INSTITUT FÜR SCHIFFBAU DER UNIVERSITÄT HAMBURG

Schrift Nr. 2370

SOME REMARKS ON THE MEASUREMENT OF SAIL AREA

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1. INTRODUCTION

With the introduction and general acceptance of 'IMS' (International Measurement System) as a second measurement rule beside the 'IOR', (International Offshore Rule) there now exist two handicap systems of international validity for offshore racing yachts.
The IOR is a 'classic' rating rule. Some few measurements at hull and rig are taken from which the final, single rating is determined. This rating shall represent the average performance potential of the yacht in all sailing conditions. Because of that and the few measurements taken, such kind of rating rules always have a more 'type forming' character, allowing fair and close racing for yachts build to the rule, but failing to rate older designs, or boats not designed with the rule in mind correctly.
Thus for the 'new' rule a different approach has been made. The offsets of the complete hull, together with the data from the sail- and water measurement were taken as input for a velocity prediction program ('VPP') in the computer. The VPP-results form the base for the handicap on the race course, allowing for different 'ratings' in different conditions.
To do the velocity calculation, the VPP needs a theoretical model of the sailing yacht. Because forces are generated by wind- and waterflow, the yacht is devided in two parts at the watersurface. The water forces are calculated by a hydrodynamic- and the wind forces by an aerodynamic calculation model.
Although the IMS is a very complex rating rule, there are some weak points where clever designers can gain some extra 'unrated' speed and in fact the first special designed IMS-yachts already appeared on the race course, undermining the original idea behind the rule.
This is possible, because every calculation model has to simplify the nature. Some remarks to this problem and the IMS have been given in /1/. On the following pages the aerodynamic model only will be presented and compared with recently derived windtunnel tests that have been carried out at the 'Institut für Schiffbau' of Hamburg University.

2. THE IMS-AERODYNAMIC MODEL

The sail aerodynamic model has been developed by G.Hazen and is described in more detail in /2/ and /3/.
For sloop rigs two cases are considered, characterized as 'upwind rig' (jib or genoa and mainsail) and 'downwind rig' (spinaker and mainsail). From the sailplan, the same measurements as used for the IOR are taken and the sail areas and their centroids are calculated, usually the biggest genoa, main and spinaker were taken into account. The projected lateral area of the above water hull and its centroid is calculated as well and a reference area of 100% foresail triangle and mainsail is defined.

For each of the single sails aerodynamic lift and drag coefficients as a function of relative wind angle are given, derived from the result of windtunnel tests on two dimensional sails. These coefficients are given in figure 1.

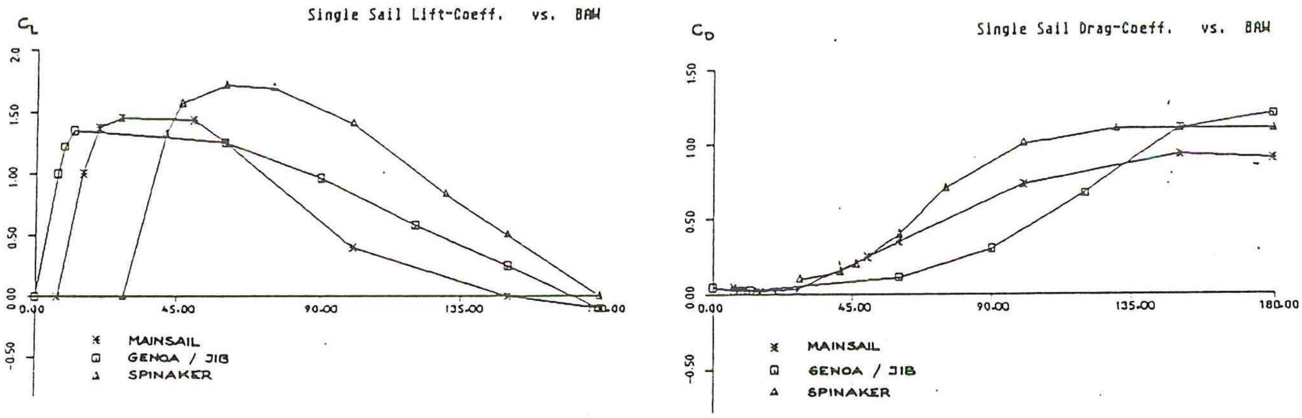


Fig.1 Single Sail Lift/Drag Coefficients

Induced resistance is calculated using the formula from lifting surface theory for elliptical loading. The resistance due to skin friction and separation drag were given constant coefficients. The blanketing of the sails among one another on the downwind courses is considered by 'blanketing functions'. Looking at them, figure 2, one can see, that they just compensate for geometrical effects.

