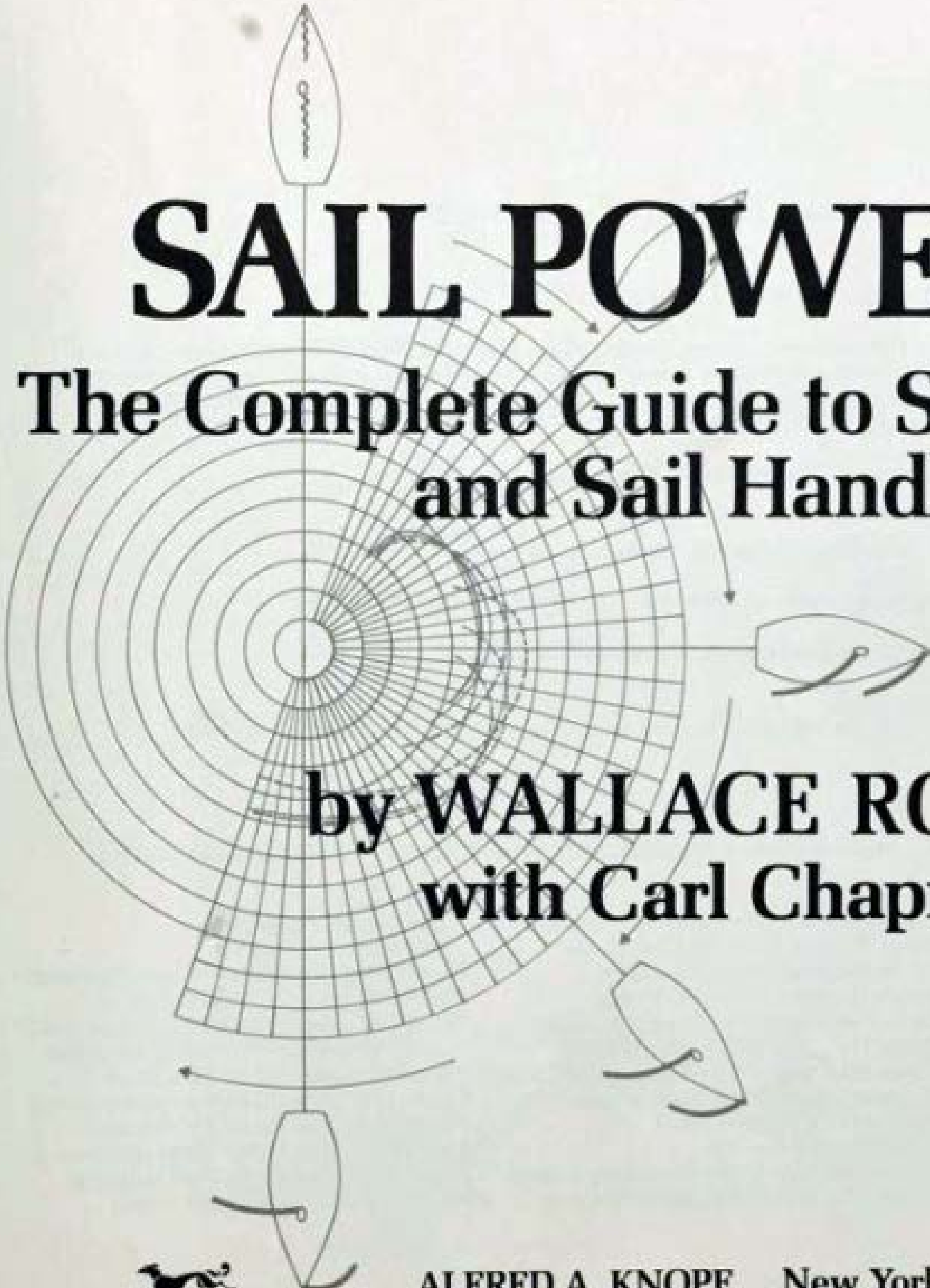


SAIL POWER

The Complete Guide to Sails and Sail Handling

by WALLACE ROSS
with Carl Chapman

ALFRED A. KNOPF New York 1975

Chapter 1

If You Could See the Wind . . .

