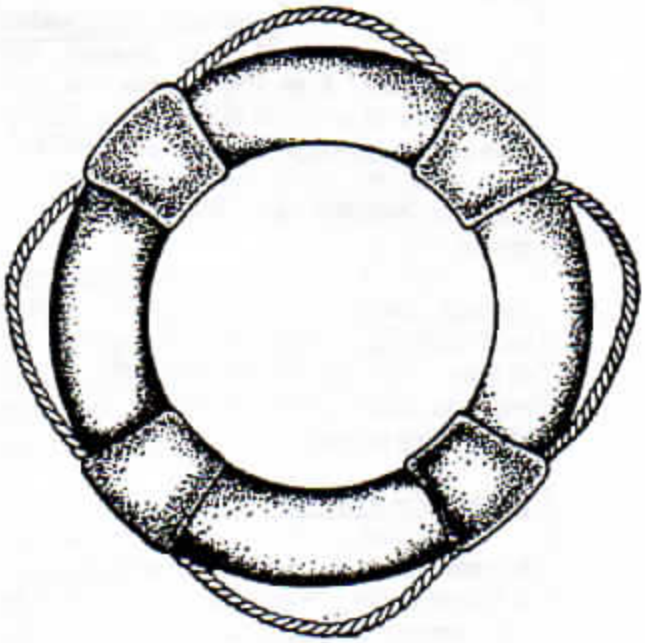
uit : Twin-keeler vol.5, issue 2 2001

Twin Keels: Still a Viable Option

By Jan Alkema

A Dutch sailor and engineer, reflecting on his sailing experiences in an Alacrity, a Vivacity 24 and a Westerly Konsort, shares his insights and optimism about Twin Keelers



Twin keelers are a well known category of sailing yachts. This keel system generally has a shallow draft and is one that allows drying out when on the hard. It is a big advantage when cruising to be able to reach quiet and shallow anchorages or stay comfortable in harbors which dry out. Another practical advantage is the ease of hauling out or careening twin keelers which makes maintenance easy.

The general opinion is that the sailing performance of the twin keeler is less than a comparable yacht with a deep fin keel—especially when sailing close-hauled. Years ago this was certainly true. The new twin keel designs, however, are showing better performance.

This article will focus on the twin keel yacht. A review of some its history will be followed by a discussion of its performance both theoretical as well as practical.

Twin Keel History

In 1969 a congress of the Royal Institution of Naval Architects was held in London. A very interesting paper was presented: "Twin-keel yachts—Development over 45 Years." In this paper the early experiences with twin keelers were described. Starting in 1922, studies , model tests and full scale experiences of this keel system were conducted and some yachts were designed and built.

The most important twin keel yachts from this period are the ***Bluebird*** built in 1924 (and probably still sailing, as the boat was observed in Holland in 1981), the ***Bluebird of Thorne I*** built in 1936, and the ***Bluebird of Thorne II*** built in 1963. The ***Bluebirds*** appeared to be very pleasant cruising yachts, reasonably fast, well-balanced, seaworthy (Atlantic crossings), with shallow draft and drying out capabilities.

In Holland in 1952, some experiments with retractable inboard bilge plates on a racing dinghy were carried out. Tank tests were carried out later on using a model of a 25-ft yacht which also had a retractable inboard bilge plates. Good results were found with asymmetrical profiles (with the convex side toward the centerline of the yacht) and an adequate toe-in angle. "Toe-in" means that the keels converge toward the centerline. During sailing only the leeward plate was in operation. Leeway could be reduced without loss of speed and ➡

hence the speed-made-good-to-windward proved to be a little bit better than the single keel version.

Up until 1960 twin keel sailing yachts were very rare. From 1960, however, the popularity grew. A lot of these early twin keel yachts had a lot of wetted surface due to the big keels and a large skeg. A lot of these boats had three keels, the center keel carrying all the ballast and two bilge keels for keeping the yacht upright when drying out.

Very few boatyards could afford the thorough studies and tank testing necessary for good results. Due to that lack of knowledge, not all designs were optimized and therefore a lot of twin keel yachts proved to be slow, especially when sailing to windward.

The Modern Twin Keeler

Nowadays a lot of yachts can be delivered with a single keel (deep or shallow) or as a twin keeler. When both the fin and twin keel versions are tested and compared, then conclusions can be drawn about the behavior of the keel system itself. Yachting magazines occasionally report the results of the comparative tests. Years ago the general conclusion was always that the twin keel version was slower, pointed less high and heeled more.

It was quite a surprise then in one of these reports in 1976 that the 28-ft ***Mirage*** proved to be as fast as the single keel version on all courses of sail. No single difference in sailing qualities was observed. Shortly thereafter the Westerly Konsort was introduced. Both fin and twin keel versions sailed equally well to windward with the twin a modest 0.5 knots slower. On all other courses, both yachts proved to be equal. Also test results of the ***Sadler 32***, with four keel options (deep fin, shallow fin, centerboard and twin keel) revealed that there were only small differences in speed and pointing ability.

From these practical reports, the conclusion can be draw that the windward performance of the modern twin keel yacht has definitely been improved. Now these yachts can sail very well to windward and still have all the advantages of shallow draft and the ability to dry out.

The question is how this improvement has been achieved and how this can be explained.

General Theoretical Aspects of Airfoils

Before going into some details of the twin keel design, here is some theory regarding airfoils. It is known that when an air or water current attacks an airfoil under an angle, some over-pressure is created on one side and some under-pressure on the other. This pressure difference multiplied by the surface of the airfoil gives the lifting force. There is also a resistance force, partly dependent on the profile resistance and partly on the lifting force (See Figure 2).

Now if one side of the airfoil is mounted to a body, it is clear that the mentioned pressure difference cannot exist near the free end. Air or water flow from the high pressure side to the low pressure side. So the pressure difference decreases near the end and therefore also the lifting force. In other words, at a free end the lifting force "leaks away" (See Figure 3).

At the other end of the airfoil, however, the body to which it is connected prevents leakage, so at that side the lifting force remains. The leakage of lifting force increases with a bigger chord length. In Figure 4, two airfoils are shown with the same surface but different span and chord. The span divided by the average chord length is called the aspect ratio. An air foil with a high aspect ratio can produce a higher lifting force with less drag than an airfoil with a low aspect ratio for the same angle of attack. High aspect ratio wings are far more efficient. Birds have high aspect ratio wings and it is no surprise that aircraft have the same.

