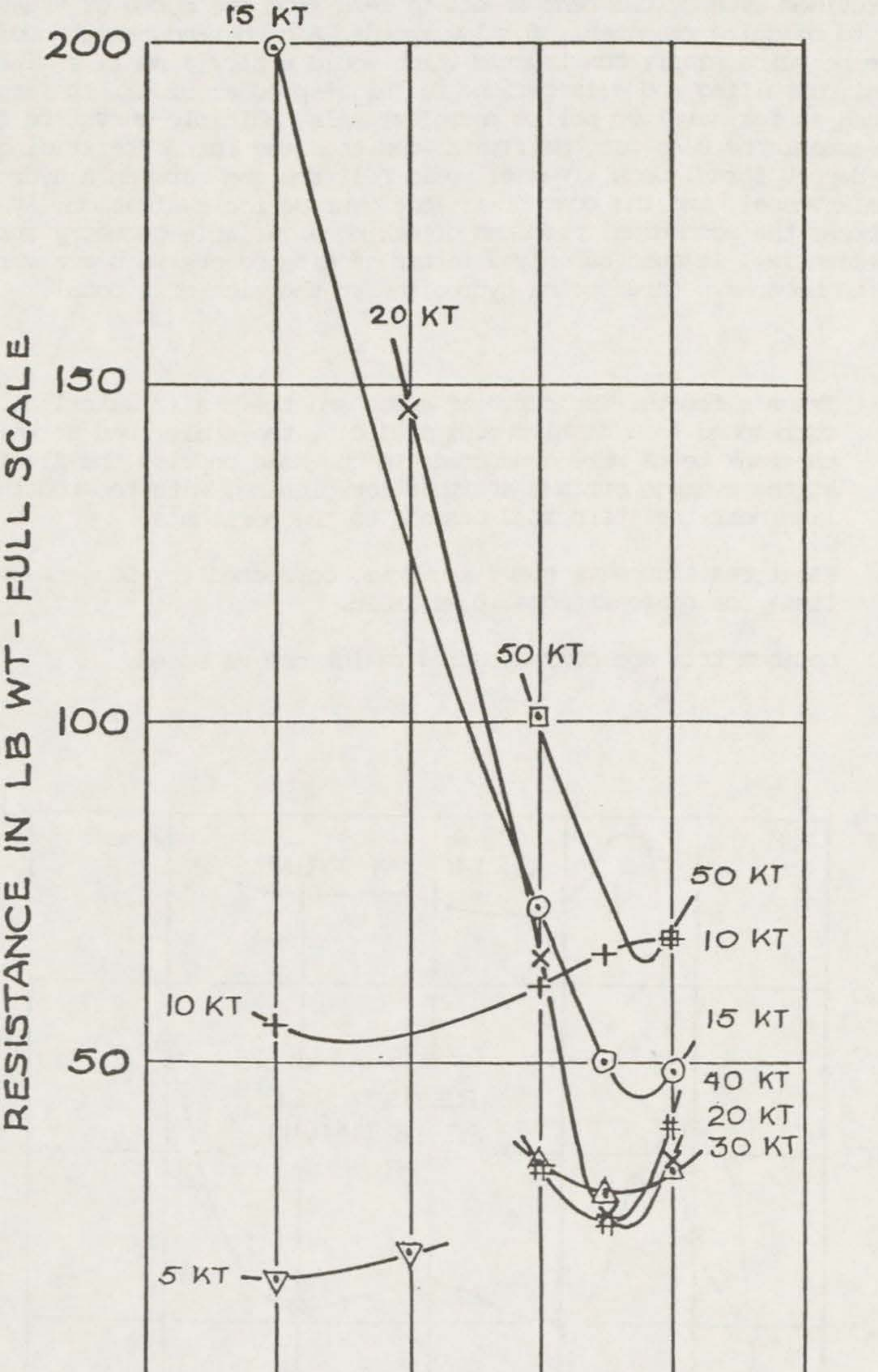

CENTRE-LINE OF DECK
SCALE
FEET
GUNWALE (ON HALF SCALE)
STATIC WATERLINE
CURVE OF AREAS
0
0.5
1.0 FT²
WATERLINE AT 10 KT
15
20
30
40

Figure 1



15 KT
200
20 KT
150
50 KT
100
50 KT
10 KT
10 KT
15 KT
50
40 KT
20 KT
30 KT
5 KT
0
0
5
10
15
20
25
RESISTANCE IN LB WT - FULL SCALE
TRIM OF DECK CENTRE-LINE IN DEGREES

Figure 2

Some possible applications spring to mind. The form of the immersed hull that can be provided even by two bent sheets is seen from the curve of areas in Figure 1 to be quite reasonable for low speeds. A club rescue-boat could therefore be quite simply constructed which would employ a small engine for economical patrolling and a larger one for high-speed missions. At larger sizes, such as for naval or police patrol vessels, multiple-curvature forms would presumably be used for the floats, and the need for softer riding would call for deep-V forms. Such a vessel would fill the gap between a hydrofoil and a SWATH vessel, and the concept is long overdue for evaluation. At the other extreme the mechanical problems of making a variable-geometry surfboard are not excessive. It must be only a matter of time before we see a surfboard which becomes a three-point hydroplane at the kick of a pedal.

FIGURE 1 Trion's floats. The curve of areas and the static waterline correspond to a displacement of 310lb, the scale load at which the tank tests were conducted. In the head-on view the float is at the average optimum attitude for planing, with the centreline near the stern at 3 degrees to the horizontal.

FIGURE 2 Float resistance vs speed and trim, corrected (by Schoenherr line) for scale effects. Load 310lb.

FIGURE 3 Optimum trim and corresponding resistance vs speed.