If you could see the wind and how it envelops your boat with complex patterns of air flows and eddies, you would have a better understanding of just about everything that follows in this book. But wind is invisible. You *can* see the physical effects of wind on a sail, but that is all. You *cannot* see what a sail does to the wind and the environment around your boat. However, since wind is a fluid, it behaves much like water, which indeed is visible and photographable. Consequently, the closest approximation to seeing the wind is seeing the water and how "sails" affect it.

Eric Twiname at the Fluid Mechanics Laboratory at Imperial College in England set out to show just this; the result was this dramatic series of photographs (Figs. 1-6). The arrows indicating the direction of flow and the hull shape are superimposed on the photographs, which illustrate how "sails" made of curved rectangles of aluminum deflect a steady stream of water. A floating powder was scattered upstream on the surface of the water and then illuminated and photographed from above. The aluminum sails were coated with a liquid to minimize surface tension.

Although these tests broke no new ground in sail research, their value is that they illustrate clearly and accurately a good deal of what is known about the wind flow around sailing rigs. Whether you are an expert sailor or a beginner, these revealing photographs should help you see the wind and understand what it does to your sails, your boat, and the boats around you.

Fig. 1
This will help you visualize what the wind does around your sails on a dead run. It approaches the boat in parallel flow lines which are split by the mainsail. The flow lines attempt to resume parallel flow forward of the mainsail. The pressure build-up on the windward side of the sail is clearly shown. Where flow lines are compressed, there is a definite increase in flow velocity.

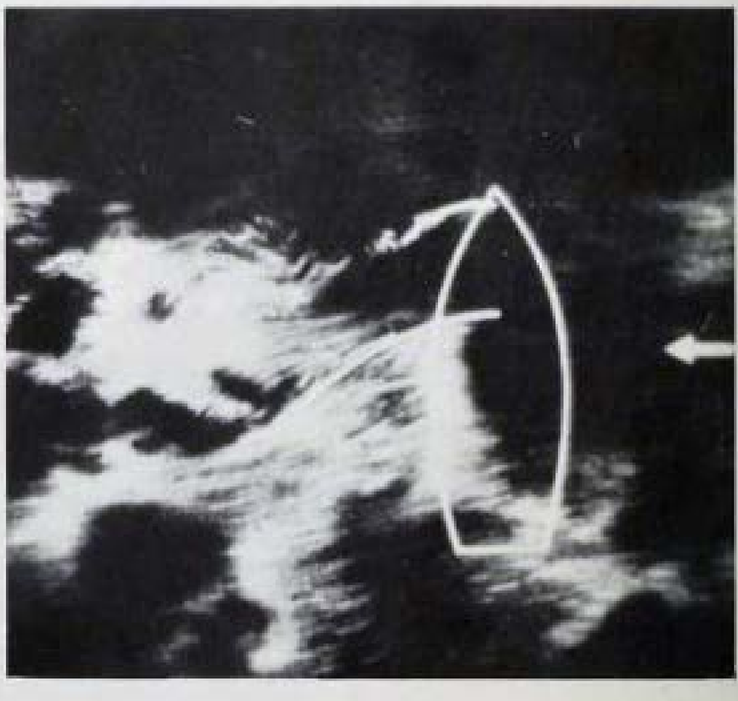


Fig. 2
With the wind abeam and sails properly trimmed, flow lines build up as they are deflected by the windward surface of the mainsail; as they pass the leech, they tend to resume their normal flow direction. There is relatively smooth flow on the leeward sides of the sails and few eddies.

Fig. 3
What happens when you have the wind abeam and remove the jib? Without the slot effect, the smooth flow on the leeward side of the mainsail is broken up by large eddies, which stall out the sail. This interruption of flow reduces the aerodynamic forces acting on the sail and decreases its driving power.

Fig. 4
When you overtrim the mainsail in a beam wind, eddies destroy most of the flow on its leeward surface, and the whole sail is virtually stalled. There is less disturbance on the lee side of the jib, which is not overtrimmed. However, by overtrimming the main, you might prevent a competitor from passing you to leeward, where there is a "hole" in the wind. Compare this area with Figure 2.