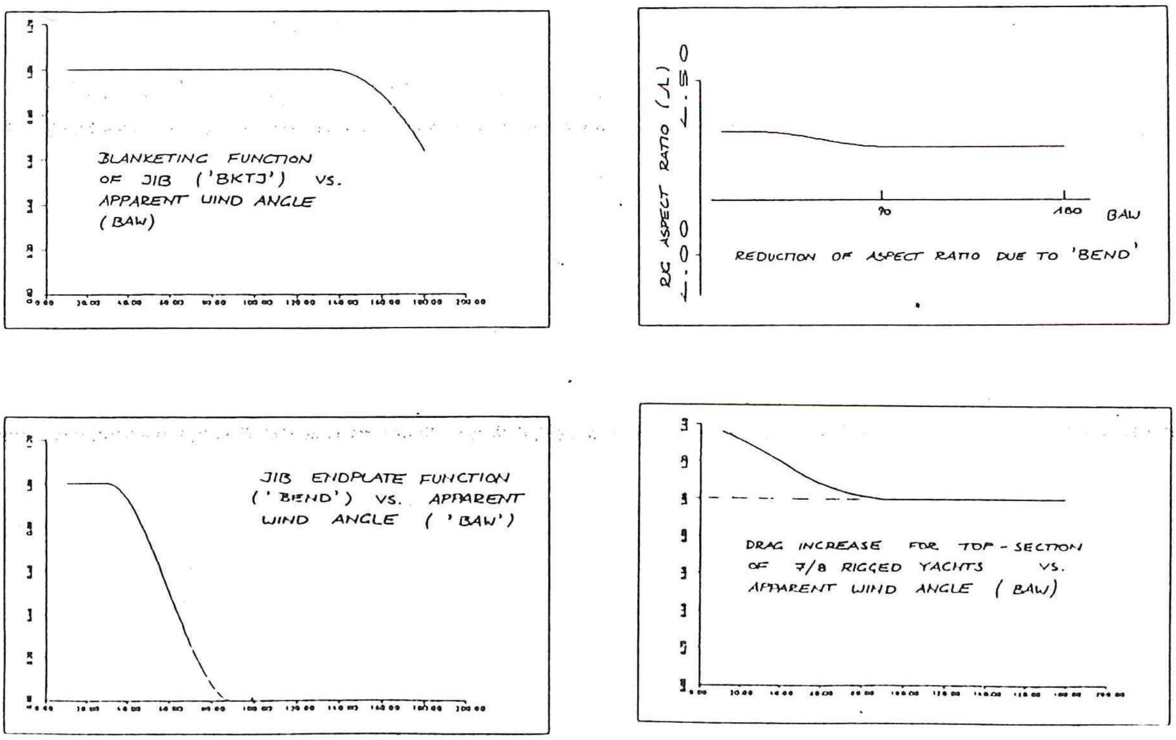
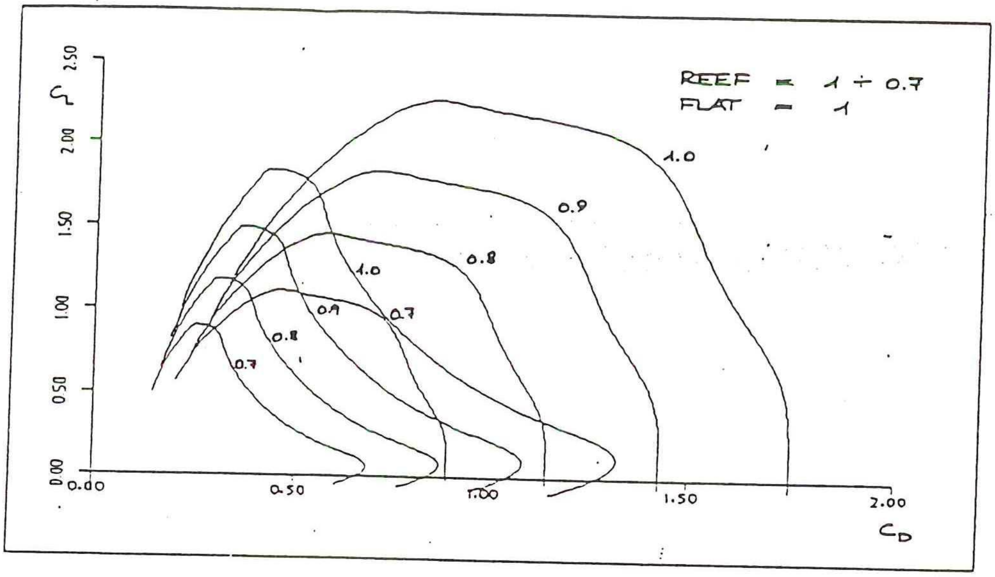


