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AMATEUR YACHT RESEARCH SOCIETY

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Developments in

YACHT DESIGN

1992

by Ian Hannay

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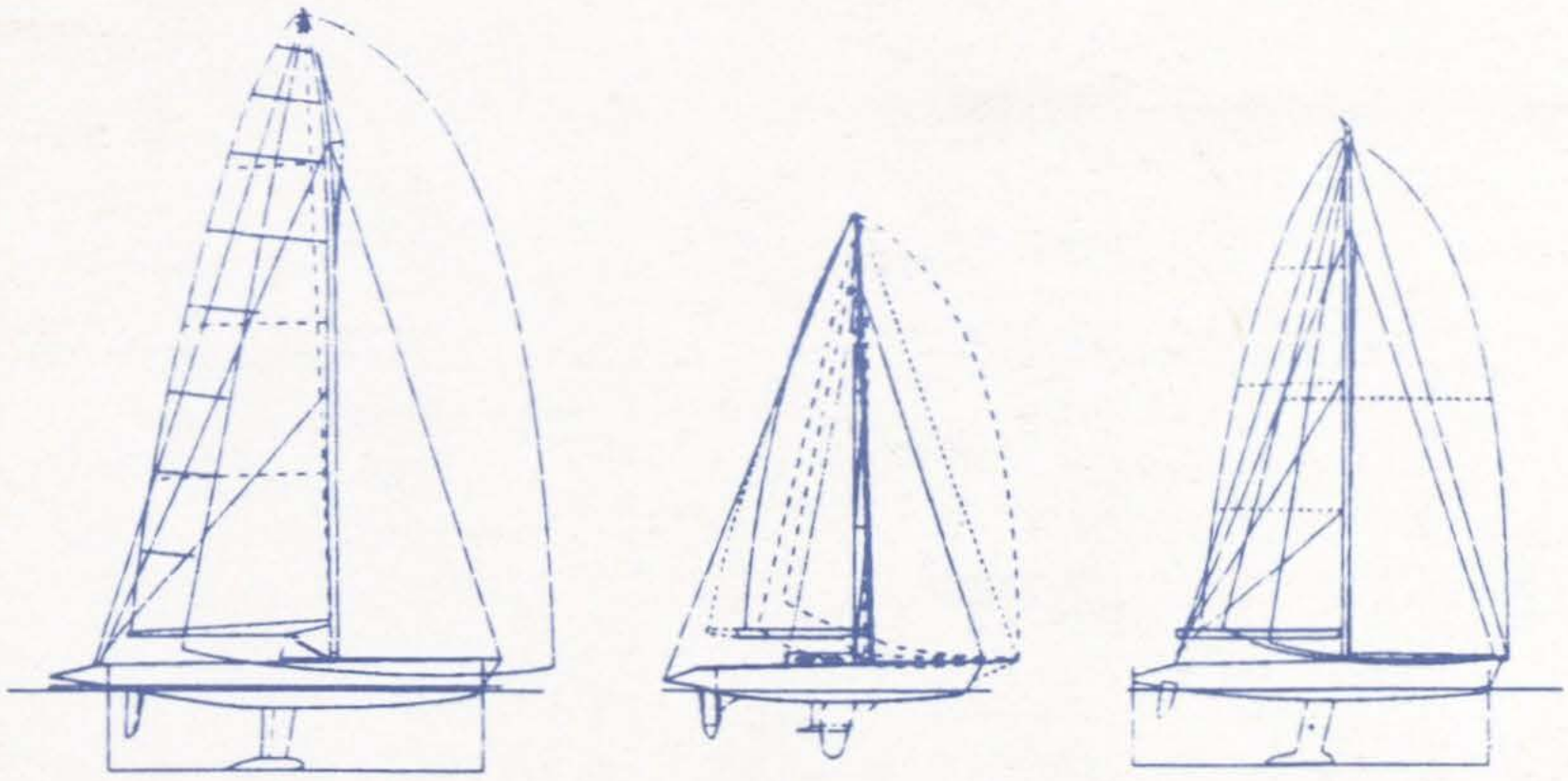

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Introduction

In order to understand the design of current yachts it is important to appreciate the factors that control them.

Most of the improvements in design and construction of racing craft come from close competition, but this development is very strongly influenced by the restrictions of the appropriate racing and class rules.

The cruising yachtsmen very rarely push their yachts as hard as the race competitor and there is little pressure to improve the performance in real terms. The aim is usually to ease handling and improve comfort. They usually try to improve their performance by imitating the racing yacht. This can be a mistaken approach, but it is strongly influenced by the perceived performance image of the racing classes.

Since the general adoption of the bermudian rig in the twenties there has been little opportunity to develop alternative styles of sail under the pressures of close racing. The restriction of the racing rules has limited the testing of new ideas. This was imposed to try and limit costs, on pressure from the yacht owners via their National Authorities and the IYRU.

The design and development of racing craft, particularly rigs has been in the doldrums for a long time, only now are we seeing new levels of efficiency beginning to emerge. There have been three areas of development that have managed to avoid the general IYRU restrictions and have managed to produce something different, these are: Sailboards, Skiffs (Sydney Harbour) and Multihulls.

The Sailboards and Skiffs managed to develop their performance well away from the restrictions of mainstream of yachting.

Multihulls have unfortunately had little close racing other than in one-designs. This has greatly limited the opportunity to develop the designs, including hull shapes, rotating masts and other alternative styles of rig. There is still a great deal to be learned about getting the best out of this type of craft.

The performance cruising yacht is a more complex problem than any racing craft, with many more factors involved and it is in most cases undesirable to follow the restrictive fashion of racing yachts. The racing and non-racing yacht have their own totally different sets of requirements that are in many cases mutually exclusive.

Just as it would be impractical and not to say dangerous to go shopping in a Formula One racing Car or a take the family for a holiday in a Le Mans type sports car, so it is equally impractical and potentially hazardous to use a modern racing yacht design for family cruising.

The problem is how do we convince the general sailing public that if they want a fast and practical cruiser it is better not to have a clone of a racing yacht, but rather something that has been purpose designed for the job.

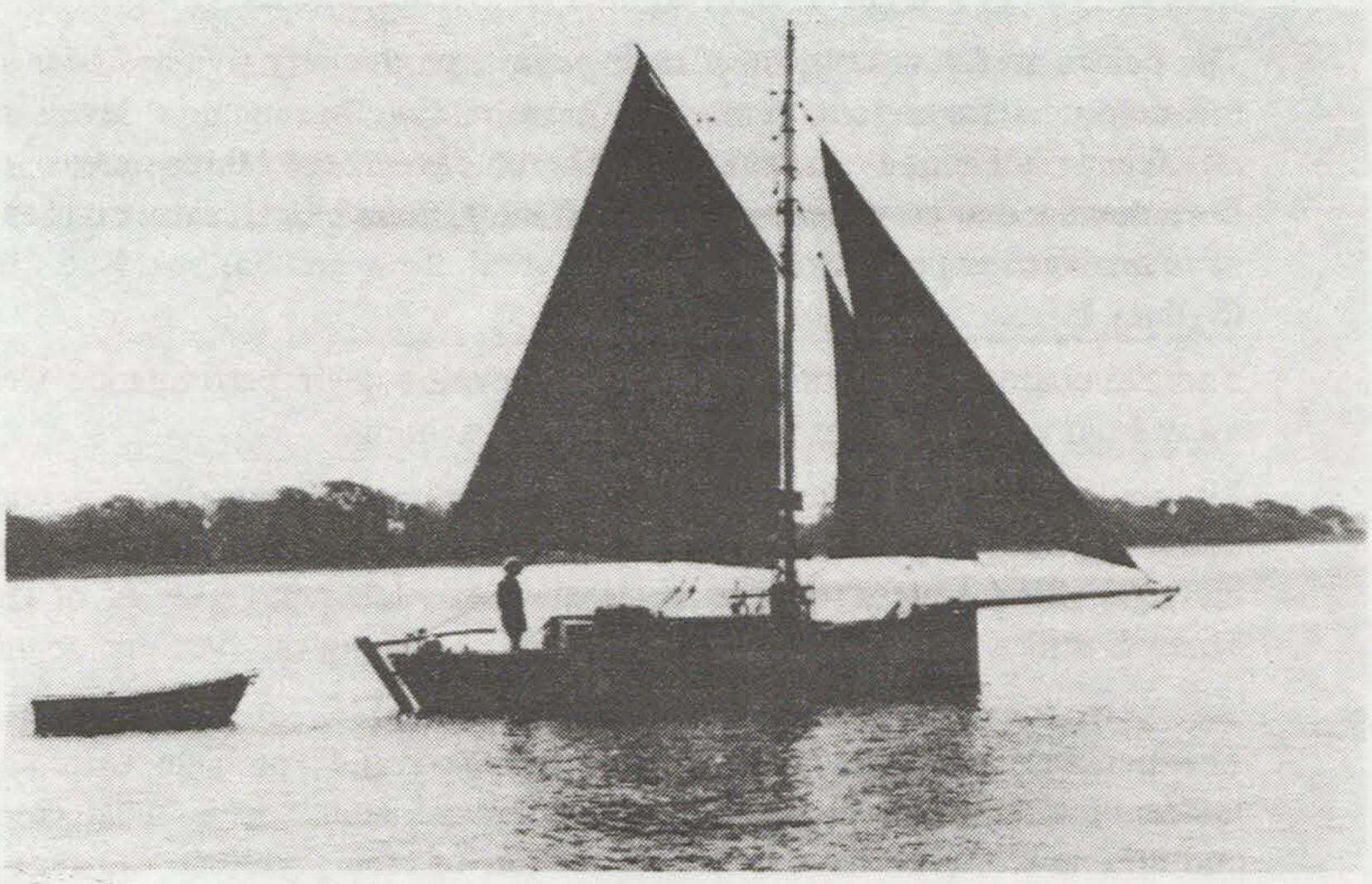
We have also got to persuade the designers and builders to build better performance cruisers. Unfortunately the image of the racing craft is always very strong selling point for those buying *apparent* speed.

The following explains how the *design, restricted* and *one-design* types of class rule operate and the direct influence they have on yacht design.

The final section explains why a yacht that is intended to do any cruising should avoid following the restrictive fashions of the racing fraternity.

These writings are the views of the author and do not express the opinions of the Society, but it is hoped that they stimulate your thoughts, enabling you to detect the influences that have gone into the making of a design and hopefully give you a better understanding of the subject when you next come to choose a boat.

Ian Hannay *Fleet* *January 1992*



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Formula One: Sail International. Pty, 7 The Esplanade, Mount Pleasant, WAust. 6153

Yacht Development 1992

Over the last hundred years the development of racing yachts has gone in cycles, with a major change in emphasis every twenty to thirty years. At the end of the last century the desire for speed pushed the Rater classes and the very large Americas's Cup yachts well beyond the technology available at the time. The craft were far from safe and often lasted for less than a season, making successful racing very expensive. The pressure to reduce costs and improve seaworthiness brought about the International Metre Classes with their scantling rules and restrictions on hull shape and rig dimensions. One-design classes such as the Star were also introduced.

In the twenties there was a change over from gaff to bermudian rigs on racing yachts as well as the introduction of symmetrical spinnakers with their limited length poles and overlapping genoa jibs.

The IYRU rules decreed that the spinnakers had to be symmetrical and have a minimum mid girth in order to reduce efficiency so that they could not be used to windward. This is still the the basic philosophy for the rules on all sails for off the wind sailing.

Overlapping genoa jibs have only ever paid when the extra area is not measured. They are a simple way of adding extra sail, but they are not efficient sails on an area for area basis and handling them requires considerable extra effort. Yachtsmen have learnt to use them efficiently and they are a major benefit to sailmakers and equipment manufacturers.

The IYRU rules insisted on triangular sails, banned rotating masts and insisted that the forestay was fixed on the centre line. Part of the reason for this was to simplify the measurement of cotton sails by measuring the rig and spars only. These traditional limitations have in effect prevented the development of any form of alternative rig for serious racing.

In the sixties there was a growth in ocean racing and the CCA and RORC cruiser racer rules were replaced with the International Offshore Rule, IOR. The aim of this new rule was to measure the performance of all types of yacht without bias, this was very soon found to be unrealistic and the yachts have developed into limited performance, low stability, expensive machines that make poor cruisers, consequently have a low secondhand value and increase considerably the overall cost of ownership.

The IOR encourages large beam, low stability and deep draft, this means that the crew weight on the gunwhale is always important for performance. None of these features are desirable for performance cruising yachts.

IOR yachts could be faster if they had greater stability and sail area for the same length and displacement (but at a higher rating).

The IMS (International Measurement System) was designed to overcome many of the IOR measurement limitations and introduces performance figures for any strength of wind. This is great in theory as it makes the racing more equal. The problem is that the race committee has to decide what the wind strength and direction was during the race and then calculate the results. This is not popular with the crews or the media as the relative positions cannot be worked out with any degree of certainty during the race and the eventual winner is decided by the whim of the race officer. This system is fundamentally flawed and is unsatisfactory for serious top-level international racing.

For club racing the CHS (Channel Handicap System) has been introduced as a secret and arbitrary rating rule that allows a variety of types and sizes of yachts to race together. This rule works until the racing becomes serious and those who want to win at all costs put pressure on the system. It will be interesting to see how this approach develops over the years.

It is a fundamental fact of nature that even with the aid of the most powerful computers the perfect rating formula is impossible to achieve. It is also undesirable in practice.

It is physically not possible for any rule to measure all the factors that effect performance and it is equally impossible to give the correct bias to each factor as new developments are always altering the importance of each feature.

If the perfect rule was possible it would mean that all the performance factors of a design would be taken into account and it would only be the action of the crew and their trimming of the sails that would contribute to the race result - just as in a pure one-design classes. There would be no real incentive to improve basic designs.

Any real measurement formula however good will always have some bias in it and it is these imperfections that give the incentive to designers, builders and owners to try and produce ever faster craft. The problem is that the effort is invested in making the most out of the rule rather than improving performance directly.

Any form of measurement rule dictates directly the style of craft produced. Regardless of what some rule makers used to claim.

There are several types of of measurement rules available.

The first is the *general* type of *rating rule* such as the IOR which tried to measure all types without bias, unfortunately this was never possible and has ended up producing expensive stereotyped yachts of limited performance and safety that are only suitable for use as daysailers after their racing life is over.

The IMS improves on the shortcomings of the IOR measurement system and includes basic accommodation requirements in the rating. In the long term this is a rule that will have only limited appeal in the real world as it is not possible to have any form of level racing and the race will always be against the clock and finally result decided by the whim of the race officers, not the sailors.

The most interesting racing is where there is no form of time allowance, crews and the public generally prefer the simple idea of the first past the post. It is likely that for the next era of sailing, handicap racing will be relegated to the level of local club racing. All professional and serious competitions will be without any form of time allowance.