These theoretical considerations are fully applicable to the keels of sailing yachts. We all know that the high aspect ratio keel (the deep fin) is very effective and, therefore, commonly used in racing yachts.

For cruising boats the deep racing fin keel can be very impractical because it can seriously reduce the sailing range in areas with shallow water. Also shallow harbors and anchorages are inaccessible. Shallower keels or centerboards are the answer, but these are less effective resulting in less speed.

A Theoretical Approach to the Twin Keel Design

The main advantages of twin keel yachts are their shallow draft and ability to dry out. Drying out means that the keels must be strong and solid enough to support the yacht in moderate wave breaking conditions when ➡

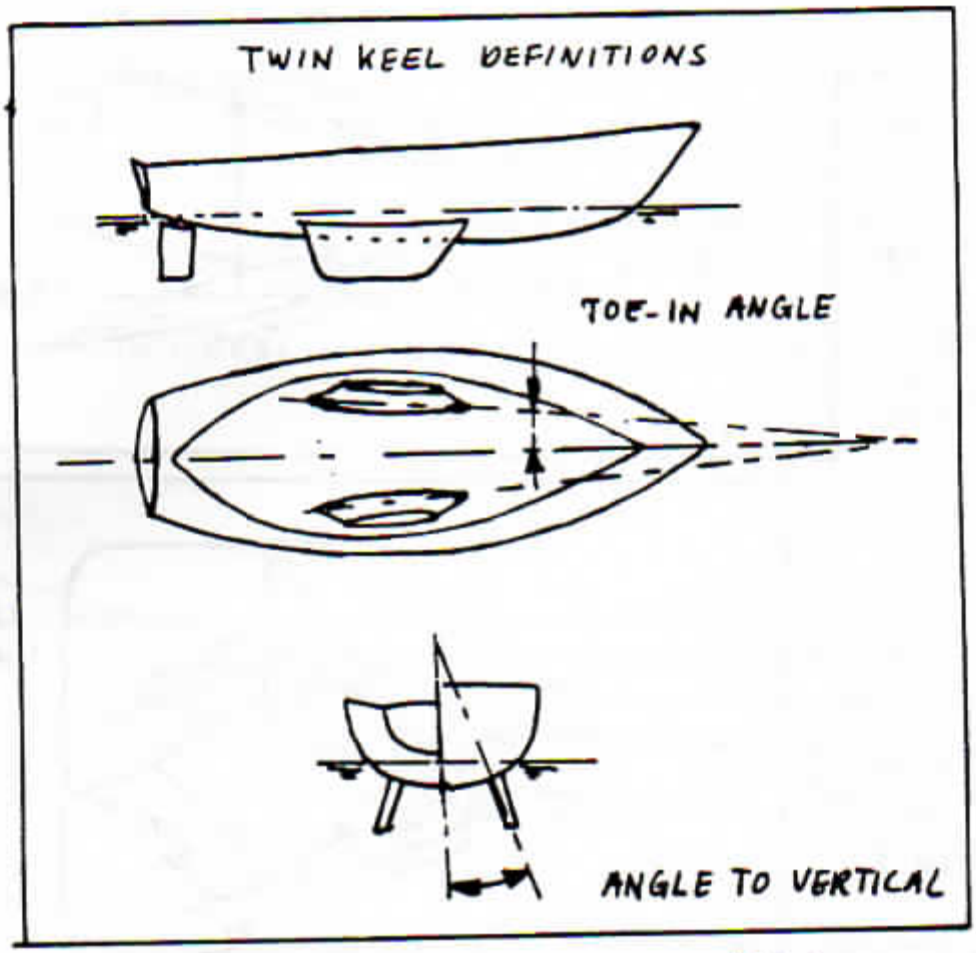

TWIN KEEL DEFINITIONS
TOE-IN ANGLE
ANGLE TO VERTICAL

FIG. 1