Fig.2 IMS-VPP Correction Functions

There are some more functions of this type, taking into account the reduced aspect ratio of the jib when the sheet is eased, opening a gap between the deck and the foot of the jib or for the additional drag/reduced lift at the topp of a fractional rigged boat.
In a first run, the computer multplies sail area and coefficients, calculates and adds the above effects for each apparent wind angle up to 180 degrees and produces a non dimensional rig polar curve by deviding with the reference area. Such a curve is given in figure 3 for the upwind and downwind rig respectively. The VPP uses this coefficient set for the calculation of the wind forces. As sails are foils that can be reefed and trimmed, two functions 'reef' and 'flat' are introduced to allow for this effects. Their influence on the polar curves is given in figure 3 and 4.



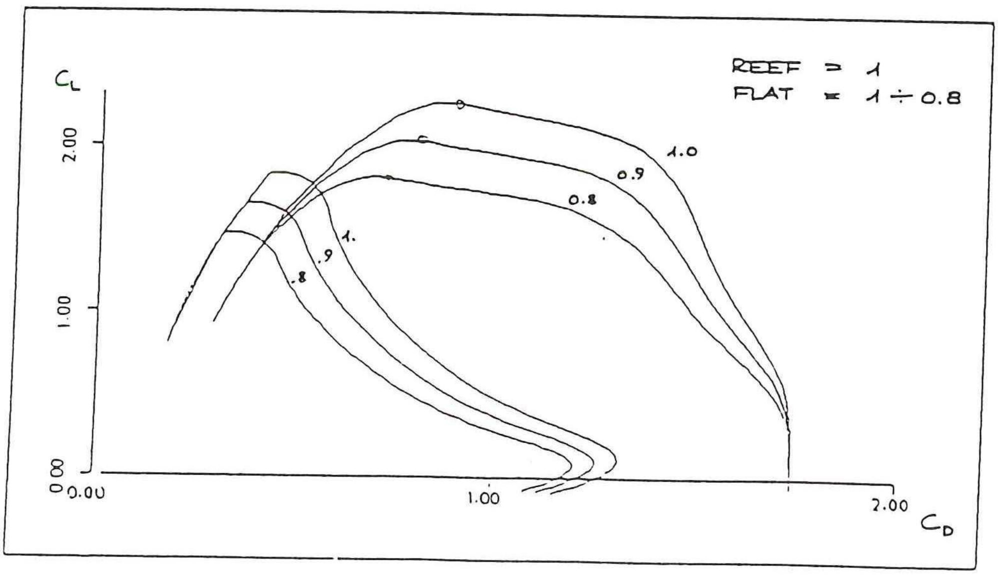
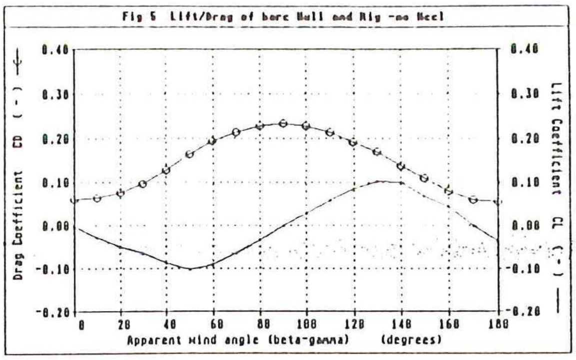


Fig 3/4 IMS-VPP Polar Curves - Effect of 'REEF' and 'FLAT'

3. REMARKS ON THE IMS-AERODYNAMIC MODEL

The IMS aerodynmic model treats the windage drag of the parasite areas as constant over the whole range of incidence angles, although from windtunnel results we know that this is not the case (fig 5).



There also might be some doubt in the assumption of elliptical loading on planforms like triangular sails and in the treatment of the heel angle influence on the the rig forces. A further 'weak' point is the way the sail interaction problem is considered.
As the total lift of the yacht is calculated just by adding the single sail areas, weighted by their respective lift coefficients, the problem of sail interaction cannot be dealed with correctly, even if the single sail coefficients have been corrected in advance for interaction effects.
If one considers two identical lifting surfaces working at a great distance, each of them produces its own circulation Γ , to which, as foil theory tells us, the lift is proportional. In this special case $\Gamma_1 = \Gamma_2$. However if the foils work in a close proximity, a new two foil system is created with its own circulation Γ_3 , which is not the sum of Γ_1 and Γ_2 respectivly, but depends on its individual characteristics.
Thus for a given distribution of sail area between fore- and mainsail the VPP might give comparable results, because the influence of the sail interaction is of minor importance in such a case. However if the relation between the sail areas is changed drastical, a comparison of different rigs leads to incorrect results.
In other words, you can compare fractional rigged boats among each other as well as masthead rigged ones, but not fractional rigged- with masthead rigged boats. *)
Another problem close related to the above mentioned, is is the treatment of foresail overlapping area. The VPP does not distinguish where sail area is positioned, although there are some signs, that the overlapping genoa area is not as effective as the rest of the sail.