The new **America's Cup Class** is a *rating rule for level racing*. The length, weight and sail area are traded off against each other within defined limits. There is no time allowance. This has the advantage that one knows the position and result immediately. The problem of this type of rule is that it is possible to produce specialised yachts such that one will always be fastest in light conditions and another that will be best in a blow. The race results then depends mainly upon the designers guessing correctly the conditions for any particular regatta.

There is a rapid rate of obsolescence with the above classes and the suitability of these craft for other uses limits their secondhand value and adds to the costs of campaigning them.

The **Whitbread 60' Rule** is a *restricted class* that limits the weight, dimensions and construction but there are no trade-offs between the various factors. This is similar to several dinghy classes.

The design options are very much less, but the racing is more equal and the rate of obsolescence should be less. The level of performance is almost entirely dependant upon the various dimensions chosen by the rule makers and these must be amended from time to time to keep the class competitive.

The 16m **Formula One** is a typical *one-design* yacht that depends upon its designers for all the parameters chosen. The rules are similar to any other class where the hulls come from a single mould, the rig from one manufacturer and all sails constructed within certain fixed dimensions.

The relative performance of this type of craft is dependant upon the cut and trim of the sails, and the effectiveness of the crew. These yachts do not become obsolete (provided the class continues to race) but the structure is perceived to becomes softer after a time and so will have to be replaced to maintain top performance. Sensibly the structure of this particular class has been over built so that each hull should have a reasonable life span.

Since the design is fixed the style will become dated, but provided the racing is of high quality this does not matter. The International Star design is now over eighty years old and it still attracts the worlds top sailors.

The America's Cup is one of the few occasions where reasonable time and effort is spent on the development of new design ideas, but inevitably there are few people involved, limiting the number of options tried. The IOR classes have many more teams putting their ideas together and this is likely to make the technical progress much more rapid.

For Match Racing or for that matter any racing the ideal for the crew is to use a one-design; a design class, such as in the America's Cup, inevitably reduces the closeness of the racing.

Round the world races are one of the few remaining types of competition where reliability is still more important than performance and so it is a good proving ground for equipment and materials that will hopefully find their way into yachting in general.

The design of a racing yacht is similar to taking an exam or IQ test. A committee devises the syllabus or set of rules and it is up to the designers and builders to pass the exam with the highest possible marks. Unfortunately the effort goes into optimising to the rule and true performance often becomes a very secondary consideration. This has been seen in the optimization of some IOR yachts where the changes made cannot have had any real significance, except in increasing the confidence of the crew! In the current America's Cup yachts this pitfall is being avoided in some syndicates by not letting the crew know what changes are made to the yachts over night.

There are many features seen on sailing craft that are the result of the racing rules rather than from the free development of performance improvement.

The sail area of a racing boat is limited by the class rules, but this is not the case for the designers of one-designs or cruisers. Genoas headsails are only used on racing yachts as a way of getting extra unmeasured sail area and spinnakers have had to be symmetrical so that they are inefficient for going to windward. The standard modern rig has been developed within the strict limits of the traditional racing rules and there has been little opportunity to develop alternatives under good close racing conditions.

The mould is slowly being broken with asymmetric spinnakers and their long poles becoming more common as is the use of full length battens and larger roaches.

The sailboards have the only modern racing rig which has been developed virtually free from arbitrary or restrictive rules. Their limitations for other

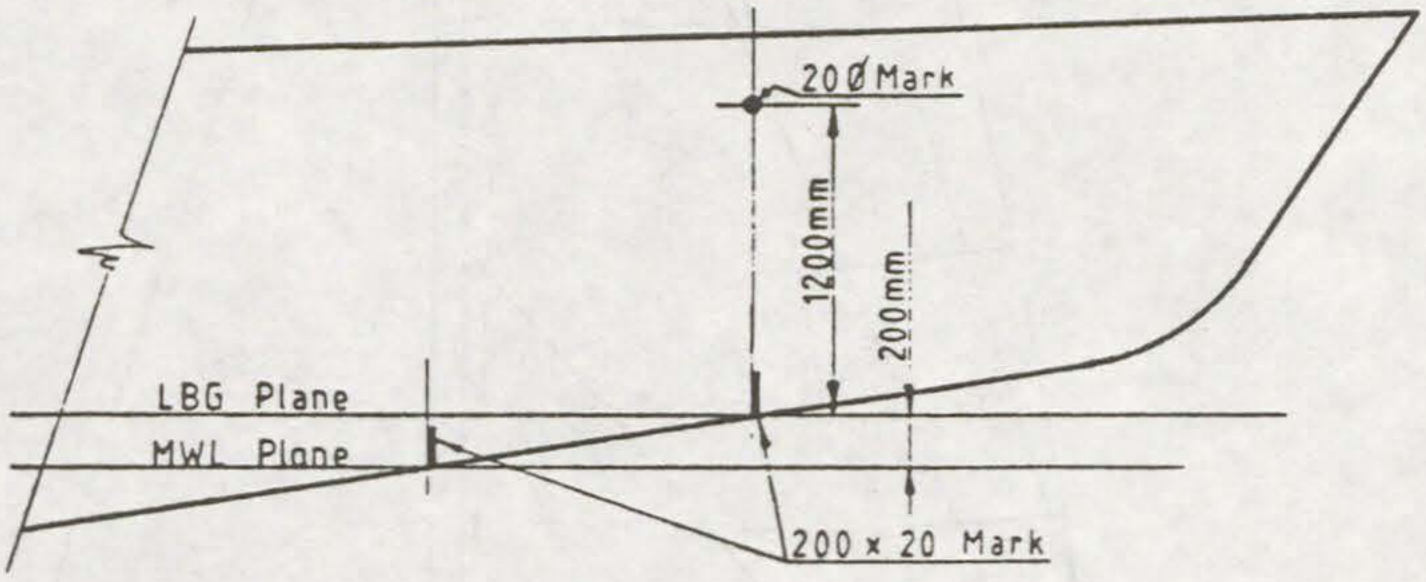
craft are the very high tensions in the rigs and any form of reefing. Top sailboard performers have a different rig for every 5 knots of true wind speed, so that winning does not come cheaply or easily even at this size.

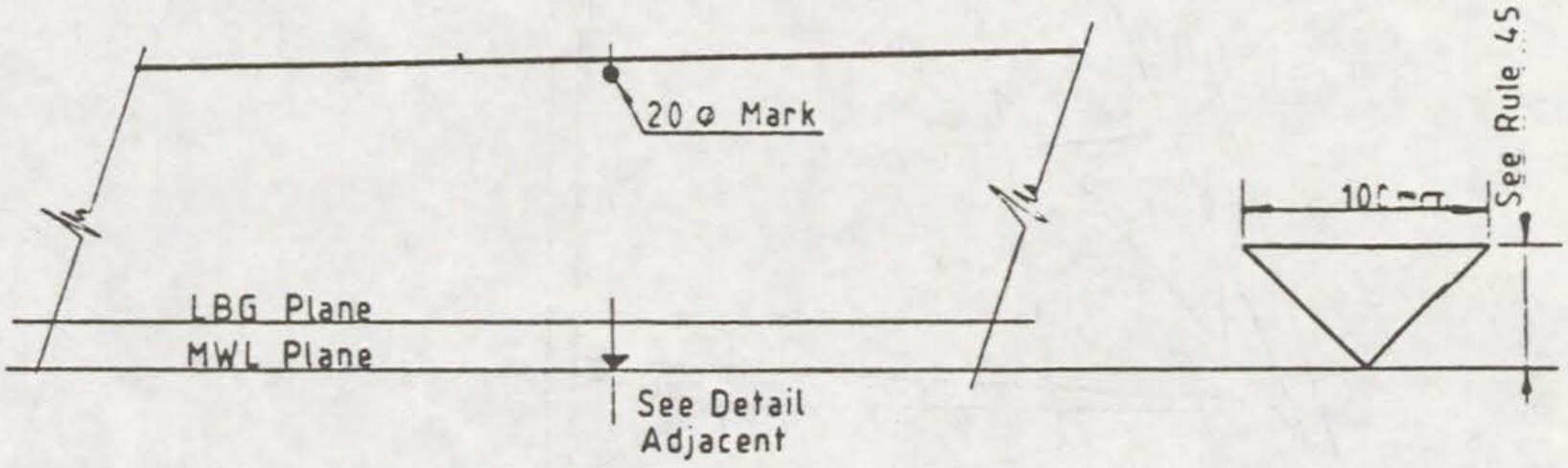
For the last hundred years or so racing yacht development has been governed by the limitations of the racing rules, the result has been that the limited performance of many current racing yachts is achieved in a costly and labour intensive way. A great deal of extra expense and effort goes into achieving an extra 0.1% in performance! Important for winning races but totally irrelevant for cruising.

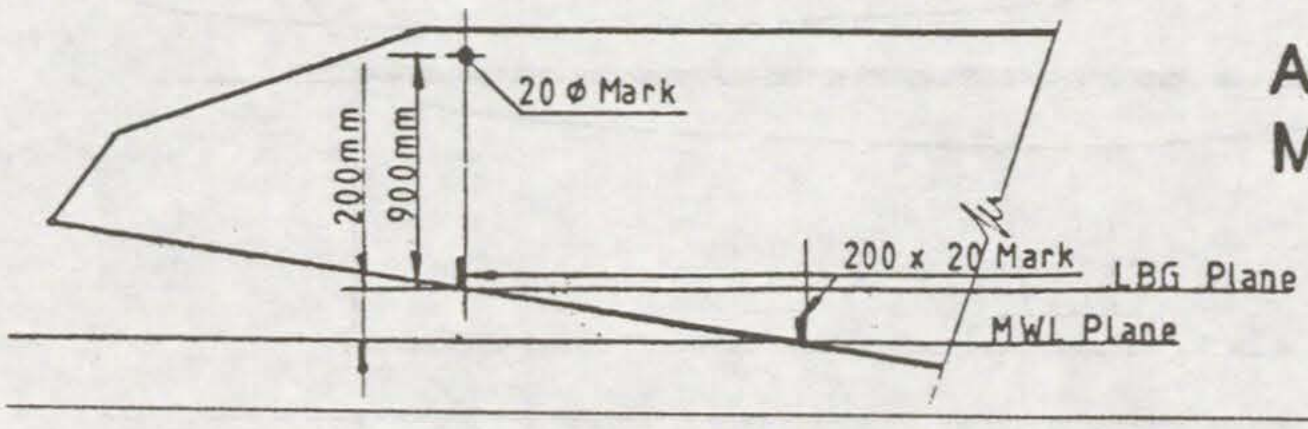
These developments have been of limited use to non-racing yachtsman as current racing designs are totally unsuitable for cruising where performance within a rule is no longer the dominant factor.

Although there are very many useful lessons learned from close racing:

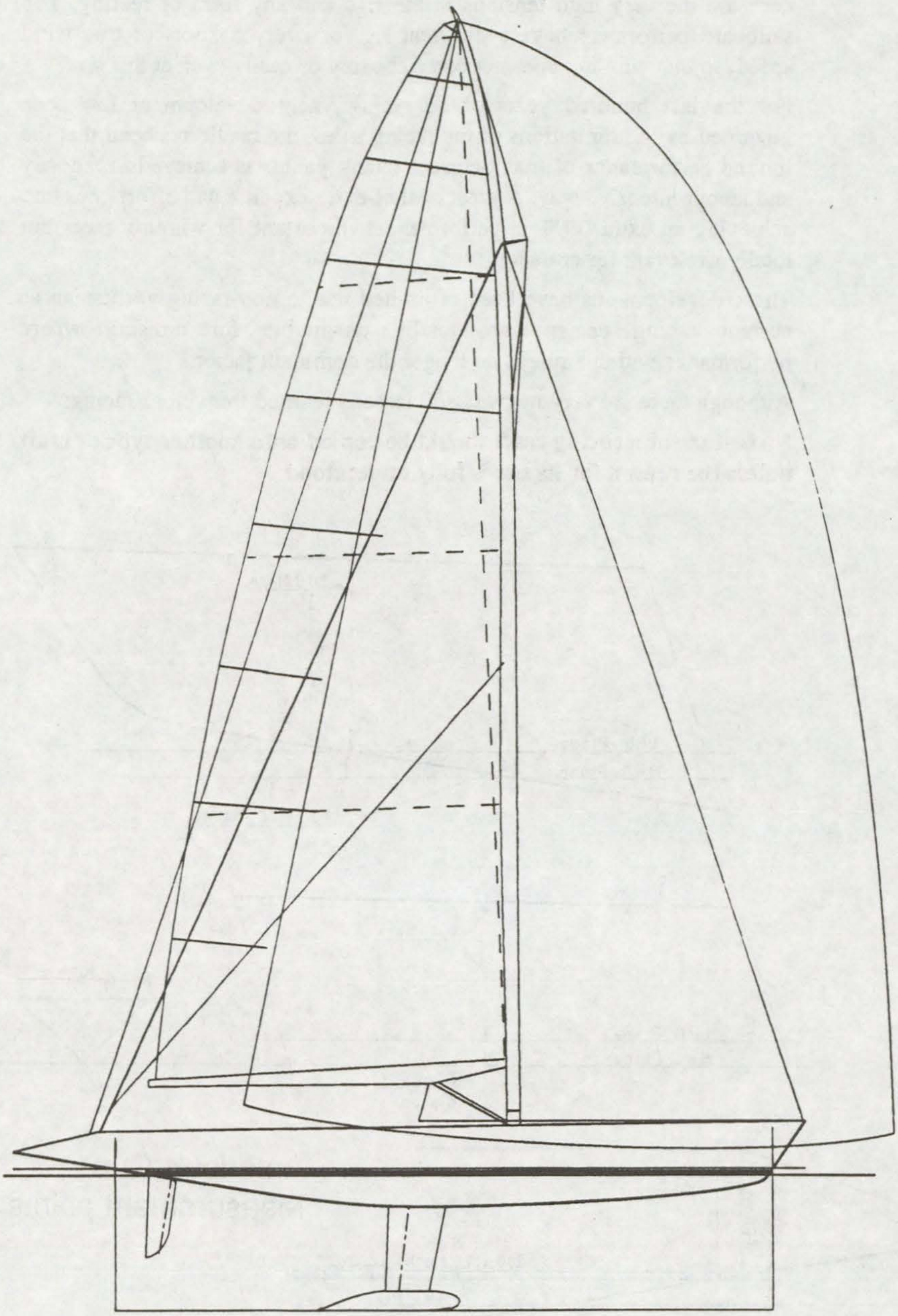
No feature of a racing craft should be copied onto another type of craft unless the reason for its use is fully understood.







America's Cup
Measurement points



THE AMERICA'S CUP CLASS

The America's Cup has replaced the Twelve Metre Rule with a larger and more exciting type of yacht. There has been talk about a new class for The Cup for many years, but it was not until the pause in activity caused by the New Zealand's big 'K' boat challenge and the subsequent court case that there was the opportunity to look for a replacement.

