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STATUS REPORT NO. 24

COMPUTATIONAL DESIGN & ANALYSIS FOR SAIL AMERICA FOUNDATION

- Boppe was against using large span winglets
- pressure integration technique - wake integration = pressure integration

REPORT PERIOD:
1 DECEMBER 1986 TO 31 DECEMBER 1986

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COMPUTATIONAL DESIGN & ANALYSIS

SUMMARY

Derivatives of the 3½ foot triangular winglet were examined in December to provide options for trading wetted area and reduced draft during the final Challenger and America's Cup races. The best $\Delta TR/\Delta S_W$ ratio was achieved with winglet tip extensions comparable to those studied by van Dam (see SR #16, pg. 37). A 4¼ foot extension is projected to yeild a 0.15 foot increment in effective span for a 3.7 square foot increase in wetted area. A 5 foot extension will yield a 0.24 foot increment for 7.8 square feet of additional wetted area

when compared to the basic 3½ foot triangular winglet. Towing tank tests performed in December confirmed the 0.3 ft. TR benefit projected by analysis for the 3½ foot winglet (see SR #20, pg. 1). Free-surface analyses were conducted to augment winglet incidence tests planned for mid-December. This study showed that winglet orientation could be optimized for various boat speeds; the higher speeds (≈10 knots) requiring more negative inclination for minimum drag than the lower speeds. Analyses were also conducted to provide fluid particle traces for S-87 at several different conditions to facilitate application of riblet tape. It is noted that flow angularity can be quite severe when going to windward. Large (17"x20") copies of the trace patterns were courier delivered to Australia during December. Recommendations were also offered at the request of Bruce Nelson to explain high drag penalties linked to rudder deflections over 4°.

DR. BEYSTER ——

THEY ARE PUTTING ON THE 4¼ FT. EXTENSION FOR THE KIWI RACE SERIES... KEEP YOUR FINGERS CROSSED

Alan C.

Van Dam's.

① How do winglets we have conform to these figures 2 & 3

1

DISCUSSION

Configuration Optimization

Early in December, towing tank tests confirmed the benefit predicted (see SR #20) for the 3½ foot triangular winglet. The gain was 0.3 foot in effective draft. It should also be noted that the refined incidence schedule (SR #23, pg. 16) coupled with proper root attachment, should yield an additional 0.05 foot^2 minimum drag benefit at 0° yaw. To confirm this new orientation and local distribution, an additional test was planned but only two attachment angles could be accommodated. Analyses were performed to provide trendings that might prove to be useful for interpreting the sparse test data. Models of S-87 were constructed with winglets set at five winglet root incidence angles. These were examined at two boat speeds; 7 and 10 knots. VSAERO drag levels are tabulated below.

TABLE 1 - EFFECT OF WINGLET ORIENTATION ON DRAG

WINGLET ROOT ANGLE	VSAERO DRAG LEVEL	
	7 KNOTS	10 KNOTS
-2.8°	0.858	9.155
-3.8°	0.838	9.088
-4.8°	0.851	9.053
-5.8°	0.893	9.050
-6.8°	0.960	9.078

The results are also plotted in Figure 1. It can be seen that the -3.8° root attachment is projected to be optimum for low and moderate speeds while an additional 1 to 1½ degrees of negative incidence might be set for higher boat speeds. Note that the near 1° bucket identified early in the program during testing of SAF-007 is apparent in these curves. Also identify that an incidence error of 1° on either side of the bucket could result in a drag penalty near 0.1 ft^2 which is significant.

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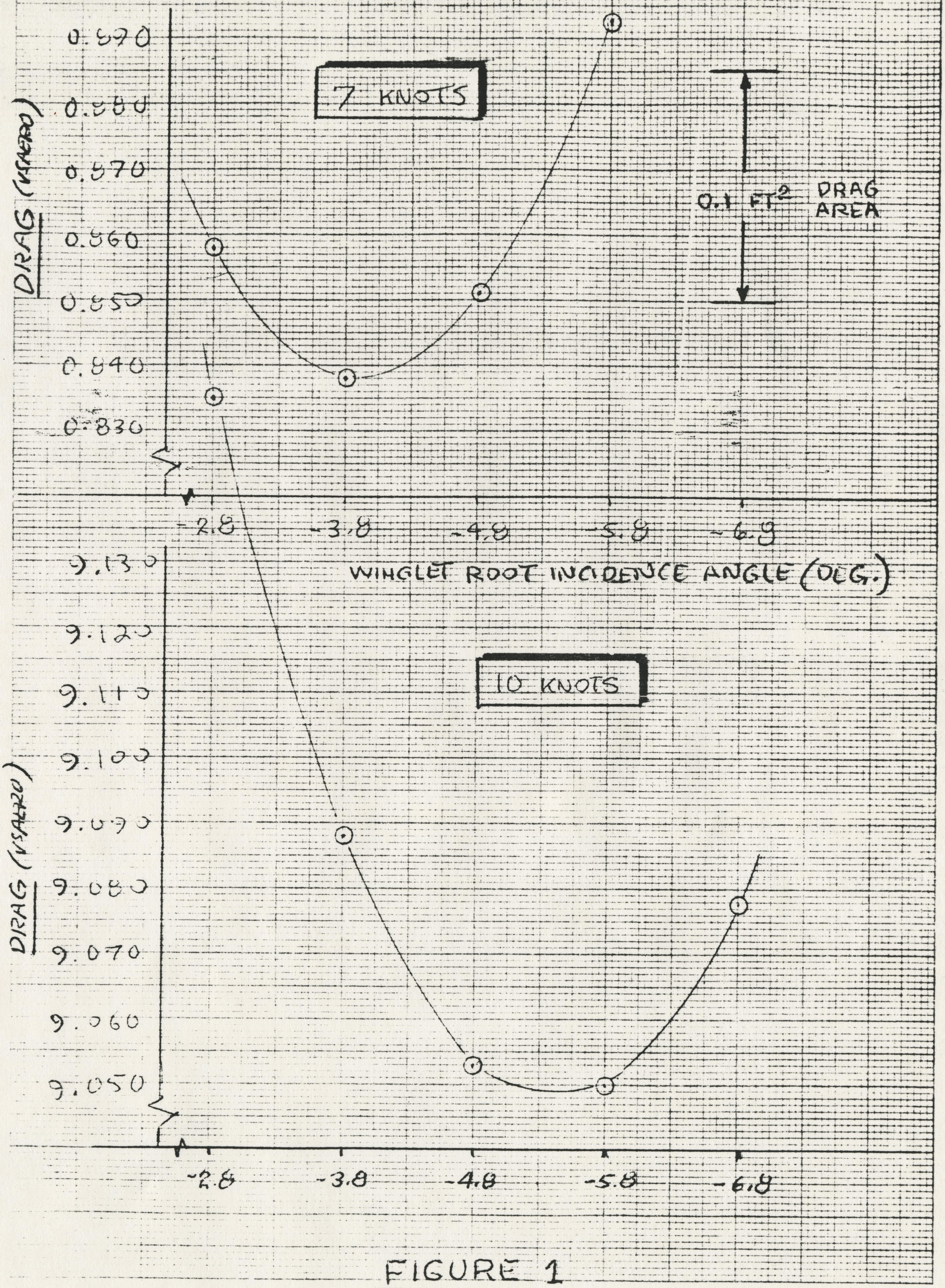

FIGURE 1

DRAG vs. WINGLET ANGLE FOR TWO SPEEDS

Next, higher span winglets were examined to derive greater TR levels should they become necessary. Figure 2 shows 4.72 and 5.00 foot half-span ogee planforms suggested by Chance and Marshall. Results found in Table 2 show a modest gain in draft for large area increments. Three additional shapes were studied as shown in Figure 3. Here, simple extensions that might be bolted on to the tip of the 3½ foot winglet were considered. All had 5 ft. half-spans. Again, Table 2 shows that the smallest "tiplet" provides a 0.1 gain in TR for 3 additional square feet of wetted area. Recall that the basic characteristics of the 3½ foot winglet were ...

$S_W = 721$ ft²
TR = 10.60 ft.

This suggests that area can be added most efficiently near the trailing edge of this type of winglet planform. This brings to mind once again, the work of van Dam (see SR #16, pg. 37).

Two van Dam-type winglets were evaluated as shown in Figure 4. Region "A" represents an efficient extension to 4¼ feet and region "B" would be for a 5 ft. extension. These shapes have a higher benefit/penalty ratio than those studied so far. Table 3 shows computed results along with results for a 4¼ foot right triangle which yields no benefit for 10 additional square feet of wetted area. Summarizing ...

TABLE 4 - TIP EXTENSION PERFORMANCE

EXTENSION	TR	S_W
A (4.25 ft.)	+0.15	+3.7 ft²
B (5.0 ft)	+0.24	+7.8 ft²

Note that time provisions for re-balance and trim will be required for the center-of-pressure shift derived from these extensions. Local section incidence angles for the higher span segments were determined by pressure equalization and the results are shown in Fig. 5.

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FIGURE 2

HIGHER SPAN WINGLET PLANFORMS

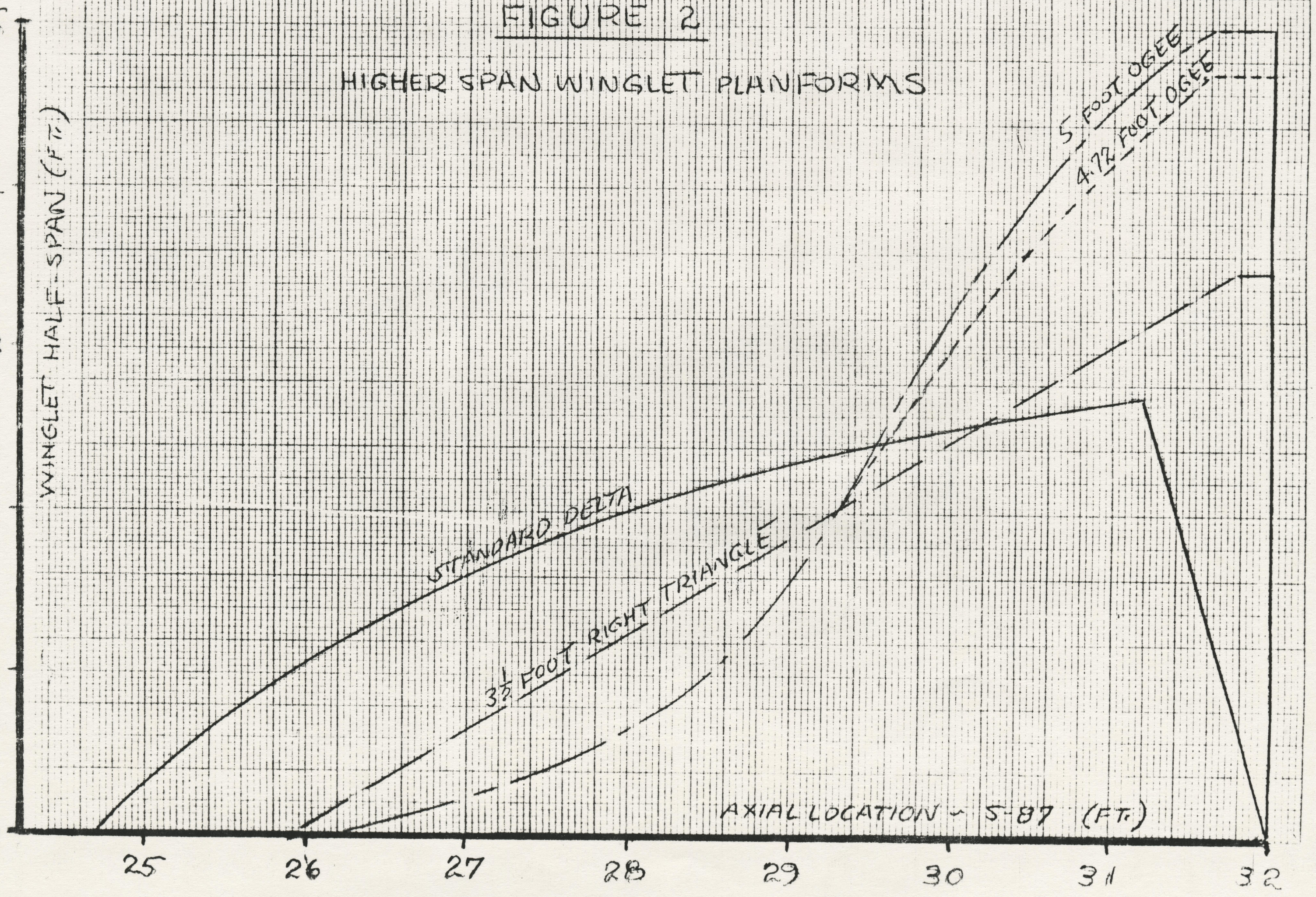

FIGURE 3

$3\frac{1}{2}$ FOOT WINGLET ADD-ONS TO ATTAIN 5 FT. SPAN

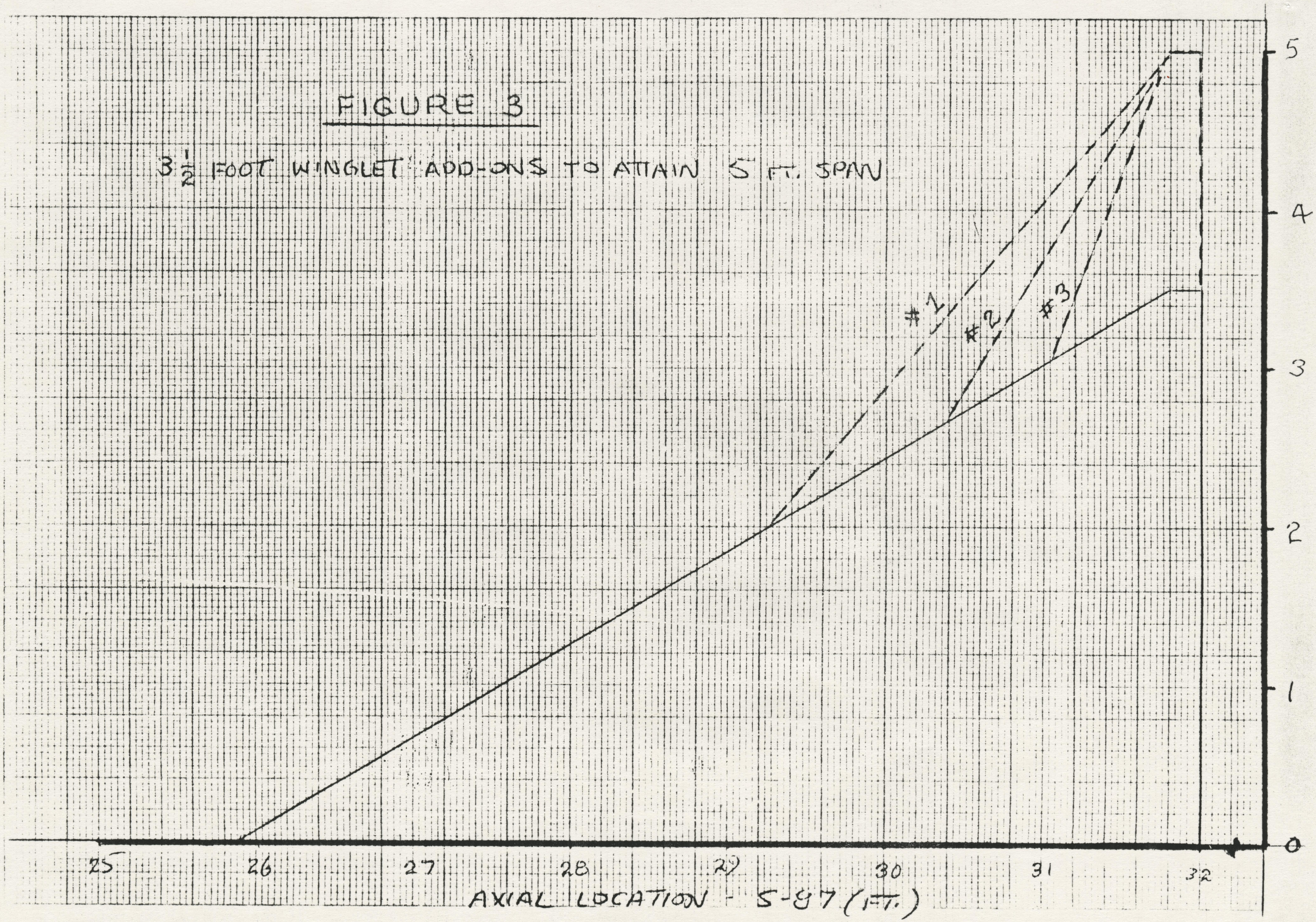

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TABLE 2

HIGHER SPAN WINGLET SHAPES

CONFIGURATION	S_W	YAW	C_L	C_D	C_{L_o}	C_{D_o}	$\frac{\Delta C_{Di}}{(\Delta C_L)^2}$	TR
Marshall High Span Winglet (5 Ft.) - Ogee planform	730	0	-0.000200	0.000620			1.039	10.57
		6	0.040310	0.002120				
Britt's 4.72Ft. Span Ogee Winglet	730	0	-0.000140	0.000625			1.008	10.74
		6	0.040865	0.002115				
$3\frac{1}{2}$ Ft. Winglet Add-ons #1	730	0	-0.000130	0.000620			1.004	10.76
		6	0.040815	0.002100				
⇩ #2	727	0	-0.000130	0.000610			1.001	10.75
		6	0.040365	0.002060				
⇩ #3	724	0	-0.000125	0.000605			1.004	10.71
		6	0.040015	0.002040				

FIGURE 4

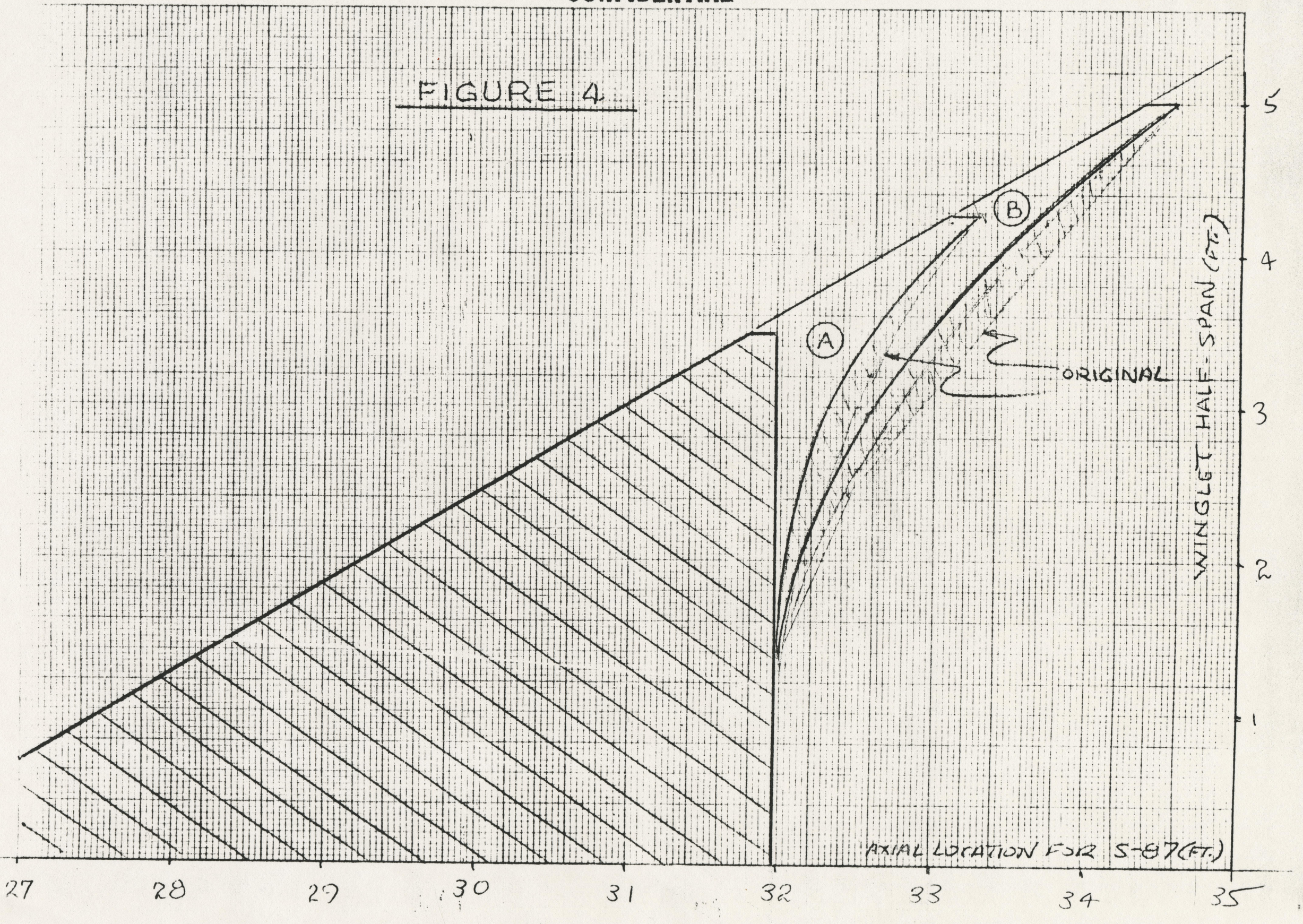
A
B
ORIGINAL
WINGLET HALF-SPAN (FT.)
AXIAL LOCATION FOR S-87(FT.)
27
28
29
30
31
32
33
34
35
1
2
3
4
5