*) Footnote:
In the judel/vrolijk design office we got aware of this several years ago, when we tried to do IOR-masthead boats. According to the VPP results, this boats tended to be much slower for a given rated sail area than their fractional rigged competitors. As this was not the case on the race course, it was obvious, that the VPP tended to overestimate the performance of fractional-riggers (or underestimates that of masthead boats). As the VPP now is the base for IMS handicapping, masthead rigged boats must be in an advantage. This might be proved by the fact, that new special IMS-designs advertized by yacht designers are masthead rigged boats.

4. DESCRIPTION OF THE IfS WINDTUNNEL TESTS

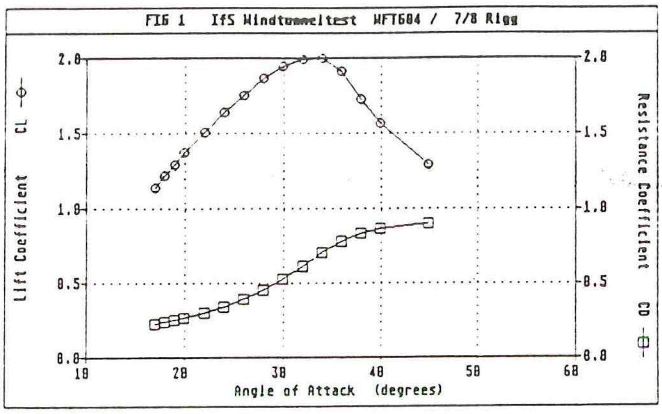
During 1988 a very complex model-test-series has been carried out in the windtunnel of the Institut für Schiffbau (IfS) on a 1:15 scale model of an IOR one tonner (the judel/vrolijk designed Container 87). The model was prepared with two different mast and shroud positions and two different rigs have been designed and built for it, the original fractional rig of the full size yacht and an additional masthead rig with the same IOR-rated sail area. Their sail plans are given in figure 5 and 6 respectively. As can be taken from table 1, their actual sail areas are quite different.

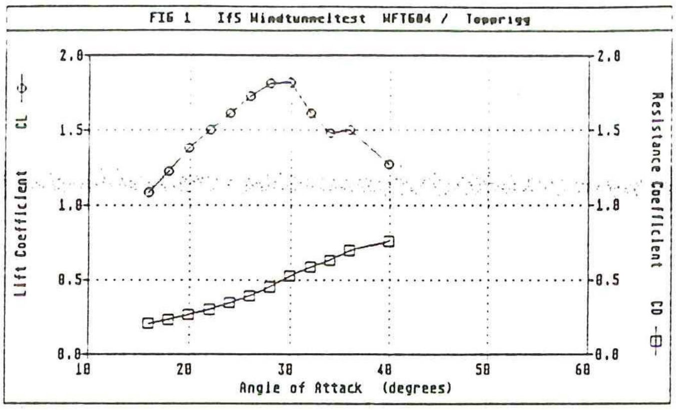
Table 1 Sail Area Comparison

	Fractional Rig		Masthead Rig		frac(%)
a) geometric areas:					
Mainsail	51.3	m2	36.0	m2	
Genoa 1	46.1	m2	54.7	m2	
Spinaker	108.0	m2			
Main+Genoa	97.4	m2	90.7	m2	93 %
b) measured areas:					
(i) - IMS -					
Mainsail	44.5	m2	31.4	m2	
Genoa 1	47.6	m2	56.0	m2	
Main+Genoa	92.1	m2	87.4	m2	95 %
(ii) - IOR -					
Mainsail(RSAM)	35.9	m2	25.8	m2	
Genoa 1 (RSAF)	45.2	m2	52.9	m2	
RSAM+RSAF+SATC	80.4	m2	80.3	m2	100 %