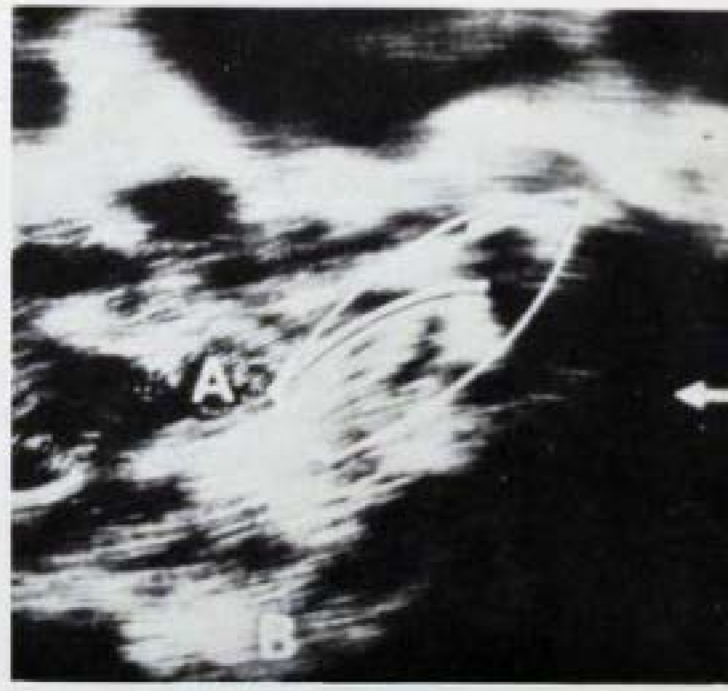


Fig. 5
Going to windward, there is smooth air flow on the leeward side of the mainsail and jib. Notice the "bad" air or disturbed flow, which would affect a boat overtaking to leeward. Also, there is a definite deflection of air flow off the windward quarter, which would give a competitor there a continual header.

Fig. 6
Going to windward with the jib removed creates a situation comparable to that in Figure 3. Disturbed air near the leech disrupts the air flow on the leeward side of the main and reduces the efficiency of the sail. This illustrates the value of the slot, which helps increase air flow on the lee surface of the main. It is interesting to note that the wind is bending even before it reaches the sail.

Chapter 2

How Sails Work

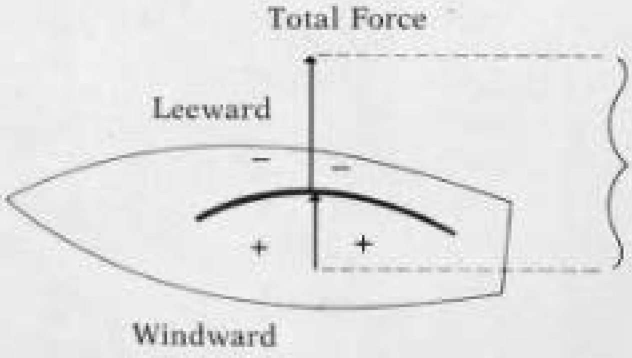
There is only one thing better than just plain sailing, and that is the satisfaction you get from knowing you are driving your boat as fast as she will go under existing conditions of wind and sea. But you cannot reach this level of expertise unless you understand how the interaction of wind and sails imparts motion to your boat.

The first thing to learn is what makes a boat go to windward. Once you have understood this, it is easier to assess what happens when you are reaching and running. To start with, think in terms of only one sail. (Two or more sails create local wind-flow conditions that interact with each other. These will be explained once you understand basic aerodynamic concepts.)

A boat is moved ahead in a windward direction by a total force acting on the sail. This total force is a combination of negative surface force (or suction force) on the lee side of a sail and positive surface pressure (or pushing force) on the windward side of the sail (Fig. 7). Both act on the sail in the same direction, and contrary to what some people think, it is the negative force on the leeward side that does the biggest job.