Many options were considered including multihulls. These would have produced by far the fastest craft but it was perceived that multihulls would be unlikely to produce close enough racing or have enough onboard action for maximum media interest. It would also have been a move away from the America's Cup tradition with large monohulls.

The new America's Cup class rule will produce neither the most advanced or the fastest yachts, but rather they are an improvement and update of the old rules to produce a pleasing yacht suitable for match racing

The aim of the new America's Cup rule is given in the preamble.

'The new class is intended to produce wholesome day sailing monohulls of similar performance while fostering design developments that will flow through to the mainstream of yachting and for yachts that are raced "around the buoys" with tenders present'.

Other points born in mind during the formation of the rule were:- The yachts must not be slower than the current 80' IOR Maxis and avoid the complexity of an IOR/IMS type rule.

It was initially envisaged that the formula would be in the form of $L + a \times \sqrt{S} = \text{Rating}$, with only a small variation allowed in the length (L), but it soon was realised that by omitting displacement from the calculation would mean that all the designs would be on minimum weight. This was felt to be too limiting for any real design options.

If compensation is made for weight in this type of rating formula it nearly always pays to go for extra weight and with no allowance minimum weight is the only option. The exception to this is where the craft is light and stable enough to plane frequently. Only an IMS type of rule with a different rating for each wind strength and direction can the corrections for weight be applicable to more than one speed/length ratio.

The principle of the new formula eventually became:

$$[\text{Length}] + [a \times \sqrt{\text{Sail area}}] - [b \times \sqrt[3]{\text{Disp}}] = [\text{Rating}] = [c \times 42\text{ m.}]$$

For a mathematically balanced formula each value within the square brackets [ ] should have approximately the same numeric value. The final factors chosen for the formula are unbalanced (a = 1.25, b = 9.8 & c = 0.388 rather than 1.25, 8.0 & 0.5).

Several computer performance programs were used to develop the rule, but as may be expected they came up with differing results. This rule has now been found to be biased towards the long and heavy corner of the matrix.

This new class is nearer to the old style of Rater rule than the International (12 etc) Metre Classes that was originally designed to replace the Raters at the beginning of this century.

AMERICA'S CUP RATING FORMULA

$$\frac{[L]+ [1.25 \times \sqrt{S}] - [9.8 \times \sqrt[3]{Disp}]}{.388} = 42.00 \text{ m}$$

$$L = LM \times (1 + 0.01 \times (LM - 21.2)^8) + \text{Penalties}$$

$$\sqrt{S} = \sqrt{SM} \times (1 + 0.001 \times (\sqrt{SM} - 16.9)^8)$$

LM = Measured Length, SM = Measured Sail area

Disp = weight in kgs/1025

(Max 25000kgs, min 16000kgs, to nearest 25kgs.)

Draft 4.000m maximum

Beam 5.500m maximum

Freeboard minimums, Fwd 1.500m, Mid 1.250m, Aft 1.200m.
All +100mm to deck level (to allow for gunwhale radius).

Penalties for $\sqrt[3]{Disp}$, Draft, Beam and Freeboard:
4 x deficiency added to L. (very penalising)

From the above the median figures are:-

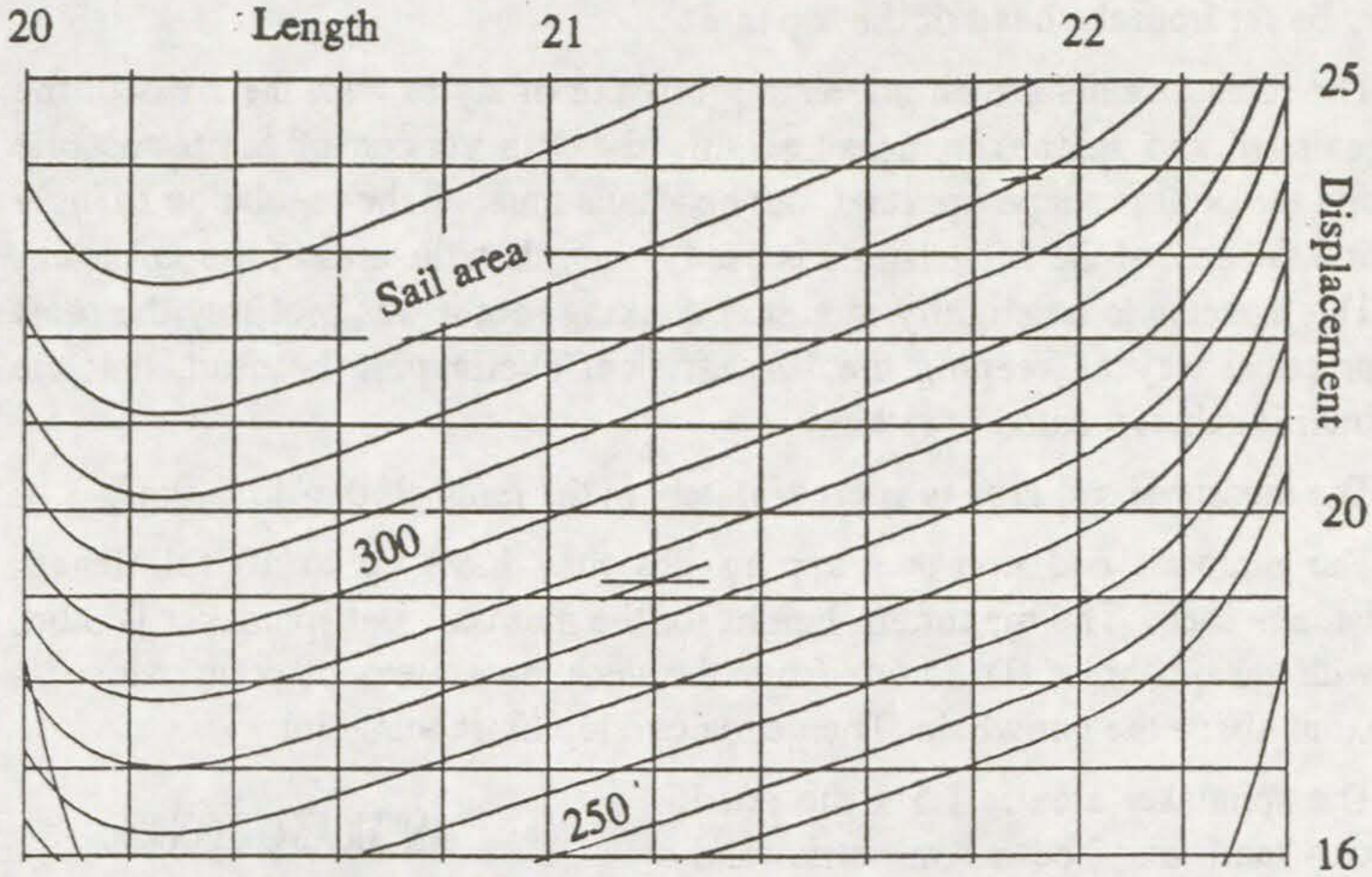
L = 21.200m,

S = 285.61m^2,

Disp = 18.73m (19,200kgs).

As can be seen there are increasing penalties for going away from these mid L & S figures with soft boundaries, but why the standard length is 21.2m not 21.0m or 21.5m and the mean √sail area is 16.9 not 17.0? This can only be some form of diplomatic committee compromise. With everything calculated on computers these days it would also have been possible to have similar soft limits for displacement. The lower weight limit of 16 tonnes appears unnecessary in the final version of the rule.

The length is measured 200mm above the waterline, with additions at the fore and aft ends for girth differences and corrections for the flare of the top sides. This correction means that the topsides may be flared without increasing the girth penalties. The maximum length between girths is about 20m, with the practical limits for measured length including the girth differences of between 20.4m - 22.0m. Measuring the length parallel to the waterline has been standard practice for a long time but there are many good arguments for using a higher measurement level at the stern, as in



America's Cup Rating Graph

effect the new Whitbread 60' Class does by measuring the length to the transom (see drawings).

The traditional thought is that added girth aft increases the sailing length when heeled, but the situation is more complex than this and has to do with the heeled shape of the hull and its angle of attack as compared with the keel. Fitting a trim tab to the keel alters the effective angle of attack of the keel and therefore its angle with the hull. The foils and hull need to be optimised together. The optimum type of keel for a broad sterned craft will differ from that of a narrow one.

No hollows or tumblehome are allowed in the hull body, except for fairings near the centre line for the keel and skeg. There is also a maximum buttock angle under the stern of 12.5 degrees. These limitations are to avoid the problems with bumps and hollows at measurement points and simplify construction, but they do reduce the options on hull shape.

The resulting hull forms will have low wave drag (unlike the 12 Metre) and therefore the lines will be designed around low wetted area and will tend to have only superficial differences, mainly in the overhangs.

The rig limitations are along traditional lines with the basic performance being limited by height and area, but why limit the forestay height to 80%, why not have it at any height the designers wish?

The 12 Metre's 75% 'I' limit came from problems with wooden masts and cotton sails on the early bermudian rigs. Gaff rigs always allowed headsails to be set from the head of the top mast.

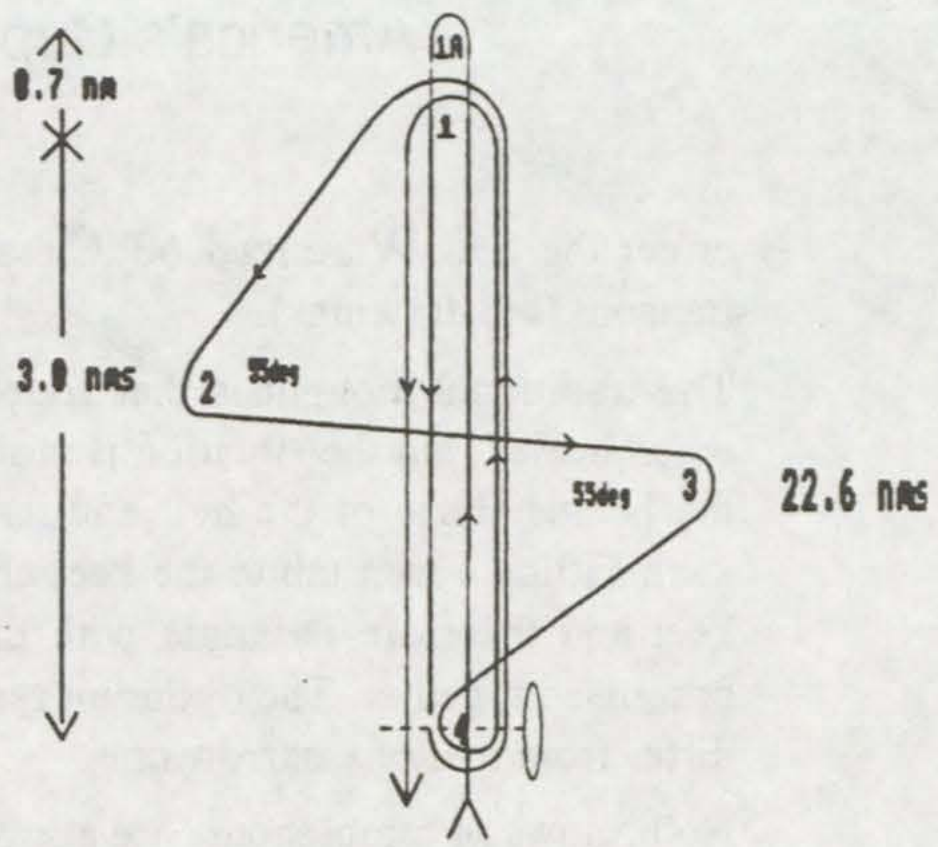
The rules on sails are an interesting mixture of styles with the areas of the mainsail and spinnaker measured directly by a version of Simpsons rule and the outline shape optional, but headsails must be the regulation triangle and the area of the foretriangle is used, rather than the area of the sail itself. This appears to be slightly muddled thinking, but it was probably the most practical way of keeping the less efficient overlapping headsail, that the traditionalists wanted to retain.

The measured sail area is approximately in the range 250m^2 to 340m^2.

The mainsail and non-overlapping jibs may have up to 10 full length battens each. The maximum height for the mainsail and spinnaker is 32m, with the jib hoist (I) 25.6m from the deck measurement point which is 0.5m above the gunwhale. The genoa overlap limit being 3m.

The spinnaker area is 1.5 x the rated area and may be asymmetric and masthead, but the hoist is limited to 1.25 x 'I' thus forcing 'I' to always be at the maximum of 25.6m, and with the spinnaker pole length limit of 1.35 x 'J' the foretriangle dimensions are influenced by the spinnaker requirements, but the spinnaker area is not controlled by the foretriangle as in most other rules.

AMERICA'S CUP COURSE



The stowage and handling of the long spinnaker pole gives scope for radical ideas but unfortunately the class at present insists upon the traditional IYRU type pole attached to the mast and any other options including bowsprits are banned. It would appear more logical if the tack of the spinnaker was restrained so that the distance from the mast was limited, but with no other restriction upon design. Under the present rules there is an argument for reverting to the old two spinnaker pole system as it requires less manpower and jumping around at the critical moment of the jibe. As a result of the racing off San Diego there will probably be a rethink over this part of the rule.

The asymmetric spinnakers are proving more efficient than the symmetrical ones in all conditions except for running in strong winds.

Since asymmetricals have to be collapsed, during a jibe they lose drive and the symmetrical spinnakers are proving more effective for very close match racing.

Genoas only appear on racing yachts when the full area is not measured. This tradition has been maintained so that the macho image with winch grinding during tacking duels does not disappear, but this arrangement is both inefficient and expensive. On the positive side media interest has encouraged the introduction of asymmetric spinnakers and the new 'S' type course that will involve two peel jibes at the beginning and end of the middle reaching leg. The starts will be to windward, but with the finish downwind more importance will have to be given to the performance under spinnaker.

To prevent the spinnakers being used to windward in light conditions the mid girth has to be at least 65% of the foot, but we will probably see masthead drifters that measure as spinnakers, unless (as rumoured) the rule makers decide to ban these sails on the designated windward legs. Allowing a masthead fore triangle would help solve this dilemma.

The masts are of carbon fibre with a minimum cross section of 300mm x 150mm and a minimum fully rigged weight of 840kgs. They may not rotate or be permanently bent and must be stepped below the waterline. For no apparent reason there appears to be a reluctance amongst the rule makers to allow masts to be stepped on deck or permit any form of permanent bend. This is all very traditional and restrictive, as are the height and dimensions of the boom. It would appear that there is a desire to have a standard set of spars for these yachts rather than allow design variation.

In the interests of reliability carbon rigging is banned but other high strength fibres may be used. The current arrangement is for 5 spreaders with a single or double forward strut to hold the topmast.

The plan is that these rules will be revised and updated after each America's Cup series and it was agreed to limit some of the possible developments in the first version of the rule in order to reduce the complexity of introducing the new class.