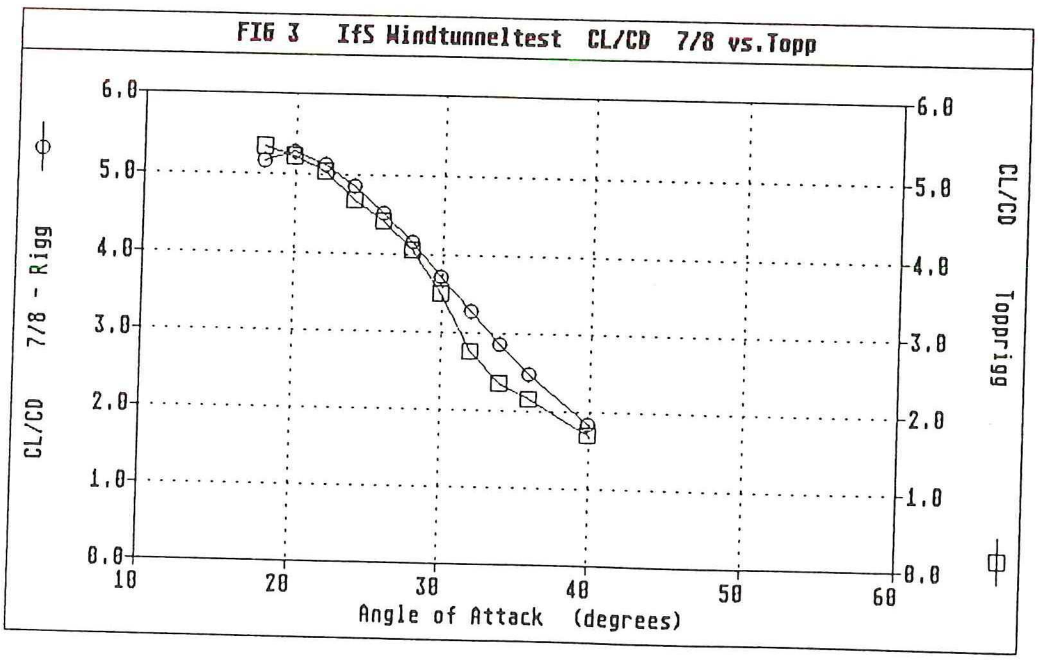
However, if the sail area calculation in the IOR formula is correct, the same forces must be generated by the two sailplans. The sails and the sail design was supplied from North Sails Germany, who succeeded in scaling their original Container sail designs down.
The model was constructed with a removable deck, so that hulls with different heel angles could be placed under it. However this limited the maximun heel angle to 20 degrees. The two masts were made flexible and the model was fitted with all trimming gear that can be found on full size racing boats. A deckplan is shown in figure 7.
The variables during the test series had been heel angle, headsails (overlapping and non overlapping, spinaker), rig type, genoa sheeting angle and mast- and sailtrim, the latter ones were responsible for the amount of time, that went into the tests because of the magnitude of possibilities to trim the sails.
As the results have not jet been evaluated, only some preliminary remarks can be made on the base of the uncorrected windtunnel data. It seems that the IOR treats the sail area measurement for the upwind case quite good. Modern racing boats sail upwind with incidence angles around 20 degrees (which is also the value shown by their windinstruments).

From figure 8 and 9 , which give some results for the upwind case with zero heel angle, it can be seen, that both rig types produce nearly the same lift and drag within this range, although the stall angle of the fractional rig seems to be higher, resulting in a higher maximum lift coefficient.





However it must be mentioned here, that this measurements have been carried out with close sheeting for upwind work, with the model turned in the windtunnel until the stall angle was reached, without easing the sheets. For an incidence angle of about 40 degrees a further 'optimum' sail trim has been searched and with this trim the incidence angle has been varied from about 30 to 50 degrees, etc.. Figure 10 shows the lift/drag ratios for the above case.



A more complete polar curve for 'optimum' sail trim and zero heel angle, compared with results from the VPP calculation is given in figure 11 for the yacht Container. For comparison the windtunnel results have been made dimensionless using the 'IMS-reference area' in this case.