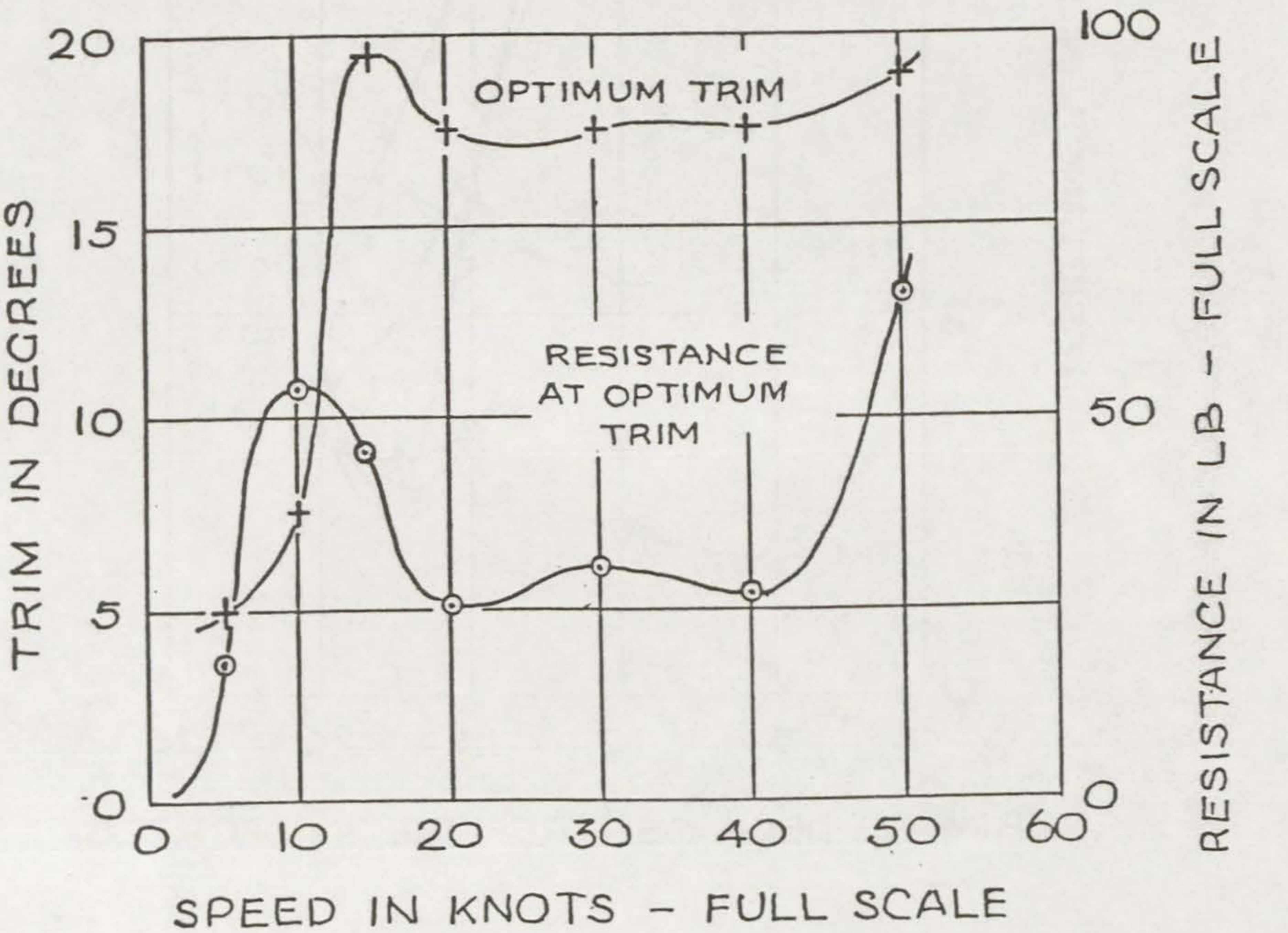


Figure 3

STABILISING PARAVANE EXPERIMENTS by Paul Ashford

Conducted from YCA Moody 34 Yacht Prophet on Turkish Lycian coast, September 1986.

Objective

The objective is to develop a paravane to run alongside and stabilise a sailing yacht.

Concept (figure 1)

The concept is a spar with inclined main foil at the aft end, connected to the yacht's mast by a load line. A control line from its forward end leading to a point on the yacht's hull would control the angle of attack. If the yacht heels away from the paravane, the angle of incidence and the pull on the load line is to increase. If it heels toward the paravane the load line is to go slack. If the paravane leaves the water it must reattach without intervention.

Procedure

The model paravane runs on the starboard side of the towing yacht. The control line is fixed to a rail and the load line is played out by hand.

Model 1a Tests (see figures 3 and 4)

This was towed at 5-6 kts. Unable to get submerged, rolled clockwise from intended angle and planed on convex face of foil. Not tried at low speed.

Model 1b

This was also towed at 5-6 kts. By adjusting the control and load lines it could be got to "catch" water. Very erratic performance, wild swoops forward, leaping out of the water, or submerging under the boat.

Test 2a (figures 5 and 6)

Load line was attached by a 3 part bridle as ab, ad and af. This arrangement, if ab is smaller than ad, tends to take over from the control line, which goes slack. Performance erratic.

Test 2b

Tight bridle attached at points b, c and d, load line attached 2 parts ac, ag.

This will tow as desired if both control and load lines are tight. As the load line was released the tension reduces, but if the load line goes slack rolls anti-clockwise until foil A surfaces. Will recover when the load line is pulled unless tangled.

Model 3a

As 2b, but foil B added to replace strop ac.

3a will tow on control line only with foil B skimming the surface. As load line tightened, the device moves ahead and loads load line. Jerky power take up, possibly because load line attachment well in board of control line attachment.

The single forward control surface was not satisfactory. If theta is say 60 deg the paravane may turn in to the towing boat under load. If theta is say . deg the paravane is liable to dive, particularly with overtaking wa.e.

Therefore second foil C was added to give model 4a.

Note: To overcome the flexibility of the thin sheets of aluminium, the tip of foils A and B are connected by a line, for structural reasons only.

Model 4 (Figures 7 & 8)

This was towed at 4 to 6 kts.

The load line attachment varied between a, b, c, d, e, f.

a and b. Stable. Performance as intended. a. preferred, smoother load take-up.

e, or f. Hopeless. As soon as load line taken up it leaps in and out of the water continuously, and may then spin and twist the load and control lines.

c or d. Better than e or f, but some tendency to "unhook" from the water.

Figure 9 is the section through the main foil, looking aft. The load line lift angle is 45 deg and performance was satisfactory at that figure. It was also tested down to about 30 deg lift angle.

I now refer to figure 10

With a lift angle of approximately 45 deg on the load line, and 30 deg on the control line, the drag angle beta projected on to the horizontal plane measured approximately 22 deg (20 deg from line square to towing yacht). A better indicator of foil performance is the drag angle between the load line and the plane at right angles to the direction of motion approximately 16 deg by trigonometry from measurement in the horizontal plane.

For best towing stability, the control and load lines should be approximately parallel (projected onto the horizontal plane), but with a good deal of latitude. Considerable divergence toward the towing yacht is permissible, or some convergence. With crossed lines it is definitely unstable. The device swings outward then back into yacht with reversed flow over foils.

Effect of waves

The device was successfully towed under open sea conditions in winds of force 3 and 4 on various courses, at speeds of 5 to 6 kts. There was rapid pitching response, with the forward foils following the surface. It was also able to ride the shallow breaking wave which formed part of yacht's wash system, with an occasional shallow dive, recovering quickly.

Behaviour

With the load line slack, the control line tows the paravane at a drag angle of some 50 deg. As the load line is tightened, it moves forward and takes up the load. The load increases as the load line is pulled in, but at a high angle of incidence the paravane will eventually reverse into the towing boat.

Speeds

The model was tested to 6 knots. A prototype of 4 times model scale will be stable to at least 12 knots, and 9 times model scale to 18 knots. At these speeds the paravane is totally dominated by hydrodynamic forces, with its weight, buoyancy and inertia being relatively negligible.

Conclusion

The objectives were met, but it is a pity that the final device looks a devil to stow on board at full scale!