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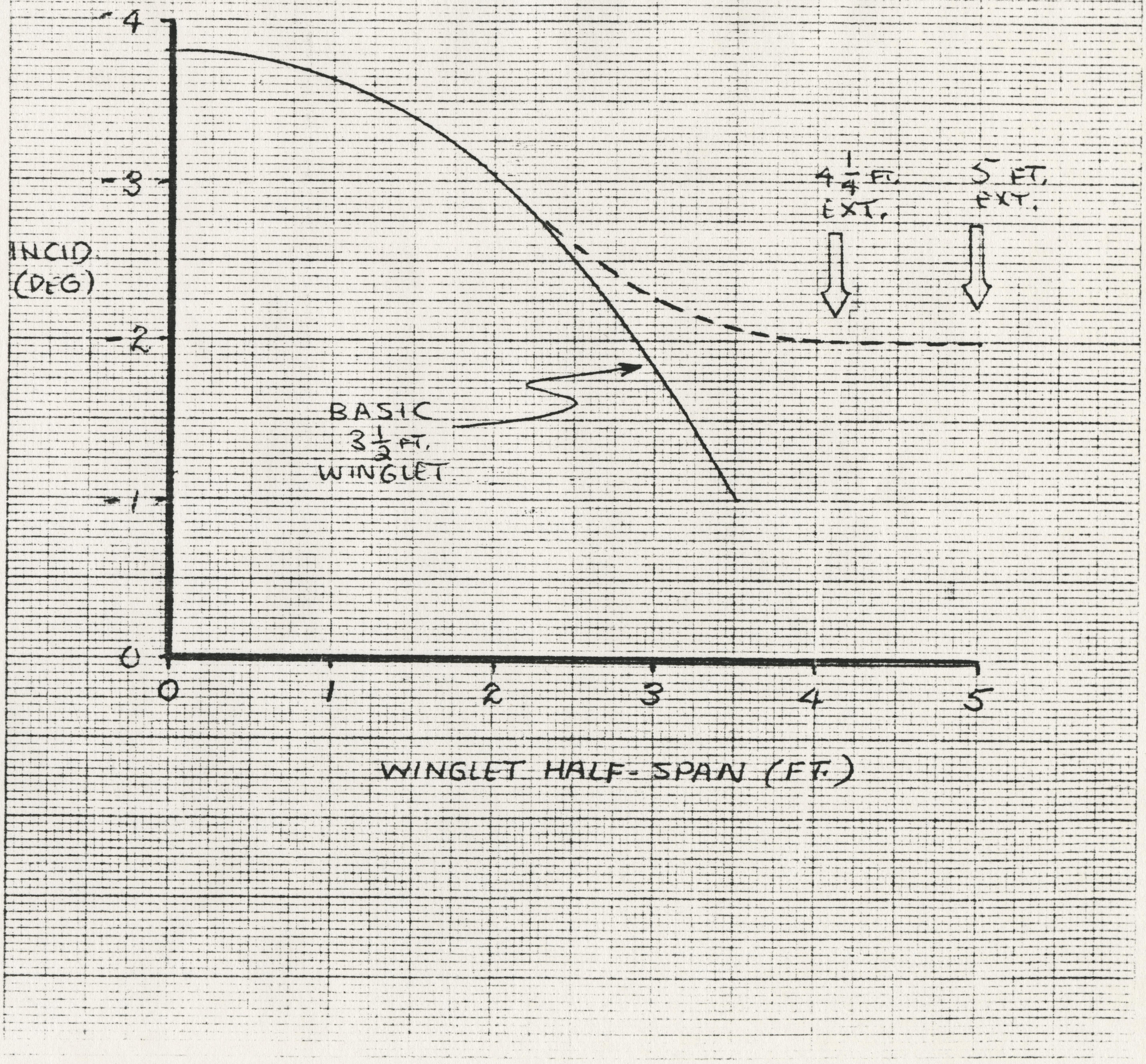
TABLE 3

VAN DAM - TYPE TIP EXTENSIONS FOR $3\frac{1}{2}$ Ft. WINGLET

CONFIGURATION	S_W	YAW	C_L	C_D	C_{L_o}	C_{D_o}	$\frac{\Delta C_{Di}}{(\Delta C_L)^2}$	TR
Initial 5.0Ft. van Dam Ext.	732	0	-0.000125	0.000595			0.980	10.90
		6	0.040305	0.002000				
Initial 4.25 Ft. van Dam Ext.	726	0	-0.000135	0.000605			0.992	10.79
		6	0.040090	0.002030				
Final 4.25Ft. van Dam Ext.	724.7	0	-0.000135	0.000600			0.999	10.75
		6	0.039985	0.002025				
Final 5.0Ft. van Dam Ext.	728.8	0	-0.000125	0.000590			0.988	10.84
		6	0.040135	0.002000				
Scaled up 4.25Ft. Right Triangle	731	0	-0.000045	0.000565			1.035	10.60
		6	0.041245	0.002115				

FIGURE 5

LOCAL INCIDENCE FOR 3½ FOOT WINGLET EXTENSIONS



Configuration Flow Patterns

Application of riblet tape has been a back-burner item for over a year... given a low probability of success due to 1) Bio-fouling (NASA estimates 1-2 hours), and 2) riblet groove alignment with the streamlines. The close boat speeds of New Zealand, USA, and S-87 at the end of the third round robin, however, places new emphasis on the need to find something to break this situation.

Flow solutions for S-87 at three conditions were created to aid in the application of riblet tape. Kent Misegades (Cray Research) asssisted in this effort by processing the panel models 1700 velocity points at control points using a Cray integration scheme. Particle trace photographs derived from this process can be found in Figures 6, 7, and 8. The table below can be used for identification.

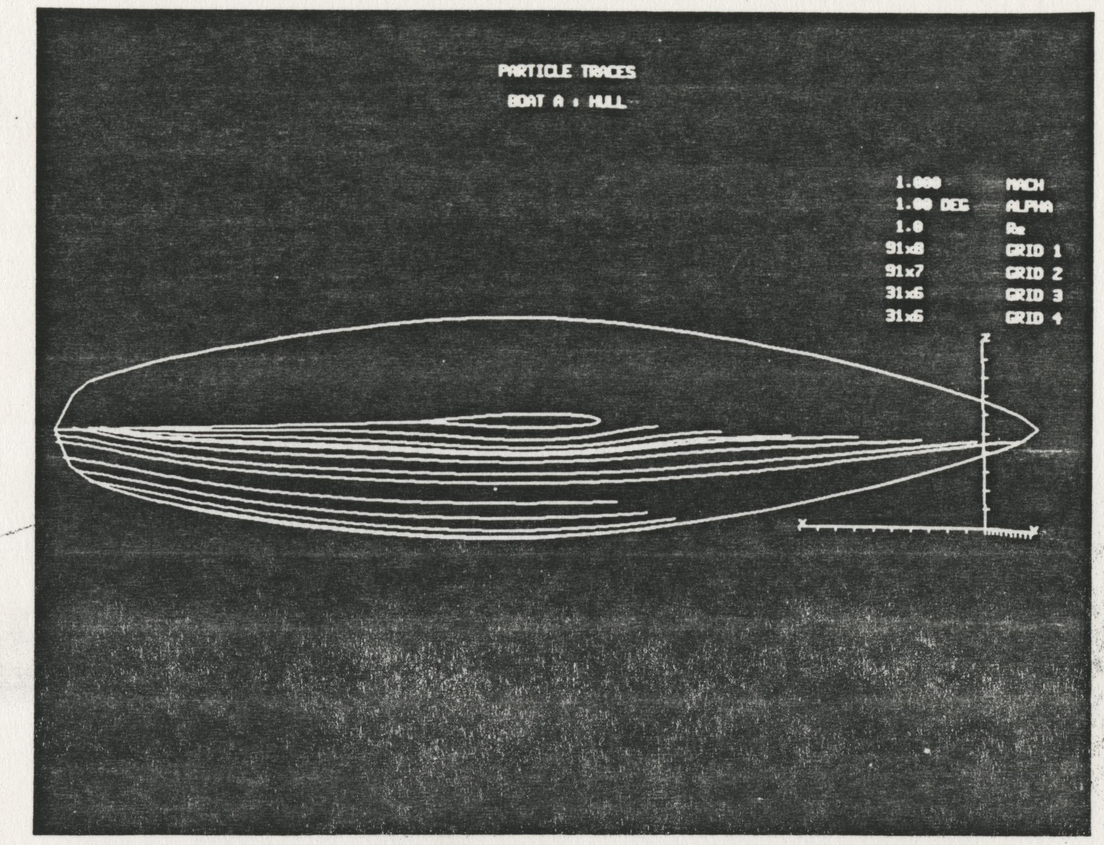
TABLE 5 - PARTICLE TRACE PHOTO IDENTIFICATION

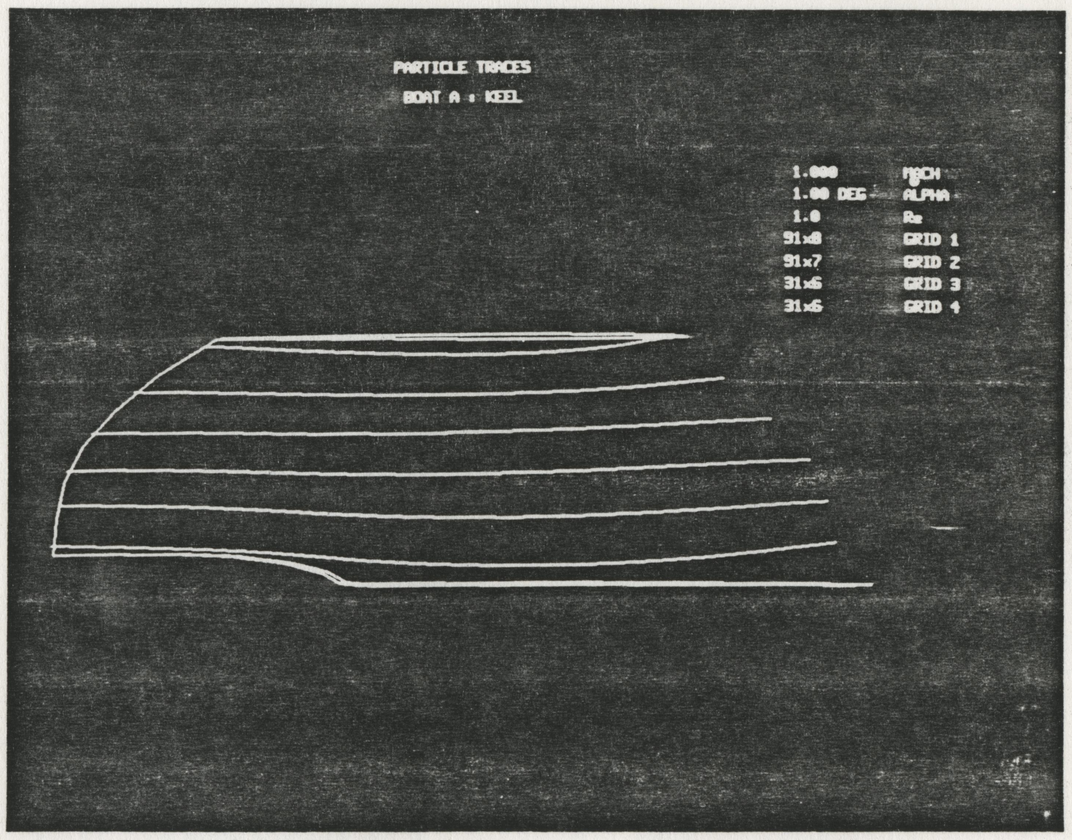
FIGURE	PHOTO SET	CONDITIONS			
		HEEL	SPEED	YAW	TAB
6	A	UPRIGHT	0 KN	0°	0°
7	B	UPRIGHT	8 KN	0°	0°
8	C	25°	8 KN	6°	6°

Thus, photo set C is representative of tacking conditions upwind while photo set B would be for downwind conditions. Photo set A is for comparison showing the effect of the free wave surface (compare set A to B). Examination reveals that during tacks, flow angularity near 20° is not uncommon and some small regions of 30°+ angularity can be identified.

Rudder Shape Optimization

Contact with B. Nelson during mid-December revealed crew concern that excessive speed was lost with rudder deflections over 4°. An explanation and "fix" were formulated based on the Navier-Stokes Code results computed earlier





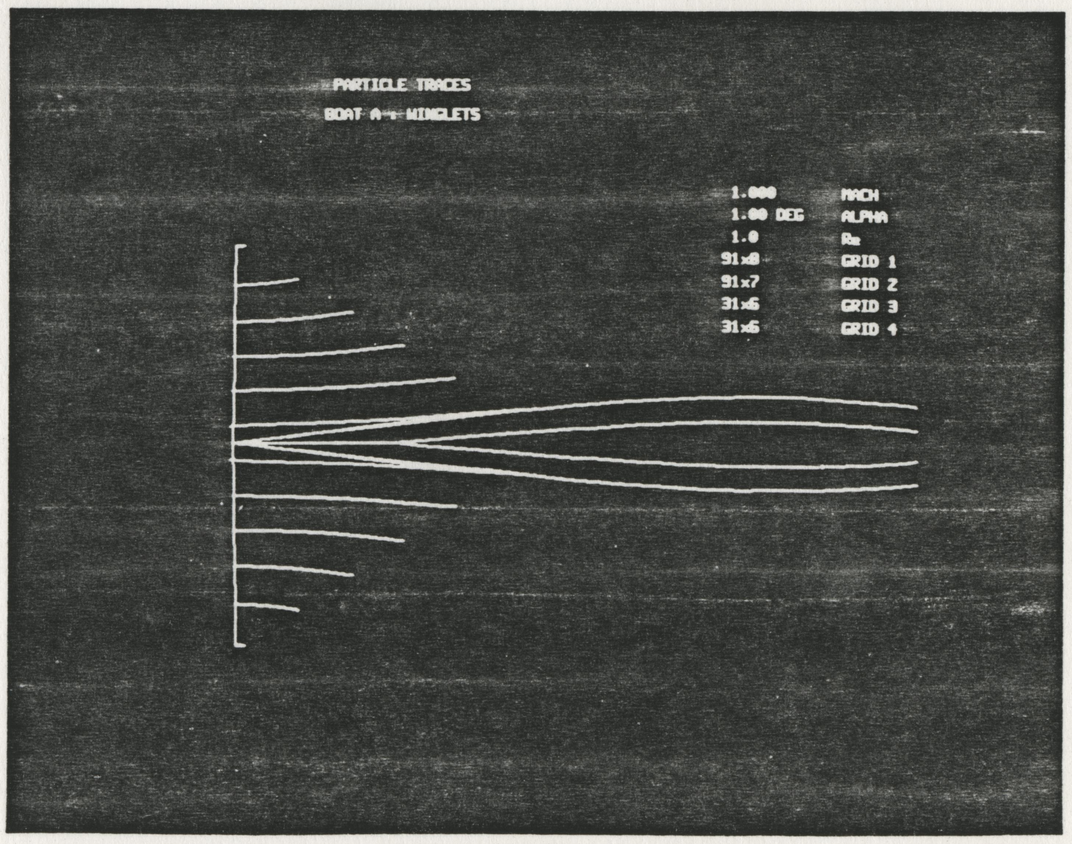
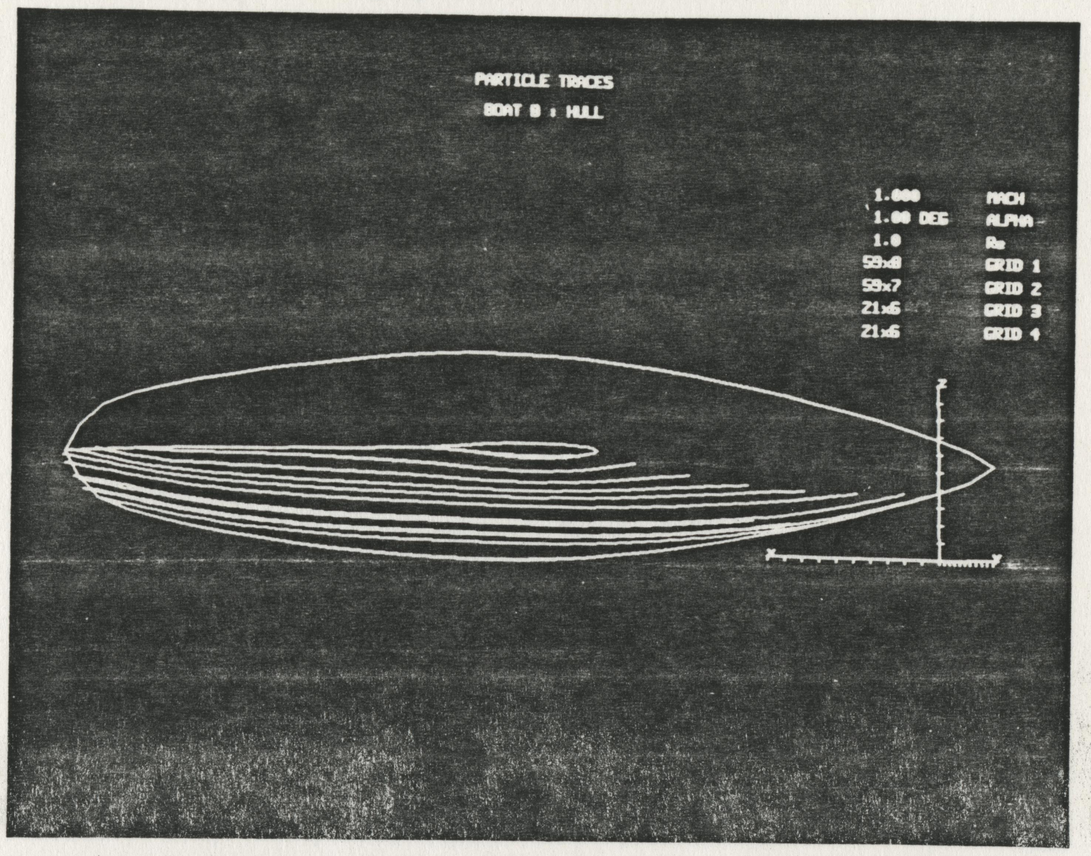
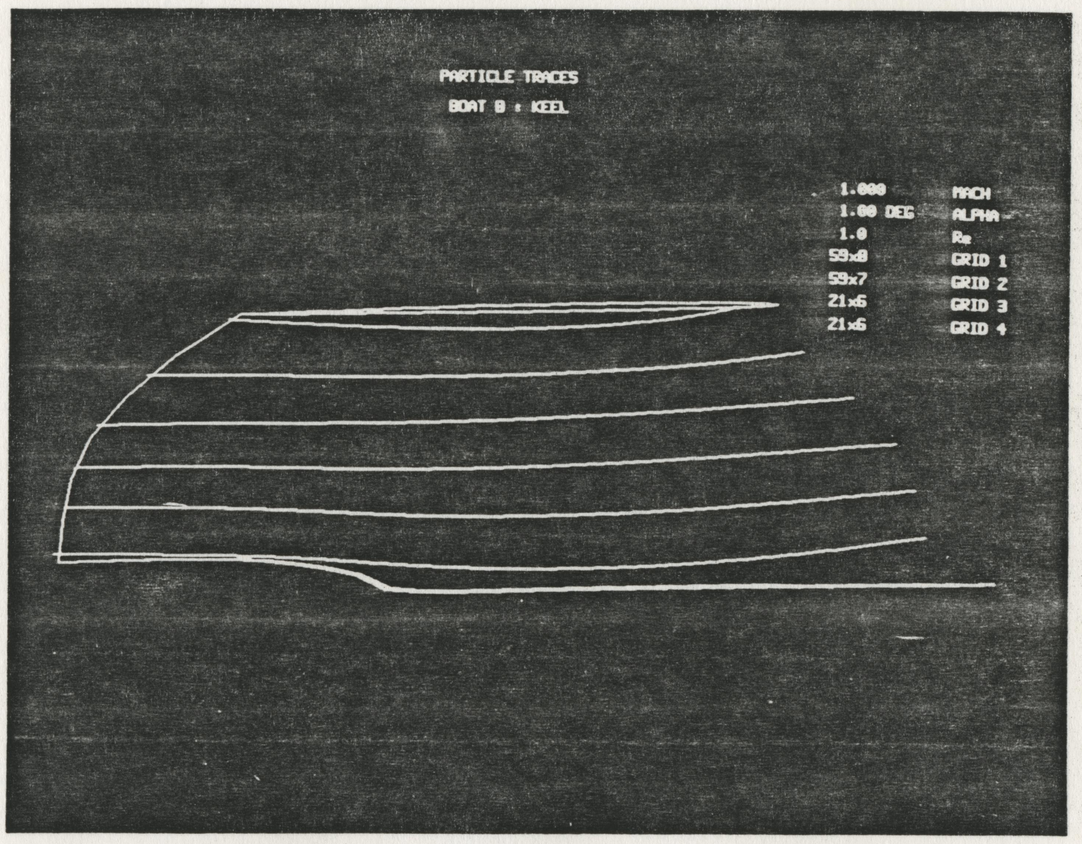