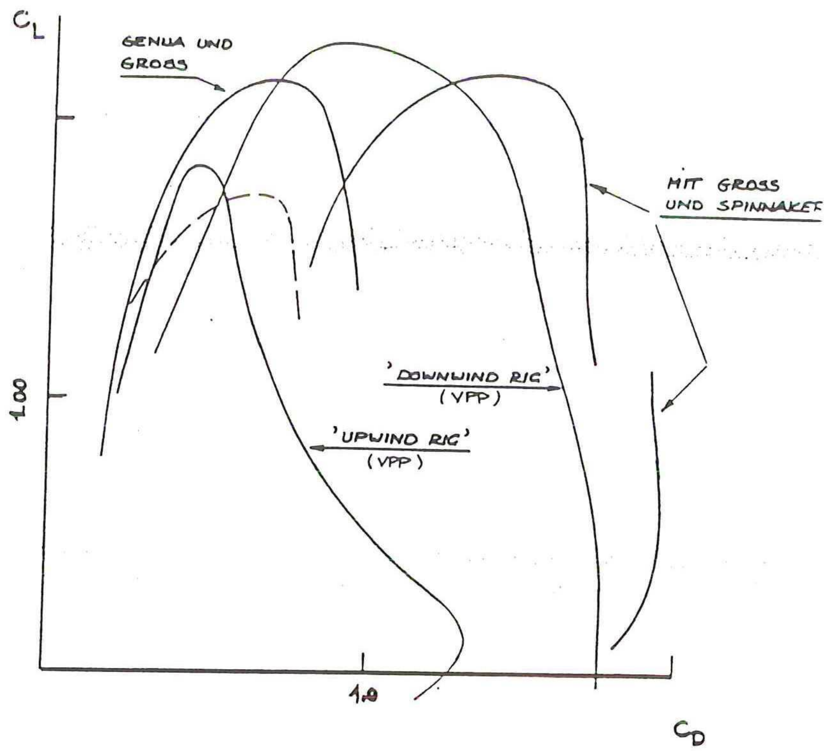


Fig 11 Comparison of IMS-VPP Polar Curve with Windtunnel Measurement for the Yacht 'Container' (—— upright) (--- 20 heel)

5. CONCLUSIONS

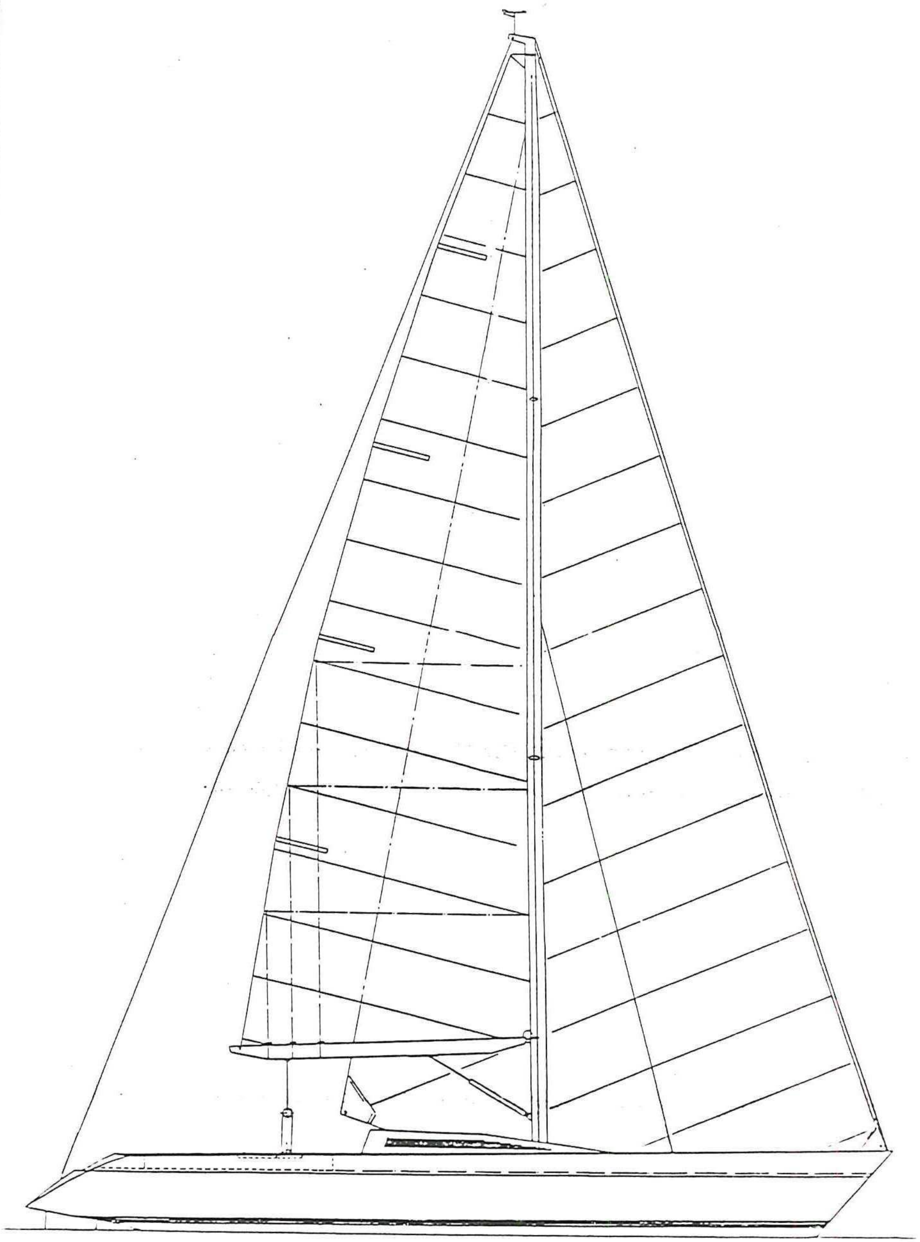
The comments above are only some preliminary remarks under the first impression of our recently derived windtunnel tests. Due to the magnitude of data (some hundret kilobytes) final results will be given at a later date.
However, as can be seen from the published data already, some corrections to the IMS - aerodynamic model for the upwind case seem to be necessary.