There are over 20 of this class sailing and a ground swell of opinion wants the class restricted even more so as not to make these current yachts uncompetitive. This is unrealistic as any design class has an inevitable built in obsolescence and the older designs will always tend to be slower. It is reasonable to predict that none of the yachts built for the 1992 America's Cup will be in contention for the following one in 1995.

Any form of fixed keels and rudders may be fitted on the centreline but only two surfaces may be movable and the hinge axis must be within 45 degrees of the vertical. Here are the traditional limitations, why must the

keel and rudder always be on the centre line? It appears to imply that there is a fear that an alternative might prove more efficient. What is the objection to twin or triple rudders, they could improve control down wind and why no centreboards?

This new class rule and the Twelve Metre before it are in direct conflict with the America's Cup Deed of Gift, to quote:-

"*Centre-board or sliding keel vessels shall always be allowed to compete in any race for this Cup, and no restriction nor limitation whatever shall be placed upon the use of such centre-board or sliding keel, nor shall the centre-board or sliding keel be considered a part of the vessel for any purpose of measurement.*"

By the wording this appears to be very significant feature yet this has never been amended or changed by any specific mutual consent clause, just quietly ignored over the years!

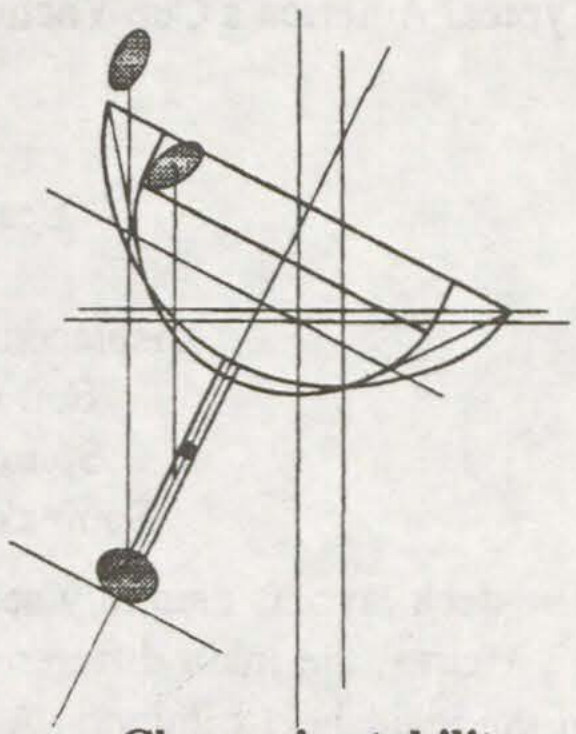
It was initially proposed that the construction would be fibreglass, but it was felt that this would give the wrong image and using the latest hi-tech materials would only add about 10% to the building costs and in theory make a longer lasting structure. The resulting skin construction is therefore of carbon/foam sandwich with strict limits on thickness, weight and modulus. All the internal structural details are unrestricted and will have to be of minimal weight. With the large rigging and keel loads on the shallow hulls the problems include making a stiff enough structure. Even with the best available construction it is felt that this type of yacht will 'soften' and be non competitive within a few seasons, so much for the endurance of hi-tech materials and the desire to keep old craft competitive. It is also proving very difficult to control effectively the use of high modulus (and very expensive) carbons, as they can all look so very similar. At present the only way to inspect the material is under a powerful microscope.

Yachts using the latest composite construction are in the forefront of the development of these hi-tech materials resulting in such problems as the Maxi deck cracking and holes in the side of Whitbread yachts. For reasons of safety the aerospace industry has be very much more conservative with these new materials and are therefore naturally very interested in the experience in the use of these materials in sailing craft.

The layout of the deck is relatively free except that the hatch sizes and positions are controlled, the cockpits may only be aft of the mast and must be between 400mm and 750mm deep. The drums of sheet and halyard winches must be above the deck, but why are there any restrictions on the deck arrangement (provided that it is water tight and above the maximum depth)? This rule appears to be a hang over from the 12 Metres and other classes where there were originally some accommodation requirements.

There could be interesting and practical developments if fuller freedom were allowed.

The ballast ratio is typically near 80% which is higher than the 'lead mine' 12 metres. This was not the original intention, but has come about through the use of low weight construction and the desire to keep the displacement high enough to prevent the yachts surfing too easily. With all the ballast in a bulb at the base of the fin keel the righting moment from the crew will be a very much smaller proportion of the total than on IOR yachts. This will have an effect on the hull sections used. It could be that these yachts will prove too stiff for the light winds of San Diego and that not all the ballast will be in the bulb.



Change in stability with max & narrow beam

The crew is limited to 16 weighing not more than 1440kgs plus one owner's representative (or camera operator who shall not contribute to the racing other than by positioning their weight aft of the helm). This rule promotes a macho image with an average weight of 90kgs. Would it not be better to have just a simple weight limit and allowing those of a lighter build a chance to participate in the America's Cup.

The first crop of yachts have not produced any great surprises as they were all designed shortly after the rule was finalised and before the venue of the current Cup races was known. They appeared to be near the middle of the rule matrix. All have maximum draft and beam. The latter is interesting as the 12 Metres had to introduce a minimum beam in the 1930s and it was not until Freemantle that there was any serious movement away from the minimum figure. Is this fashion or is there some unseen fundamental difference in these types of yacht?

The second generation show an increase in size and sail area, with small fore triangles (J) and have the cockpit going through to an open transom. This reduces weight and windage. From a structural point of view it is better to have a continuous cockpit floor running from side to side and through from the mast to the transom, treating the side decks as non structural. This would avoid the high stress points created by the cut-outs in normal deck layouts, at the expense of slightly reduced torsional rigidity.

If these yachts follow the trend of other classes we can expect the average length and sail area of the most successful yachts to increase as the class develops and the current consensus is that the optimum design for the

current rule will be near the maximum weight and length, with small penalties taken for length and sail area.

Typical America's Cup Yacht dimensions are:

LOA 24m(78')
LWL 18m(59')
Beam 5.5m(18') max
Draft 4m(13')
Displacement 23,600 kgs 52,000lbs
Sail area 316m²(3400ft²)
Spinnaker 474m²(5100ft²)
Spinnaker boom 10.0m+ (33'+)

The deck layouts naturally started off by being a mixture of IOR Maxi and 12 Metres, the main difference being whether the helmsman is fore or aft of the mainsheet trimmers. As more is learnt about the handling of the new long luffed asymmetrical spinnakers and alternative arrangements are developed, we can eventually expect to see a distinctive style of deck layout to appear on these yachts. The current trend on all racing yachts is to simplify and lighten all equipment as much as possible.

There are reports of some interesting keels, but it is more likely that the subtleties of the underwater foils may not be apparent to the untrained eye. There is certainly plenty of scope for development in this area. Refinement of keel foil performance is still in its infancy. With the relatively deep draft, the theoretical performance advantage of a new style of keel may not be worth all the extra time, risk and cost involved. Sophisticated laminar flow keels and other sophisticated designs have proved failures on their initial outings, thus the psychological advantage of the exotic may be disappearing.

A fundamental design problem for this class is reducing the interference between the hull and the foils to a minimum while maintaining a suitably strong structure to control the twist and bending with up to 20t of lead at the bottom of the narrow fin.

Wing keels increase the effective depth and this reduces the induced drag, with a draft of 4m this will only be an advantage in light winds where the extra wetted area of the fins is a disadvantage. The effect of a simple bulb is to reduce the effective span and drag it is likely that there will be rather more subtle shapes for the ballast.

Bow rudders have been tried by a few teams, but in the swell off San Diego they lift out and ventilate easily, loosing lift. There does not appear to be a lee helm problem with the long spinnaker booms, provided that the yacht can be heeled and produce an asymmetric bow wave system. The shorter 'V' bow overhang is a better shape for this, but too much stability could

prevent enough heel angle being achieved.

The emphasis on keels design within all teams is not surprising as the last two Twelve Metre challenges were won with the help of radical keels. Not only are modesty skirts being fitted to the yachts when they are lifted out, but petticoats are also used and not removed until the craft is out at the race course and refitted before returning!

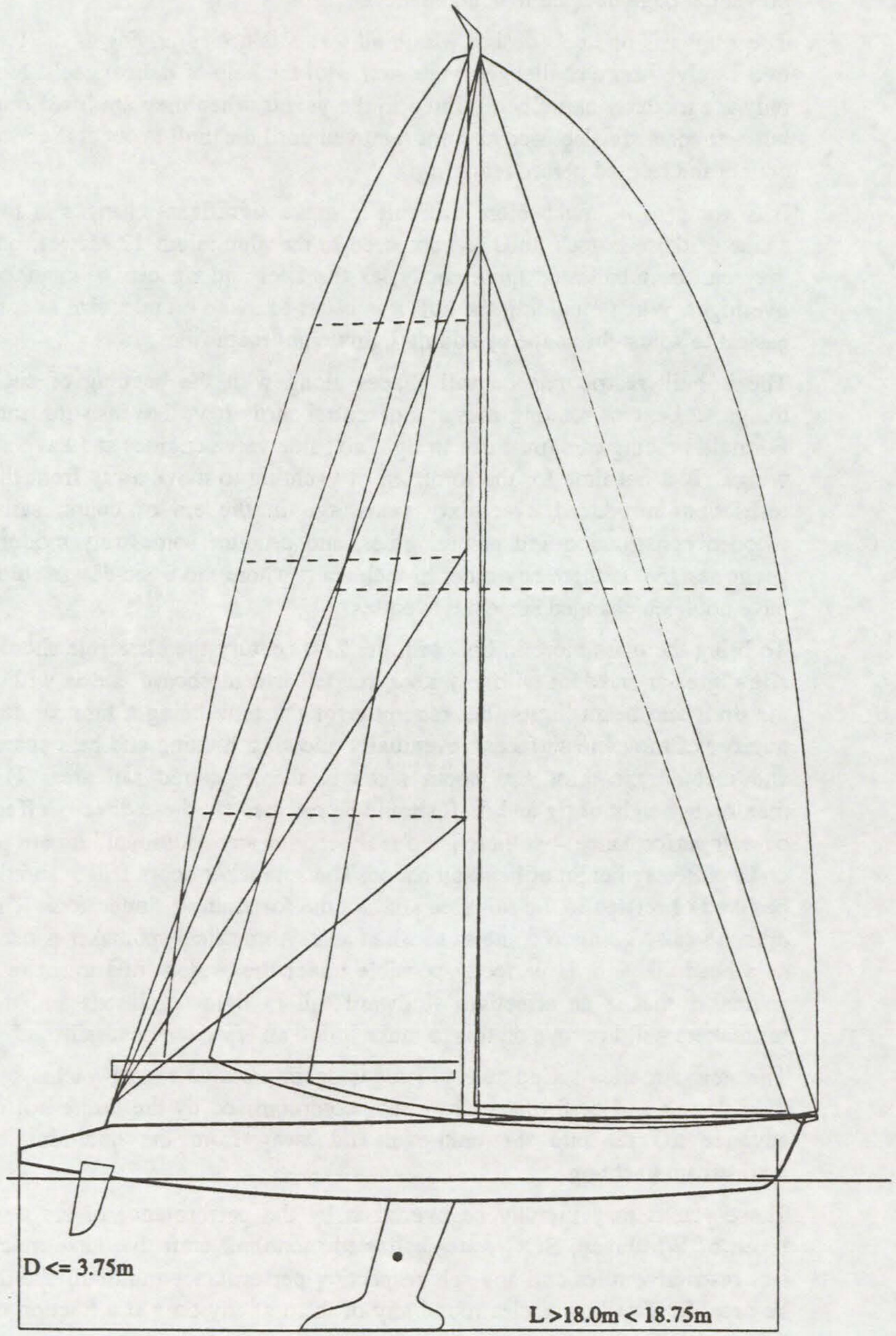
It is going to be much more difficult to make significant changes in the shape of these hi-tech hulls as compared to the aluminium 12 Metres, but they can be reballasted quite easily, as the keel and rig can be changed overnight. When moulding the hull it is better to make it under size as it is easiest to adjust the shape by adding lightweight foam filler.

The in-built restrictions on sail shapes along with the banning of such things as bent or rotating masts and centreboards it is like insisting that Formula I racing cars must use straight six, side valve engines and have no wings. Is it not time for the forefront of yachting to move away from the restriction introduced over sixty years ago in the era of cotton sails, wooden construction and natural glues, and produce some truly modern yacht designs. Is there any other hi-tech sport where the basic design rules have not been changed since the twenties?

To bring the class more in line with the 21st century the class rule should allow greater freedom with any keel, rudder or centreboard that is within the draft and beam limits (but retaining for the time being a limit on the number of movable surfaces), eventually allowing rotating and bent spars, and include the mast and boom areas in the measured sail area. The maximum height of rig and draft should be retained (as these directly effect overall performance) but there is no real need for any additional limitations on the forestay height or headsail shape. The spinnaker boom length should be fixed or related to the sail area and not the foretriangle dimensions. The crunch is also going to come as to when an asymmetrical spinnaker is used as a headsail, as it is perfectly possible under the present rule to make a spinnaker that is an effective windward sail in light conditions and the sailmakers will improve on this to make it into an effective headsail.

The new America's Cup rule is producing impressive racing yachts but their design and performance has been compromised by the desire not to advance too far into the unknown and away from the traditions of mainstream yachting.

These yachts may literally be overtaken by the performance of the new breed of Whitbread, BOC water ballasted monohull craft that have much less restrictive rules and any self respecting performance multihull should be capable of sailing circles round any of them at any time at a fraction of the cost.


D <= 3.75m
L >18.0m < 18.75m

Whitbread 60 Rule

INTRODUCTION

The 1993-4 Whitbread Round the World Race will have two level rating classes, the IOR Maxis and the new Whitbread 60' Restricted Class. Both classes will be racing boat for boat without any form of time allowance.

The cost of a Whitbread Maxi campaign has become close to that of an America's Cup challenge and with the BOC 60' single-handed water-ballasted yachts putting up some outstanding performances, it was realised that it was time to introduce a newer style of less expensive and more advanced type of offshore yacht.

The Whitbread 60 Rule was first published in January 1991 (and subsequently updated). This class is designed to limit costs with a fairly tight set of rules with relatively little scope for individual designs and strict limitations in the use of expensive materials. There are maximum dimensions and sail areas, with restricted weight, but there are no trade offs between any of these factors.

This is a restricted class rule in the same vein as some dinghy classes, to keeps down the cost and reduces the chances of designs being outdated too rapidly, but there is still plenty of scope to make the optimization of the overall design and operation, a challenge to any team.

COURSE

The course is around the world from Southampton to Southampton via the Southern Capes and can be divided into two main section:-

The Atlantic, where good all round performance is required with some emphasis on light winds to get through the doldrums.