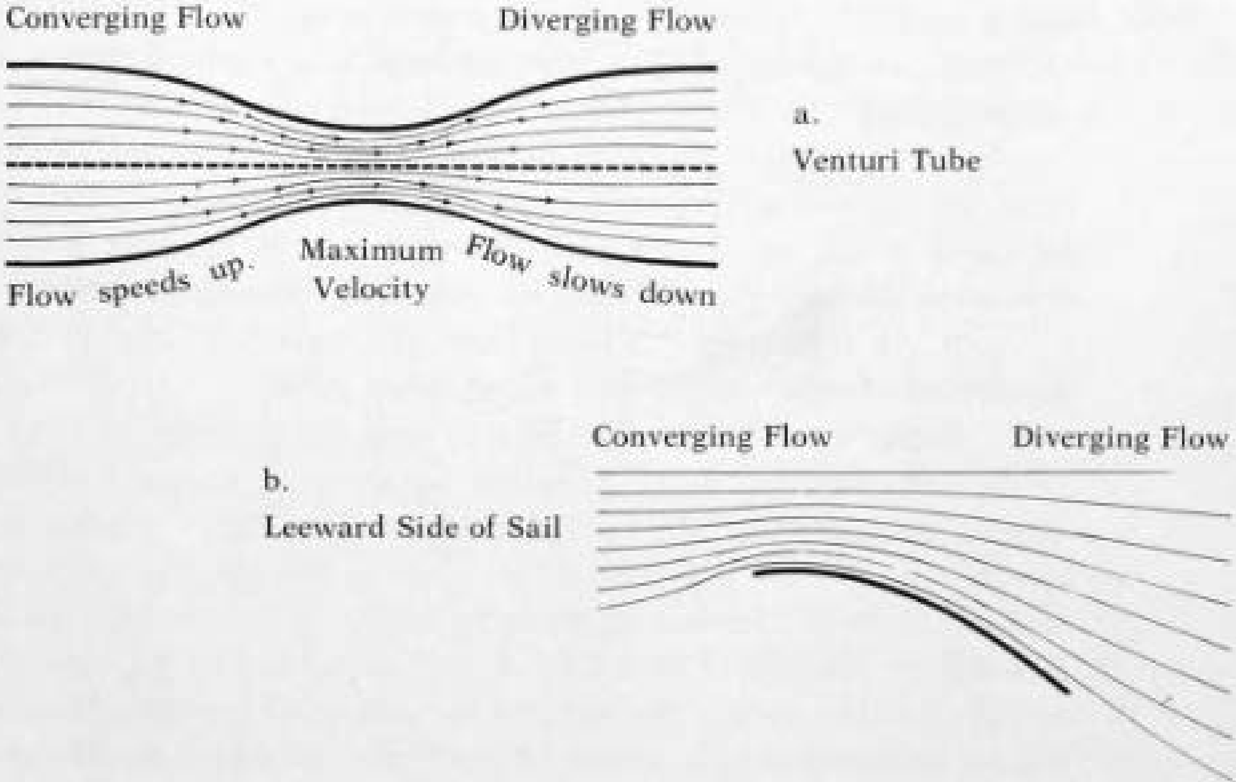
Since this is the most important force, let us see first how it is developed. Negative pressure results from an increase in the velocity of air flow over the lee side of the sail. Such an increase in air-flow velocity in

Fig. 7



relation to the velocity of the surrounding free air steam causes a decrease in pressure within the faster-flowing air—a phenomenon discovered in 1738 by Daniel Bernoulli (Fig. 8).

Fig. 8



Among the many attempts to explain why the velocity of air flow increases on the convex or lee side of the sail have been those which equate a sail with an airplane wing. This widespread theory holds that the air has to travel faster over the greater length of the wing's curved upper surface in order to rejoin the air on the underside of the wing, thus causing increased velocity of flow over the upper surface. This is not a valid explanation for either the sail or the wing. It conveniently ignores the fact that some wings are symmetrical; although the air has the same distance to travel both on top of and underneath the wing, the velocity of flow over the upper surface is faster than that over the underside. Actually, when any wing is operating at peak efficiency, the air particles that split at the leading edge do not rejoin at the trailing edge; the particle traveling over the upper surface arrives at the trailing edge well before the particle on the underside of the wing. The same thing happens around a sail.

What is the real explanation of this phenomenon? First, you must understand certain facts about the behavior of air.

1. The free air stream normally flows in straight parallel lines, but the flow is attracted toward low-pressure areas and repelled by high-pressure areas.

2. Air at low speeds (under 126 m.p.h. at sea level) is considered incompressible.

3. Although it generally resists changing its parallel flow direction, an air stream *will* adhere to the convex side of a curved surface, providing the curve is not too divergent to the direction of the free stream. If the curvature becomes too deep, the air stream will rejoin the parallel flow.