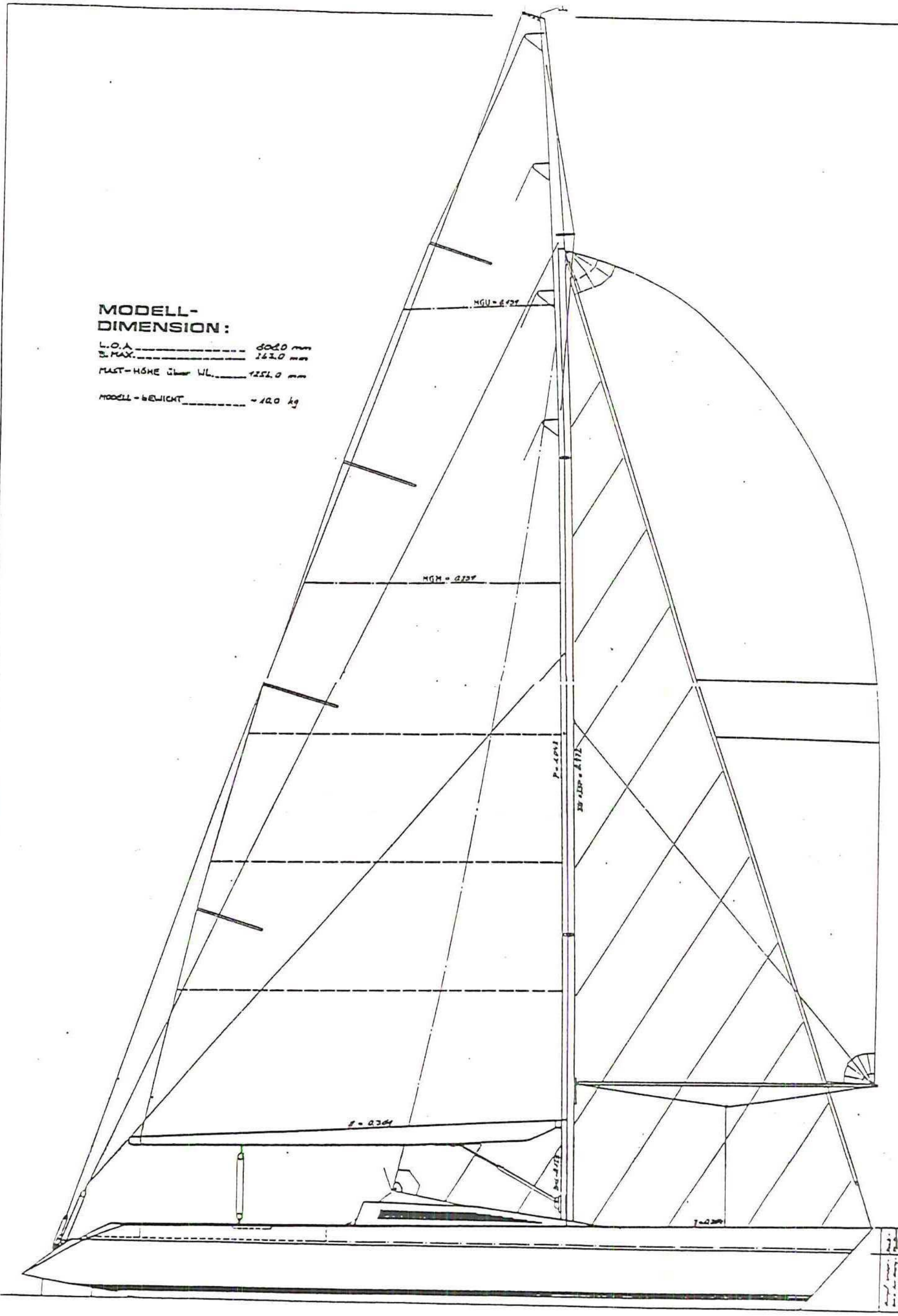
6. LITERATURE

/1/ Conradi 'Geschwindigkeitsprognose für Segelyachten' Lecture held within the Kolloquium 88/89 at the Institut für Schiffbau, Hamburg