FIGURE 6

S-87 PARTICLE TRACES - UPRIGHT, $V = 0$, $YAW = 0°$, $\delta_T = 0°$





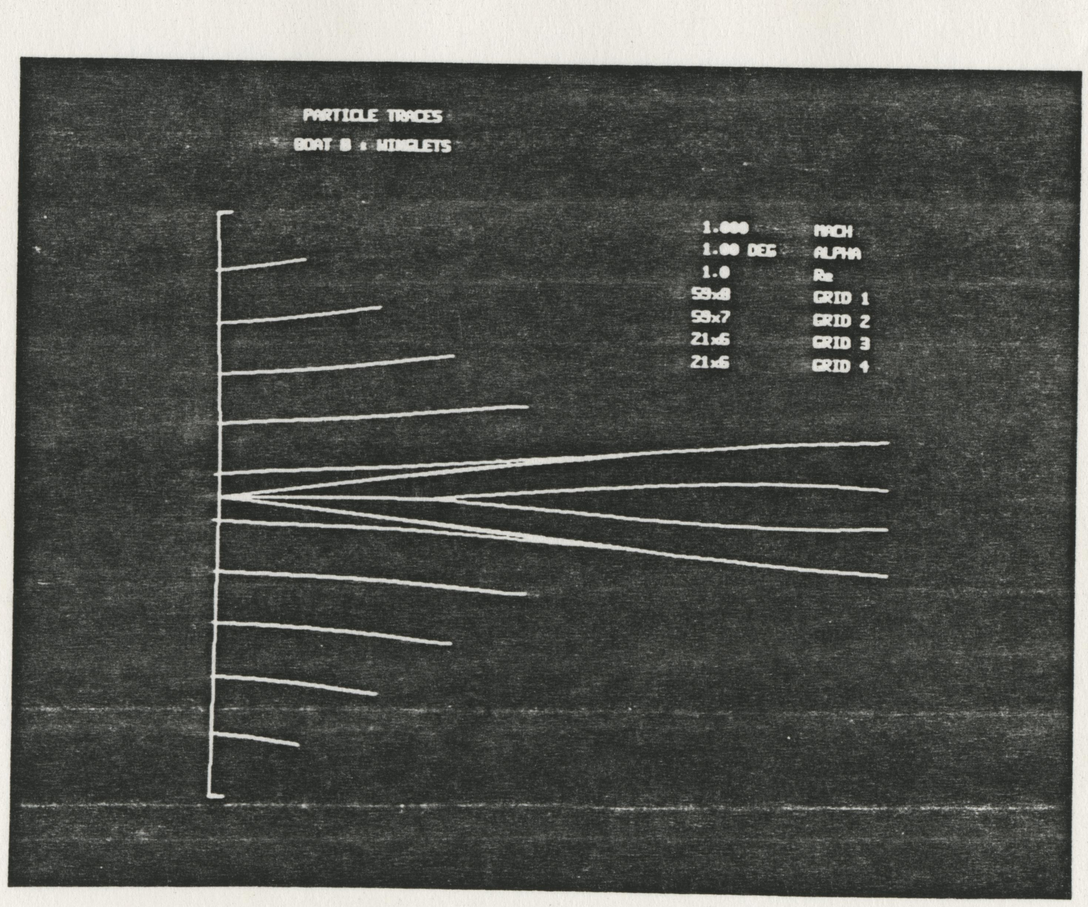
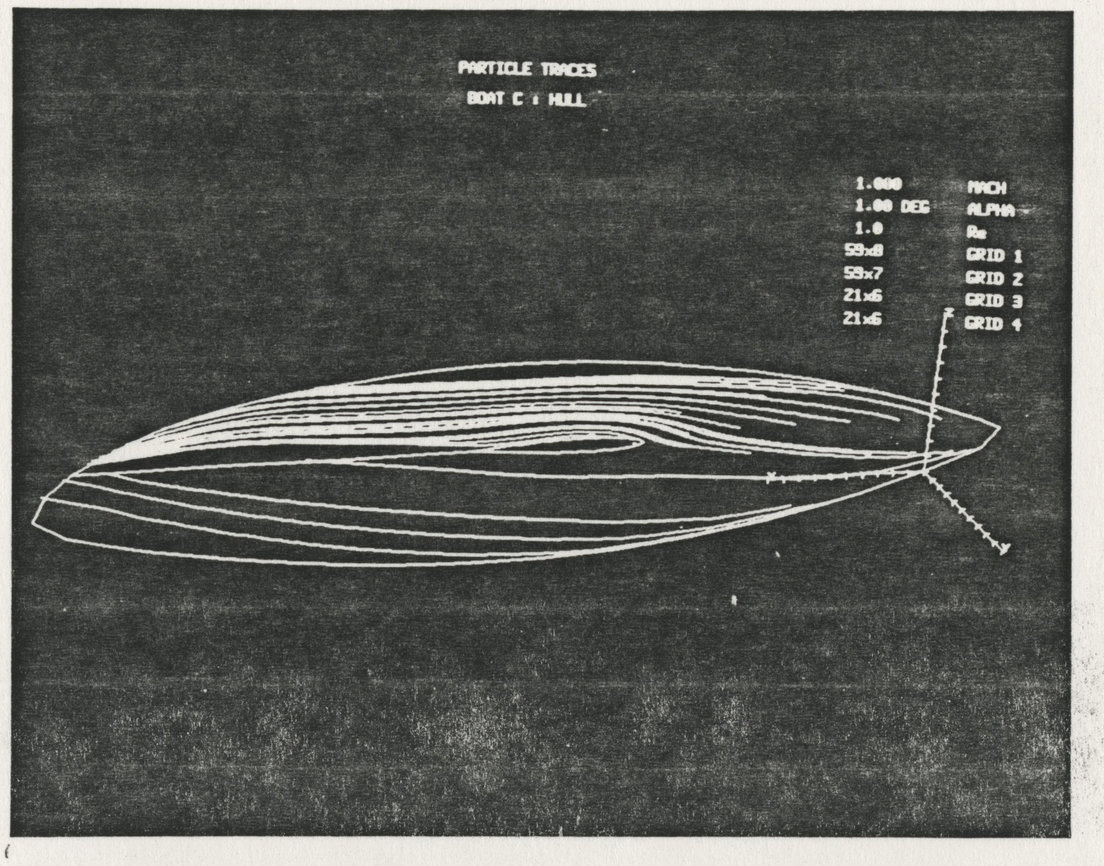
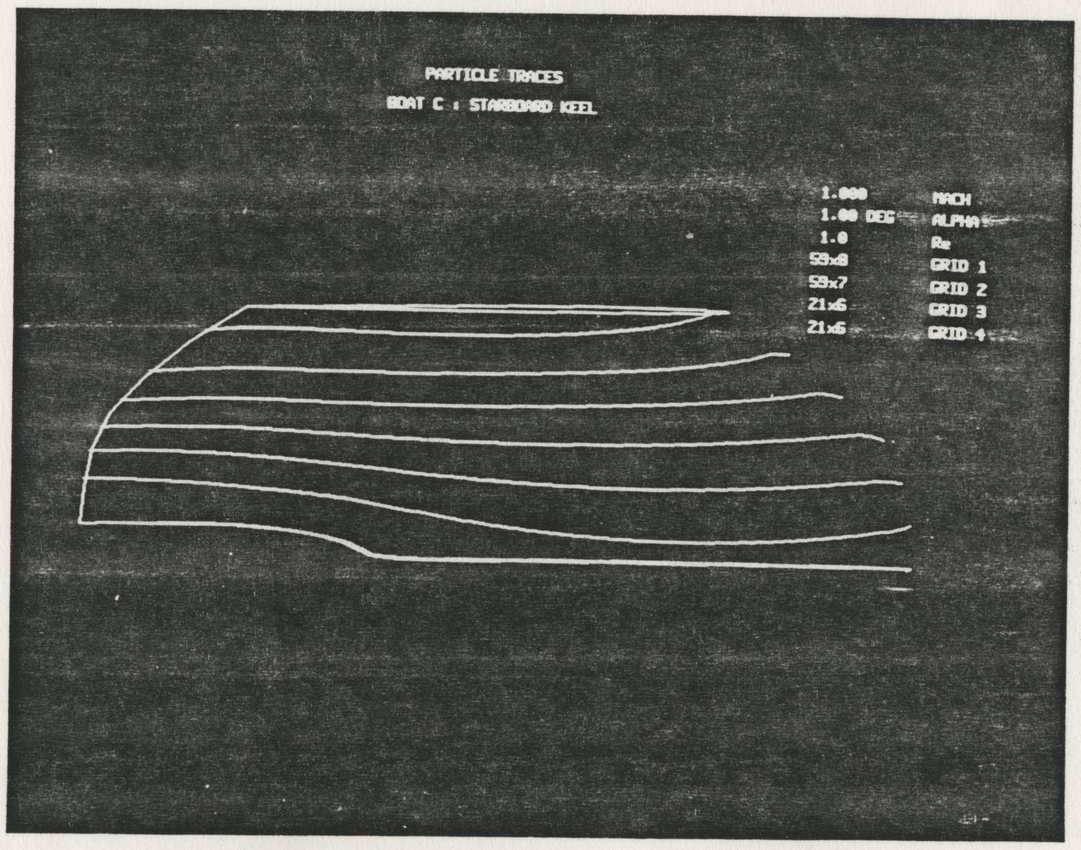


FIGURE 7

S-87 PARTICLE TRACES - UPRIGHT, $V = 8$ KN, $YAW = 0°$, $\delta_t = 0°$





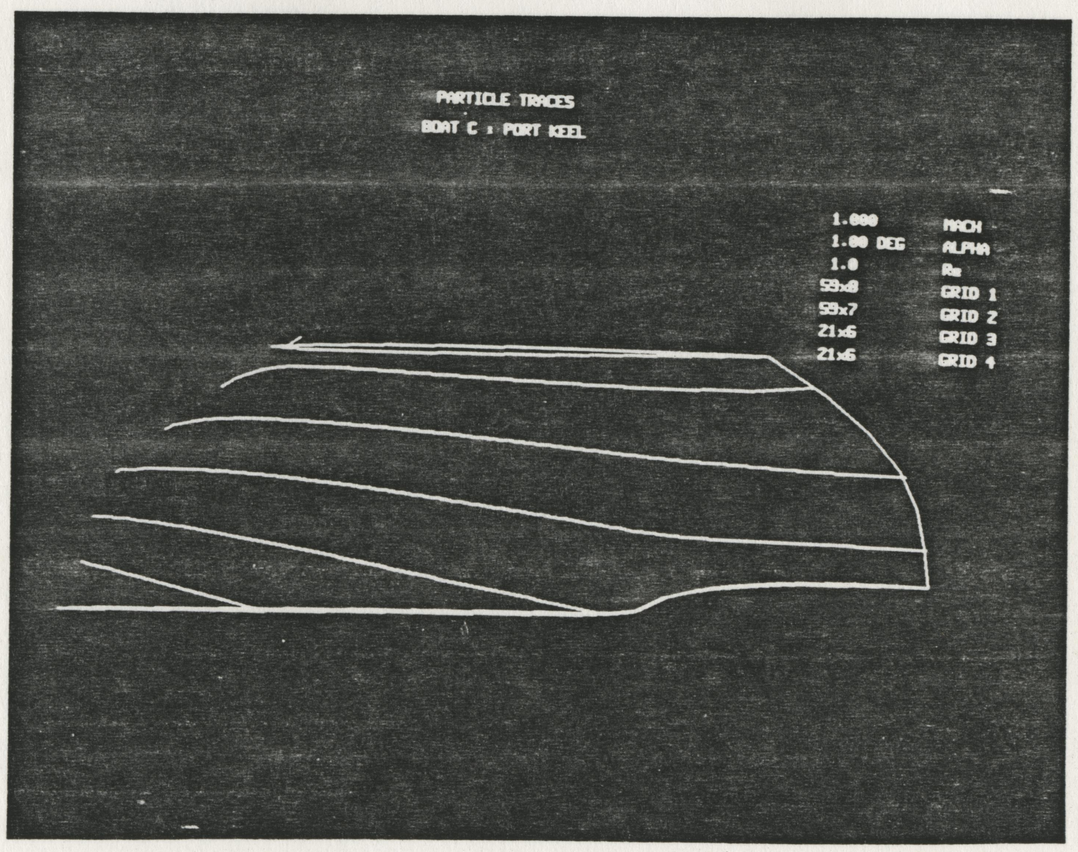


FIGURE 8

S-87 PARTICLE TRACES - $V = 8$ KN, HEEL $= 25°$, YAW $= 6°$, $\delta_T = 6°$

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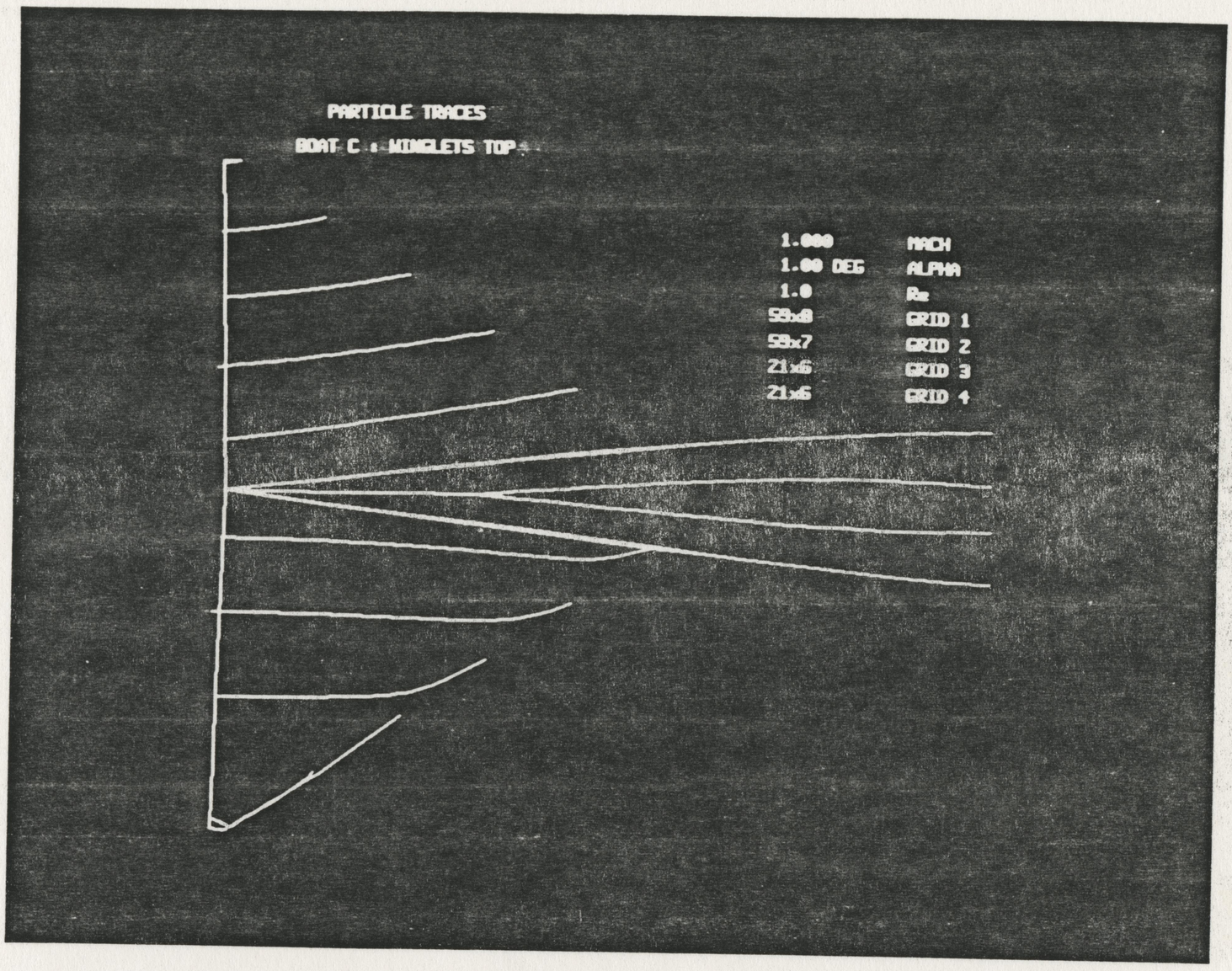


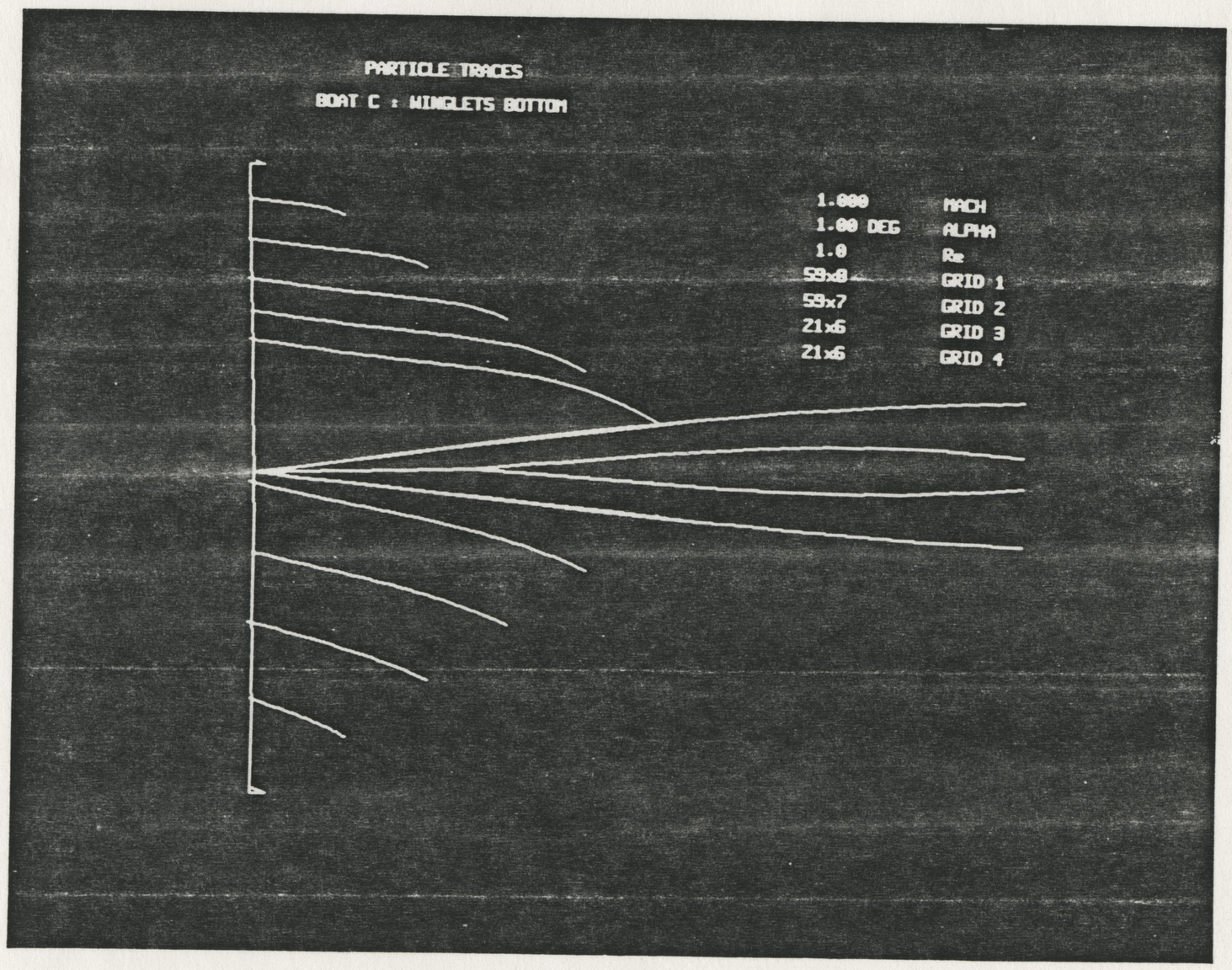


FIG. 8 (CONT.)

(see Fig. 8, SR #22) and full scale flow visualization (see Hopkin's memo ... 16 April '86).