6th January 1988 Paul Ashford

PAUL ASHFORD'S STABILISING PARAVANE EXPERIMENTS

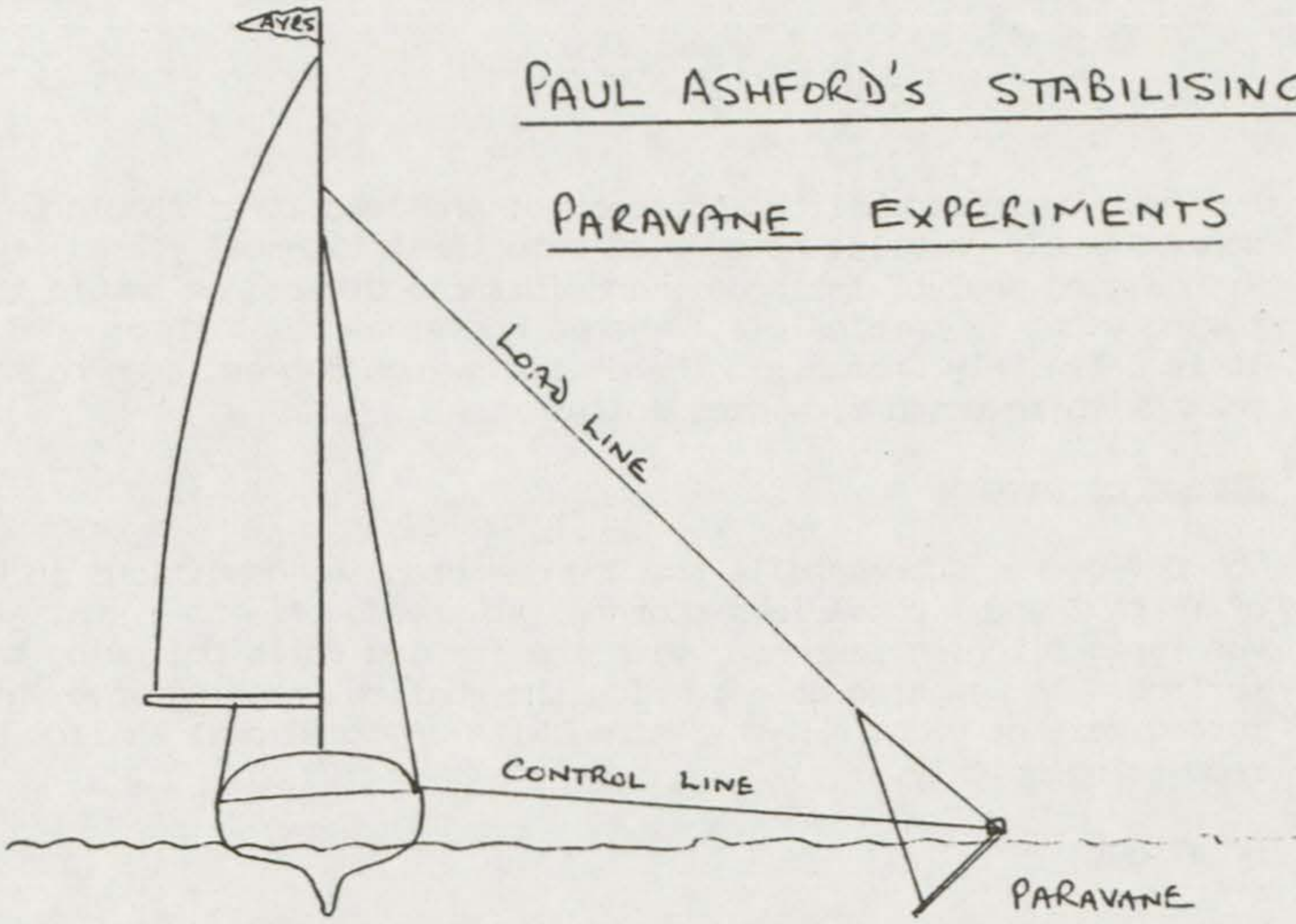
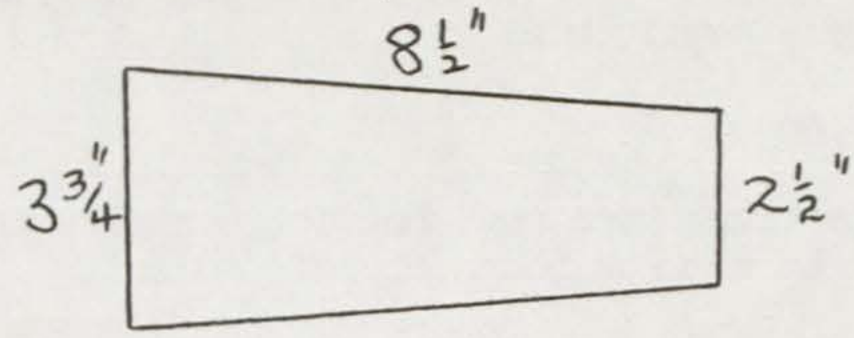


FIGURE 1 - THE CONCEPT

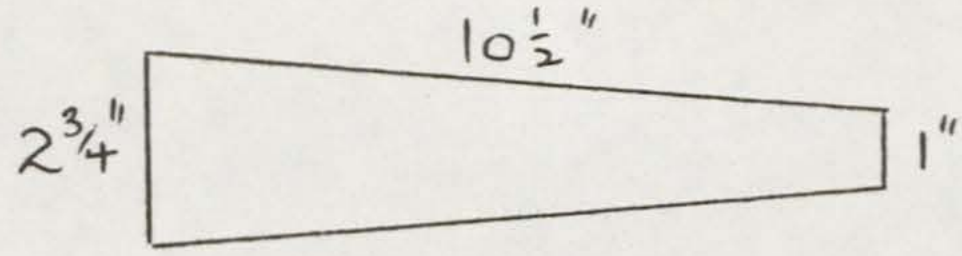
BODY SPAR - 20" × 7/8" × 1/2"

ALUMINIUM FOILS - 1/16" PLATE

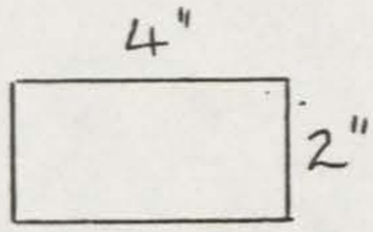
FOIL A - 1 OFF



FOIL B - 1 OFF



FOILS C - 2 OFF



TERYLENE TOWING LINE 2 mm DIAM.

STAINLESS PAN HEAD SELF-TAP SCREWS - 1/2" × 6 ; 3/4" × 6

FIGURE 2 - COMPONENTS.