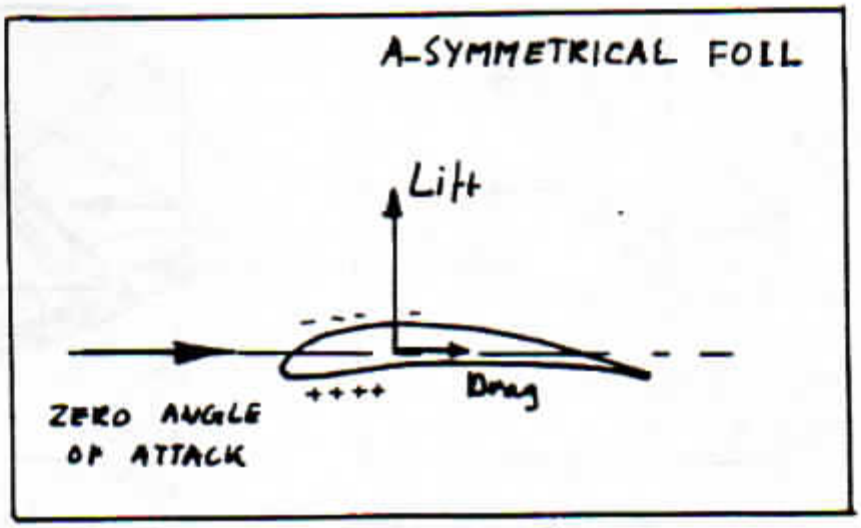

A-SYMMETRICAL FOIL
Lift
Drag
++++
ZERO ANGLE
OF ATTACK

FIG. 5

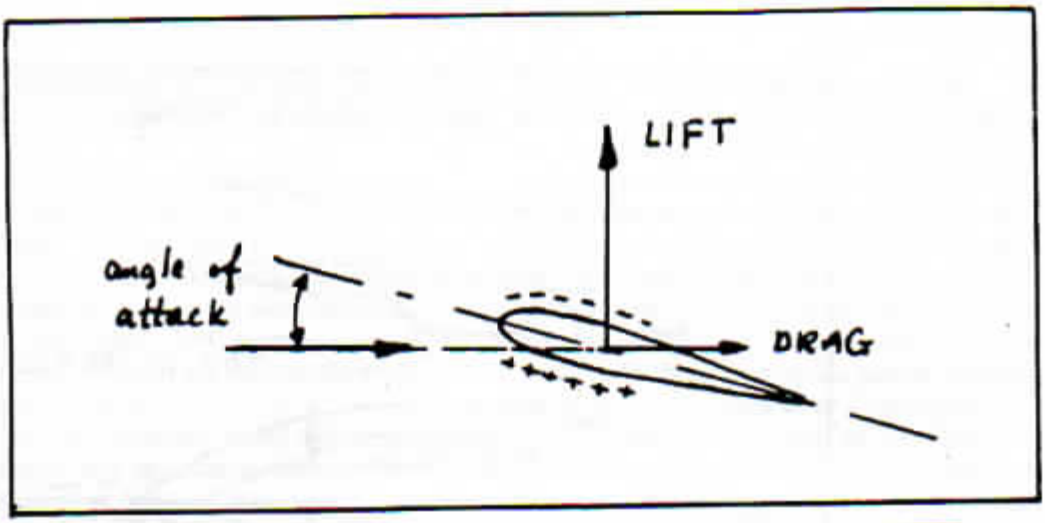


FIG.2

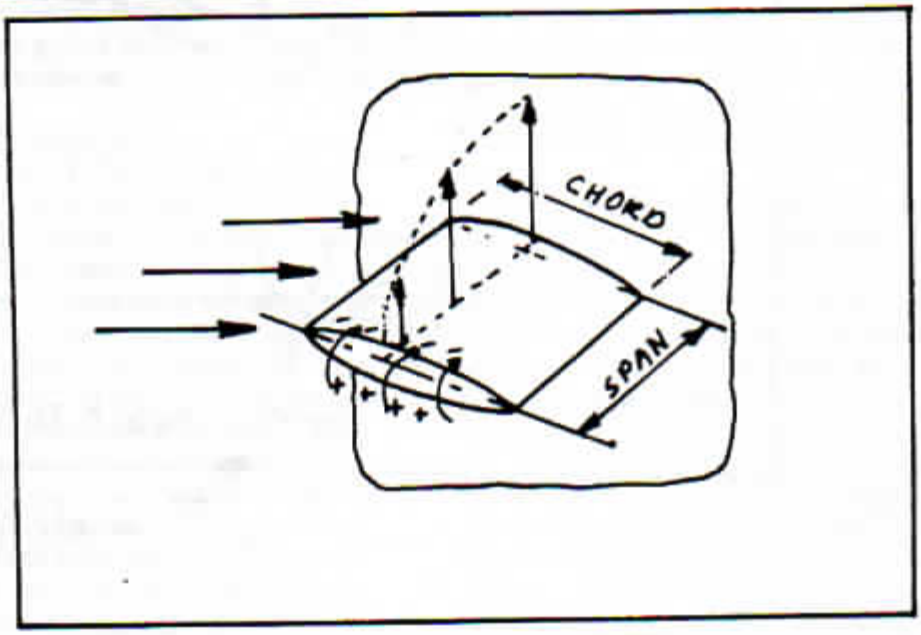


FIG.3

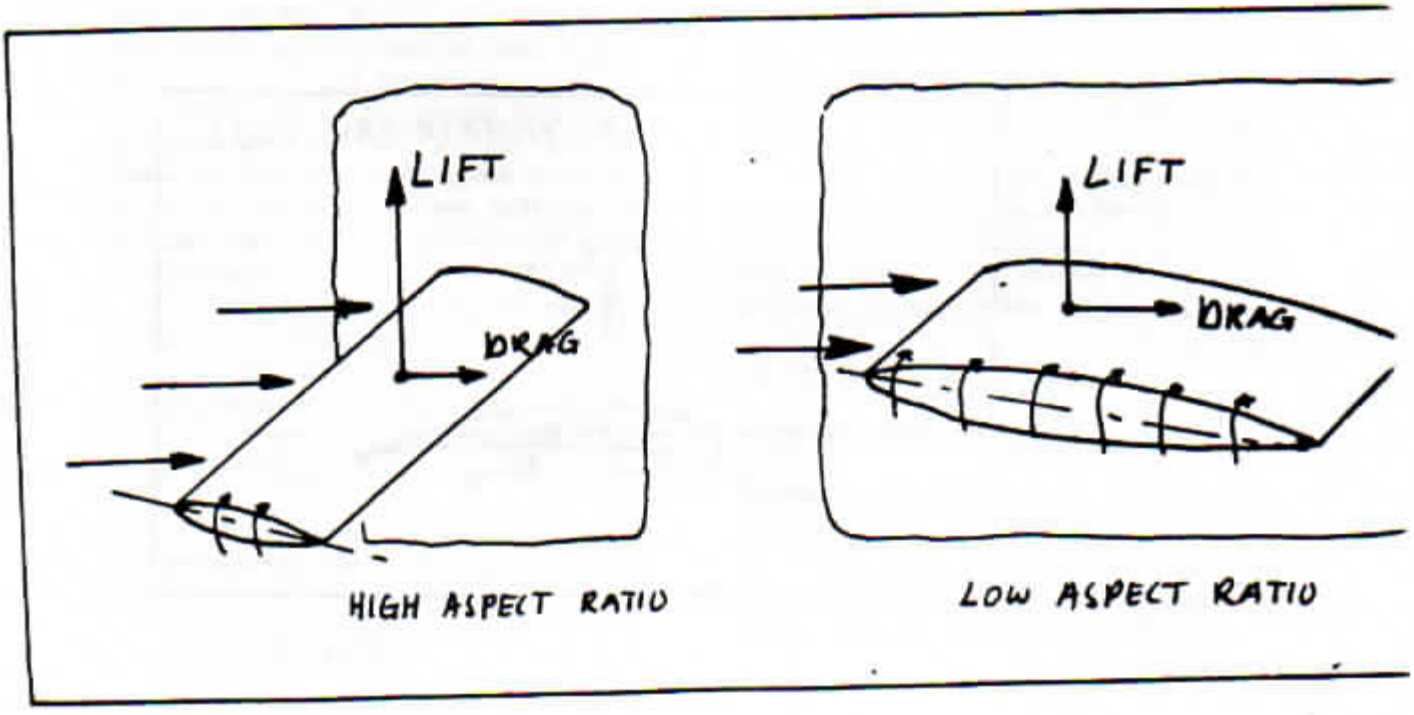


FIG 4

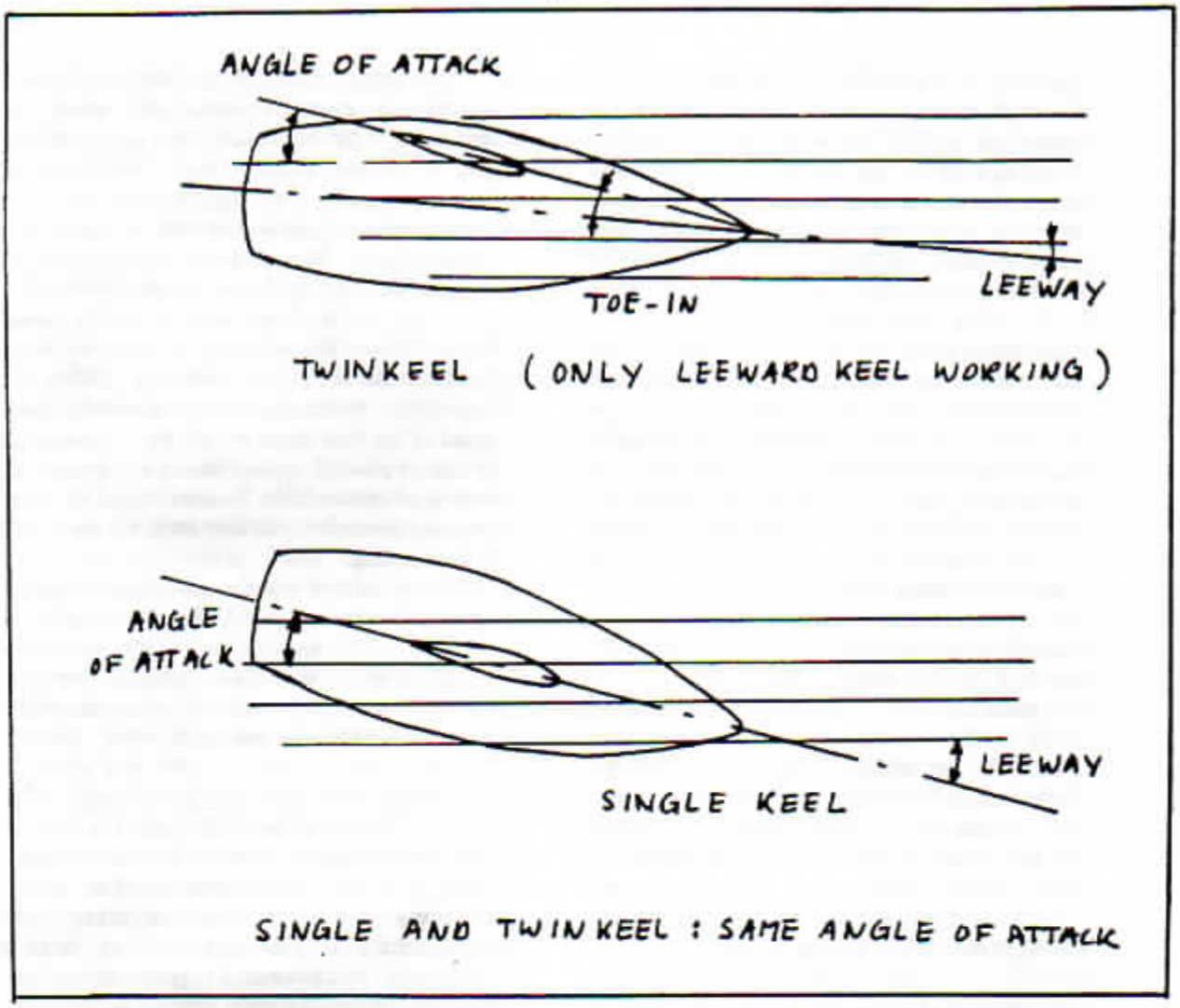

ANGLE OF ATTACK
TOE-IN
LEEWAY
TWINKEEL (ONLY LEEWARD KEEL WORKING)
ANGLE OF ATTACK
LEEWAY
SINGLE KEEL
SINGLE AND TWIN KEEL : SAME ANGLE OF ATTACK