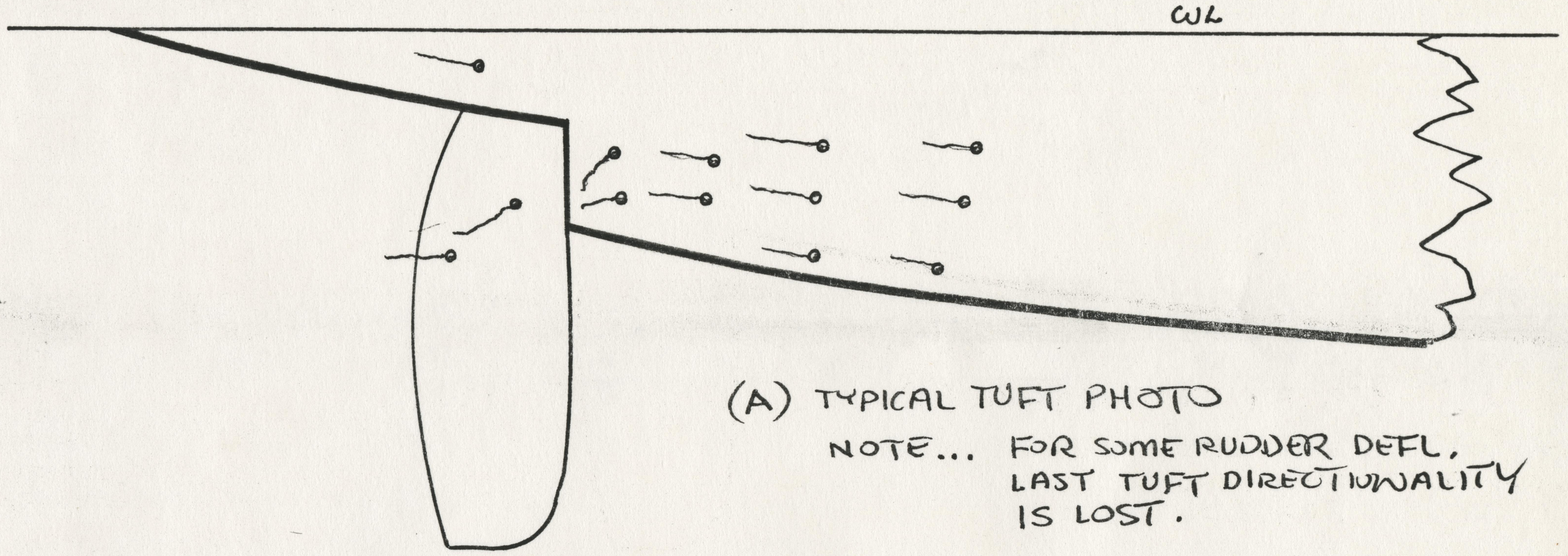
Typical tuft photos are summarized in Figure 9-A. Note that the afterbody of S-87 now resembles the Hull Model 6 diagram in Figure 8 of Status Report #22. It is suspected that a small (about 1 foot) flow separation patch exists at all conditions in the cove region of the skeg. This patch extends over the upper rudder surface and closes downstream of the rudder trailing edge as sketched in Figure 9-B. Pressure spikes at the rudder-skeg juncture and aggravated adverse gradients induced by rudder deflections greater than 4° probably combine to enlarge the separation bubble causing the last tuft on the rudder to break away. This problem might be mitigated by removing rudder surface area behind the skeg region and adding it on to the tip where clean flow can be expected. This should have a double benefit. First, less area is present to aggravate the skeg cove separation patch and so the separation region under deflection should be reduced with lower drag expected, and second, higher efficiency of the larger span rudder will reduce the deflection angle required for a given turning moment.

Miscellaneous

It was learned during the particle trace project that Cray is providing help to foreign syndicates too. Additional details are not available at this time. A brief paper at the end of this report (CALTECH Egineering Magazine) provides more details on Francis Clauser's novel concepts. Recent newspaper articles of interest are also included. Dicussions with F. Dvorak (Analytical Methods Inc.) reveal thet the Kookabura syndicate is still actively involved in analysis and modifications.

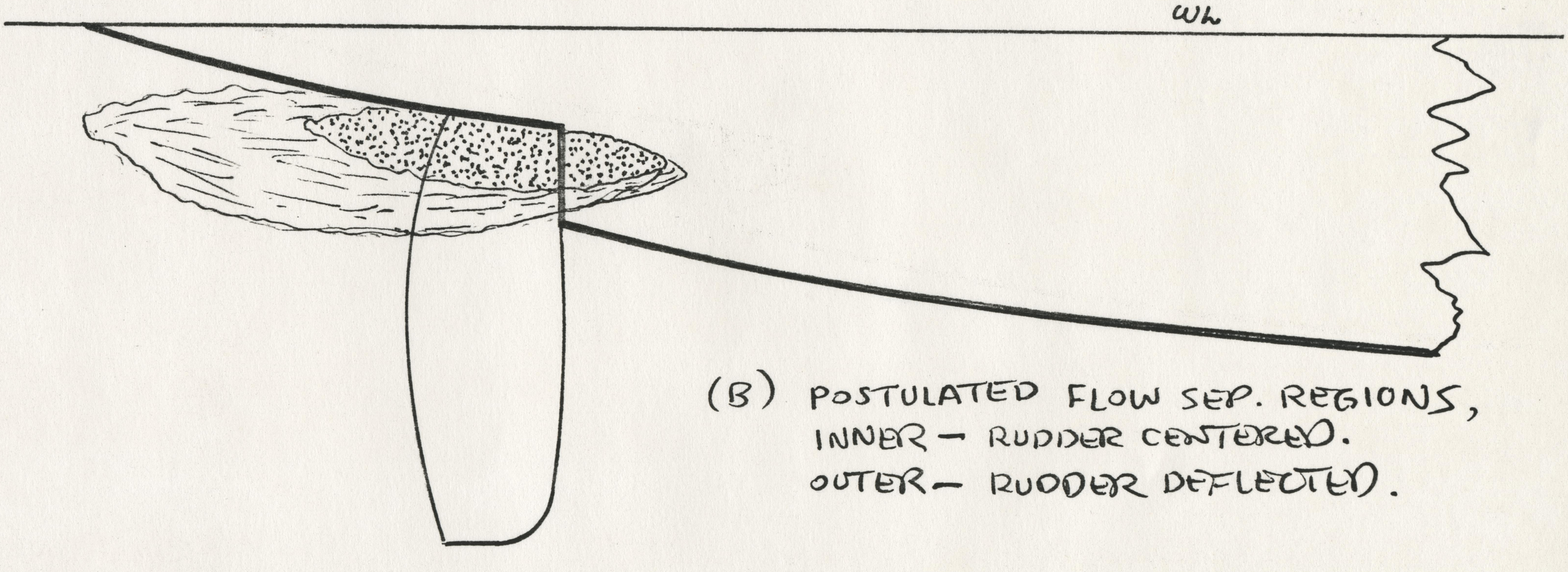
FIGURE 9

RUDDER/AFTERBODY FLOW SEPARATION & RUDDER MOD.

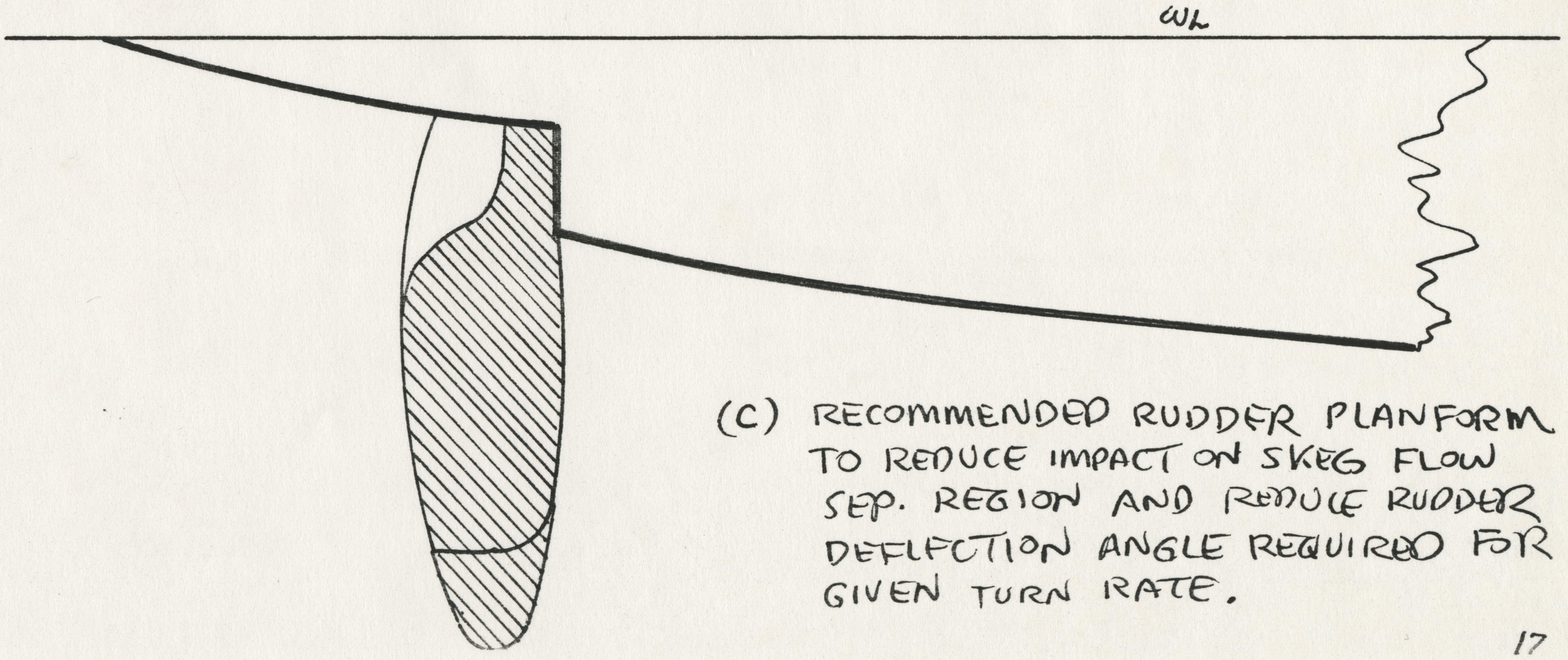


(A) TYPICAL TUFT PHOTO

NOTE... FOR SOME RUDDER DEFL. LAST TUFT DIRECTIONALITY IS LOST.



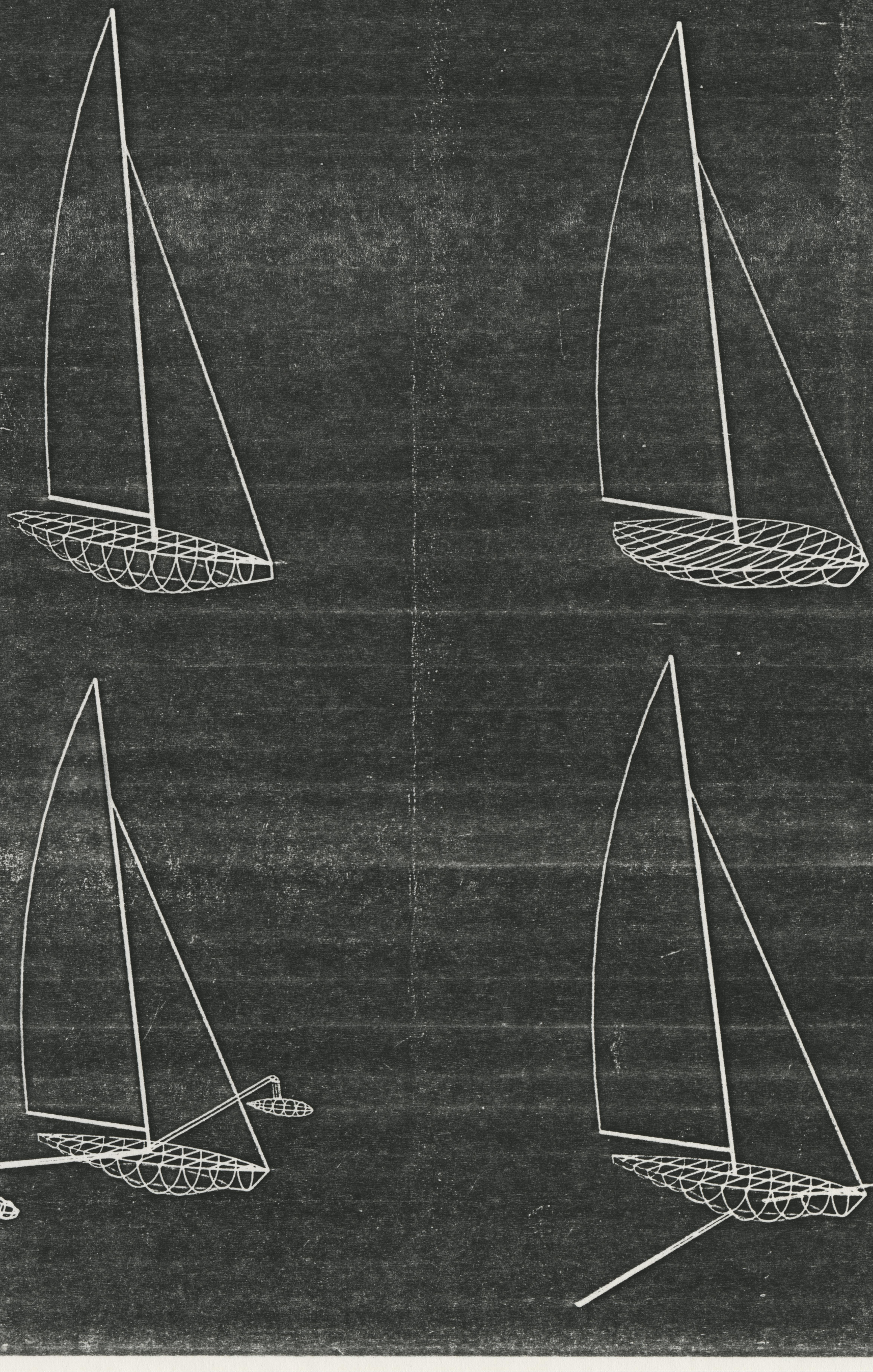
(B) POSTULATED FLOW SEP. REGIONS,
INNER – RUDDER CENTERED.
OUTER – RUDDER DEFLECTED.

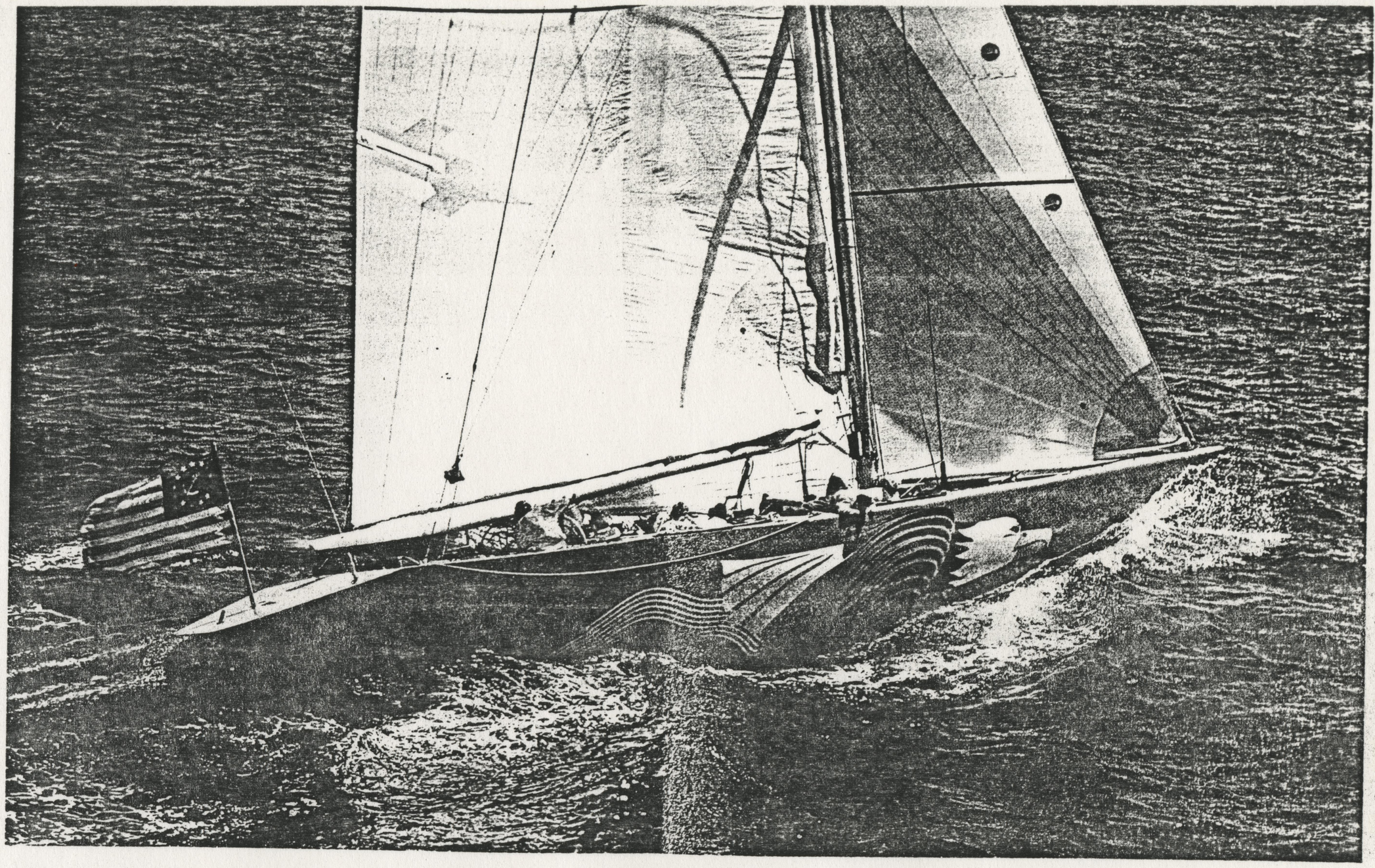


(C) RECOMMENDED RUDDER PLANFORM TO REDUCE IMPACT ON SKEG FLOW SEP. REGION AND REDUCE RUDDER DEFLECTION ANGLE REQUIRED FOR GIVEN TURN RATE.

November 1986 California Institute of Technology

ENGINEERING & SCIENCE





The Boat That Almost Was

by Francis H. Clauser

Above: Eagle, *currently competing among the America's Cup challengers in the waters off Perth, was built by the Newport Harbor Yacht Club as their conventional 12-meter yacht.*

IN THE LATE SUMMER OF 1984 Chuck Newton approached me at lunch in the Athenaeum and asked if I would be willing to meet a man who wanted to talk to me about the America's Cup. That man turned out to be George Tooby, BS '35 — almost a classmate of mine — who proposed that I sign on with the Newport Harbor Yacht Club to bring aeronautical science into the design of its America's Cup challenger.

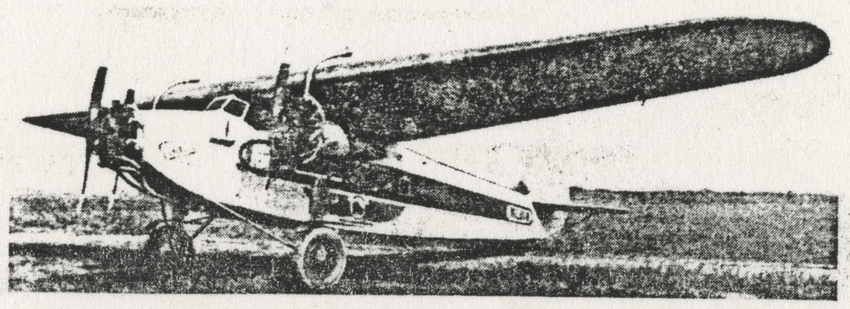
I had never designed boats before, but my interest had already been piqued by the 1983 America's Cup race of 12-meter yachts. Before that race a number of my sailor friends had assured me that the United States was sure to win the cup again, as it had consistently for the past 132 years. These friends said that we had the finest crews in the world and that furthermore, the art of 12-meter yacht design had reached a pinnacle of perfection in this country. When the Australians won with their winged keel, the question naturally arose in my mind: Is the design of these yachts as advanced as I had been led to believe? The Australian keel wasn't that radical. If this was really supposed to be the state of high technology in yacht design, I thought it might be interesting to see how it looked from an insider's point of view.

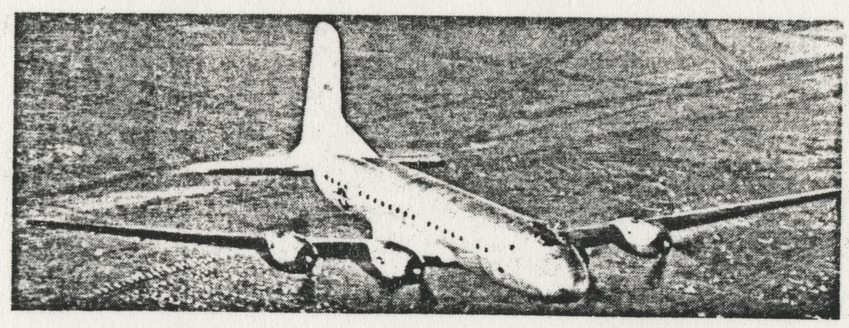
So I began to study the various America's Cup contenders over the years, particularly the 12-meter yachts that had been racing since the competition was resumed in 1958 following the hiatus of World War II. I was immediately struck by a parallel with my early experience in aeronautics. In the 1920s airplanes were designed mostly by intuition. When scientific knowledge was applied to air-

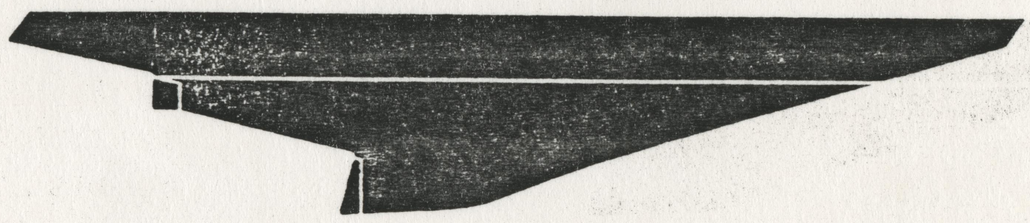
plane design in the 1930s, earlier intuition frequently turned out to have been grossly wrong. For example, pilots often complained that the early airplanes had problems with stability and control. Science in the 1930s showed that the tail surfaces (elevators and rudders) had been much too small.