MODEL 1a - SPAR & MAIN FOIL A ONLY

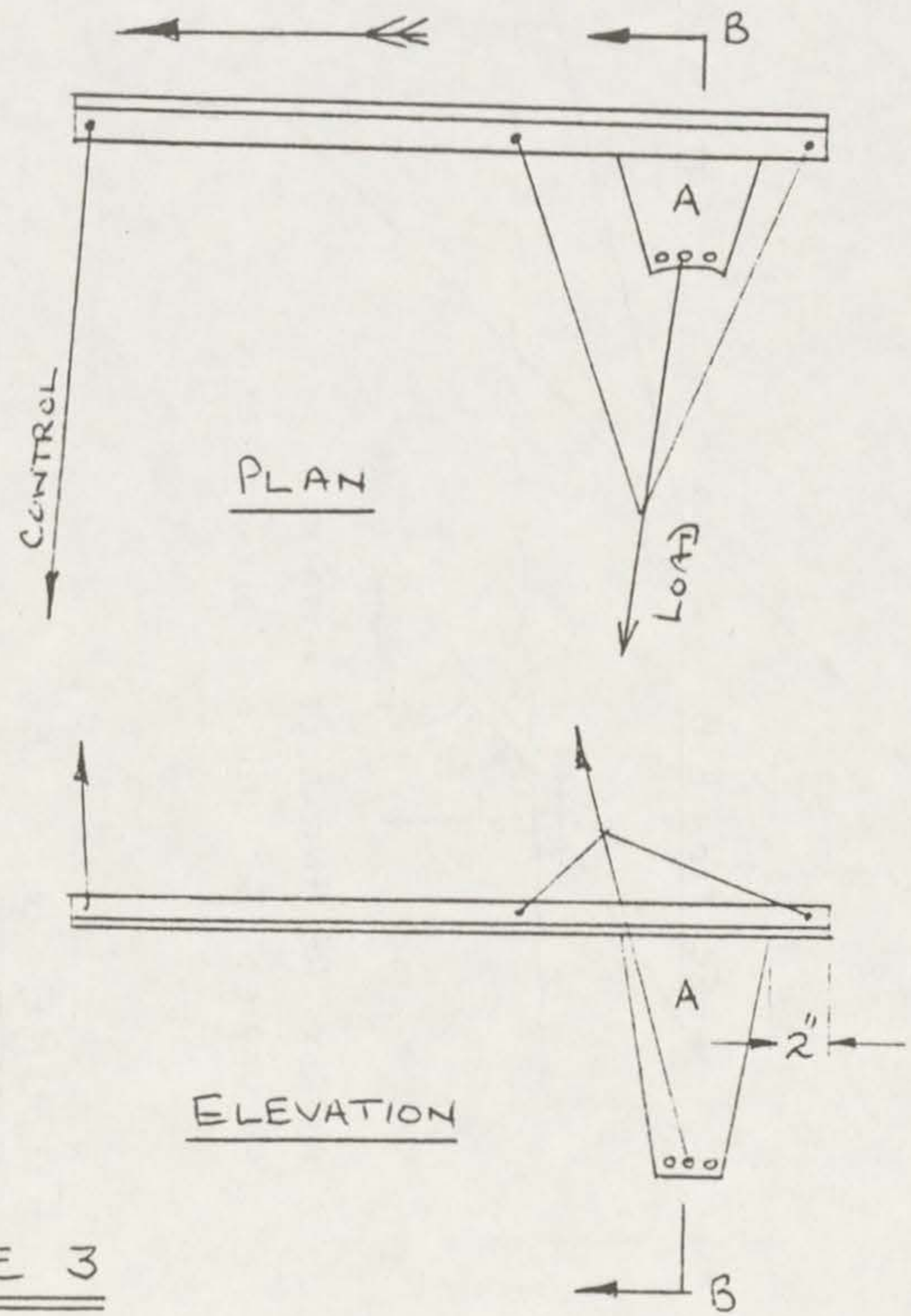
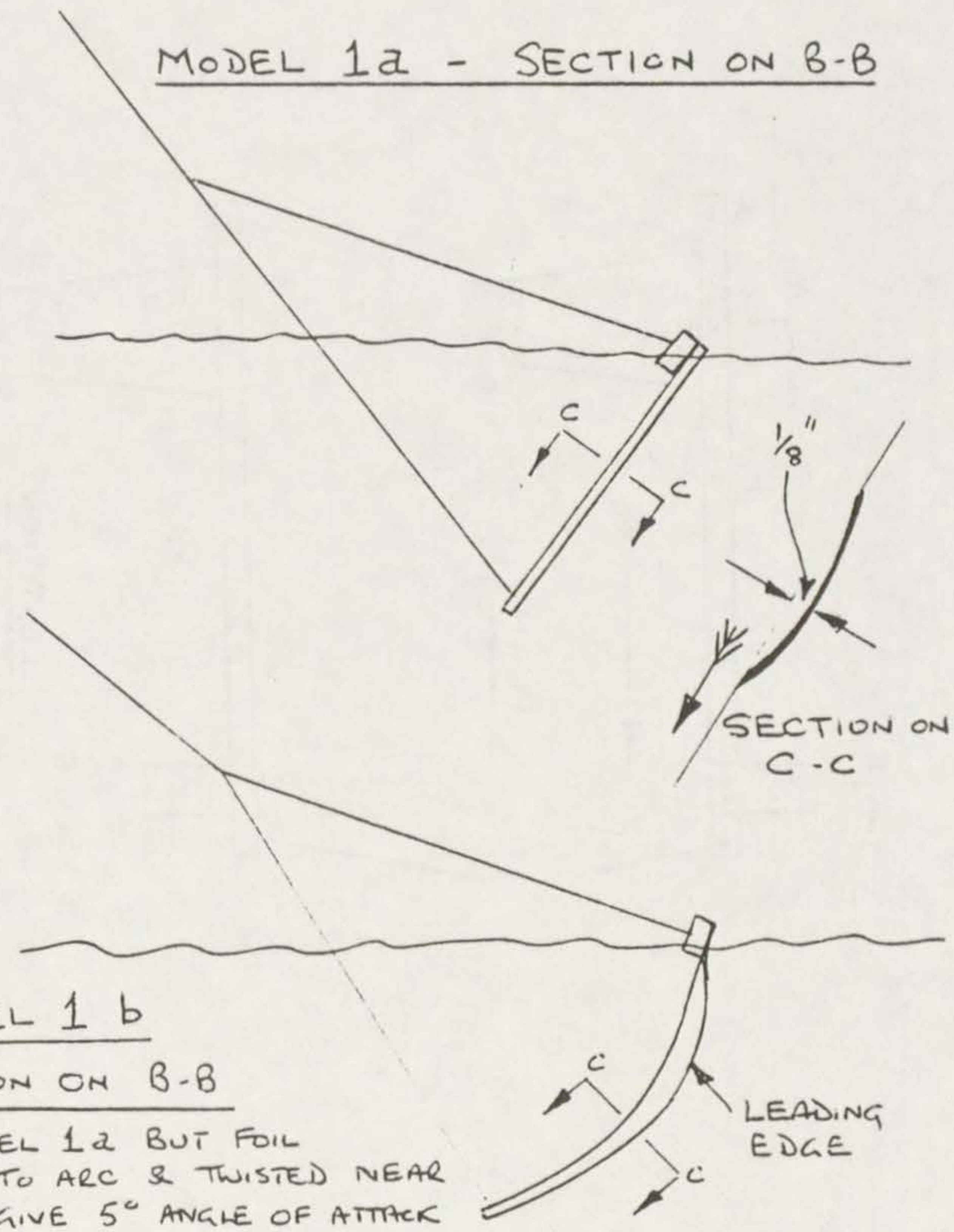