The Southern Oceans, where good handling characteristics and offwind performance will be more important.

HULL

The sailing length is measured from a point 0.1m above the waterline at the bow to the aft end of the transom and may not exceed 18.75m or 61.5'(and less if an aft girth measurement exceeds a set figure). This will allow some of the less extreme BOC yachts to fit into the class and it is possible that future singlehanded races will also use this rule.

No hollows are allowed in the hull shape, except for fairings in way of the rudder or keel and in the topside sections near the bow. There are minimum radii of curvature and no tumblehome to avoid distortions in the way of measurement point and water ballast tanks, also to the ease manufacture.

Tumblehome was used in many classes up to the sixties, but is now severely discouraged or banned by most rules, including this one (fashion?).

The shape of the bow profile is limited by the rule with the rake of the stem fixed between upright (0°) and 25°. The fore foot will have to have quite a sharp curve which will not help the directional stability downwind in a seaway. If a little more freedom were allowed there would be the possibility of a developing a more directionaly stable profile than the current IOR short V bow.

Twin rudders are allowed provided they are both placed aft and the width is limited to .25m, so that no wide endplates may be fitted. For optimum windward performance the rudder(s) should be near the aft end of the waterline, but off the wind it is better to have them as far aft as possible. With twin rudders they should be splayed at about 30° and short enough that the windward one is clear of the water at the optimum angle of heel.

RIG

The maximum dimensions of the rig and mast are fixed, with no restrictions on the engineering detail, except for the types of materials used. With no minimum weight to the rig their is a maximum mast section. The America's Cup class has the other option of a minimum weight and size of section. The boom has to be at a standard height above the deck and the low gooseneck arrangement such as as fitted to the BOC boats and multihulls is banned, as is any form of external boom stiffening. This would appear to be an arbitrary limitation that has minimal effect on cost or performance, but makes boom breaking more likely. The target will be to produce the lightest practical rig that can withstand the rigours of the race, including the inevitable knockdowns.

SAILS

The maximum area of each sail is fixed (mainsail 117m^2, jib 83m^2, spinnaker 300m^2 and drifter 135m^2), with the shape of mainsails and spinnakers optional, but in line with tradition headsails must be triangular. With the total area of the jib measured it will be less efficient to set these sails as overlapping genoas, resulting in the foot of the foretriangle (J) being around 8 metres. This allows a wide base for the shrouds (giving a lighter and a stronger rig). With the spinnaker pole and bowsprit limit of 8.5m, any bowsprits will be short.

One spinnaker may be measured as a masthead drifter of up to 135m^2 weighing not more than (area/8)kgs. This is in effect a 150% light masthead genoa and will be the most important sail when a spinnaker is not set. With the high stability of these craft this sail could be set to advantage

in 20 knots of apparent wind, some drifter! Spinnakers of over 255m² may be set from the masthead, but also have a maximum weight (area/12)kgs so that they will be expensive to set in strong winds. It appears that the sail plan rules have not been fully worked out and that the implications of this masthead drifter and narrow spinnakers do not appear to have been fully realised. The construction and upkeep of these two sails will have a disproportionate effect on the overall performance. Will the maximum weight limit apply to repairs carried out onboard? It is likely that this rule will have to be modified for the class to succeed in the long run. Why not just let all the yachts set what sails they like within the spar dimensions?

The optimum mainsail shape will differ for the two parts of the course. For the Atlantic a sail with a good roach will be important for light weather and windward performance. In the Southern Oceans a smaller roach, longer foot and higher clew will probably prove more efficient.

The total number of sails onboard is limited to 2 mainsails (of the same shape), 6 jibs, 7 spinnakers and one drifter plus a storm jib and trysail. Even though the full length battens should increase the life of the sails, there will be a need for extended sail repairs onboard particularly to the masthead drifter and spinnakers, with a major rebuilding programs at each stopover.

CREW

The minimum crew is six and the maximum weight 1000kgs. Each member contributing over 1% to the weight and 0.5% to the wetted area, but less than 1% of stability it is important that extra crew members as not limiting the performance.

It is likely that the best performances will be put up by the smallest crews that can cope with the work load. This will mean that the best performance may be achieved by moving away from the conventional watch system and use a rolling system that varies the number on deck to the prevailing conditions. The use of labour-saving sail handling techniques will be beneficial and this could eventually benefit the cruising yachtsman.

Crew experience is very important, not only for the overall performance of a campaign, but in raising sponsorship. It is desirable that at least one senior member of the crew should have taken part in a previous Whitbread race and at least one member of the crew should have had several seasons of racing at Admiral's Cup, Olympic or a similar level.

The experienced members of the crew should be available to the design team at an early stage as the basic layout of the craft can make a great deal of difference to the overall performance as it is important that the designers and crews fully understand each others requirements.

The optimum crew numbers will reduce as experience is gained with the class, but as autopilots are now just about the only electronic aid not allowed, a minimum of two extra two crew will be needed for the helm.

Abilities required onboard include:- Cook, Medical, Sailmaking, Navigator, Route Planner, Sail trimmer, Boat performance, Rigger, Boatbuilder, Engineer and Diver.

DECK

The deck design and equipment needs to reflect the limited crew numbers. The layout should avoid the labour intensive, split second operations of round the buoy racers and be more kind to the wind and water that will be rushing over the deck.

The aim will be to bring most the controls aft and keep the crew within a protected area of the cockpit for much of the time. It should be possible to jibe and tack without leaving the cockpit.

Roller furling headsails may prove an effective way of reducing the work.

ENGINE

The rules stipulate the minimum propeller installation along with the position, weight and size of the engine so there will be very little variation in this area.

AUXILIARY MACHINERY

A minimum of 190kgs of generators, desalination plants, freezers, batteries and a satellite transceiver must be carried and all must be mounted near the centre of the boat.

CONSTRUCTION

The minimum weight, dimensions and limitations on materials for the shell are laid down, which is basically fibreglass, kevlar and foam of minimum density 70kg/m^3. The internal structure may also use aluminium. There must be three watertight bulkheads including an anticollision one in the bow and shown by calculation that the yacht has a minimum of 0.15m (6") freeboard with any one section flooded.

Only conventional aluminiums and metals are allowed for fittings, no titanium or the like. Carbon may only be used in rudders, spinnaker booms, bowsprits and battens, but it is not allowed in the fin keel.

BALLAST

These craft may carry up to 2500 litres of water ballast either side of the centreline, this represents 15% of the weight and increases stability by

25%, in addition the fixed ballast will amount to over 70% of the weight and will produce 70% of the stability. Crew weight will be less significant in terms of stability, with each member contributing less than 1% of the total. The water ballast is the equivalent of thirty people sitting on the rail, it requires no feeding and can be thrown overboard when not required! This is the logical way to go with ocean sailing performance.

These boats will be very stiff and be able to carry full sail in apparent winds of over 25 knots. The down wind performance in a blow will be very exciting and limited by directional control.

Having most of the ballast in a large bulb at the base of the fin gives the maximum righting moment and sail power in strong winds, but this is at the expense of extra wetted area and resistance resulting in reduced performance in lighter conditions and downwind. The maximum width of the keel is limited to 0.6m preventing winged bulbs.

There must be a positive righting moment up to 125° of heel, both with and without waterballast. This would not appear to be a problem with the very high ballast ratio and most of the weight at the base of the fin.

The optimization of the ballast and keel design will be an interesting area for development and could use some of the techniques developed for the current America's Cup yachts. The secret is to control the way the fin flexes as it becomes loaded up and ensure the sections remains efficient hydrodynamicaly, both to windward and at high speed down wind.

DEVELOPMENTS

The rule is such that all designs will be very near the maximum length, beam and draft, with minimum displacement. This will make all the hulls superficially very similar and some builders are planning to produce standard hulls. This should help reduce the expense and simplify any campaign with minimum loss of performance, but the winner will almost certainly come from a custom one-off design that has been well prepared. This is not the kind of craft that you can throw into the water and expect to get the best out of it straight away.

The cost of one of these sixty footers is expected to be about a third that of a new IOR Maxi, with the running expenditure very much dependent upon the standard and number of the crew selected, the level of support required and the length of the work up period.

The main variation in the hull is with the amount of rocker on the centre line. Large rocker for low wetted area in for light conditions and windward performance. With a flatter boat being better for off the wind in a blow. The light displacement and high stability will make these craft plane very easily.

The areas of this rule that have most scope for performance improvement are with the rig and sails, keel and rudders, deck arrangement and internal structure, as well as with the composition and training of the crew.

The BOC water ballasted yachts have proved very fast, with their performance limited by the strength and endurance of their single crew. Producing a fully crewed version of this type of yacht will highlight the control and stability problems of the designs in strong winds.

When running, rolling dynamics and directional control are the limiting factors, not stability (the deep keel may cause dynamic·instability and rhythmic rolling).

Modern deep draft bermudian rigged yacht with balloon type spinnakers are dynamically unstable downwind and unfortunately neither this rule nor any of the other of the current yacht racing rules allow the effective development of any other possibly more efficient and stable downwind sails.

It is likely that the running performance of these craft would be improved by using a low aspect ratio sails which can be much more stable and dampen out roll, allowing more sail to be set in strong winds.

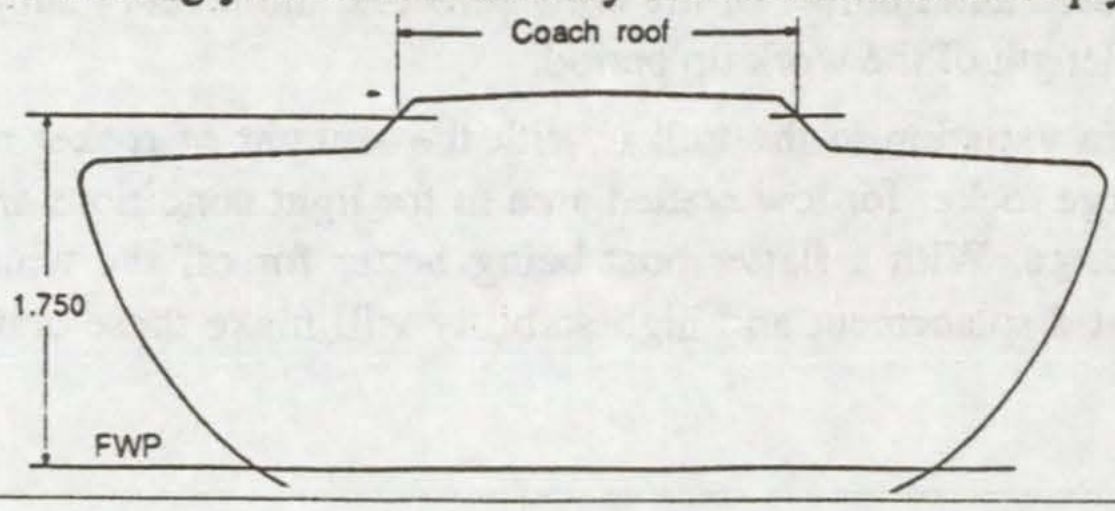
As with any new class we can expect the first few examples to be fairly conventional with the more advanced developments not appearing until just before the start of the next Whitbread Race in September 1993.

It is most likely that in some conditions these yachts will be faster than the IOR Maxis so there will be some interesting armchair sailing (with the aid of the BT onboard satellite television) during the next Whitbread Race.

The BOC 60' singlehanded yachts have shown one way of achieving fast passages with much smaller resources. Let us hope that the new WR 60 will progress this development.

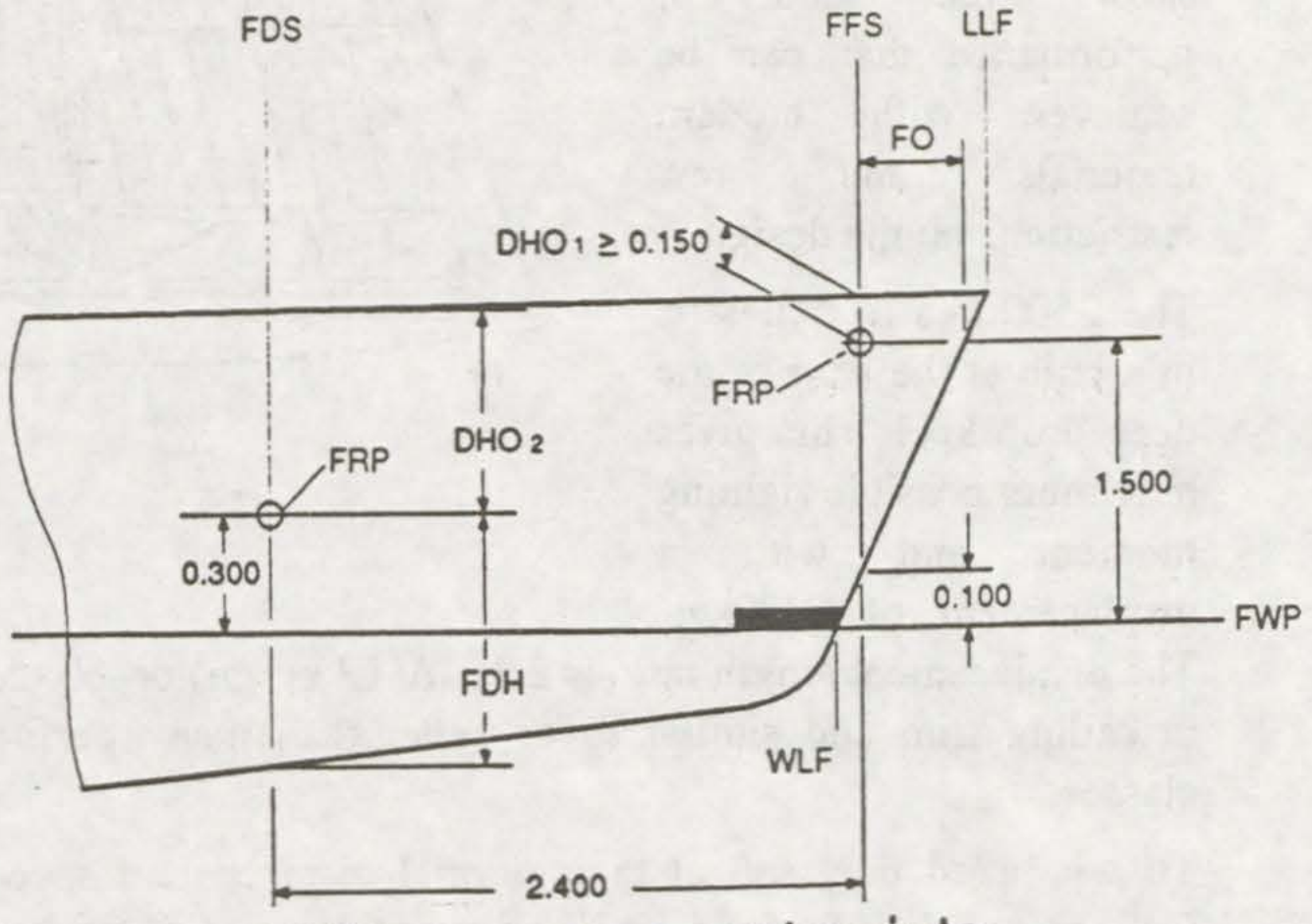
These are the ocean going version of the new type of skiff classes, with their asymmetrical spinnakers and large righting moment.