FIG.6

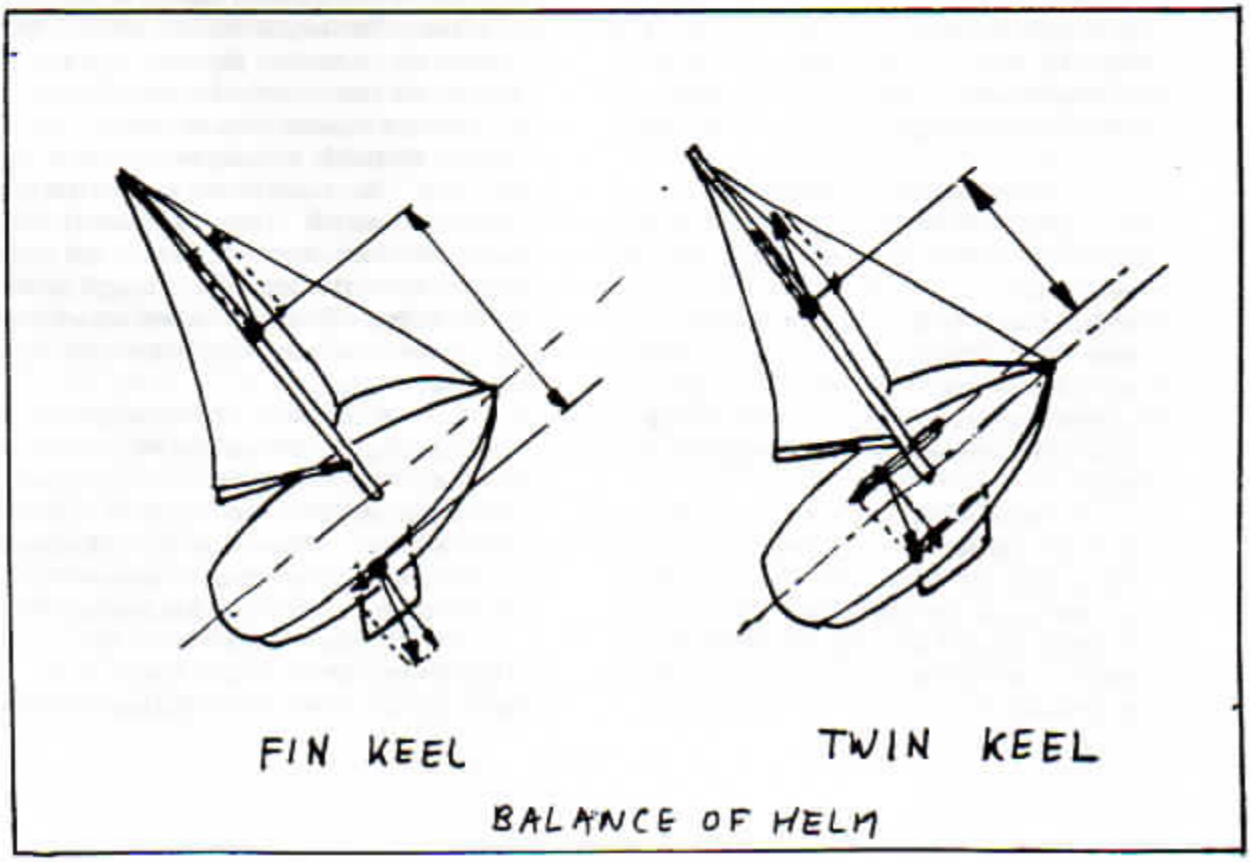

FIN KEEL
TWIN KEEL
BALANCE OF HELM

FIG.7

aground. It is the drying-out-ability that limits the draft to some extent. The shallower the water, the smaller the forces of the breaking waves and the smaller the bouncing of the yacht on the beach. So from that point of view, the designer is inclined to give the yacht long shallow keels. We know today now ineffective these long shallow keels are.

The keel system can be improved when high aspect keels are applied. To achieve this the draft of the boat will increase and/or the chord length of the keel will decrease. But now the boat is no longer suitable for shoal water sailing and safe drying out. But there are other well-known tricks to improve the twin keel system: the variation of the vertical system, the use of a toe-in angle and/or the use of a-symmetrical keels (See Figures 1 and 5).

When the keels are angled to the vertical plane, then when the yacht is heeled the leeward keel has a nearly vertical position. On the other hand, the windward keel is becoming more ineffective due to its more horizontal position. The efficiency loss of the windward keel is not so serious as this keel always comes above water due to waves and also encouraged by the trough in the wave system around the boat. In total, this angling of the keels itself give a small improvement but in combination with the toe-in there is more gain.

The trick of toeing-in in is that the leeway of the hull can be reduced with still the same angle of attack of the leeward keel (See Figure 6). So the crab-wise motion of the yacht, which always costs extra drag, can be reduced or eliminated with a proper choice of the toe-in angle.

The same effect of reducing leeway can be achieved with a-symmetrical keels. Note that the convex side of the keel profile must be towards the centerline of the yacht. The leeward keel produces side force without or with only a small angle of attack, or in this case with zero or small leeway angles. Reduced leeway and reduced drag are advantageous when sailing to windward as it increases the speed made good to windward.

In downwind conditions, when no side force is required to counterbalance the sail forces, then the toe-in angles and/or the a-symmetrical profiled keels give some more drag. So the amount of toe-in and the a-symmetry is a compromise between the windward and running performance.

To get an idea of the effects of all those variables, a set of calculations for speed and leeway angle has been made for a typical sailing boat in windward conditions. See Table 1. Numbers 1 and 2 are single keelers. Note the obvious effect of the aspect ratio on speed and leeway angle. Keel 3 (twin keels with high aspect ratio) appears to be an effective system. When the weather keels come above the water, however, then the leeward keel is much more "loaded" and the leeway increases. When the keel surface is increased (as in Number 4), the speed of the boat drops a little bit. The change is vertical position and toe-in angle improves the twin keel system (See Number 5 and 6), as it does not produce much side force but inevitably has some drag.

I carried out the calculations for the ***Mirage***, the ***Konsort*** and ***Sadler 32*** for both keel versions. It appeared that the calculated effectiveness of both keel systems were very close so that only small differences in sailing performance could be expected.

Practical Experiences with Twin Keel Yachts

There is an interesting point in the twin keel concept regarding helm balance. When a yacht is heeled, the center of effort of the sail forces moves to leeward. On a single keel yacht, the center of effort of the keel forces moves to windward. A big distance between both centers of effort can create a lot of weather helm. When twin keelers are heeled, the leeward keel takes most of the forces from the water, and because the leeward keel is on the lee side of the yacht, the distance between both centers of effort is smaller, effectively reducing weather helm (See Figure 7). This explains why twin keelers have good helm balance. There are, however, other aspects to be considered. Some twin keel yachts have more weather helm due to a high position of the ballast. Excessive heeling can ruin the nice balance and make the twin keel yacht again hard on the helm.

A drawback of all twin keelers is that when sailing in a head sea, there will be noticeable amount of slamming when oncoming seas are caught under the top of the windward keel and hull. Although it does not seem to present any problems—even in heavy weather—it does make the boat a little less comfortable.

A point to remember is that a twin keeler, when heeled, has a deeper draft. So when the heeled boat touches the bottom, it ➡

is easy to be clear again by simply easing the sheets. When a twin keeler, however, runs aground upright with both keels, then it can be very difficult to get the boat free again. On a single keeler, it is just the other way around.

All the sailing boats I have owned had twin keels. The first one, an ***Alacrity (or Hurley Holiday)***, was 19 ft long with a draft of only 2 ft. The boat was very stable due to its relative board beam. The balance of helm was excellent but the sailing performance was disappointing—especially when beating to weather.

The second boat, a 24-ft ***Vivacity***, had a draught of only 2 ½ ft which made the boat very suitable for tidal estuaries and cruising between isles and sandbanks. Many times we set the boat on a bank or anchored in shallow creeks for the night instead of being packed in the crowded marinas. The performance of this yacht was better than the first but still not as good as comparable boats. We did not care much about speed, however. Its suitability for shallow waters and estuaries were the most important factors for us.

It had solid keels with a reasonable wing profile. They were very suitable for drying out, even in moderate breaking waves. There was no toe-in or a-symmetry in the design. We found the boat a little tender and it heeled a lot when pressed. When heeled beyond a certain angle, a lot of weather helm developed. Apparently the advantageous effect of the twin keels on the sail balance was completely diminished by excessive heeling.

Our present boat is another twin keeler, a ***Westerly Konsort***. It is 29 ft with a generous beam of 11 ft—making it a very roomy boat. She draws only 3'2 ½". The boat is very stable and can her sail very well. The twin keels are well designed. The sections are symmetrical with a toe-in of 2 degrees. The keels are winged out under an angle of 20 degrees with the vertical plane. The keel surface is smaller, relatively speaking, than that of our previous boats, but the aspect aspect ratio is higher. The boat sails very well to windward and outperforms most of the comparable boats with a single keel of the same draft or somewhat more. The balance of helm is also very good when heeled. Due to the great form-stability, the heeling angle is seldom more than 20 percent.