FIGURE 3

MODEL 1a - SECTION ON B-B



MODEL 1 b

SECTION ON B-B

AS MODEL 1a BUT FOIL CURVED TO ARC & TWISTED NEAR SPAR TO GIVE 5° ANGLE OF ATTACK

FIGURE 4

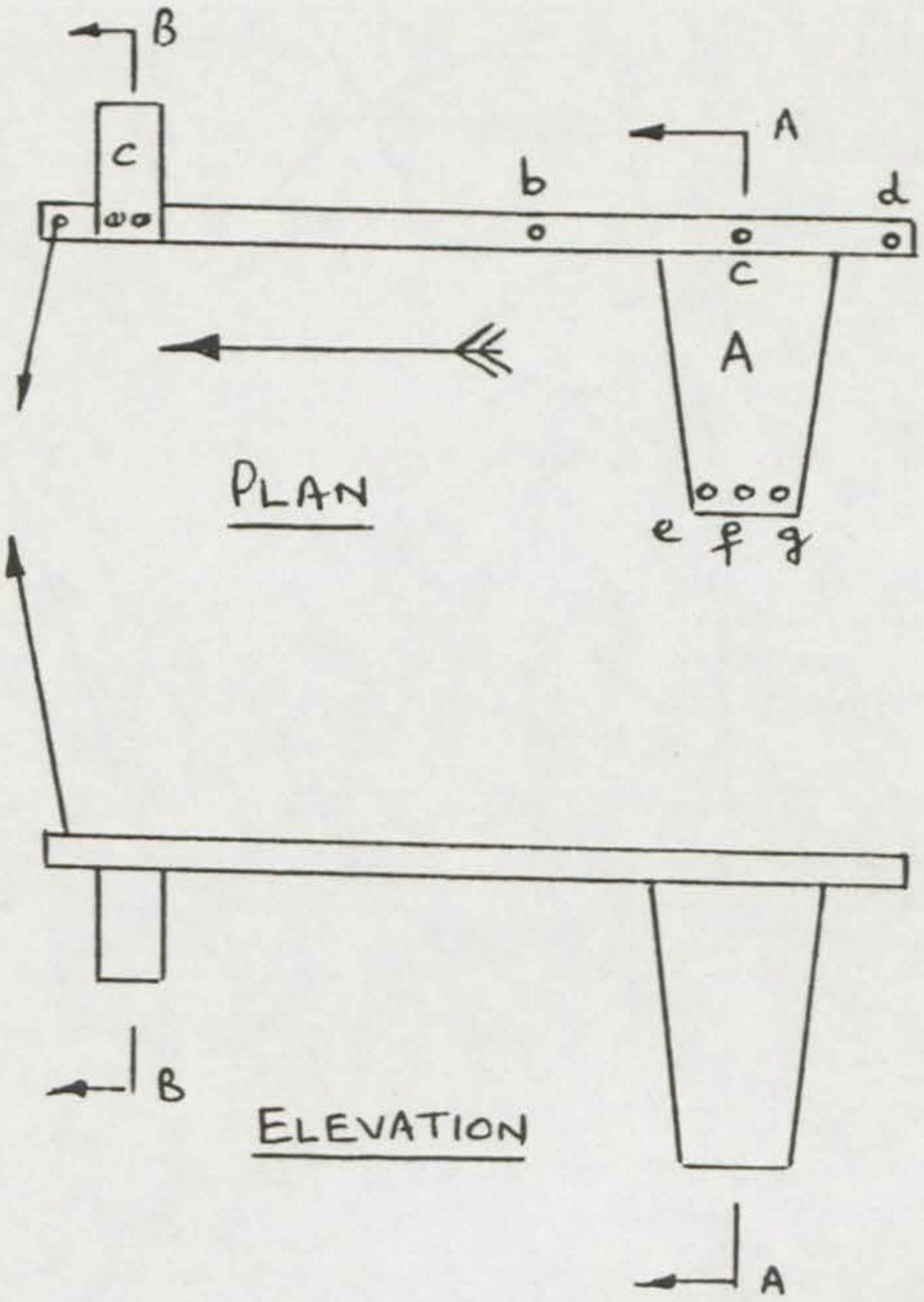


FIGURE 5 - MODEL 2a AS MODEL 1 b + FOIL C. AT BOW.