Despite their apparent extreme design characteristics and very restricted rule, it is probable that these Whitbread 60' Class yachts will produce more benefits for the cruising yachtsman than any IOR or America's Cup yachts.

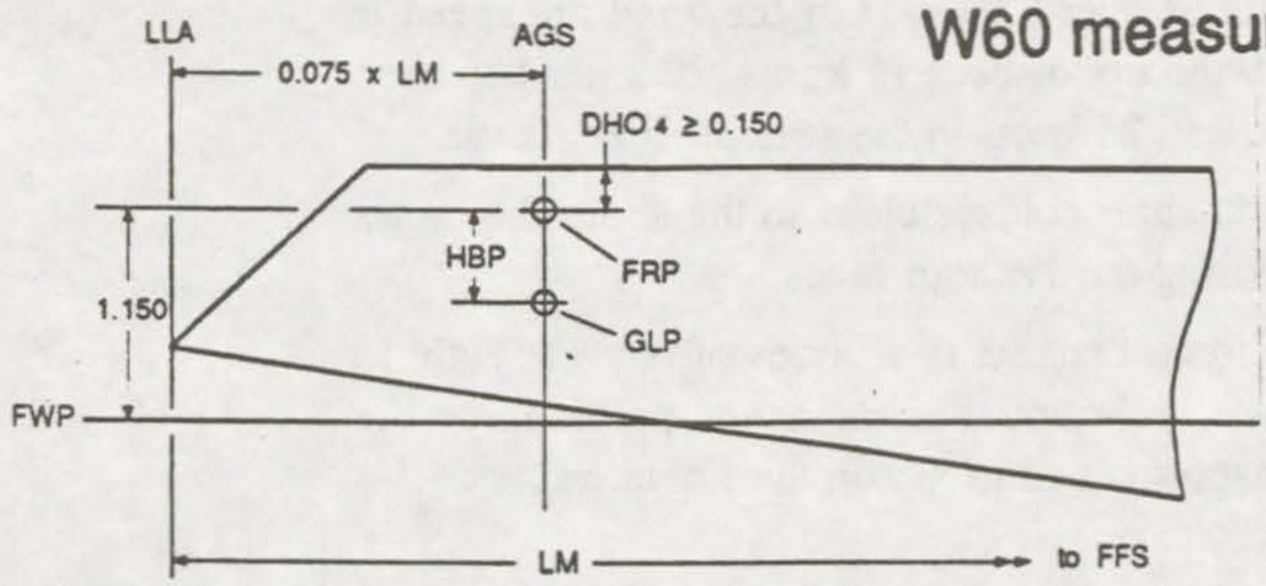


Typical measurements of a W 60

	Metric	Imperial	
LOA approx	19.5	64	
LWL approx	17.4	57	
Beam max	5.25	17.2	
Draft max	3.75	12.3	
Disp max	15,000	33,090	
Disp min	13,500	29,770	
Water ballast	2550	5625	
Measured 'L' max	18.75	61.5	
Rig Ht max	26.0	85.3	
Forestay Ht max	21.5	70.5	
Base Foretri. approx	8.0	26.25	
Spin boom max	8.5	27.9	
Mainsail max	117	1260	10 battens max
Jib max	83	893	4 battens max
Spin. asym. max	300	3260	midG.>65%
Masthead drifter	135	1450	wt<(area/8)kgs

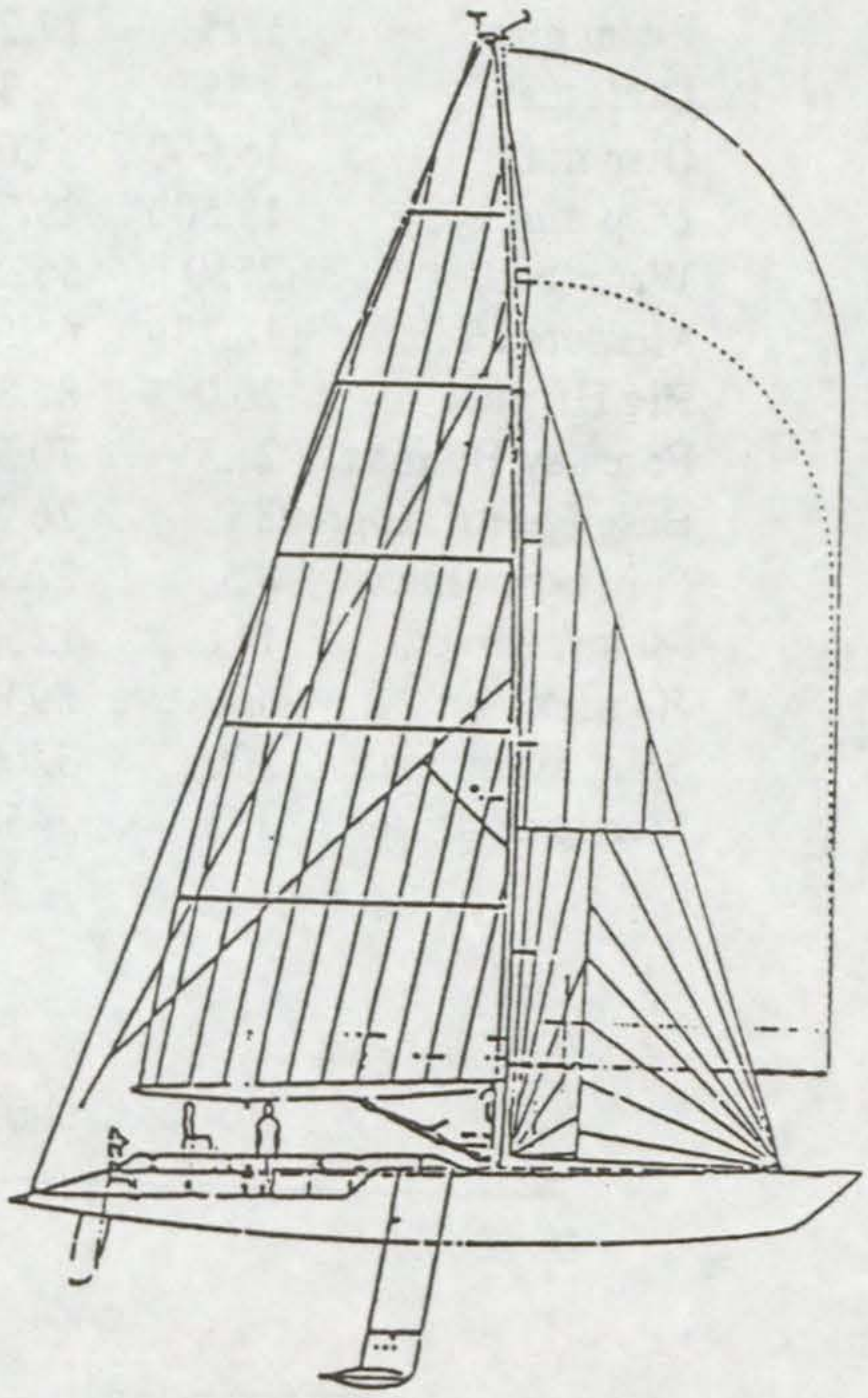


W60 measurement points



Formula One Class World Yachting Grand Prix

16 Metre One design



This is a 52.5 foot light displacement keel yacht shows the kind of performance that can be achieved with modern materials and few restrictions on the design.

The 2500 kgs of ballast is in a bulb at the base of the deep drop keel. This gives maximum possible righting moment and with a displacement of 5360kgs.

The displacement length ratio is 2.25 (Δ/ L^3 kgs/m) or 60 ($\Delta/.001\ L^3$ ton/ft) in sailing trim and similar to or better than many performance dinghy classes.

To windward they sail at their normal displacement speed of 7.4 knots ($2\sqrt{L}$ m or $1.1\sqrt{L}$ ft) for a VMG of over 6 knots. Off the wind the speed is normally in excess of the true wind up to about 15 knots. 20 knots has been recorded in San Diego Harbour and 26 knots in the seas off Freemantle.

These are fun yachts to sail with short courses close to the shore the crews of 9 or 10 are kept very busy during the 1½ hour races.

The professional Grand Prix Circuit consists of a series of races at eight to ten venues around the world with substantial prize money provided by the sponsors. All the boats are transported as a group on their own trailers.

ULTIMATE CLASSES

A new style of monohull with large outriggers is now well established, developed from the Sydney Harbour Skiffs and the International Moth.

These craft are not particularly light due to the weight of the outriggers and crew, but they have a good righting moment and a big sail area for a lively performance.

The American Ultimate 30 is a free restricted class that is proving expensive to keep in top condition.

The European Ultra 30 uses similar rules but has a one-design hull. The spar dimensions are fixed, but any sail may be set from them.

The performance of these classes is controlled by the basic fundamentals of weight, length and righting moment. In light winds the windward performance is limited by the maximum height of the rig and depth of centreboard (minimises induced drag and so reduce the total drag angle). Of the wind the spar dimensions limit the maximum practical area that can be set effectively. It has been found that the optimum size of spinnaker is only about half the maximum size that can be set. Sail area is like money:it is not so much how much you have but how you invest it that dictates the performance.

A new Olympic Class is to be based on the ultra style, with the width and weight adjusted for each crew to maintain a common sailing weight and righting moment. This should make for much more level racing.

Other one design classes should make much more effort to equalise righting moments and all up sailing weight, so as to make the racing situation more equal.

The International Fourteen class has always managed to keep in the forefront of development and are now close to this latest style with their twin trapezes and large asymmetric spinnakers.

The aim of this type of class is to provide a high performance, practical restricted class of relatively low cost and easy transportation.

A practical problem is that they are easily capsized and it is often not possible for them to be righted without outside assistance. They need to be more practical if they are to become popular. To encourage better developments the class rules could include:-

The boat must be launched and sailed by the crew only, without any outside assistance. Any boat that requires outside assistance between the start of launching and hauling out is liable to disqualification. If the venue is such that outside assistance or support is essential then the race organisers must provide suitable and similar facilities for all competitors.

Cruiser Design

Introduction

The style of cruising yachts has changed over the years from converted work boats to modified racing yachts and into a true type of their own where the style is dictated by the desires and dreams of their owners.

The concept of a performance cruising yacht is more complex than that of any racing boat, as the spectrum of requirements over the designed life of the yacht is very much larger. There are features on current racing yachts that are are desirable on all cruisers and others that should be avoided as they detract from the safety and performance of the design.

Well over 95% of cruising craft, sail or power, mono or multihull spend 95% of their time at their moorings and very few examples test the soundness and seaworthiness of the concepts to the full. This is reflected in the design and construction of many current craft. Some are little more than marinised caravans or motor homes and are kept in marinas, the nautical equivalent of the caravan park. With very little experience of these designs operating in severe conditions their real abilities, safety and seaworthiness are left open to speculation.

Definition

It is assumed that the modern cruiser is expected to provide "home" comforts when moored up, but also be capable of carrying its crew in a comfortable and safe manner from one place to another. Older designs often fell short in the first requirement and it is in the second that many modern designs fail in one way or another.

History

The first cruising yachts were adaptations of working boats and usually operated in a local environment, this changed when a few were taken on extended voyages, such as Slocum with Spray or more recently the Pyes in Moonraker. These types of craft are strong and slow. This style of sailing developed the desire for the traditional or work boat form of yacht.

Once yacht racing had become established many of the older racers were converted into cruisers. This started the Cruiser/Racer as a type of yacht with an image of speed and weatherliness, with many builders selling standard designs on this basis.

The original idea behind the CCA and RORC rules was to allow cruising yachts to race together across the open sea. This situation was generally maintained until the introduction of the IOR which does not discourage the more extreme performance designs. The resulting style of racing yacht has become totally unsuitable for conversion into safe cruisers and little of the

development in recent years has been of benefit to the cruising yachtsman, in fact since there is a strong desire to follow racing fashion the current breed of racing yacht is detrimental to the design of fast and safe cruisers.

Choice

When buying a cruising boat there are many rational and emotional (or irrational) decisions to be made and in many ways most people buy a dream rather than a purely practical choice. The problem is that sometimes these dreams can turn into nightmares due to incorrect choices and a lack of understanding of all the relevant factors involved.

Performance

The racing and cruising yachtsmen have very different perceptions of performance.

For top racing yachts a 1% margin (36 secs/hr or 15 mins/day) is significant and designers often incorporate ideas that might give less than 0.1% (3.6 secs/hr or 1.5 mins/day) improvement, but many design features are also dictated by making the best within the class rules and have very little relevance outside it.

The sort of performance difference that a cruising sailor might be interested in is around 5% or more (3 mins/hr or about an hour per day).

In practical terms the minimum speed difference that is likely to be of any significance to the cruising yachtsman is probably around 2% (1¼ mins/hr or 30 mins /day).

If you seriously claim to be interested in performance improvements of less than 2% when cruising then you should ensure that you have the bottom scrubbed every week, a folding or feathering propeller fitted, all sheets manned and trimmed continually, as well as working the tides and wind shifts, with the crew sitting on the gunwhale! Without this your micro performance improvements will be of no significance.

Since many racing boat features are for as little as 0.1% improvement the cruising designs should not copy racing boat features unless all the reason for their use are fully understood.

Requirements

As a general rule cruising boats needs to be:--

Easily handled, as it may at times be operated by a minimal crew.

Good manoeuvrability for getting in and out of the marina, but also directionaly stable in open water so that the helm does not have to be held all the time and make it easier on the autopilot. These factors are conflicting and it not easy to come up with the best compromise straight

off the drawing board. It is surprising what poor handling some designers, builders and owners put up with. One can only assume that they have never had the experience of sailing a docile and easily handled yacht and believe that it is normal and macho to have to work on the helm all the time.

Few designers or builders spend any time on this important subject as on demonstration sails the marina parking problem is predominant, this results in many cruisers having spade rudders which are far from the ideal in open water.

The accommodation should to be comfortable for living aboard in harbour, but with enough suitable berths and galley for use at sea when doing longer overnight voyages.

Size

The usual quote is that the size of the ideal cruising yacht is 10% bigger or 50% smaller than you present boat. Size is of real practical significance and not just a financial consideration.

Yachts under about 9 metres tend to be more suitable for long weekends and gentle coastal hops with a good marina at hand.

From 10 -12 metres appears to be the most popular size with small crews. The forces involved are normally within the power of most people.

At around 12 metres the complication of the design tends to escalate and maintenance become a significant problem. The forces are much larger and things such power windlasses become not just a pleasant addition but a necessity.