As I looked at the America's Cup yachts, my immediate reaction was that they must have had stability and control problems with their very small rudders located in the wake of both the hull and the keel. And it turned out that indeed a previous America's Cup skipper, Bill Ficker of *Intrepid* in 1970, claimed that "the present breed of 12 meters is very difficult to steer and keep 'in the groove.' *Intrepid's* biggest difficulties were experienced when tacking in light weather. It was not easy at all to get her moving again on the wind and to regain the speed of the previous tack." Other helmsmen said the yachts needed constant control to keep from yawing in moderate weather. Comments from the designers of these yachts make it clear that they didn't know how to solve this serious problem. It was at this point that I concluded that the design of 12-meter yachts probably had not reached the peak of scientific perfection that everyone seemed to think.

Ever since a group of New York millionaires first challenged the British yacht clubs in 1851, the America's Cup has been a race not between nations but between yacht clubs. It was set up as a series of match races every three years between a single defender and a single challenger. The defenders and the challengers would hold their own series of eliminations to choose one boat to represent them. But there are different rules for each side. The winner of the challengers' elimination races would represent its home yacht club, while the defender must sail under the colors of the yacht club that holds the cup — until 1983 the New York Yacht Club. This had been a galling experience for all the other American yacht clubs, particularly since the







The Fokker Trimotor 10-passenger transport (top) was typical of the intuitive designs of the 1920s. The Douglas Globemaster (bottom) was designed during World War II. It typifies the changes brought about by the revolution in aeronautical science during the 30s and 40s. The author designed the wing and tail sections on this airplane, and he holds the patents on the ailerons and flaps.

New York Yacht Club had grown almost insolent about its superior position in the race. Australia's winning of the cup made it possible for other American yacht clubs to dream of winning the cup. At present a total of 13 yachts are vying for the opportunity to challenge Australia in the waters off Perth — one each from England, Canada, and New Zealand, two each from France and Italy, and six from the United States.

When George Tooby decided that it would be appropriate for the Newport Harbor Yacht Club to enter a challenger in the next America's Cup race, he formed the money-raising *Eagle* syndicate and hired Johan Valentijn as Newport Harbor's chief designer. Valentijn, a young, Dutch naval architect, had designed *Liberty*, the unsuccessful American defender that had lost to the Australians in the 1983 cup race, as well as an earlier contender, *Magic*, for the New York Yacht Club. In the fall of 1984 I (as chief scientist) joined forces with Valentijn to build one-third size models of *Liberty* and *Magic* (the latter having been purchased by the *Eagle* syndicate) — to be tested in the large towing tank

Figure 1: The 12-meter yacht Intrepid *was typical of the America's Cup contenders of the l960s and 70s. These yachts experienced the same type of stability and control problems that airplanes of the 1920s did.*

in Escondido. This was to establish a database of known characteristics of these two yachts so that we could compare future models with these two well-known quantities.

The *Eagle* syndicate had laid out a program to build two yachts, for which their fund raising goal was $8-10 million. The first of these was to be a conventional yacht, incorporating whatever improvements could be made on *Magic* and *Liberty*. The second was to be as radical and innovative as we were capable of making it. Valentijn and I agreed that he would spend almost all of his time on the conventional yacht, and I would devote most of my effort to the more radical second yacht.

Early in my work with Valentijn I was struck by the great difference in our perceptions of what constitutes a good streamlined shape. Both theory and experiment long ago led aerodynamicists to conclude that the typical airfoil or airship shape shown in Figure 2 has the least resistance. Also shown in the figure is the typical shape associated with boats. Any tendency to see a similarity between them is dispelled when one realizes that in one case the pointed end is forward and in the other it is backward. When we tested the model of *Magic*, I persuaded Valentijn to tow it backward as well as forward. The results, shown in Figure 3, were a shocking revelation to Valentijn. I kidded him by saying the reason we lost the cup was that we were sailing the wrong way around.

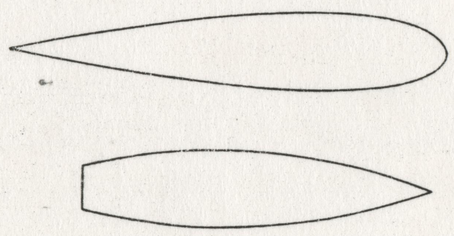


Figure 2: The airfoil or airship (top) is the aerodynamicist's concept of a well-streamlined shape. In contrast, the typical boat shape (bottom) is designed to travel the other way around.

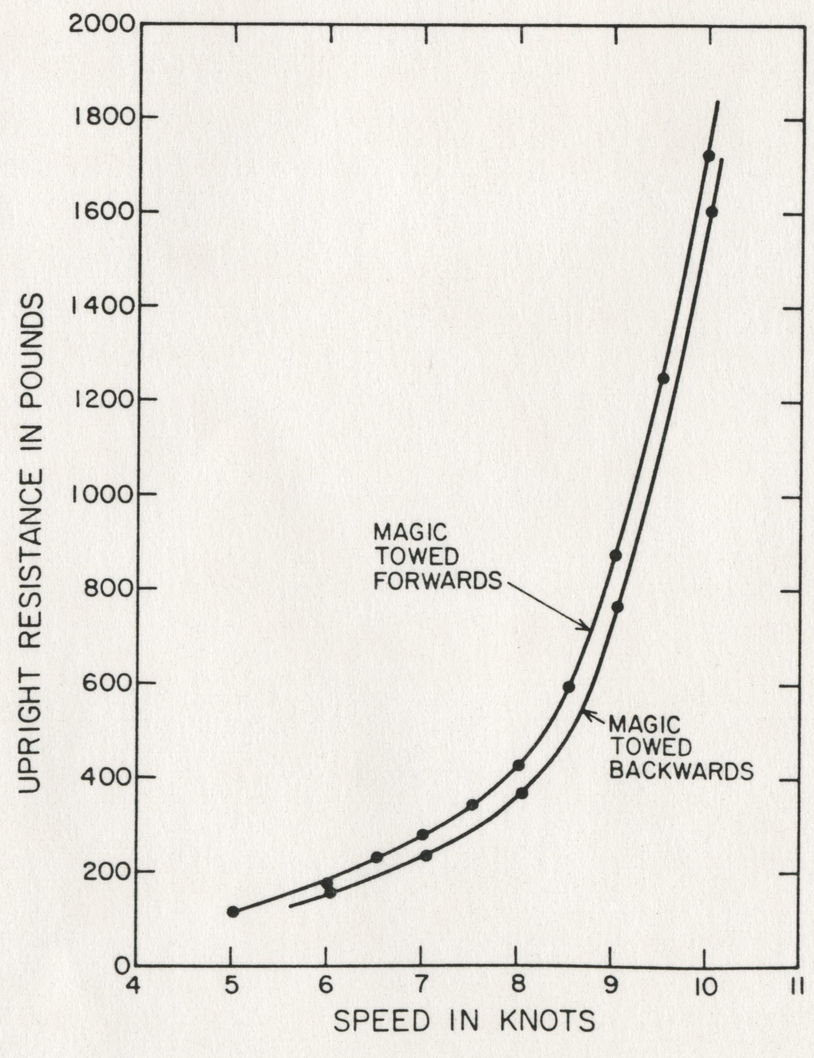


Figure 3: Towing tank tests on Magic's *hull (without keel and rudder) showed that it had less resistance when towed backwards rather than forwards.*

Unfortunately, his conventional boat ended up still sailing the wrong way around in my opinion.

What *is* a 12-meter yacht? For an America's Cup designer, this always looms as a key question, since it defines the limits to his innovation and creativity. As originally laid down, the rules were intended to be sharply and clearly defined. As the rules are written, two quite different lengths are involved. One of these lengths, LWL, is the length on the waterline from the bow to the stern (or to the rudder post if this is farther aft), when the yacht is afloat without a crew. This length has nothing to do with the 12-meter rating but serves to limit the yacht's displacement and draft. The displacement must not be less than the volume given by

$$\left(\frac{\text{LWL} + 0.75}{5}\right)^3$$

all in meters. Otherwise the yacht is penalized in its rating by double the deficiency. The draft must not exceed 16 percent of the LWL plus 0.5 meters. Here the penalty is three times the excess. The second length, L, is directly involved in the 12-meter rating. It enters the all-important formula

$$\text{Rated length} = 12 \text{ meters} = \frac{\text{L} + 2\text{d} - \text{F} + \sqrt{\text{S}}}{2.37}$$

Here d is the girth difference, F is the freeboard, and S is the sail area, all in meters. (I do not know the origin of the factor 2.37; without it, these would be 28.44-meter yachts.)

The definition of L is a study in complexity. Imagine a plane 0.18 meters (7 in.) above the waterplane. This defines new bow and stern points, and the first part of L is the distance between these points. The second is a girth measurement from a point on one side of the bow 0.6 meters above the original waterline, around and under the bow, and up to the corresponding point on the other side. From this is subtracted 1.2 meters, and the result is multiplied by 1.5 to give the second part of L. The third is a corresponding measurement at the stern, except that here the multiplying factor is 0.33. The forward girth measurement (when multiplied by 1.5) has a minimum value of 0.54 meters, and if the actual value is less than this, the minimum value must be used. The aft girth measurement similarly has a minimum value of 0.4 meters. In practice most yachts have measurements close to these minimums.

The girth difference measurement, d in the formula, is taken at the keel. It's the difference in length between a chain following along the hull from a point "a" above the waterline down along the keel to a point 1.5 meters below the waterline, and the length of a chain stretched tight between these same two points (Figure 4). The freeboard, F, is an average distance from the deck to the water plane. Since it is subtracted in the formula, it encourages the designer to build high decks. There is a maximum value of 1.21 meters permitted for F, however, and most designers use this maximum value. When L, d, and F have been determined, the sail area must then be chosen so as to give the yacht a 12-meter rating, that is, to fit the formula. If we add the requirements that the beam must be at least 3.6 meters, the height of the mast must not exceed 25 meters, and the height of the jib must not exceed 18.75 meters, we have the basic answer to the question: What is a 12-meter yacht?

There are other subtle but important restrictions, however. One is that there be no hollows in the hull between the waterline and the deckline except in the region near the rudder — a rule that excludes catamarans and other multi-hull craft. A second restriction states that below 1.7 meters under the water plane, no width can exceed 3.6 meters. This was adopted to limit the span of the wings on Australian-type keels.

A third restriction requires construction in accordance with the "scantlings" established by Lloyd's Register of Shipping. These are an archaic set of construction specifications that almost completely rule out significant structural innovations. In effect they require that, regardless of a 12-meter yacht's total displacement, the hull minus its keel must weigh approximately 17,000 lbs.

And finally, for 12 meters competing in the America's Cup races, there is an additional rule that requires the length of the yacht at a plane 50 mm (2 in.) above the water plane to be at least 44 ft. long.

Given all the variations that are possible, why is it that almost all 12-meter yachts weigh close to 57,000 lbs. and have an overall length of 66 ft. and a waterline length of 46 ft.? To figure out why, we must first explore some of the fundamental facts of hydrodynamics so that we can understand why a good yacht goes fast. When a ship travels at low speeds, the principal resistance it encounters is from the skin friction of the water as it moves along the wetted surface and from the eddies off the stern that are created when the streamlines fail to close in behind the ship. These resistances increase roughly as the square of the ship's speed.

At higher speeds wave resistance also comes strongly into play. At first many small waves form; as the speed increases, the waves increase in both length and height, and the pattern becomes less complex. Finally there comes a speed for which there is simply a wave crest at the bow, a trough along the midship and a final crest at the stern. Spreading out from this wave pattern at the ship itself is a great train of waves extending out in a chevron to the rear. At higher speeds this wave train carries off large amounts of energy, resulting in a large increase in resistance of the ship. This wave resistance can become so great that it overshadows the frictional resistance (Figure 5).

It was an Englishman, William Froude, who in the last century showed that the wave pattern of a ship is governed by the dimensionless ratio $V/\sqrt{gL}$, that is, velocity divided by the square root of the acceleration of gravity times length. This important result enables us to predict the wave resistance of large ships from tests on smaller scale models. Another Englishman, Osborne Reynolds, also working in the last century, showed that fluid frictional resistance is governed by the dimensionless ratio VL/ν, that is, velocity times length divided by kinematic viscosity. Using

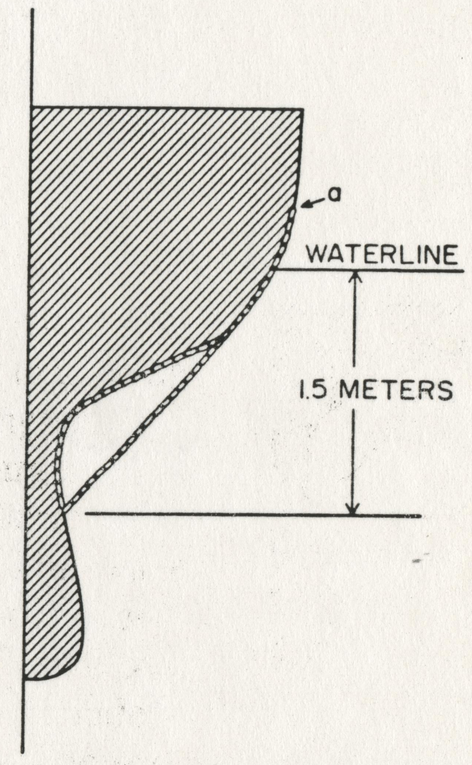


Figure 4: The chain midgirth measurement is the difference in length between a chain running from point "a" along the hull to a point 1.5 meters below the waterline and a chain stretched tight between those points.

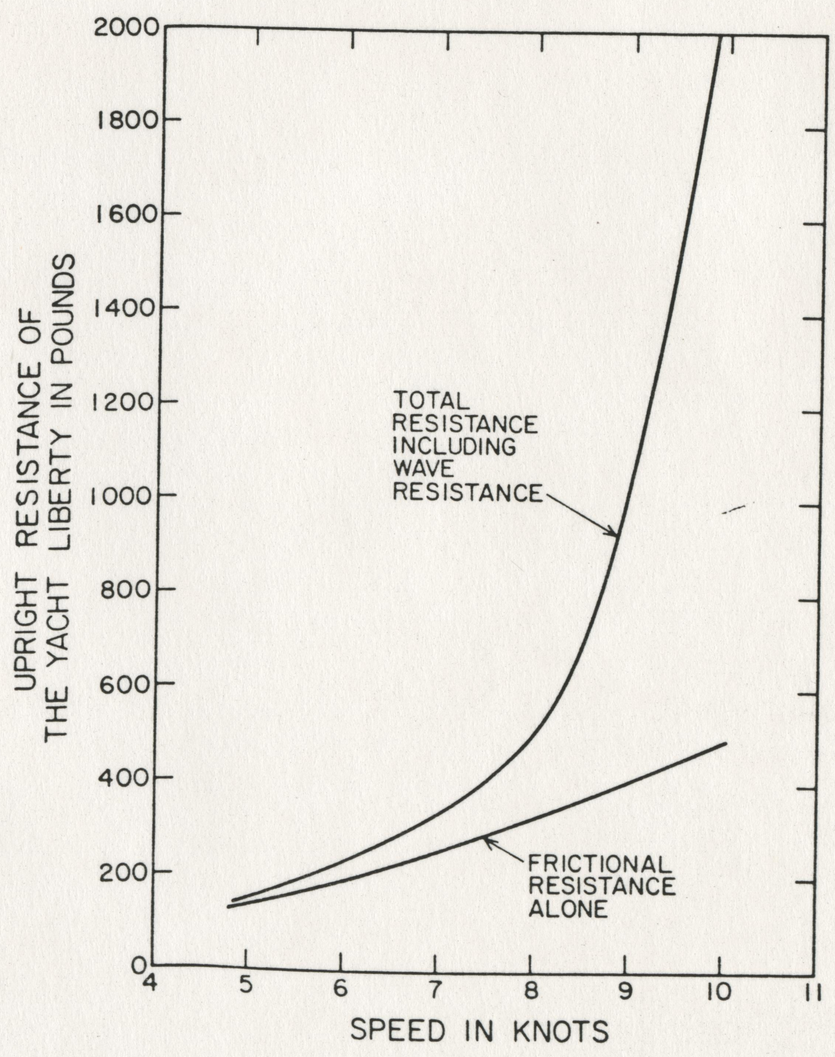


Figure 5 shows results from towing tank tests on a one-third-scale model of the 12-meter yacht Liberty. *Note how wave formation causes the total resistance to rise rapidly at higher speeds.*

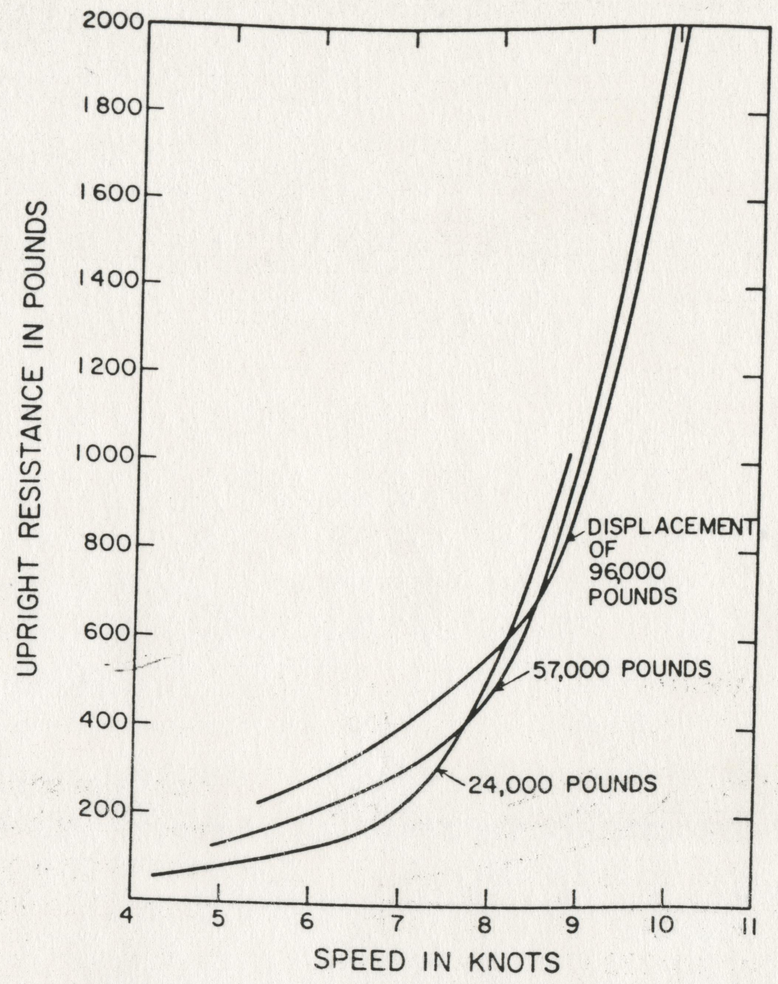


Figure 6: Towing tank data have been scaled up to show the effect of size on the resistance of typical 12-meter yachts.

this result we can scale up the fluid friction of a model to that of the full-sized ship.

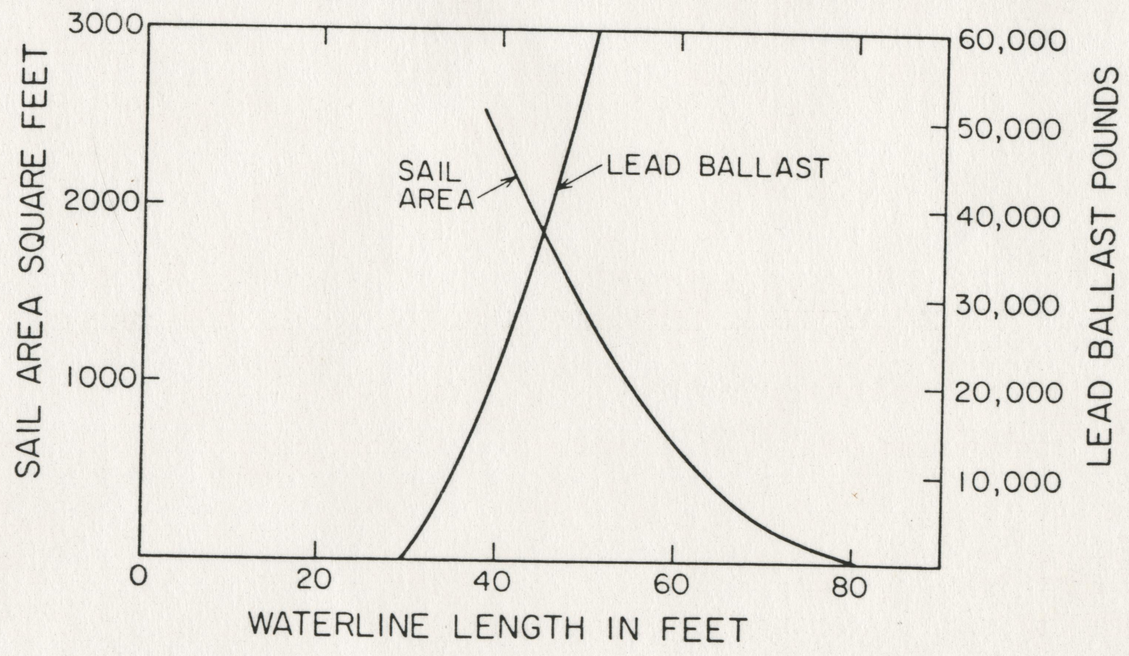
The first question that faces the 12-meter designer is: How heavy should the boat be? If *Liberty* were to be built in three sizes, 24,000, 57,000, and 96,000 lbs., with waterline lengths of 33.6, 45.6 and 54.8 ft. respectively, how would their resistances compare? Using our towing tank data and the scaling laws described above, we can calculate the resistance curves for these three yachts (Figure 6). At low speeds the lightest boat, being smaller, naturally has the least resistance. But at higher speeds the picture changes. For the longer boats the rapid rise in wave resistance does not begin until proportionally higher speeds are reached. Consequently their total resistance is lower at high speeds, where they enjoy a superiority that progressively gets better with length.