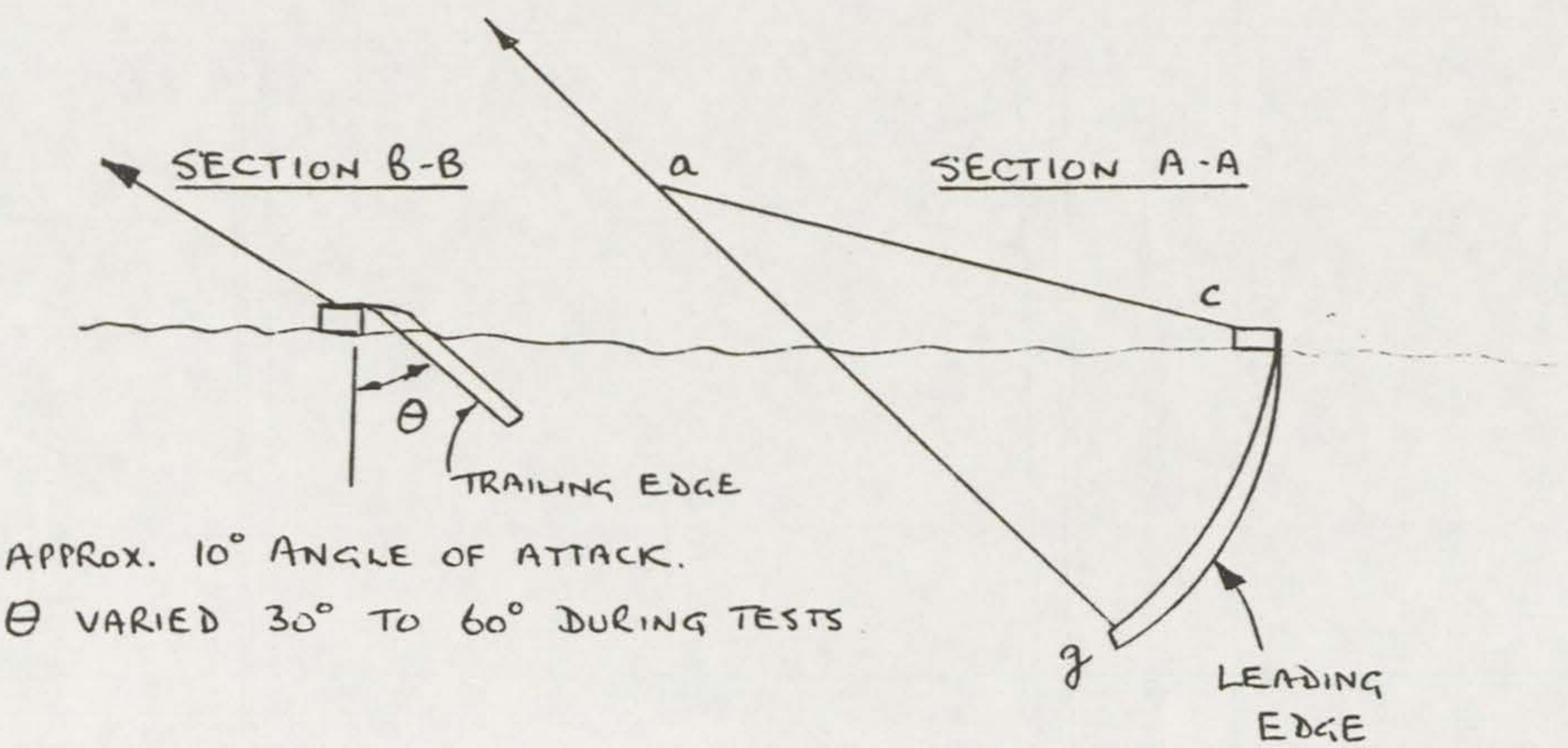


FIGURE 6

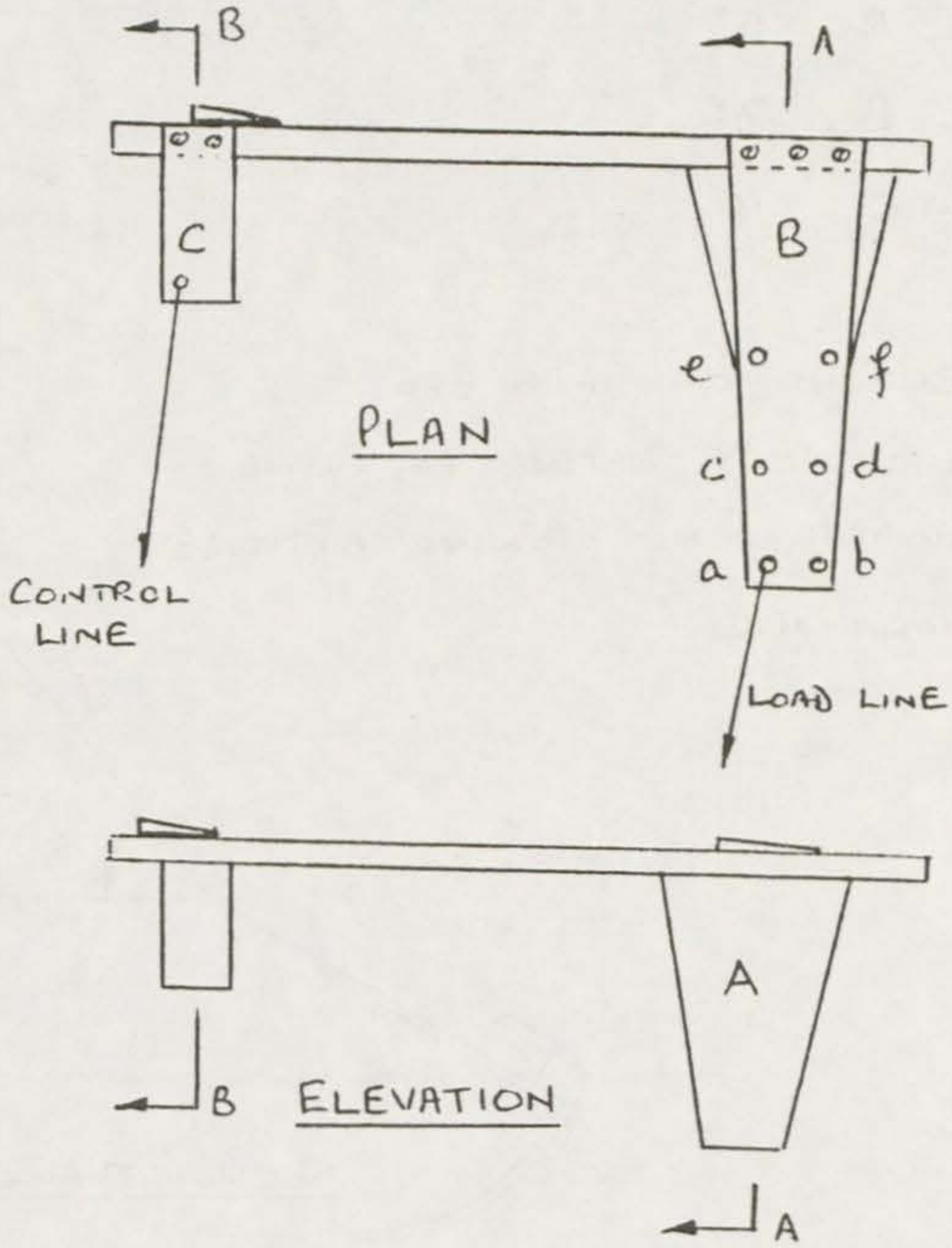


FIGURE 7 - MODEL 4

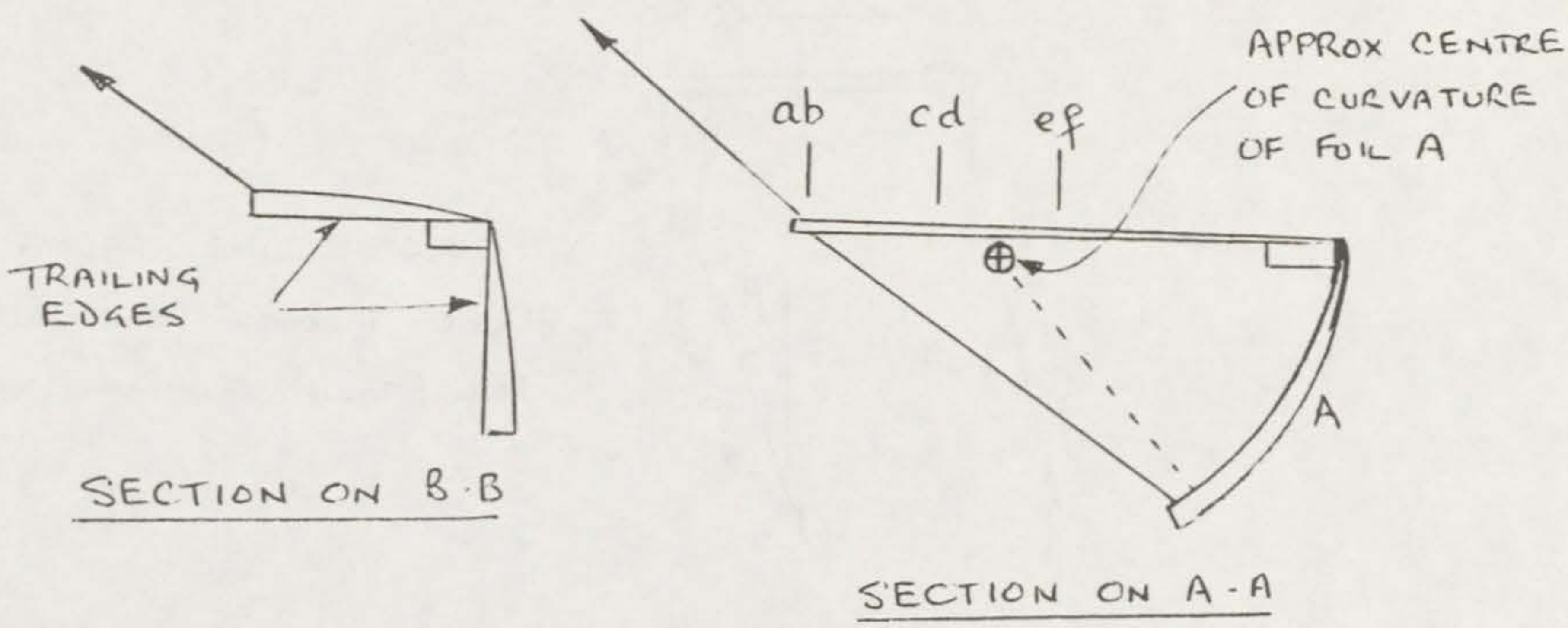


FIGURE 8

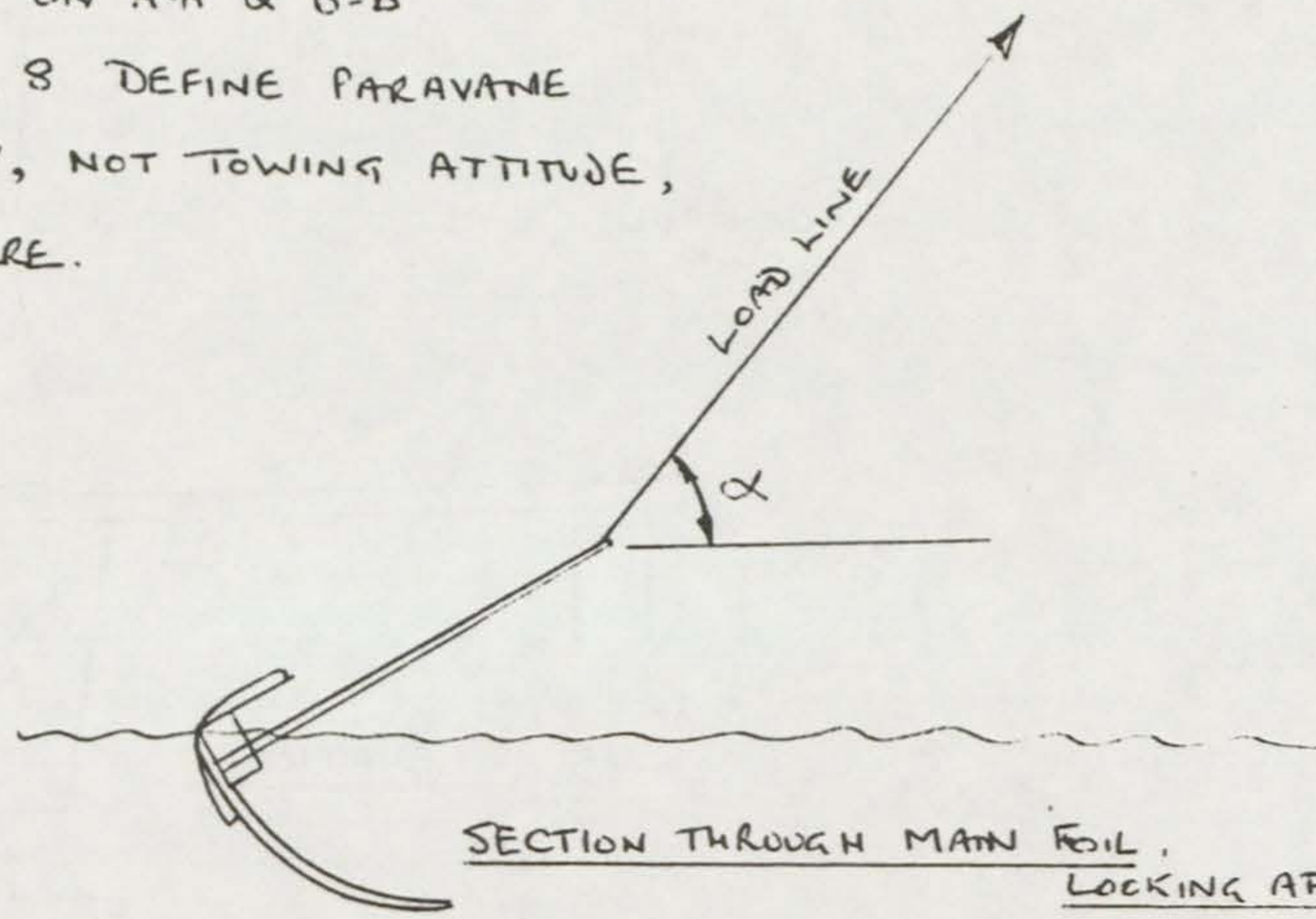
ANGLES OF ATTACK, RELATIVE TO SPAR:-

FOIL A, 5°

FOIL B, 3°

BOTH FOILS C, 10°

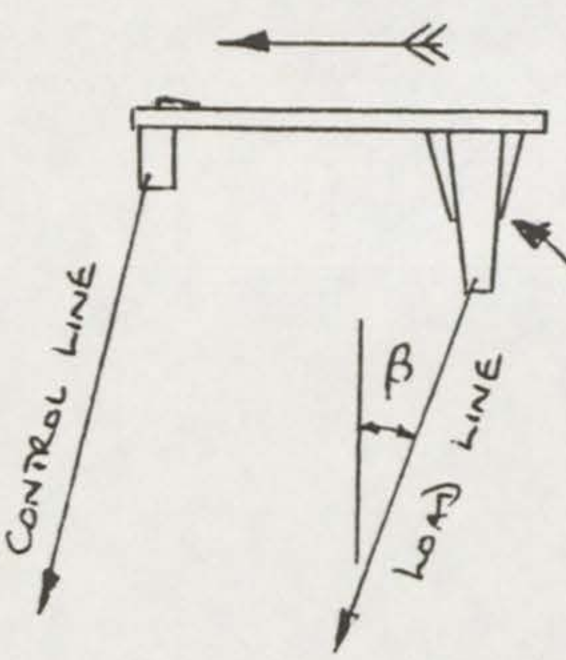
NOTE: SECTIONS ON A-A & B-B
IN FIGURE 8 DEFINE PARAVANE
GEOMETRY, NOT TOWING ATTITUDE,
SHOWN HERE.



SECTION THROUGH MAIN FOIL,
LOOKING AFT.

LOAD LINE LIFT ANGLE α. PERFORMANCE SATISFACTORY AT α ≑ 45°, ALSO TESTED DOWN TO ABOUT α = 30°.

FIGURE 9 - MODEL 4



PROJECTED LINE OF LOAD LINE PASSES THROUGH REAR EDGE OF FOIL (TOWED FROM HOLE a)

FIGURE 10

Letter from George Chapman

The Rock
South Brent
South Devon
TQ10 9JL

14 July 1990

Dear Roger,

Paul Ashford's report of his experiments with a "Bruce Foil on a string" is a useful addition to AYRS knowledge, and follows his work on his model of SHALIMAR (AYRS 106, page 32) when he used a rigid boom to connect the foil to the hull.

I have always been chary of relying on a foil clinging to the water both because it might pop out and because it's downward component depresses the hull adding drag. Even so, Gerard Horgan's huge "Hooded Claw" (my childrens' epithet) worked, and Sid Shutt's inverted foil on a string from the masthead also worked. (AYRS AIRS No 8, page 41). He patented his device, so as far as I recall there is no description of it in the AYRS writings, though doubtless it is available in the US Patent Office. (Note for AYRS patentees: PLEASE quote the number of your patent(s) !)