By 15 metres you are getting away from the cottage into the problems of a substantial country house,

At 20 metre you are already into the small hotel business with the supervision and if you are not living aboard maintenance schedules becoming very significant.

For an easy cruising life it is better to go for the smallest boat that will fulfil your accommodation and performance requirements, A larger yacht will bring some extra comfort at the expense of additional problems and a lot of extra expense.

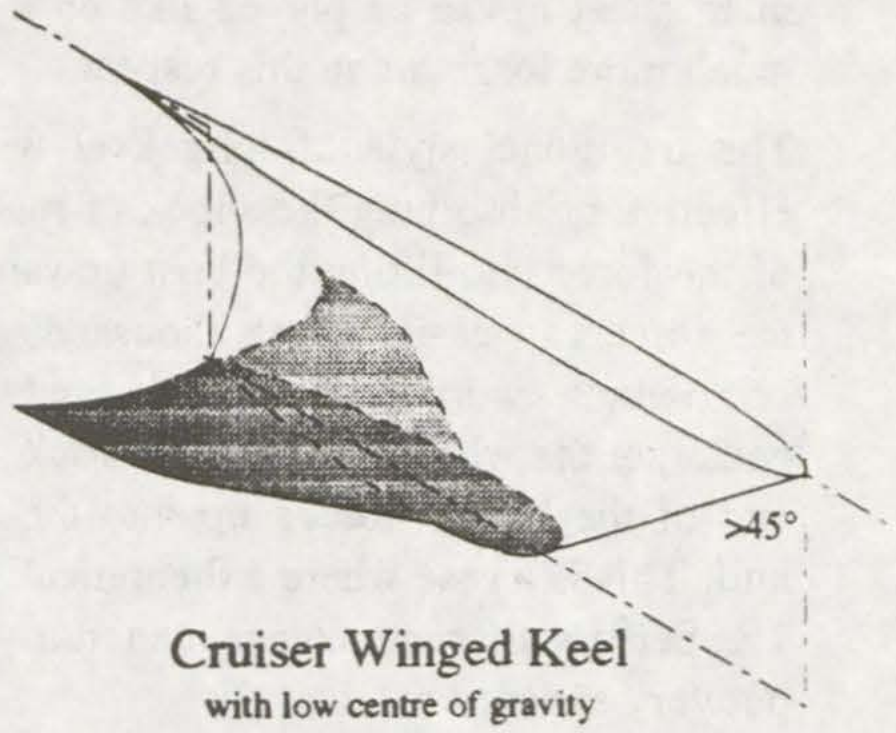
Draft

If you cruise from marina to marina and have no desire to explore the small bays or estuaries on the way then a deep draft keel is of little consequence, but to explore any quiet bay or cove then a deep draft can be severe disadvantage and limits the use of the yacht. Any shallow draft craft will always have a larger potential cruising areas than a deep draft one.

More important than draft is the depth of the centre of gravity of the craft, but remembering that excessive stability can make for an uncomfortable motion and reduce performance in lighter winds. The least motion is when the centres of buoyancy and gravity are close together.

There is no practical reason for a cruising yacht to have a deep fin keel, except as a fashion accessory as the performance advantage is very small indeed and it severely curtails the cruising options.

A long base to the keel is very useful for any cruiser so that it is able to take the ground against a wall or be hauled out on a conventional slipway. Your yacht may normally be lifted out with slings, but it is much safer ashore with a longer keel.



Cruiser Winged Keel
with low centre of gravity

The full draft of the keel should be used to place the ballast as low as possible. IOR keels have a high centre of gravity and deep draft because of the way the rule operates and is totally irrelevant on all other types of yacht.

Your normal sailing grounds may have a soft bottom, but there are many wonderful cruising areas that are rocky and it is inevitable that any yacht will hit the bottom at some time or other. The modern style of fin keel (deep or shallow) is very susceptible to causing expensive damage to the hull as the aft end is pushed up into the hull. The traditional highly sloped keel just lifts the yacht up and any serious damage is rare.

A centreboard can greatly help a cruising yacht's performance, if an easy way of keeping it clean can be found, not all cruising grounds have sling hoists available and a fouled board is little better than none at all (this can also be a problem with multihulls without suitable cleaning facilities).

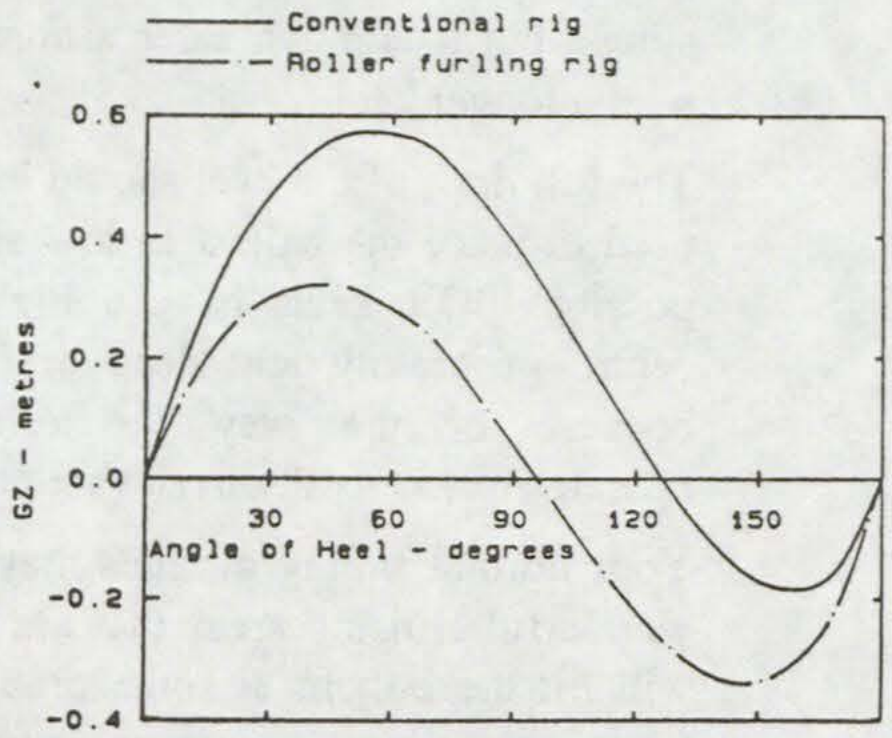
Some yachts with centreboards have no fixed keel below the hull, this can be a serious problem when taking the ground, as a rock could easily puncture the hull where it is not protected by the ballast. This type of arrangement is only suitable for mud or sand and well away from rocky coasts. Experience over the centuries has shown that for practical reasons the fixed keel or skegs should be at least 0.3m (1') and more makes it easier to work on the bottom. Shallow fins and keels dampen the roll when underway and are an important part of the comfort factor. Deep keels can at times induce roll due to the effect of hysteresis. A low aspect ratio keel is always much better at dampening roll in a seaway.

Twin bilge keels have received a bad press over the years, but this is mainly due to the rest of the design having poor efficiency. Where bilge keels have been fitted on efficient hulls there is in fact little real difference in performance as compared with a single keel and if some of the latest keel technology were applied this difference could almost be eliminated.

The limitation with twin keels is that there is a rapid drop off in efficiency when the weather keel lifts out. To achieve a reasonable performance the main sheet has to be played like on a dinghy. The single keeled yacht is much more forgiving in this respect.

The traditional style of long keel with its raked leading edge is very effective in absorbing the shock of running aground, by transposing much of the force into lifting the boat upwards. With a modern fin keeled yacht the force can easily cause thousands of pounds worth of damage and endanger the whole vessel as the back end of the keel is forced up into the hull. This is a case where a theoretical 1% performance advantage can turn out very expensive.

Most keels are of low aspect ratio (depth/length <2) where the outline profile has very little effect upon efficiency and so there is no practical reason not having the front of the keel raked back by at least 45°.



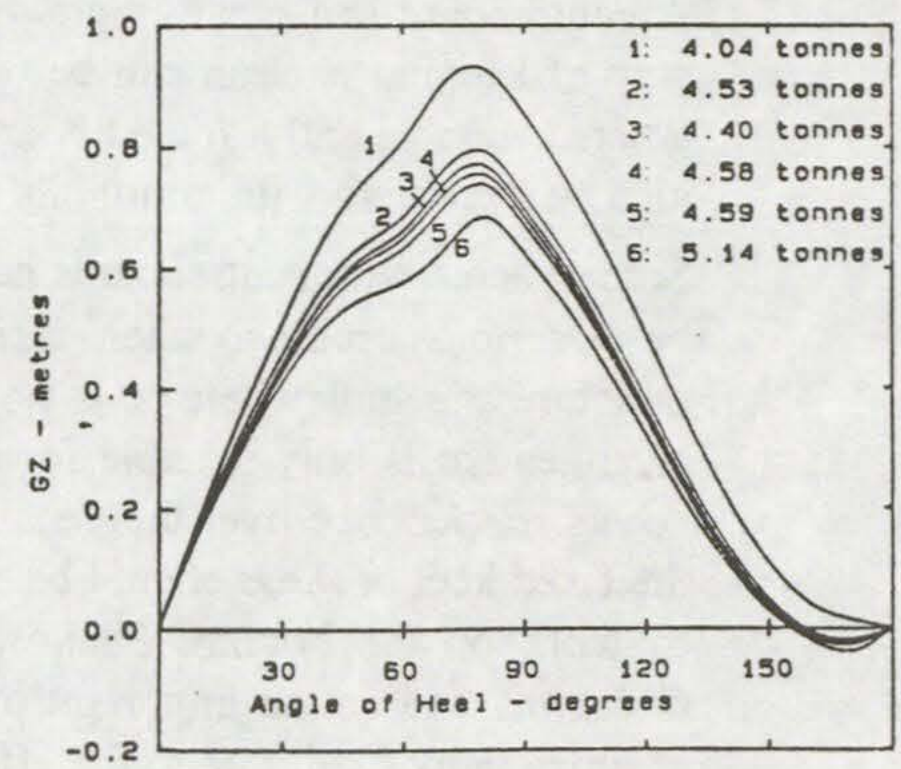
Stability curves with different rigs on same hull

Stability

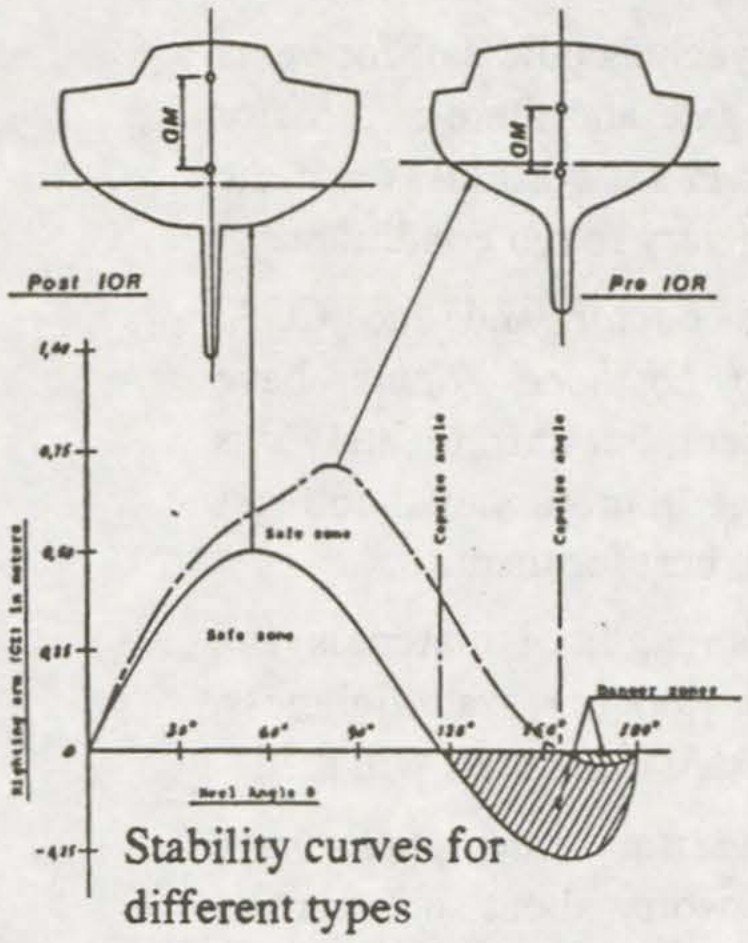
This comes in two forms static and dynamic. The dynamic one can be difficult to measure as it is the sum of all the hydrodynamic forces on the hull as these are changing all the time and can exceed the static forces.

The hydrostatic stability is an important aspect of any design, it not only helps with the ability to sail of a leeshore in strong winds but also indicates how likely any particular craft is to capsize from the effects of the wind.

One significant feature is that all



Change in stability with different loadings



Stability curves for different types

stability factors are dependent upon the loading of the craft. A yacht may have a very good range of stability as supplied by the builders, but once it has been loaded with cruising gear and in-mast and headsail furling have been fitted the picture can become very different.

The chances of a roll over can be greatly reduced if the yacht has plenty of reserve stability when knocked down by a wave and the roll is momentarily slowed as the rig hits the water at around 110°-120° (90°+20° maximum slope of a non breaking wave).

The dangerous part of stability curve is the area under the inverted stability zone. This area may be reduced by lowering the centre of gravity and reducing the beam, particularly at deck level. It is not always practical to eliminate the negative area entirely, but it is desirable to have a vanishing angle (zero stability) of at least 135° (45° beyond horizontal) in seagoing trim. Once a yacht is inverted the rig, if it remains intact, acts as a very effective damper and can prevent the craft from being righted by wave action. On the other hand free surface water below will assist in the righting, therefore it is desirable that some water finds its way below when a yacht inverts.

The sea alone can be at times be rough enough to capsize any craft and one at least one occasion it has been recorded that a multihull was turned over by the seas and then turned back the right way up again some time later.

Seaworthiness

Is the ability to undertake any planned voyage and in the event of unexpected conditions, to reach port without outside assistance.

The requirements of seaworthiness should not be confused with emergency equipment such as the life rafts, which are like parachutes in aircraft and are only used when things have already gone seriously wrong. Safety equipment such as life lines and fire extinguishers are to help prevent things going seriously wrong.

The desire should be to have craft and crews that are capable of looking after themselves and that do not expect to rely upon the safety services and others to get them out of trouble.

No craft can ever be 100% seaworthy. All that can be stated are the likely chances of problems, severe or otherwise, occurring in a given set of conditions.

The 1979 Fastnet Race showed how very many yachts could sail for years without trouble and then along comes a severe gale and there is a major disaster. This tragedy started the current interest in seaworthiness and the handling characteristics of modern sailing craft in very rough conditions.

Tony Marchaj's *Seaworthiness the Forgotten Factor* and the CCA, *Desirable and Undesirable Characteristics of Offshore Yachts*, have become the standard reference books on the subject, but unfortunately this area of design still receives very minimal coverage in professional colleges and it is left to designers to 'guess' what will work best for them.