In Figure 8, I have compared the three boats on the same scale. It is very obvious that the last boat (Konsort) is another sort of twin keeler. The smaller keels give a better sailing performance, but also make the boat less suitable for drying out, although we sometimes experience the keels sinking some 10" in the sandy bottom because of the smaller dimensions of the keels. The free hanging rudder is also more vulnerable when taking the ground, and, therefore, we are more careful and only dry out when the weather is good or conditions are sheltered.

Twin Keels and Boat Size

Small boats can benefit more from the advantages of twin keels. The necessary lateral surface on small yachts is less than on larger yachts. If we specify a maximum allowable depth of say 3 ½ ft, then the small yacht can have really fin-like keels with a relatively high aspect ratio, and therefore the better efficiency. One of the English boat yards has already discovered these possibilities and are describing their yacht as a twin fin yacht. For a draft of 3 feet 3 inches, an effective aspect ratio of approximately 2 has been achieved, which is a very good value for a twin keel yacht. (Also compare with Figure 8)

Future Twin Keel Developments

A point already discussed is the fact that on most points of sailing, the relatively ineffective windward keel is spoiling the performance of the twin keel system to some extent. It may be that a system with twin keels with retractable boards or plates could give good results. This idea was also presented at the Congress mentioned earlier in this essay.

When both plates are retracted, the boat can be sailed on all courses except beating, with a very shallow draft. For windward sailing only, the leeward board has to be lowered, which in the heeling situation is situated in the optimum place. All the tricks of high aspect ratio, a-symmetrical sections and toe-in angles can be applied without drawbacks or compromise. The boards should be retracted inside the twin keels leaving the interior of the boat uncluttered. (See Figure 9) The two retractable boards are no more complicated than a single centerboard. The only difference is that there are two.

As has been discussed, the tendency in twin keel design has been towards higher aspect ratio and smaller keel sizes, making the keels more fin like. A limit to this tendency is ➡

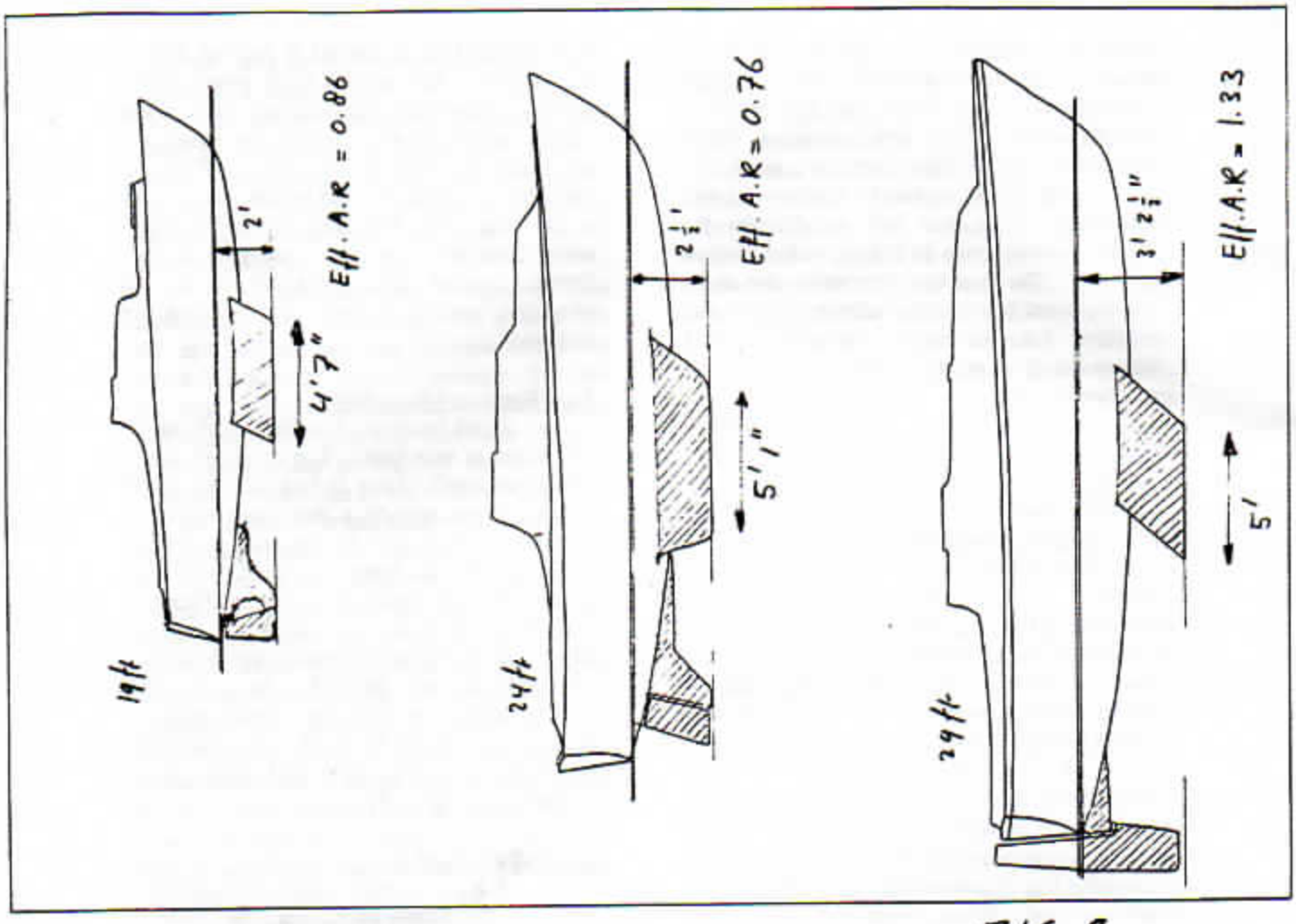

19ft
Eff. A.R = 0.86
2'
4'7"
24ft
Eff. A.R = 0.76
2½'
5'1"
29ft
Eff. A.R = 1.33
3' 2½"
5'