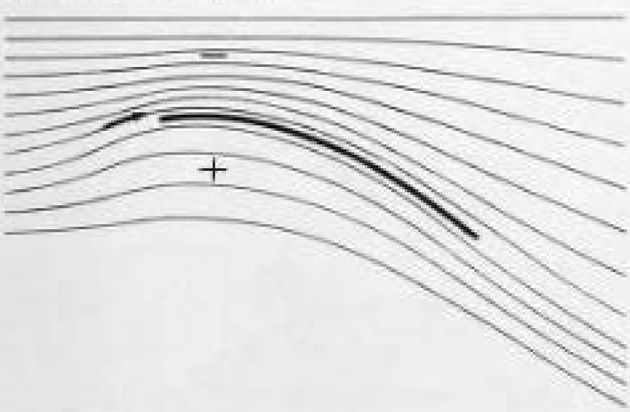
4. Air speeds up as it flows through a restricted area, as G.B. Venturi discovered in experiments with constriction tubes.

Using these principles, here is why the velocity of flow increases on the convex or lee side of the sail or aerodynamic shape. The flow adheres around the outside of the curved shape and, in order to follow the curve, has to bend out toward the free air stream. But the free air stream has a small amount of inertia and tends to maintain its straight, parallel flow. This can be thought of as a kind of wall or barrier to the outward curving air. The combination of the bulge of the convex shape and the inertia of the free air stream creates a narrow channel through which the initial volume of air has to travel. But air is essentially incompressible and cannot compact. And so, in order to get the same volume to flow through this narrower space, it speeds up. This is the reason why the velocity of flow increases on the lee or convex side of a sail.

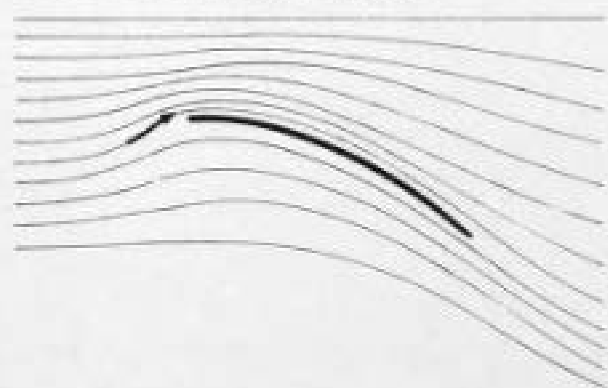
Once this happens, Bernoulli's theorem applies: an increase in air-flow velocity in relation to the surrounding free air stream causes a decrease in pressure where the faster air flow occurs. Thus a low-pressure field forms on the lee side of the sail. This low-pressure area is not only the source of the negative or suction power acting on the sail, it also sets up an important aerodynamic chain reaction which leads to the forming of even greater negative pressures. New air approaches the leading edge of the sail where it must split; when it does, more of this air mass is attracted to the newly formed low-pressure area on the lee side (Fig. 9). Thus, an even greater mass of air must travel faster to pass through the same gap. This results in greater decrease in pressure, which, in turn, attracts even more of the air mass. The chain reaction continues to build until the maximum flow velocity for the existing wind condition is reached, and a maximum low-pressure area is created on the lee side of the sail. This low-pressure area is the strongest aerodynamic force acting on the sail. It is important to understand that the flow is speeded up only until it reaches the deepest point of the curved shape. Up to this point there is converging flow and increasing velocity. Beyond the deepest point of the curve, there is diverging flow and the velocity slows down until it is again the same as the free air stream.