The classification societies only consider the strength of materials and fittings, they are not interested in stability, down flooding, watertightness, or the effects of damage. They do not even interested if the craft will sail!

The customers naturally assume that all the necessary calculations have been done as a matter of course and they rarely worry about such matters when buying a boat, but it is only in the last few years that *any* serious stability or flooding calculations have been done and there is still no information available on most of the craft on the market to-day.

The current Whitbread regulations are an attempt to include some new seaworthiness factors such as hydrostatic stability and watertight compartments directly within a class rule.

The current stability screening systems are open to abuse and have allowed much of the Sail Training stability requirements to be bypassed. To-date the seaworthiness rules screening angles are arbitrary and based on experience with previously established styles of boat and do not take into account the very serious effects of down flooding or damage.

It may surprise many customers of new craft that little or none of the design effort goes into seaworthiness. The main thrust usually being that similar craft have proved safe in the past and a new design is a development of a previous ones. The problem is that since most craft do not venture far it is very likely that the previous designs have never been tried in rough conditions, or if they have it has never been reported back to the designers or builders. The availability of cheap computers and programs means that the hydrostatic stability curves can be calculated for all yachts provided the lines are available.

Boat building has always been a cottage industry that uses the trial and error method of development, but the problem of how to measure seaworthiness in a realistic and practical manner is at last beginning to being addressed by the professional bodies. Unfortunately production runs of yachts are far too short to finance tests on boats with anywhere near the same thoroughness as aircraft, but some of the principles of the airworthiness flight test system might prove practicable at sea.

Boat Show & Marina Sales

Most people first step aboard their boat at a show or marina, judging from the success of many current designs, this would appear to be where the sale is made and the marina is where it will stay, with little consideration given to the handling and comfort in less ideal conditions. For instance it is often suggest that putting in practical hand holds puts off prospective purchasers. The same might have been said of seat belts or protective padding in cars some years ago, we now treat them as part of the normal equipment. We need to educate the yachting public and fit out yachts more safely. It is partly the responsibility of those commenting on and selling boats to educate the buying public into what are the desirable characteristics of a practical and safe craft. It is sad reflection on the market that most craft are sold on image and price alone.

The sailing magazine tests on yachts can at best only be very superficial but they often have technical detail that implies to the uninitiated a greater depth of investigation than is in fact the case. Trying to imitate the 'Which' type of car test report, which are carried out over several months, with an extensive series of rigorous tests, can be very misleading.

The trial outings can only give the general ambience and some handling characteristics of a craft, any deeper knowledge would require a variety of conditions and many days to find out the practical pros and cons of any design.

In practice, everyone (customer, yachting magazines and sales staff) rely upon the the reputation of the designer and builder to produce seaworthy and acceptable products yet these may never have been tested seriously.

Power Craft

The main aim of motor boats appears to be to spend the shortest possible time between anchorages, their accommodation is never designed for extended use at sea and their range and areas of operation are limited by fuel supplies, powerboat owners do not expect to spend long periods at sea.

Not having to rely on the wind for propulsion make schedule keeping very much easier and therefore attractive to those who live to tight schedules.

The layout of this type of craft is dominated by styling and accommodation requirements and can be considered in most cases as a marinised caravans or for the less mobile, country cottages. They spend most of their time in marinas and have little interest in anything more than the most basic seaworthiness requirements.

For speed in open water the hull needs to be long and narrow with possibly a V bottom. The shorter fat designs may have a higher top speed on smooth

water and roll less at anchor, but they will be less comfortable in a seaway.

The standard square stern on modern motor boats is very inefficient hydrodynamicaly at anything but high speeds, creating an excessive amount of wash and causing problems for others including unnecessary erosion of the banks of rivers and canals. This is almost as bad as driving along in a car leaving a great cloud of smoke behind you. Of course you can do both with a motor boat!

All powered craft should have a significant wake speed placarded at the helm position. This is the maximum speed at which they can travel while producing a wave system that will not endanger small craft or canal banks and for many designs this will be well below the maximum speeds quoted for harbours or rivers. Older designs with rounded sterns produce much less wash. Wake or spray is a good measure of the inefficiency of a design.

For practical purposes all propellers and rudders should be protected by a skeg to reduce damage when grounding and reduce repair costs.

The hull design of a power boat is very much more simple than any sailing yacht, with image and domestic arrangements the dominant factors. Fortunately there is very little demand for cruising versions of the offshore power boats so the more extreme design features are avoided.

Multihulls

The modern multihull has many of the features of the ideal cruising yacht. They are relatively fast, can have roomy accommodation, but not always headroom, lots of deck space, shallow draft and positively buoyant at all times.

On the down side they cannot fit into a standard marina (but are suitable for mud berths where available) and tend to have high windage which can make an acceptable windward performance in strong winds a problem.

If you want to sail faster than a displacement boat they are very weight conscious, 10% extra weight can reduce the performance by more than 10%. Cruising multihulls will always be a great deal slower than their racing counterpart and the vast majority are little faster than a similar sized monohull.

The depth of any fixed keel should be kept as small, since the side force they can produce can cause a capsizing moment in rough conditions. It is better to have centre boards that can be raised and allow the craft to blow sideways. It is often safer with only the weather one down in strong winds.

The appearance of the latest multihulls is a great advance on some of the earlier designs, but to the sailing public in general they are still very much

for a minority of enthusiasts and in many areas the lack of suitable marina berthing and lifting facilities can prove the dominant factors for rejecting the multihull option.

Since multihulls tend not to be in marinas it can also appear to newcomers that they are outcasts from the normal sailing world. This is a great pity as multihulls can make ideal cruiser, where the drinks are much less likely to get spilt, so could satisfy the requirements of the vast majority of owners.

Propulsion

Just as commercial aircraft have two or more engines for reasons of safety, so all boats that venture out into the open sea and more than an hour or two from shelter should have two independent methods of propulsion. To be seaworthy both systems should be capable of being used in adverse conditions.

Sailboards suffer from the lack of a suitable method of propulsion when the crew is exhausted.

For a dinghy the two systems would be sails and oars.

In a motor boat the requirement is covered by two independent engines with separate starting and fuel supplies.

For an auxiliary yacht the two systems should be sail and motor, but how often is it that one or other of the systems is not equipped to deal with strong winds and rough seas (particularly the rigs on some motor sailers).

If a craft has only one reliable method of propulsion it is very much less safe and should proceed so that the loss of the propulsion system does not put the craft into immediate danger.

Many commercial ships rely on a single engine, but they are maintained by professional crews that can normally cope with running repairs and it is also worth a rescue tugs time to go out and give big ships assistance.

Engines

The modern diesel engine is a very reliable piece of equipment, but the whole system is only as good as its weakest link. It is often the ancillary equipment that fails first. The *complete* installation must be carried out and maintained to a high standard. No single failure should stop the engine.

A full service of the engine and its systems must be carried out at least twice a year, but if the engine is run for over 200 hours per annum then more frequent servicing is essential.

Where an engine is the only means of propulsion in adverse conditions it is most important that extra care is taken with the installation and maintenance.

The main factors are:-

Starting. When the engine is not left running throughout the voyage there should be an alternative method of starting (i.e. a spare battery and starter motor or a manual system). Do not rely on a single starter motor.

Fuel Supply needs to be protected from dirt and water. The filter system should be easy to check and clean at sea. A twin filter system allows the engine to remain running during this operation.

Cooling systems need to have good filters and be capable of rapid cleaning and replacement of pumps, preferably with some form of audible warning.

Warning systems are useful to draw attention to impending trouble, but they should be operated by a separate system from the gauges otherwise a failure of the gauge sensor will also cause a failure of the warning system.

The overall reliability of the engine installation is to a great degree dependant upon the knowledge and ability of the crew to deal with the regular engine maintenance requirements and emergency action.

Too often people treat their boat engines and equipment like their car and take their boat to sea without ever considering what to do if the engine stops unexpectedly. It is not realistic to stop and call out the equivalent of the AA as is now done in some parts of the boating world.

Repairs

During the life of most yachts they are going to require serious maintenance. Some designs are easier to repair and some are susceptible to expensive damage.

A dent in the gunwhale of one yacht that might cost few hundred pounds to repair can cost thousands of pounds on another. The more expensive types of repair are to replace the aluminium toerail on a production yacht or repair a deep fin keeled yacht that has run aground.

Current production yachts have all the fitting out done before the deck goes on, this can cause problems later when minor damage has to be repaired. A good design will allow for access to awkward corners in later life, ample space to service the engine and enable its removal at a later date.

Some yachts are so lightly built that they cannot even take the rough and tumble of laying in a marina and cracks appear in the gel coat of the top sides within a few months. Riding out a gale unattended in a marina can cause very much more wear and tear than lying to a good mooring. Boats are not well designed to survive the wear and tear of the dockside.

Just as the strength of a dinghy is dictated by the handling ashore so the critical design factors of cruising yachts may have little to do with being out at sea.

Conclusion

Most of the performance improvements for yachting in general come from close fleet racing or the longer endurance races, but it must be remembered that the design of a racing yacht is dependant almost entirely upon the rules under which it has to race and these may not be totally relevant in any other situation.

Cruising yachts that are copies of racing yachts will be slower and less safe than the original design. Ease of handling with a small crew is essential.

Non racing yachts can be made as fast as an IOR craft, if they are not over loaded, by simply increasing stability and sail area. This is done by putting all the ballast at the base of the keel and extending the foot of the rig with a longer boom and a bowsprit for an outer topmast forestay. Overdoing the draft and stability can make the motion less comfortable so deep draft is not a requirement. The least motion is when the centre of gravity is close to the centre of buoyancy.

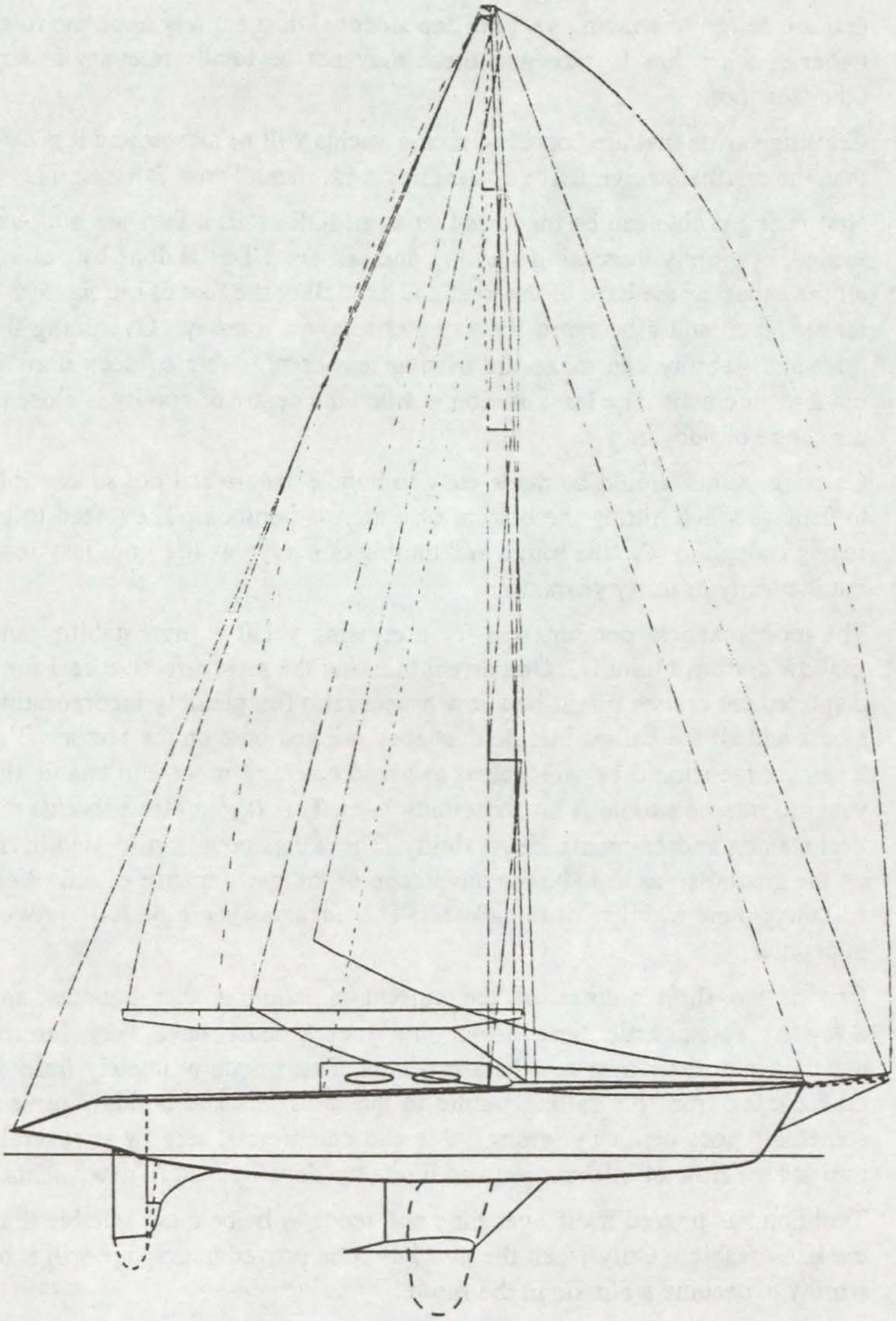
Cruising yachts should be made easy to handle ashore and not susceptible to damage when hitting the bottom or a marina pontoon. They need to be strong enough to take the rough and tumble of every day life - not just now, but in twenty or thirty years time.

The most practical combination for a cruising yacht is high stability and shallow draft (multihull?). On current thinking the most effective keel for a displacement cruiser might be a low aspect ratio fin, possibly incorporating a tank and all the ballast in a delta shaped winged bulb on the bottom. The leading edge should be well raked to avoid catching ropes and enable the yacht to ride up should it hit something hard. This layout also prevents the keel stalling and helps manoeuvrability. The wings could act as stabilisers on the ground so as to have the advantage of the performance of a fin keel and the ground stability of bilge keels. This idea has yet to be fully proved in practice.

One of the shortcomings of the current situation is that builders and designers spend little time afloat and they usually have very limited experience of their own or others products. There is unfortunately little or no feedback from the sailing public to the designers and builders (unless something goes seriously wrong), this and commercial secrecy is severely limiting the flow of information and limits the development in new yachts.

Tradition has proved itself over time and tends to be be more reliable than the latest fashion. Only when the *new* has been proved in practice will it be worthy to become a *classic* in the future.

It is probably better to buy a yacht from designers and builders who frequently sail their own and others products and avoid racing gimmicks.



Conversion of an IOR yacht into a Faster Cruiser

All ballast on the bottom of a reduced draft keel (and increased sail area if required).

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