Sid Shutt also managed to make his device tack, following round astern of the boat, and this was described in some publication but I regret I have forgotten which.

Basically any sort of foil which "flys" (whether in air or water) on a string is analogous to a kite, and from there one can see the similarity of hang gliders, the hapa (another towed inverted foil), minesweeping "kites" which hang under streamlined floats (Oropesas), and the latest are the blades of the Brunton-Weil Autoprop. At first sight this is a totally confusing propeller, but it is a stroke of genius as the blades are pivoted on - presumably - ball bearings and take up the correct angle of attack whatever the speed and direction of the water past them; this latter being the combination of rotational speed and speed through the water. The principle could also be applied to water (and air) driven turbines. I have made a small one for trial on my 5Kg outboard but await the rains so there is enough water in our leat to cover the prop.

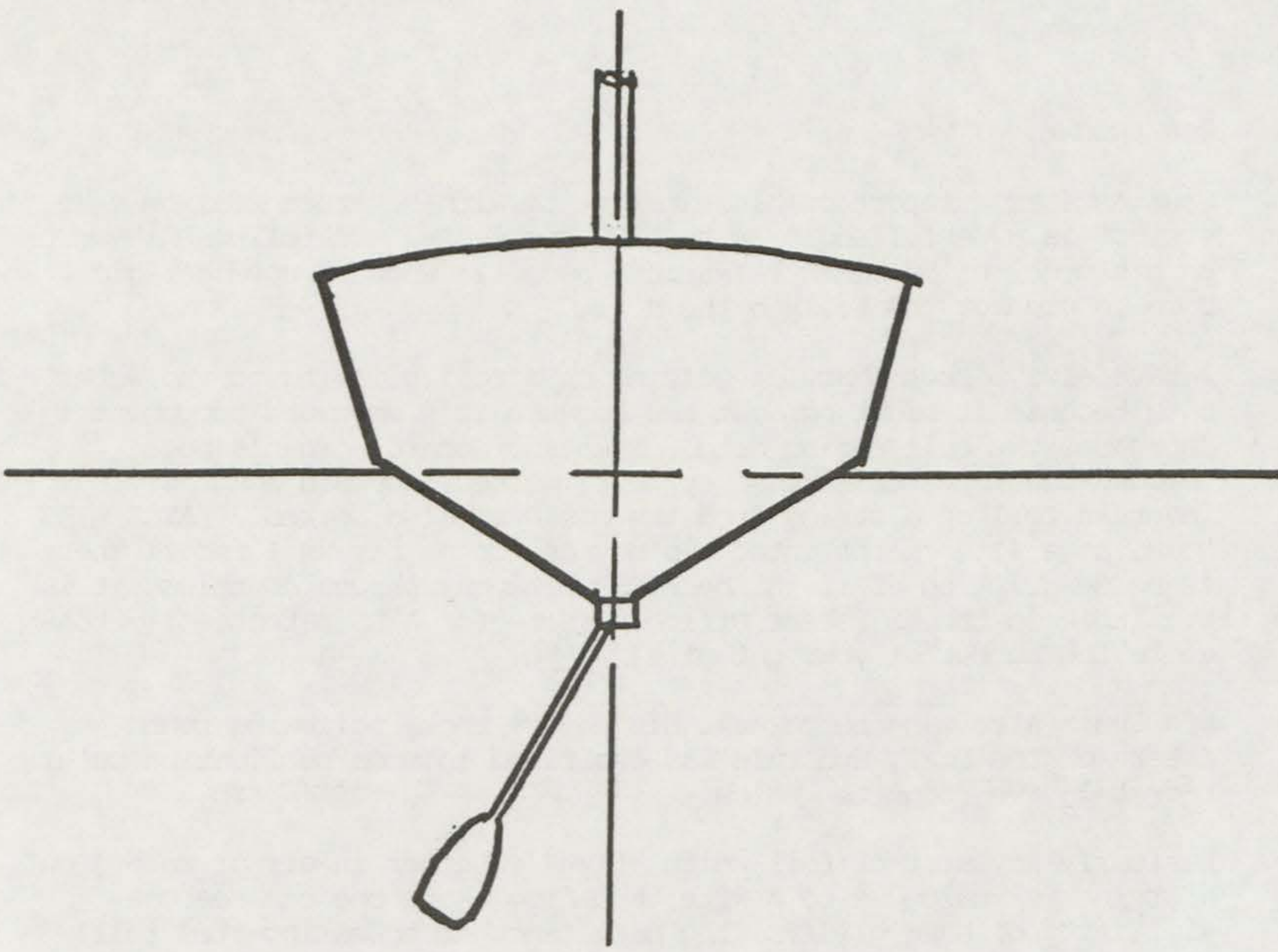
Combining the minesweeping kite and float as Paul has done means less wire and less hassle launching and recovering, and if the string snaps, the device will not sink. So I say carry on and try one at full size. As a confirmed multi-huller, anything that can be done to keep monohulls upright is worth doing!