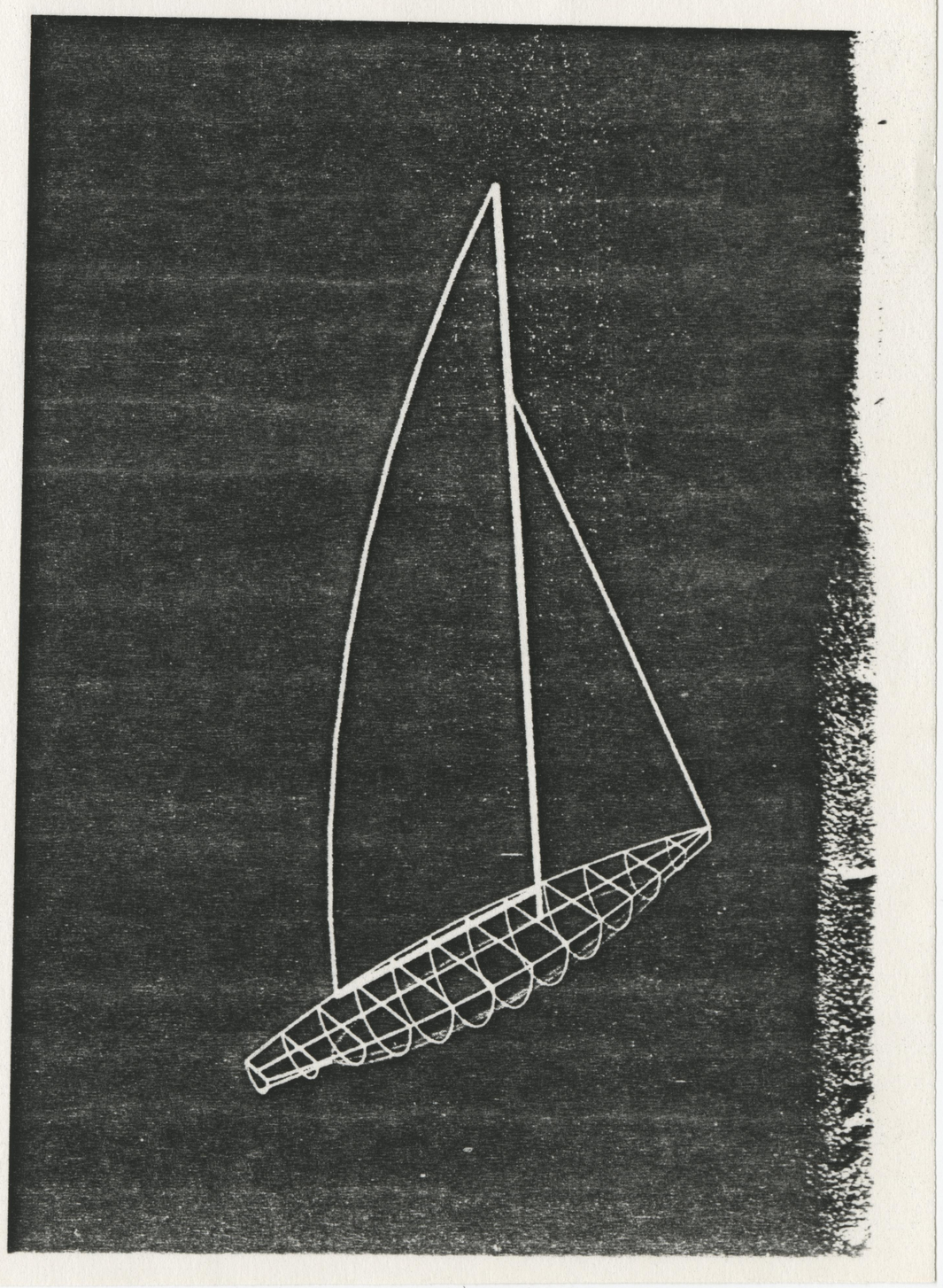
In Perth the winds are expected to be strong, and in most of the races the yachts will be pushed right up into this high speed range. So it would seem that designers of 1986-87 America's Cup yachts should strive for the greatest length they can get. And indeed, the first models that Valentijn and I built after our benchmark tests were larger, heavier versions of *Liberty*.

But if we look back at the 12-meter rules, we see that as the size of the hull (length, girth, and freeboard) goes up, the area of the sail must come down. For a typically proportioned hull, this leads to the relationship of sail area to length shown in Figure 7. Clearly, under the 12-meter rule the 96,000-lb. yacht with its 54.8 ft. of length would be required to have a much smaller sail. This result seems to indicate that, instead of a longer, larger hull to gain the advantage of high speed, the designer should be aiming for the smallest boat possible to have the greatest amount of sail area.

The hull must, however, be constructed in accordance with Lloyd's scantlings, which specify that the hull structure (minus keel) shall weigh no less than approximately 17,000 lbs. regardless of the displacement of the yacht. The 57,000-lb. yacht will thus be able to have 40,000 lbs. of lead in her keel, while the 24,000-lb. boat can have only 7,000 lbs. In a 12 meter the principal factor that enables the yacht to stand up in heavy winds is the enormous amount of lead ballast down in the

Figure 7: Under 12-meter rules, as the hull of a conventional yacht increases in size, the sail area must be decreased. The lead ballast permitted for upright stability goes up with length, leading to a design dilemma.





keel. In fact, all 12 meters have keels much larger than hydrodynamics alone would dictate, simply to house the lead. Our tank tests showed that the great advantage of the Australian winged keel lay not in the hydrodynamic properties of the wings themselves, but in the fact that the shape of the keel and the wings permitted the center of gravity of the lead to be significantly lower.

Figure 7 also shows the amount of lead ballast permitted in 12-meter yachts of various sizes. This now puts the designer's task in sharp focus. If he designs a small hull, it can have large sails, but even light winds will blow the boat over because of its small righting moment. In contrast, a large hull will have a very large upright stability, but it will be permitted to use only small sails. These opposing constraints dictate that most 12-meter yachts end up with waterline lengths of 43 to 48 ft. and with gross weights of 50,000 to 65,000 lbs.

It was in the fall of 1985 that the design of Valentijn's conventional yacht *Eagle*, was completed, and my ideas about a radically new boat began to crystallize. In international offshore racing a new class of fast ultra-light boats has been sweeping the field. How do they do it? There are several ways of gaining upright stability other than by placing lead in the keel, and ultra-lights do it by using broad beams with shallow-draft hulls. In spite of the success of this idea, it doesn't seem to have occurred to 12-meter designers to explore this avenue.

What would a 12 meter look like as an ultra-light? The conventional 12 meter with a gross weight of 57,000 lbs. has a righting moment of about 160,000 ft.-lbs. when it is heeled 30°. The keel with its 40,000 lbs. of lead provides about 145,000 ft.-lbs. of this. The remainder is made up of an unstable moment of about 38,000 ft.-lbs. from the hull, mast, rigging, and sails, and a stable hydrostatic moment of about 53,000 ft.-lbs. provided by a waterline beam of approximately 11 ft.

An ultra-light with a gross weight of 24,000 lbs. (less than half that of the conventional 12 meter) would have a length of 33.6 ft. compared to the 45.6 ft. of the conventional hull. To comply with the America's Cup rule, it would have to have a length of 44 ft. at a height 2 inches above the waterline. So it would have long, nearly horizontal overhangs both fore and aft.

One purpose of designing an ultra-light is to be able to use much greater sail area. My calculations indicated that to be able to stand up in the wind, it would need 40 percent more righting moment, that is 160,000 × 1.40, or 224,000 ft.-lbs. when it heels 30°. Here the righting moment is to come from a broader beam, rather than from a heavy keel. This will require a waterline beam of 20 ft. rather than the conventional 11 ft. Being much lighter and broader of beam, the draft of the lightweight hull at 1.5 ft. will be much shallower than the usual 4.5 ft. Entering the dimensions of such an ultra-light hull into the 12-meter formula gives a sail area of approximately 2,450 sq. ft., which is much greater than the typical 1,750 sq. ft. for 12 meters. Referring back to Figure 6, we see that the lightweight hull has the advantage of significantly less resistance at low speeds, and the larger sail area would much more than make up for its greater resistance at higher speeds.

It has been found that lightweight, broad-beamed boats can readily get up and plane like a surfboard on the forward face of a wave. They frequently reach speeds of 14 to 18 knots. The reason for this is simple. For a planing hull the resistance, instead of rising sharply at high speeds as shown in earlier

continued on page 26

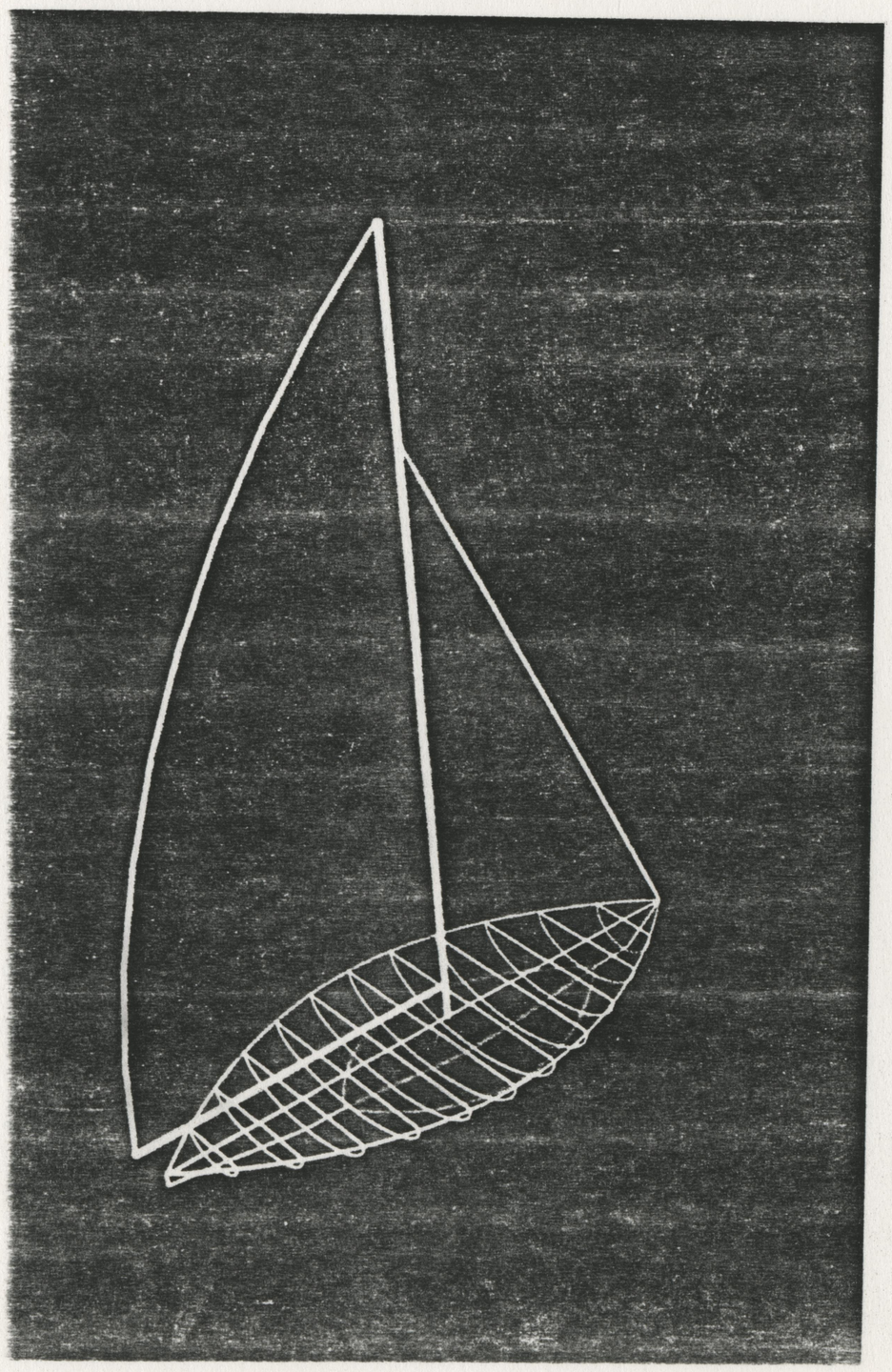
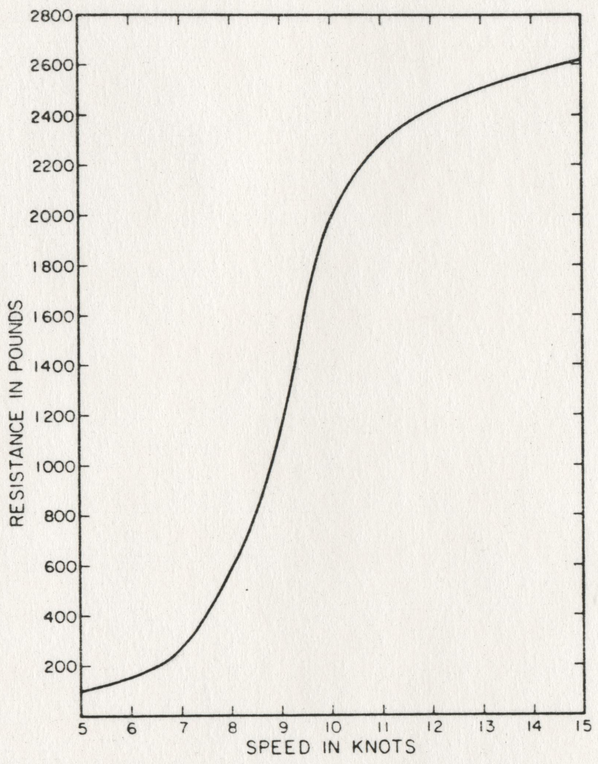


Figure 8 (far left) shows a conventional 12 meter in computer graphics created by Bob Bolender. Figure 9 (to its right) depicts a broad-beamed, lightweight hull, which is permitted to carry a much larger sail. It can plane like a surfboard.

America's Cup contenders in 1983, Liberty *(top) and* Australia II, *illustrate the running room that they require when both have mainsails and spinnakers out.*

Figure 10 indicates that the upright resistance of a planing hull (with a gross weight of 24,000 lbs.) levels off at high speeds. This will permit it to surf on larger waves.



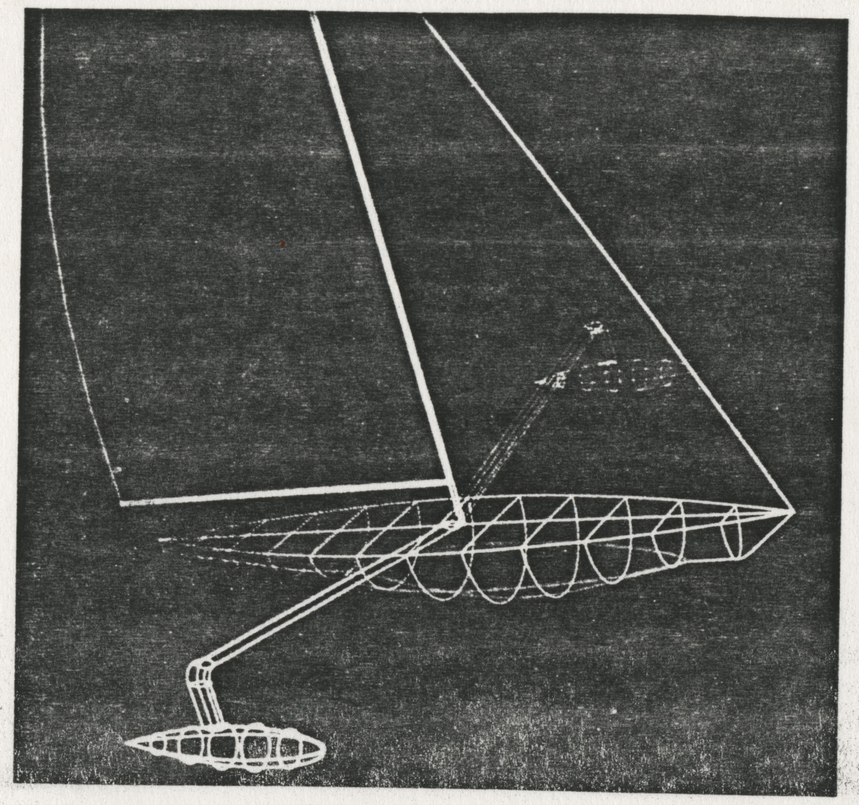
figures, levels off as indicated in Figure 10. Although sails cannot provide the several thousand pounds of thrust to cause a hull to plane, ocean waves frequently have slopes of 20 percent or more, and for a 24,000-lb. yacht, this gives a forward thrust of 4,800 lbs. or more — quite enough to cause it to plane.

Besides a wide beam, there are other ways to provide upright stability for an ultra-light hull. When a sailboat is running before the wind, it has the mainsail out on one side and the spinnaker out on the other. On a 12 meter each of these sweeps out to a distance of about 35 ft. on each side of the boat. This establishes the "running room" that must be permitted under the rules.

This suggests the possibility of deploying pontoons on outriggers within this running room in order to obtain upright stability instead of using lead ballast. If the pontoons are out of the water when the boat is in the upright position (all 12-meter measurements are taken in the upright position), they would not be classed as extra "hulls." In fact, they can be lying on the deck when the yacht is measured. And if the outriggers are deployed above the deck level, they would be classed as "booms" and thus not in violation of the "hollows in the hull" rule.

If the pontoons take the place of lead ballast, the wetted area of the keel can be reduced by about 140 sq. ft. If one of the pontoons has this much wetted area, then using an airship shape, such a pontoon could have a buoyancy of 6,000 lbs. When deployed on a boom 35 ft. long, such a pontoon would give a righting moment of 230,000 ft.-lbs., an even greater moment than provided by the wide beam of our earlier lightweight hull (and far greater than provided by the conventional lead keel). Perhaps even more important, the pontoons would prevent the yacht from heeling more than about 15°. This would be a significant advantage, since a great deal of sail power of a conventional yacht is lost when it's heeled as much as 30°. Pontoons could also be changed just as sails are changed. When light winds are anticipated, small pontoons with less resistance could be used, and extra-large pontoons could be substituted in heavy winds.

The required upright stability for ultra-lights can also be provided by "ailerons" extending out 35 ft. on each side of the boat. Each of these long thin wings could be rotated about its axis so as to provide hydrodynamic heeling moments when the yacht is under way, acting in the same way as ailerons on an airplane. Since almost all of the 12-meter measurements are



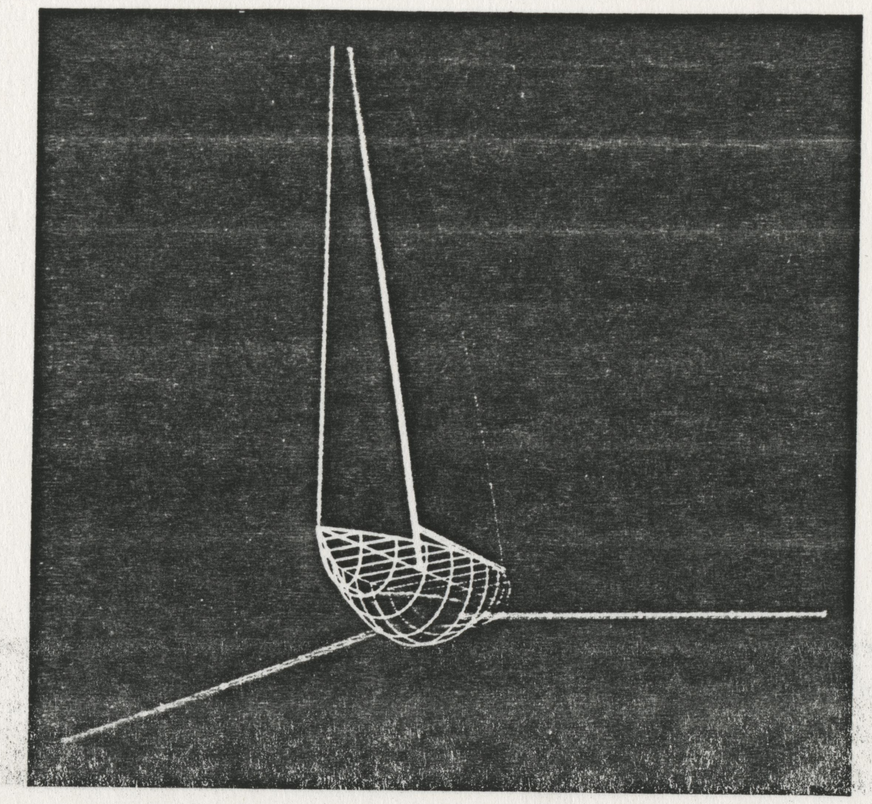


Figure 11: Pontoons on outriggers (far left) can provide upright stability and also keep the yacht from heeling more than 15°. The underwater "ailerons" in Figure 12 (to the immediate left) can also provide upright stability. Such solutions as broad beams, pontoons, and ailerons render a heavy keel unnecessary and make an ultra-light hull feasible.