FIG 8

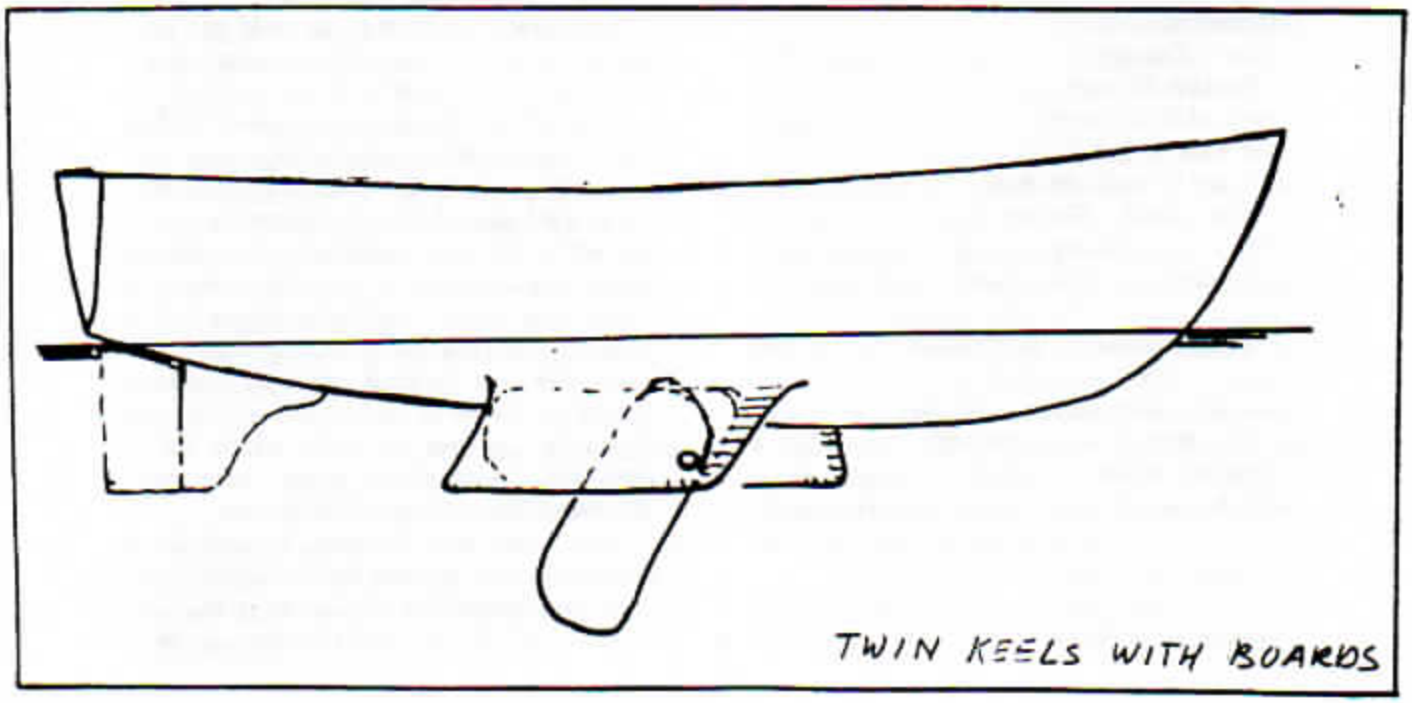

TWIN KEELS WITH BOARDS

FIG. 9

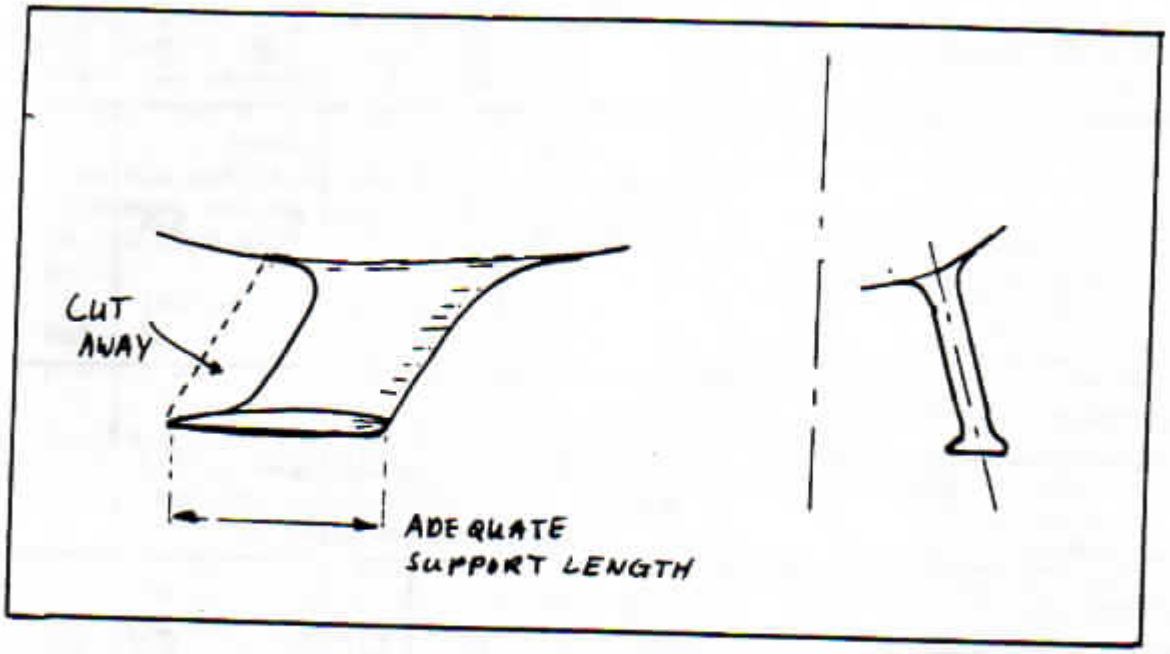

CUT
AWAY
ADEQUATE
SUPPORT LENGTH

FIG. 10

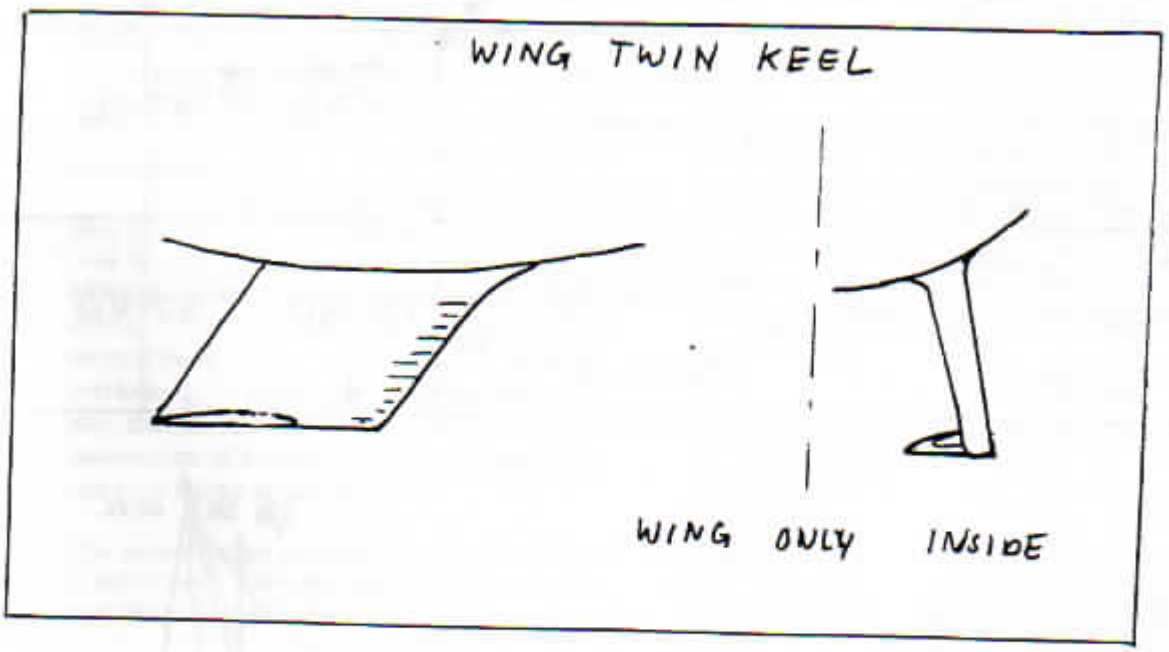
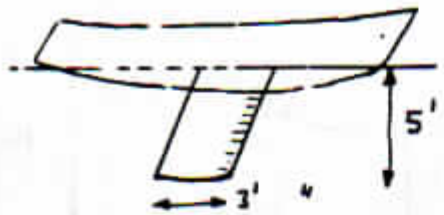

WING TWIN KEEL
WING ONLY INSIDE

FIG. 11

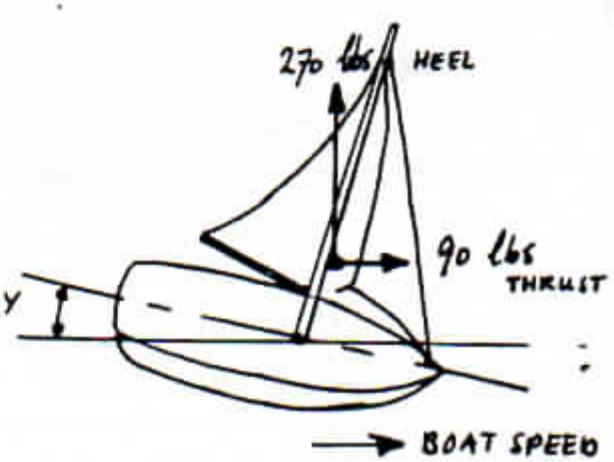
Tabel 1.

	KEEL TYPE	KEEL SURFACE	EFF. ASPECT RATIO	BOAT SPEED (KNT)	LEEWAY	WEATHER KEEL NOT ACTIVE BOAT SPEED	WEATHER KEEL NOT ACTIVE LEEWAY
	SHORT DEEP FIN	16 FT²	3	5	5,15°		
	LONG SINGLE KEEL	16 FT²	1,33	4,6	9,3°		
	TWIN KEEL VERTICAL NO TOE-IN	16 FT²	2,66	5	5,4°	4,8	8,9°
	TWIN KEEL VERTICAL NO TOE-IN	32 FT²	1,33	4,79	4,8°	4,6	7,8°
	TWIN KEEL 20° WINGED OUT NO TOE-IN	32 FT²	1,33	4,75	5°	4,66	6,7°
	TWIN KEEL 20° WINGED OUT TOE-IN 1.5°	32 FT²	1,33	4,71	4,5°	4,66	5°

SAILING TO WINDWARD

HEELING ANGLE 20°

MODERATE WIND



the stability of the boat when drying-out. Still is looks possible to design a high aspect keel with the ability of safely standing on it. An idea is given in Figure 10. Keels shaped in this way may have the following advantages: high aspect ratio and reduced keels area for good performance; good and safe support for dryin out; and lower position of ballast for bette stability.

This keel profile is used on some singl keel yachts, but in my opinion it is just a promising for twin keel yachts—where it is no common to my knowledge. (One example however, is the French yacht RM 10.50—a shown in *Voile* Magazine, January 1999—where the keels have bulbs or pods at the base.)