Yours sincerely,

George Chapman.

A NEW WAY OF SAILING FASTER
SWING KEEL, WITH NARROW HULL

By Neil Lamont, Barnes Bay, Bruny Island, Tasmania 7150.



I have tested a 5ft long model and will next build a 20ft "model" . Then a cruiser around 40ft. The principles are that a narrower hull generates less drag. The hull sails with the masts nearly vertical, which again reduces drag.

Everybody consulted had doubts about safety when the sails get backwinded and the ballast keel is on the wrong side. But I have done tests on this by putting the model onto the opposite tack with ballast remaining on the wrong side. The heel was not excessive, and the sailing speed was reduced. The hull dimensions, ballast weight and position were all guessed. The arrangement might, with luck, be the best, but further experiments will investigate changes. It has two masts, and the sails are low aspect ratio.

This is clearly something well worth while trying out.

Meanwhile, for more information; write to me.

Neil Lamont.

AYRS PUBLICATIONS

			Price
1	Catamarans	1955	£3
2	Hydrofoils .	1955	£5*
3	Sail Evolution	1955	£5*
4	Outriggers	1955	£3
5	Sailing Hull Design	1956	£3
6	Outrigged Craft	1956	£3
7	Cat. Construction	1956	£5*
8	Dinghy Design	1956	£5*
9	Sails & Aerofoils	1956	£5*
10	American Catamarans	1956	£5*
11	The Wishbone Rig	1957	£5*
12	Amateur Research	1957	£5*
13	Self-Steering - (BK)	1957	£8
14	Wingsails	1957	£5*
15	Catamaran Design	1957	£5*
16	Trimarans & Outriggers	1957	£5*
17	Commercial Sail	1958	£5*
18	Cat Developments	1958	£5*
19	Hydrofoil Craft	1958	£3
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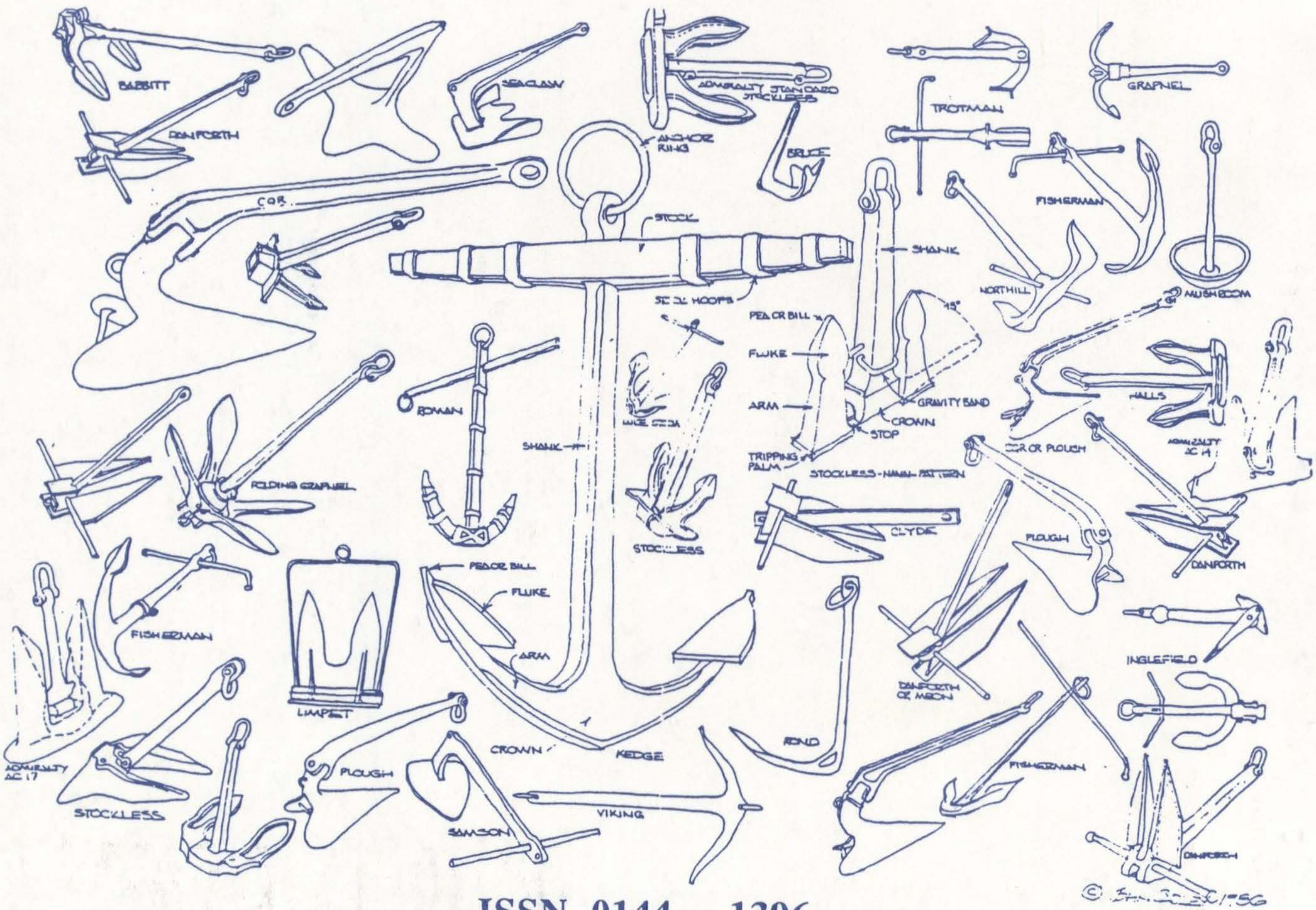

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