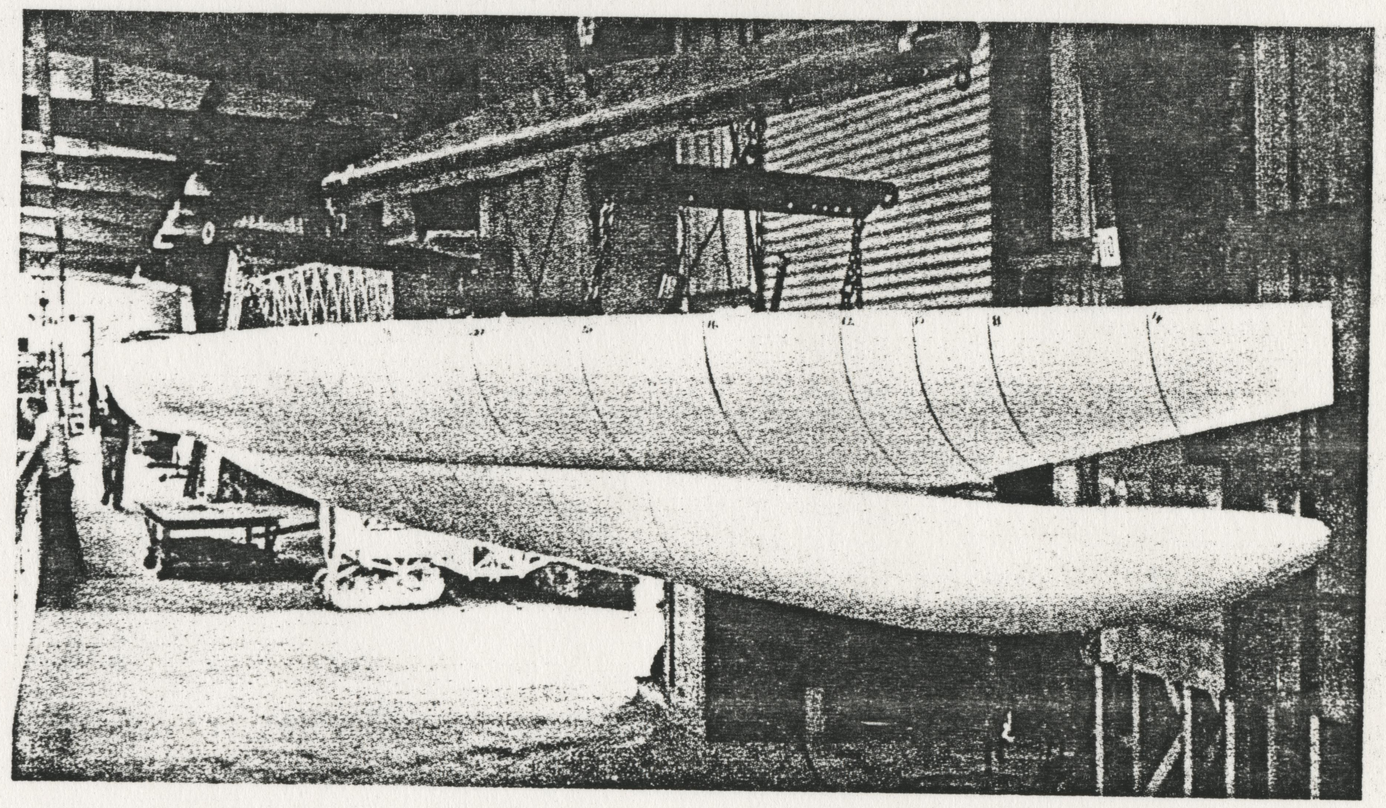
Below: Later this last summer the author had this 40-percent-scale model built and tested to explore further the potentialities of the underwater proboscis.

taken at or above the waterline, there is nothing to prevent this. In fact, an official interpretation of the rule says that the hull may be of any shape below 150 mm (6 in.) below the waterline as long as it does not exceed the length between the fore and aft points 180 mm above the waterline.

If these wings, made of carbon fiber composites, have chords of 12 in. and thicknesses of 2.5 in., they can support the loads that are required to keep the yacht from heeling under the force of the sail. Such wings would have about 140 sq. ft. of wetted area, about the same amount that would be saved if the lead were removed from the keel. So the fluid friction would be approximately the same as that of the larger keel, but with the very great savings in weight that would make the ultra-light hull possible.

Ailerons would have a significant advantage in heavy winds. As wind strength increases, the forces go up as the square of the speed. With a conventional keel, the heeling of the yacht increases rapidly with increasing winds, and once it has reached 30°, the sail area must be decreased (reefed) to prevent the yacht from heeling farther. As a result of the decreased sail area, the yacht's speed no longer increases with increasing wind speed. In contrast, the power of the ailerons goes up with the square of the boat's speed, enabling the yacht to stand up straight even in the strongest of winds. So the yacht could take full advantage of higher winds without sacrificing sail area and thus speed, as shown in Figure 13 on the next page.

The fact that the 12-meter rules



give the designer great freedom in shaping the portion of the hull that is 6 in. or more below the waterline suggests still another avenue to explore: Is there a way of making a boat with a small waterline length have a much larger wavemaking length?

We often see supertankers and other commercial vessels with bulbous bows that are designed to reduce their wave resistance at a specific speed. The reasoning that leads to the bulbous bow concept is relatively simple. The bow of a ship cutting through the water creates a wave crest, which initiates the train of waves that spread out behind. It is known that if a sphere is towed just under the surface of the water, there is a slight upwelling ahead of the sphere, but a large trough is created immediately behind it. This also initiates a train of waves that spread out behind it. But where the ship's waves start off with a large crest, the waves from the sphere start off with a large trough. If this trough could be positioned to counteract the crest, they would cancel each other, and the wave resistance would be nearly eliminated. It turned out indeed that by placing a bulb underwater out ahead of the ship's bow and joining it smoothly into the hull lines, the bow waves could be dramatically reduced.

One problem was that the interaction of the two wave systems was altered by a change in the ship's speed. A bulb that would produce a favorable interaction at one speed could produce unfavorable interactions at other speeds. For commercial vessels that spend their time traveling at one speed, this was an acceptable restriction. But for sailboats, which travel at a wide variety of speeds, bulbous bows have appeared in the past to have little chance of success.

Earlier we have seen that it is the Froude number, $V/\sqrt{gL}$, that governs the wave patterns of ships. Commercial vessels typically travel at Froude numbers between 0.25 and 0.30. In contrast, 12-meter yachts in moderate to heavy winds travel at Froude numbers of 0.37 to 0.45. At these higher values the wave pattern is simpler. This should make the design of a 12-meter bulbous bow simpler and should permit it, if properly designed, to be effective over a wider range of speeds.

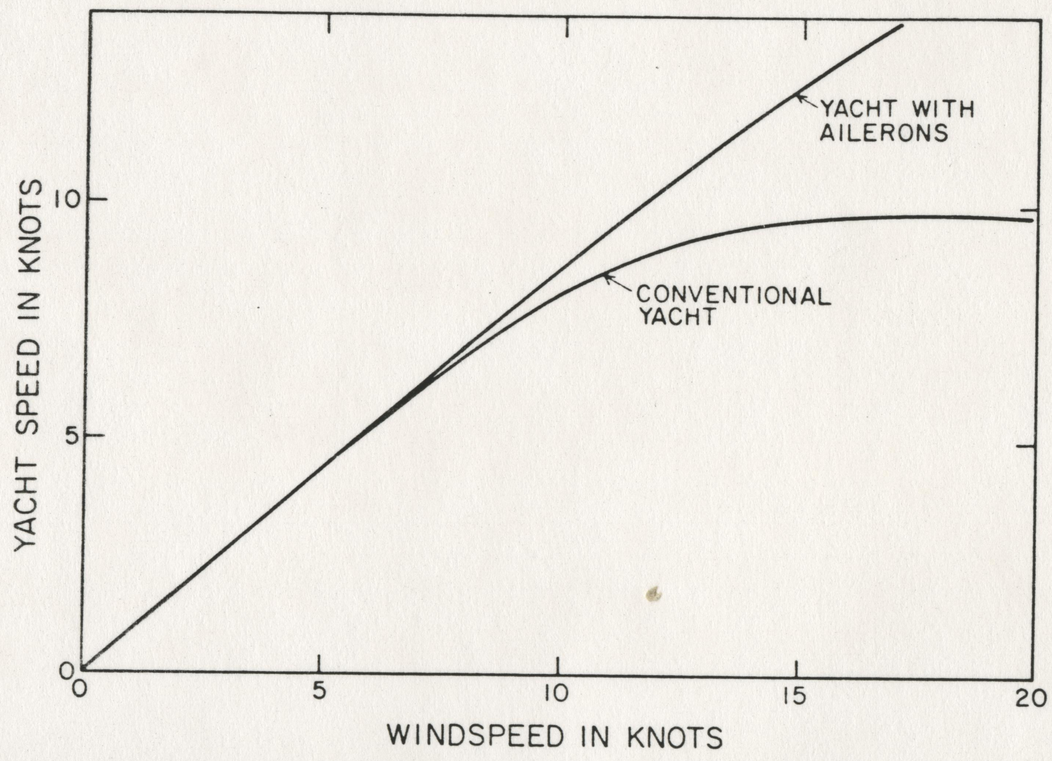
The concept of a bulb producing a beneficial interaction with the bow is a useful one, but it misses an important point. The wave resistance of a hull is proportional to the fourth power of the slenderness ratio of the hull. The bulbous bows on tankers are merely small add-ons. However, the 12-meter rule gives the designer great freedom to make the bulbous bow almost any shape he desires as long as it is at least 6 in. under the waterline. Such an underwater proboscis can thus extend far out ahead of the bow without increasing the measured length. And it can provide a significant addition to the displacement so that the hull itself can be greatly slenderized.

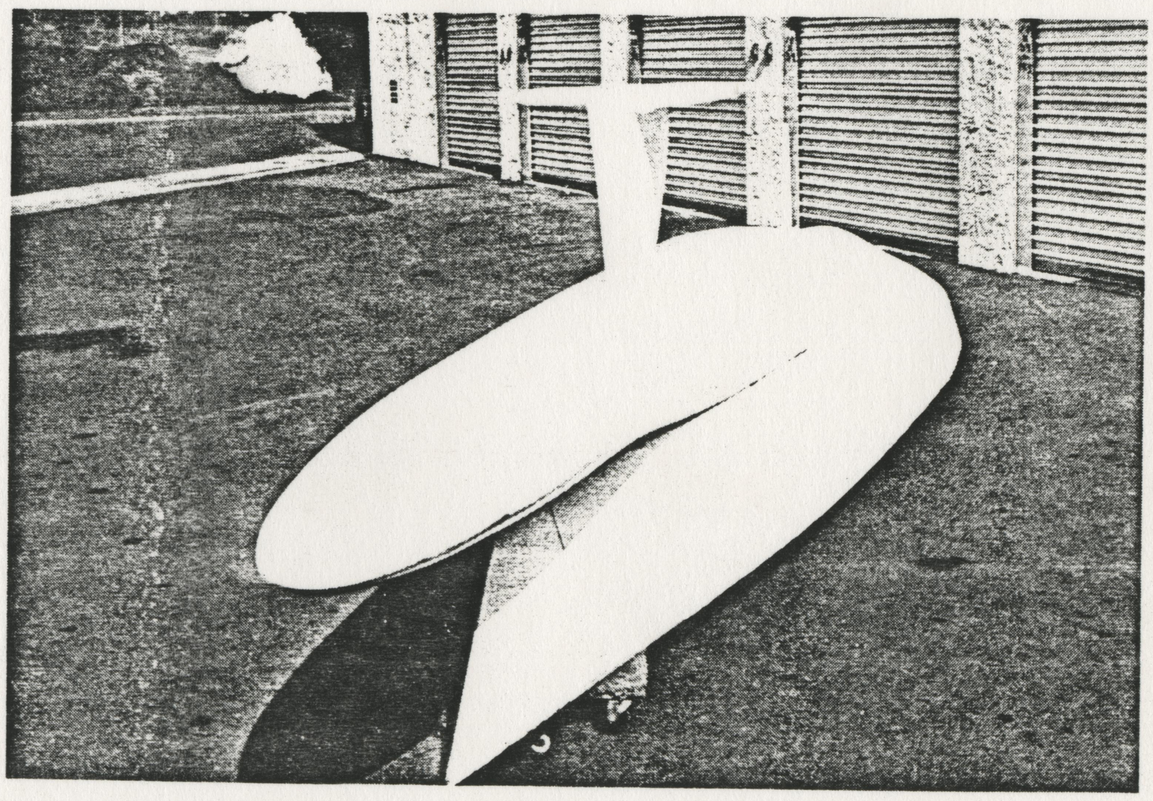
Let us consider again an ultra-light with a gross weight of 24,000 lbs. and a waterline length of 33.6 ft. Again, using nearly horizontal bow and stern overhangs, we can meet the America's Cup rule for a minimum length of 44 ft. at a plane 2 in. above the waterplane. And with proper shaping of the bow and stern we can have a measured length which will again allow a sail area of 2,450 sq. ft. Further, the 12-meter rule will permit a total underwater length of 44 ft. Hence the proboscis can extend 44 minus 33.6 ft., or 10.4 ft. out ahead of the bow.

All of this accomplishes two important things. First, the wavemaking length of 44 ft. is now nearly equal to the 45.6 ft. of conventional 12 meters. But more importantly, the light weight (24,000 lbs. vs. 57,000 lbs.) and the long underwater proboscis lead to a hull whose slenderness ratio is about half that of the conventional hull. This implies that the wave resistance will be reduced to a small fraction of that of the conventional hull. So much for theory and computer calculations. How will such a hull really perform?

When all of this was coming into focus in my mind in November 1985, construction was just beginning on Valentijn's conventional yacht *Eagle.* Unfortunately, the *Eagle* syndicate was a half-million dollars in debt. The construction costs for *Eagle* began to mount rapidly, and ahead still lay the need for sails, masts, booms, and so on.

Under these circumstances the board of directors of the *Eagle* syndicate became deeply divided on the question of planning for the second, more radical boat. Tooby, chairman of the board, and Gary Thomson, syn-





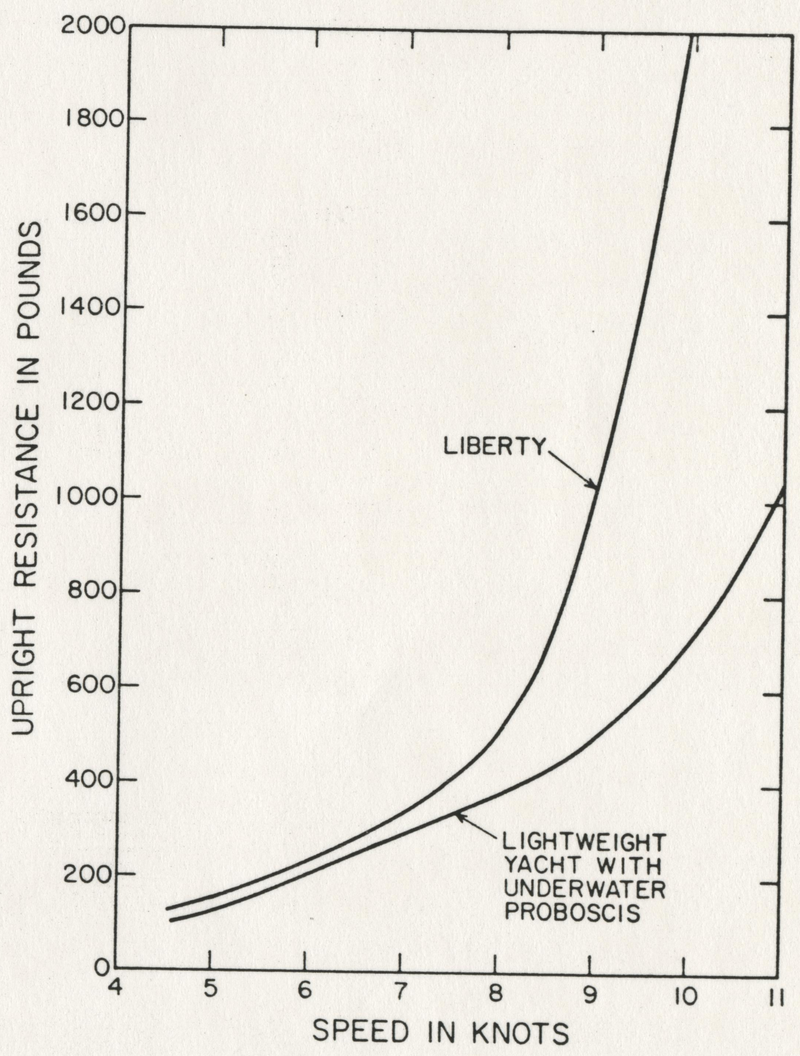


Figure 13 (above left): Since the power of the ailerons goes up with the square of the boat's speed, a yacht with ailerons could take full advantage of high winds. A conventional yacht would have to reef its sail, thus leveling off its speed, to keep from heeling too far.

Figure 14 (above): Towing tank tests showed the slender, lightweight model with an underwater proboscis with the same resistance at 11 knots as Liberty *had at 9 knots. The* Eagle *syndicate insisted that these tests on the model at the left be conducted with* Eagle's *keel rather than with pontoons or ailerons.*

dicate president, were enthusiastic about building and testing a model of my proposed hull with the underwater proboscis. But Valentijn and other members of the syndicate were opposed on the grounds that this would take away funds needed for *Eagle*.

It was not until March 1986 that a decision was made to make funds available to build a 40-percent scale model of the lightweight boat with the underwater proboscis. Even though this boat was designed to be used with either pontoons or ailerons, members of the syndicate insisted that it be tested with the keel and rudder used on *Eagle*, ostensibly to have a direct comparison.

Early in April we were able to test this model, and the results were little short of spectacular. They are shown in Figure 14 in comparison with *Liberty*. At low speeds the resistance is lower because of the smaller size of the lightweight hull. At higher speeds, instead of the usual disadvantage that a smaller boat has, the underwater proboscis, combined with the slenderness that it makes possible, gives the ultra-light the truly remarkable advantage in decreased resistance that theory had predicted. The ultra-light has the same resistance at 11 knots that the conventional hull has at 9 knots. And on top of this, the ultra-light can carry 40 percent more sail area. Advantages such as this usually occur only in a yachtsman's wildest dreams.

These results created quite a commotion within the *Eagle* syndicate. Tooby and Thomson (who had witnessed the towing tank tests) were highly enthusiastic. Others were less so. Because of an ever-increasing dearth of funds, there was now the danger that if a new hull were to be built, work on the original hull might have to be stopped. But perhaps the most critical factor facing us all was the question of time. To compete in the America's Cup, all yachts had to be measured and certificated by September 1, 1986. In order to meet this date, construction on the new hull would have to begin by May 1, and it would have to be flown to Perth by air cargo.

During the last two weeks in April, Thomson and Tooby made a heroic effort to raise an extra million dollars to build the new boat. But by May 1 it was clear that there was no chance of meeting this goal, and the syndicate decided to focus its efforts on the conventional boat.

At this point Tooby and I decided to resign from the *Eagle* syndicate and approach the New York Yacht Club (of which Tooby was a member) to see if at this late date they would have any interest in undertaking the design and construction of such a radical hull. The members of the New York Yacht Club syndicate expressed enthusiastic interest, but the boat-building firm that had constructed all of the NYYC's 12-meter yachts (as well as *Eagle*) told them that it was too late to design and build a new hull, particularly such a radical one.

By this time the New York Yacht Club had already built two versions of its yacht *America II* and was in the process of launching a third, since the first of these had proven to be a poor contender. Although it was too late to design and build a new boat, the boat builders said that it might be possible to take the first boat, cut the entire bottom out of it, and put in a new bottom. They thought they could do that by September 1.

Tooby and I went back East for a lengthy meeting with representatives of the New York Yacht Club and their designer. We laid all our cards on the table, describing in detail the design of the hull and the towing tank tests on it. The NYYC members were at first skeptical but then admitted that in all their computer studies they had never uncovered the great potential that our tests had demonstrated. They said they would have to confer with their various committees. Tooby and I came away buoyed up.

A week later we received a letter from the chief operating officer of the *America II* syndicate full of praise for what we had done but then saying that they had decided not to go ahead with such a radical project. It thus became clear that the current America's Cup races would be run without any of the ideas that I have described here.