/2/ Poor 'The International Measurment System' Washington, D.C., August 1986 (Published in Germany by 'Deutscher Segler Verband)

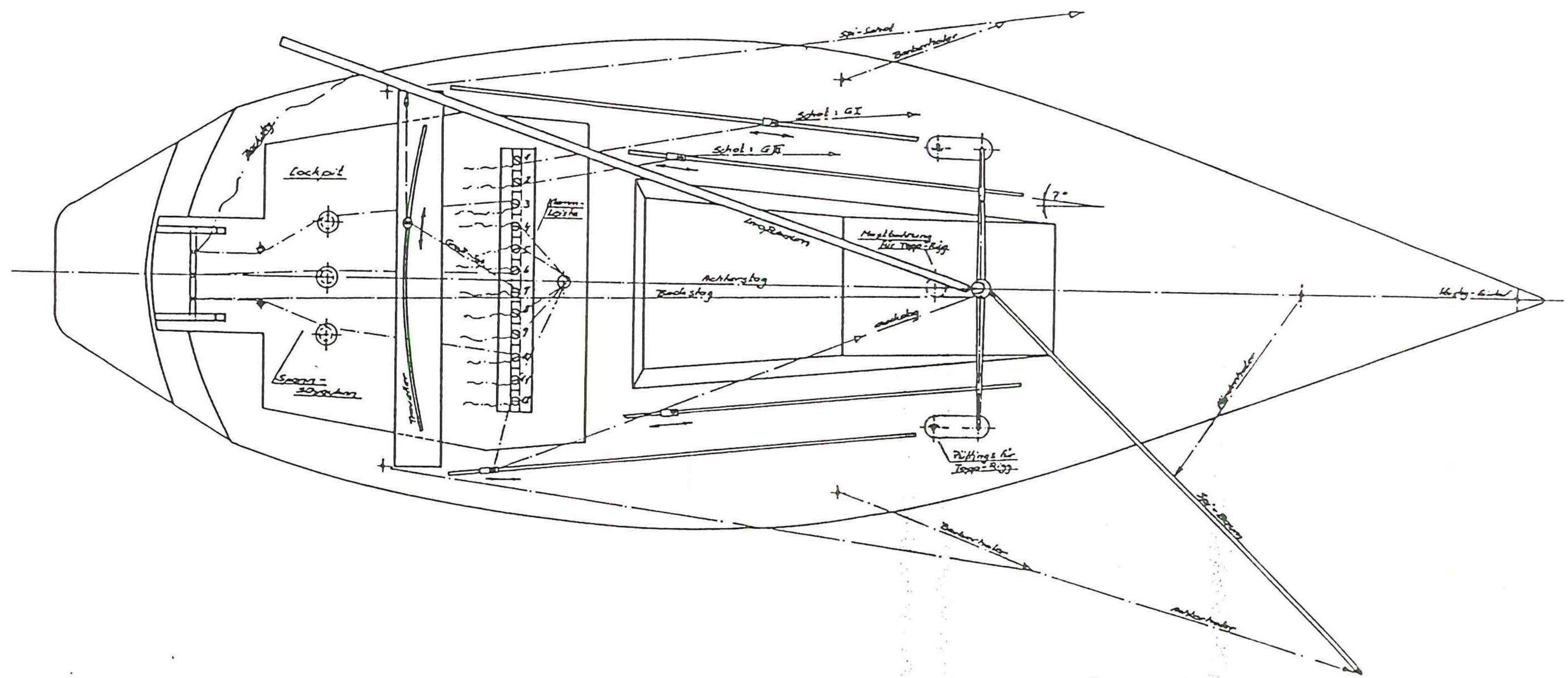
/3/ Hazen 'A Model of Sailing Yacht Aerodynamics for Diverse Rig Types' SNAME, New England Yacht Symposium, March 1980




MODELL-
DIMENSION:
L.O.A. 6020 mm
B. MAX. 1620 mm
MAST-HÖHE über WL. 1251.0 mm
MODELL-GEWICHT ~12.0 kg

Draufsicht : MODELL MIT 7/8 - Rigg

Sc. : 1:35 ¹⁾



Segeleinstell-Vorrichtungen

1. – Schot G I
2. – Schot G II
3. – Backstag Bb.
4. – U.-Liek Strecker
5. – Spibaum - Niederholer
6. – Achterstag
7. – Großschot
8. – Barberholer (Stb./Bb.)
9. – Achterholerschot
10. – Backstag Stb.
11. – Spi - Schot
12. – Zwischen - Backstag

1) : zur Großausführung

Nitzelt 88