A new and exciting development could be the use of end plates just at the bottom of the keels. The idea of an end plate has been successfully used in the wing keel of the Australian yacht in the America's Cup races. End plates prevent the leaking of useful lifting force and, therefore, improves the efficiency. It may be expected that the improvements on low aspect ratio keels are much bigger than on already efficient high aspect ratio keels. So a typical application could be the twin keel system, which has a relatively low aspect ratio. Another advantage could be the enlarged support area at the base of the keels; when drying out , this would help prevent the keels from settling into the bottom.

Conclusions

Most modern twin keelers are no longer slow sailing boats. When properly designed, the twin keeler can be a shallow draft boat with pleasing windward sailing properties. In this article, I have offered an explanation for the improvements in performance without overlooking the limitations. New developments may lead to an even better keels system for a combination of shallow draft, drying out ability and good sailing performance. ♦

[The editors are not conversant in all of the theory presented here. They offer this fascinating essay to stimulate thinking and discussion.]

Jan Alkema and his wife began sailing a Hurley Holiday (same as an Alacrity 19) more than 30 years ago. With the birth of their daughter, they moved up to a Vivacity 24. Soon a son joined the family, and in 1979 the Alkemas purchased *Strunder*, a Westerly Konsort. The family has been sailing together on *Strunder* now for over 20 years. Jan, age 57, has a Master's degree in Mechanical Engineering and works as a Technical Manager for a Dutch dredging company, a job that takes him around the world.