As I look back on my two years' initiation into the design of America's Cup yachts, I am amazed at the great difference between the hyperbolic claims of "high tech" innovation that appear in the press and the design of the actual yachts now contending in the waters off Perth. The designers of most of these yachts are outspoken proponents of the "2 percent school," that is, that what it takes to win the America's Cup race is a 2 percent advantage. This is being borne out in Perth. In a four-hour race, the difference between the winner and the loser is usually less than five minutes.

Still, I am convinced by our tests that improvements of tens of percent are possible. What lies behind this difference in point of view? Almost certainly it can be traced to the secrecy that surrounds the design of 12-meter yachts. There is almost no scientific literature on the subject. Each designer jealously guards his store of information. The usual intellectual discipline that exists when scientific ideas are published and subjected to the examination of others is almost entirely lacking. I have become aware of a long list of intuitive ideas that sailors and designers alike cling to that I am convinced are nonsense. Perhaps with this article I can convince others to publish their ideas and, in the process, to see how well these ideas stand up under scientific scrutiny.

One risk I run in doing this is that publishing this article may cause the rules to be changed. Although the rules as originally written were intended to be well defined, the keepers of the rule book, being human, couldn't quite let go of the strings of control. Not in the rules themselves but in the instructions to the measurers, they inserted the following paragraph:

"If from any peculiarity . . . the National Yacht Racing Union . . . is in doubt as to the application of the rules or instructions . . . it shall report the case to the International Yacht Racing Union, who . . . shall award such certificate of rating as it may deem equitable; and the measurement shall be deemed incomplete until this has been done."

As a result, almost every innovation is challenged on the basis of this "peculiarity" instruction. The IYRU has maneuvered so that it can make quite subjective judgments as to what it will permit. The New York Yacht Club people told me that a number of decisions have been made solely on the basis of what the IYRU deemed "good for the sport." It remains to be seen whether broad beams, pontoons, ailerons, or underwater proboscises will be good for the sport. □

NEWSDAY - 17 DEC '86

America II's Lament: Boat Was Just Too Slow

By Dave Knickerbocker

Fremantle, Western Australia — What went wrong with the New York Yacht Club's America's Cup challenge? The club's America II syndicate spent $15 million to build three boats, 12 winged keels and close to 100 sails.

It had the pick of the best 12-Meter sailors in America and the crew trained and raced together for two summers in Newport, R.I., and three summers on the Indian Ocean off Fremantle. It was an unprecedented campaign, even by today's standard of multi-boat, multimillion-dollar programs. Yet it fell short. For the first time in 135 years, the New York Yacht Club will not be sailing for the Cup. What went wrong?

"I don't have an answer for you," said John Kolius, America II's skipper, when he faced reporters Sunday night after his elimination from the challengers' semifinal. "If I did I wouldn't be in this spot, would I? It will take a couple of months to figure that out."

Who was to blame for the failure? "My personal feelings and the feelings of my friends are more important to me than rhetoric as far as what we did wrong," Kolius answered.

The consensus among competing sailors and knowledgeable observers was that Kolius, 34, a Darien (Conn.) sailmaker, Olympic silver medalist and a veteran of the 1983 Cup defense, was saddled with a boat that was slow at the start of the racing in October and, if anything, became slower still in the final days.

Neither Kolius nor syndicate members would lay their failure at the door of the boat's designers, Sparkman & Stephens of New York, but their statements before and after defeat leave little room for another conclusion.

"I don't think you can get anything more out of that boat than they [Kolius and his crew] got out of it," said Arthur Santry, commodore of the New York Yacht Club, "and we're extremely proud of them. I don't think anything more could have been done."

"A little bit more boat speed would have been helpful, particularly at the end," said Bill Packer, the syndicate manager. "What we found is that the other boats progressed mightily . . . [and] had superior boat speed to ours. We think our crew work was superb and, in fact, I think we beat some boats out there in December who might have even been faster than us."

But Packer also had praise for the boat's architect. "I felt that Bill Langan [chief designer at Sparkman & Stephens] did a superb job," he said.

Early in the going, when he was tied in first at the end of the first racing series with New Zealand and Dennis Conner's Stars & Stripes, Kolius said America II was "as radical a boat as you would expect from a conservative designer." Later, as his challenge foundered, Kolius all but conceded that the boat was flawed from the beginning.

"We were ready to sail when the first series started and I think that we made the boat look a li[illegible] b[illegible] better, maybe, than it was early on. So maybe we hid a little of that," he said.

"Ninety percent of America II's problems were design problems," said Gary Jobson, Cup racing analyst for ESPN, the sports cable network, and a veteran of three defense campaigns, including the taste of victory as Ted Turner's tactician aboard defender Courageous in 1977.

"In October, they were clearly the best in boat handling and sail handling. They were excellent, they couldn't have been better," Jobson said. "Their sails were excellent and they had the largest inventory in Fremantle. But they should have known in October that they were slow and started doing something about it. They probably did know, but they underestimated how much the other boats could improve."

During the November break between the second and third rounds, the syndicate announced a number of changes on the boat, including a new mast and a new winged keel. What the club did not announce, probably for tactical reasons, was that the new keel was slower and had been replaced after extensive testing with the old keel. That fact came out when America II was eliminated.

Tom McLaughlin, the syndicate's sailing director, said the changes made were calculated experiments aimed at improving boat speed and were not signs of panic. Yet the sailors who raced against her in the final round believe the boat was slower.

"A mistake a lot of designers made was that they used Australia II, the boat that won the Cup in 1983, as a benchmark for their own designs," said Bruce Kirby, designer of ninth-place Canada II. "It was easy to improve on the original design and build a boat that was faster than Australia II. But by 1985 Australia II was a slow boat and being a little faster wasn't good enough. You had to be a lot faster."

"This is a game where we've learned that imaginative boats are going to win," Jobson said. "Conservative boats don't pay off."

NEW YORK TIMES - 21 DEC '86

America's Cup

Computer Is Accurate on Cup Semifinalists

By BARBARA LLOYD
Special to The New York Times

FREMANTLE, Australia, Dec. 20 — When Dennis Conner's designers were gearing up for the 1986-87 America's Cup challenge last spring, they used a computer to simulate a kind of sailing war game.

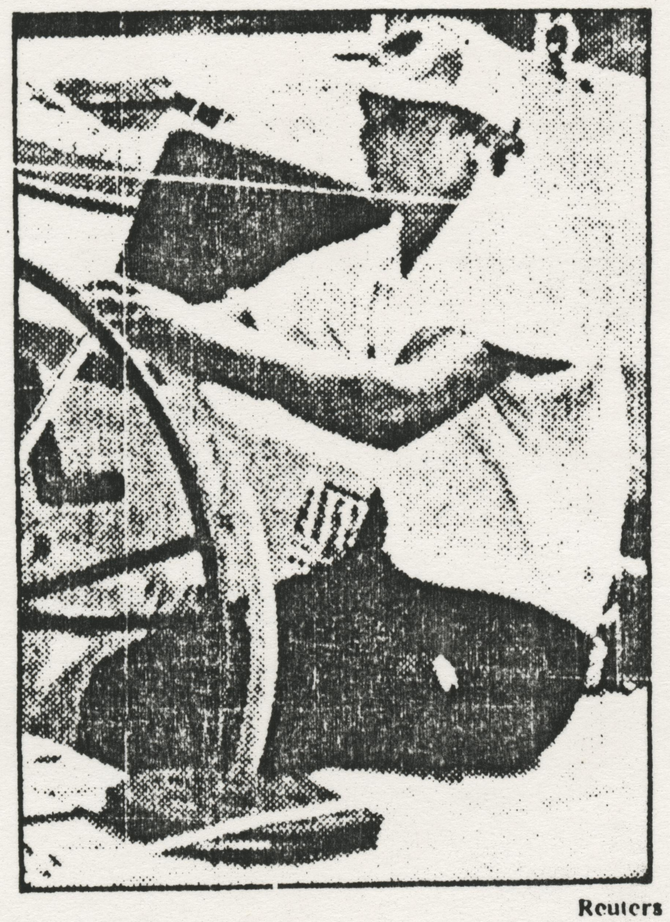
Taking what they knew at the time about each opposition boat, they plugged numbers into a computer to simulate its shape, weight, sail plan and crew strength. Then they ran their own series of boat races, 100 in a day, in mock competition.

John Marshall, the team's design coordinator, said during a recent interview that when the results were in, they were largely a mirror of the semifinal scorecard here. Tom Blackaller's USA was unpredictable. The results showed up in "peaks and valleys." As for Chris Dickson's New Zealand, the front-runner in the elimination series, the computer simulation showed a series of races in which Conner's team won or lost by small margins.

"Stars & Stripes should win, provided that we sail well," he said of the final competition. "Any slip-up, and we lose to New Zealand."

The semifinals are scheduled to begin Dec. 28 in a four-of-seven-race series: New Zealand versus French Kiss, and Stars & Stripes against USA. In the next week, each team will be making boat alterations consistent with the leap-frogging in design that has characterized the entire challenge series.

USA is the most radical design here. But there are nuances in the design of the other three top boats that show brush strokes of independent thinking. It is a factor that has played a key role in separating winners from losers.



Reuters

The skipper for New Zealand, Chris Dickson.

Stars & Stripes was designed to be competitive in the blustery conditions that prevail here in an Australian summer. It upset Conner's plans when the winds turned abnormally light in November. "It was a wrong move," said Malin Burnham, the president of Stars & Stripes syndicate. The design team compensated by taking ballast out of the boat for the next series.

Burnham said the team came here prepared to make some mistakes. "We did not come down here thinking we had to be number one in the semifinals," he said. "We still wanted to leave some room for experimenting." Stars & Stripes is radical in its hull shape. It is unusually full in the ends, a shape intended to enable it to capitalize on the waves that the boat generates while moving through the water.

"It looks like an ugly duckling in flat seas," said Marshall. "But when the wind blows, she fits in with the waves to where she looks right."

Stars & Stripes sails best upwind. If Conner fails to gain a lead in the upwind legs of a race, he has less chance of passing another boat downwind, said Marshall.

Change for Better Hoped

Stars & Stripes was put into a workshed within 90 minutes of finishing the last race in the December trials. The winglets on the boat's keel were removed in preparation for a change that the syndicate said would give it a 95 percent chance of substantially improving boat speed.

New Zealand has taken a radical approach in its design, yet the differences are subtle. More than any other boat here, New Zealand has proved fast in any wind condition. Design experts agree that the boat appears to be well balanced and more stable than most.

Beyond the streamlined hull, designers took a radical step by building with fiberglass. "If we win the America's Cup, it will be because we built two identical fiberglass hulls to start out with," said Ron Holland, one of New Zealand's three designers.

The Kiwi Magic team has done what no other 12-Meter team has done: When it decided to challenge for the America's Cup, it built KZ 3 and KZ 5 to use as test models — one as a control and the other a test base. In analyzing the results, the team knew what to put into its third and final boat, KZ 7.

Fiberglass turns out a hull that is smoother than its aluminum counter parts. Metal plates create uneven surfaces on a boat that require as much as 1,500 pounds of putty. The weight is poundage that in most cases could be put to far greater advantage in the keel.

Blackhaller's Boat a Surprise

Blackaller's boat is the upstart of 1986. Few could have imagined, given USA's performance in the early trials, that the boat would improve so dramatically.

But as a part-time race car driver, Blackaller appears to have more tenacity than most in coping with an unruly boat. "When the wind blows hard, sailing a 12-Meter is very much like driving an Indy car or a Formula One car," he said. "Disaster can strike at any instance to anyone."

Blackaller's boat began the trial series as the lemon of 12-Meter racing. Its torpedo-shaped keel was a joke at first. A series of refinements to the underwater bow and stern blades, and to an intricate dual steering system, has turned San Francisco's boat into a serious contender.

French Kiss is a boat with a shallow midsection and a relatively small sail plan compared with other boats here. On a reach, she has proved to be one of the fastest. On one breezy day, she sailed at 20 knots, a speed almost unheard of with 12-Meters.

The team led by Marc Pajot is not considered as competitive as the other semifinalists. But given the wide swings in boat performance that undermined the fall trials, few have discounted the French Kiss effort. The team has removed its kee. and is replacing it with another.

NEWSDAY, WEDNESDAY, DECEMBER 31, 1986

Conner Wins Third as 'Doctor' Calls

By Dave Knickerbocker

Fremantle, Western Australia — The Fremantle Doctor gave Dennis Conner a clean bill of health. If there were any worries that recent modifications to Stars & Stripes to improve her light-air abilities had sapped her heavy-weather prowess, they were laid to rest yesterday when the Doctor, the stiff summer sou'wester, made a call.

In winds of 24 knots sweeping in from the Indian Ocean, and on lumpy, foam-streaked seas, Conner made it three in a row over his old sailing rival, Tom Blackaller on USA, in the best-of-seven America's Cup challengers' semifinal. Conner commanded the weather berth at the start, shifted into overdrive and powered around the 24.1-mile course to win by 2 minutes, 23 seconds.

In New Zealand's 13-second win over French Kiss that gave New Zealand a 3-0 lead in their semifinal, the seemingly flawless Chris Dickson, the 25-year-old skipper of Kiwi Magic, made one of his rare errors when the spinnaker wrapped around the jib at the second mark. The French, trailing by only 1½ lengths, grasped the opportunity and sailed through the inside of the turn and into the lead.

French Kiss, a light-air sparkler in the challengers' round robins, underwent major modifications before the semifinal began. Three feet of her stern was chopped off to reduce weight above the waterline, her mast was moved forward about a foot and the tips of her keel wings were widened. The changes appear to have made the French much faster in a breeze. They were fast enough to hold off the Kiwis for the next five legs.

On the last leg, a few hundred yards from the finish, Dickson pulled even and when the French tacked alongside in an attempt to steal Dickson's wind and drive him off the course, Dickson luffed sharply, swinging the bow of his boat into the wind. Marc Pajot, skipper of French Kiss, was slow to react and the boats scraped topsides.

"It was just a kiss," Pajot said. He also admitted he was at fault. "It was a good luff, but I was too slow getting away." Because there was contact, French Kiss must be disqualified by the international jury when it gets around to hearing the case. But that won't make any difference on the scoreboard. The well-timed luff gave Dickson the opening he needed.

"There's no question that French Kiss is quicker now than she was in the round robins," Dickson said. "But we had a little edge in speed and we were able to stay close enough to break through when we had the chance." Dickson blamed the foul-up at the second mark on a broken spinnaker pole fitting. "It very nearly cost us the race," he said.

Meanwhile, Blackaller was baffled by his third loss. "We were going as good as we can go," he said. "We were going a tenth of a knot faster than we were going against Stars & Stripes in the third round robin, but they were going a tenth of a knot faster than we were. That means that Dennis has found a magical two-tenths of a knot of speed. I don't know where he found it, but you've got to watch him. He's pretty tricky."

"I didn't think there was much difference in speed between the boats," Conner said, "but once in a while Tom slows down for a moment. Maybe his unique double-rudder system gets out of kilter. When he slows down, we gain half a boat length and we don't give it back. After a while, those half-boat lengths mount up."

To reach the challengers' finals on Jan. 13 — the winner of which will meet the Australian defender for the America's Cup — French Kiss and USA each must win their next four races.

Today and tomorrow have been designated as lay days for observing the New Year. The fourth race will be sailed Friday.

Australia IV, Kookaburra II Triumph

Fremantle, Western Australia (UPI) — Syndicate chief Alan Bond's Australia IV roared back into the lead of the defenders' series while Kookaburra III skidded to second after absorbing a 50-second defeat by stablemate Kookaburra II yesterday.

In the battle for the right to defend the America's Cup, skipper Colin Beashel tamed the strongest winds yet of the semifinals to pilot Australia IV to a 14-second victory over Steak'n Kidney, which slipped to 4-30. Australia IV (25-9) has 65 points, Kookaburra III (27-7) has 59, Kookaburra II (20-14) has 46 and Steak'n Kidney has 18. The series resumes Friday after a two-day break.

It's Stars & Stripes vs. Kiwis

Conner's yacht sweeps USA, qualifies for challengers' finals

By Dave Knickerbocker

Fremantle, Western Australia — Stars & Stripes and New Zealand made clean sweeps of the America's Cup challengers' semifinals and will meet head-to-head in the finals Jan. 13. The winner of that best-of-seven series will take on the Australian defender in Cup matches beginning Jan. 31.

Before yesterday's fourth win over USA — by 43 seconds — the radical but unlucky challenger from San Francisco, Dennis Conner, skipper of Stars & Stripes, told his crew, "Only nine more races to go," an optimistic promise they would take the finals and the Cup series without a loss.

But it was Chris Dickson, the 25-year-old skipper of Kiwi Magic, who radiated youthful confidence after his boat coasted to a 2:44 victory over French Kiss. "We are here to win races," Dickson said, "and we enjoy winning races. The reward of winning is what we're out there for. The momentum keeps going. Motivation is not a problem for us. We've spent a year working to get where we are and we've won 37 out of 38 races, and 28 in a row. We've won two of our three races against Stars & Stripes. Obviously, we'd like to carry on with that record."

Dickson's only loss in the series was by 49 seconds to Conner in the challengers' first round robin Oct. 17. He won their two subsequent encounters by 32 and 59 seconds.

"All we've got to go on is the three races we've had to date against Stars & Stripes. They're certainly a different boat now from what they were and we're certainly a different boat as well," Dickson said. "We're very confident with our boat. We're very happy with our boat from light air right through medium and fresh air. We've got a boat, or maybe *the* boat, or the only boat, that is as good as the best in all conditions. We've got a boat that goes right across the spectrum of wind conditions."

"I think the challengers' finals will be a great series, similar to the semi-finals," Conner said. "Whichever boat happens to come out on top will be competitive with the defender. If anybody told you that they knew the result of this series right now, it would be fabrication. I don't see how anyone could know. We haven't sailed against each other long enough in these conditions to really have an idea what the boat speed is. I really can't say what will happen. Both of us are probably reaching the top of our game at the right time."

AP Photo

Stars & Stripes skipper Dennis Conner gives thumbs-up sign after victory

Conner said no major changes would be made to Stars & Stripes (31-7) during the 10-day break in racing, but there would be some modifications. "We've known for a long time that if we have more weight in the boat and less sail area, we go faster in heavy weather, and if we have less weight and more sail area, we're faster in light weather," Conner said. "What it comes down to is tweaking the boat for the wind conditions we expect in the finals."

Yesterday's breezes, which ranged from 16 knots at the start and built to 24 knots at the finish, were typical of the Fremantle Doctor, the summer sou'wester that arrives most afternoons like clockwork. In the match against USA, Conner had a slight edge on the starting line and led at every mark to win by 43 seconds, the equivalent of about seven boat lengths. Tom Blackaller challenged his old sailing rival only once when USA, with one of her brilliant but erratic bursts of speed, pulled nearly even. Conner tacked very close to USA to head off the rush, and Blackaller unfurled his red protest flag. But he withdrew the protest after the race, letting the result stand without the intervention of the international jury.

"Other than being a failure, our campaign was a very stimulating experience," Blackaller said. "I don't feel let down at all. We took our strongest technological stab with a radical boat, and if we'd had more money and time to tune up the boat, I think we'd have had a different result."

Blackaller said he would help Conner prepare for the finals in any way he could, but he didn't think there was much assistance he could provide. "We'd be happy to lend them whatever gear that our meager little syndicate might have that his big, gorilla syndicate might want to borrow," he said. "I kind of doubt that we have anything that they don't have."

Blackaller said USA, which has two rudders — one in the bow and one in the stern — and is the only 12-Meter keel here without wings, would not make a good trial horse for Conner. "Our boat is so weird that I don't think you can tune anybody up with it," Blackaller said. "We have enough trouble keeping it under control ourselves."

"I am happy with the experience," said a mournful-looking Marc Pajot, skipper of French Kiss, after his elimination from the semifinals. "We had only the one boat and not the match-racing practice. But I will try to be back in 1990 [for the next Cup challenge]."

Where that will take place is anyone's guess.

Steak 'n Kidney Out of Trials

Freemantle, Western Australia (AP) — The Royal Perth Yacht Club excused last-place Steak 'n Kidney from the America's Cup today, leaving Australia IV, Kookaburra II and Kookaburra III in the battle to represent Australia. Steak 'n Kidney did not have enough points (18) to reach the defender finals, which start tomorrow.

CONCLUDING REMARKS AND RECOMMENDATIONS

- van Dam-type tip extensions appear to be an efficient means for enhancing upwind performance of the 3½ foot triangular winglets. Wetted area will increase, however, and it is suggested that any implementation be accompanied by vibration investigations while underway.

- Turning efficiency might be improved by removing rudder area behind the skeg and placing it where the tip of the rudder is now located. This will reduce aggravation of the skeg flow separation patch and place rudder surface in clean flow thus reducing the total deflection required for a given turning/trim moment.

- Flow visualizations for S-87 reveal severe flow angularity with geometry and conditions anticipated while going to windward. Any application of riblet tape should include detailed examination of tape strip leading edges and groove clogs brought on by Bio-fouling.

- Winglet inclination might be optimized for specific speeds. A high-speed optimization (∽10 knots) would require an additional 1½ degrees negative incidence.

WORK PLANNED FOR JANUARY

- None ... I think we're done.