Fig. 9
Progressive Building of Flow Patterns

1. The flow begins.

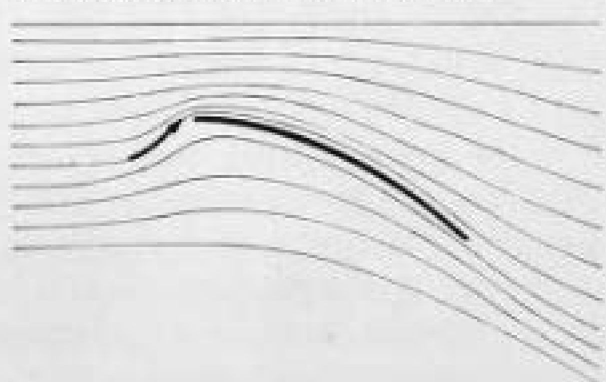


2. The flow builds in strength.



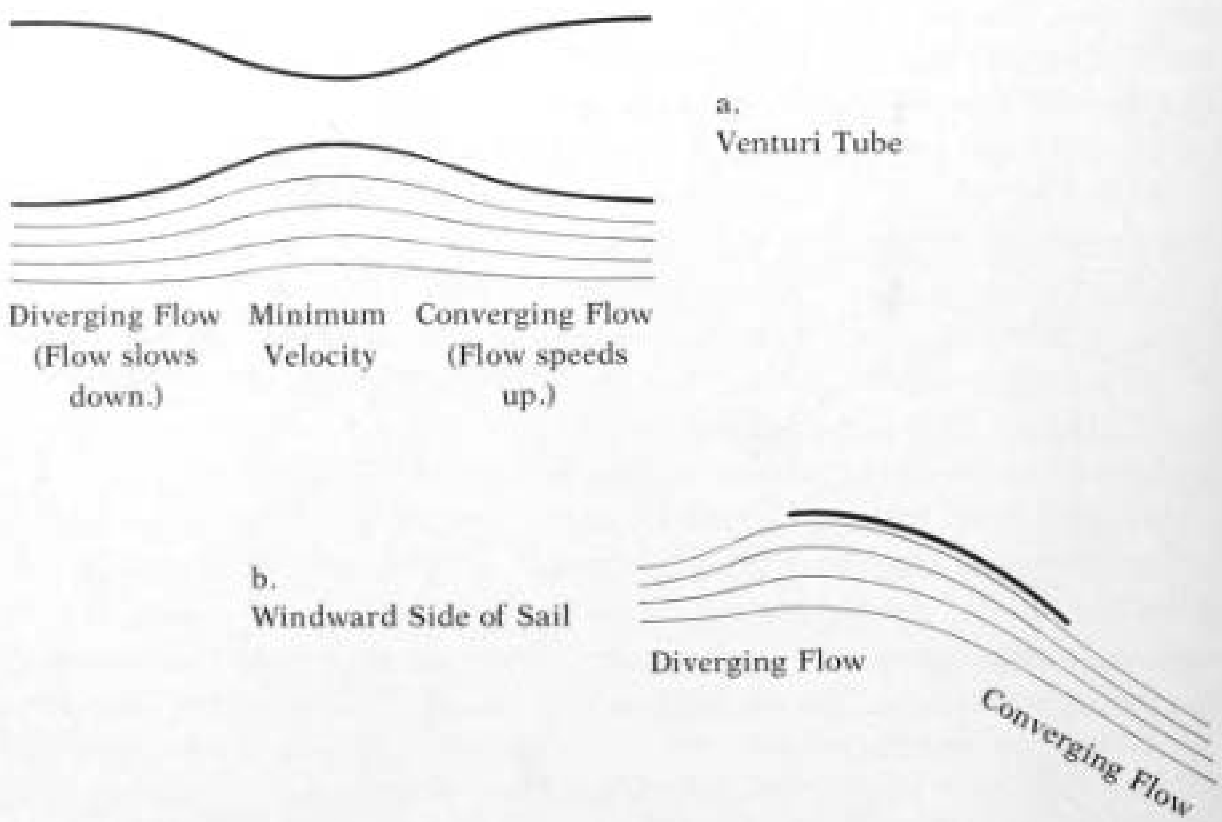
Once the flow pattern begins, a greater percentage of the approaching air mass is attracted to the negative pressure area and repelled by the barrier effect caused by the positive pressure on the windward side. Thus, the point at which the air mass splits in front of the sail changes location until, when maximum flow is developed, it is a good bit farther to windward than when the flow pattern began.

3. The flow reaches its maximum.



On the windward side of the sail, just the opposite is happening. As more volume flows over the lee side, there is less of the air mass remaining on the windward side to flow through the expanded space between the concave side of the sail and the free air stream. Thus, the velocity of the air flow slows down, and since it is traveling at a lower speed than the free air stream, it creates a positive pressure area on the windward side of the sail. This action can be compared to the flow outside the constricted area of the Venturi tube (Fig. 10).

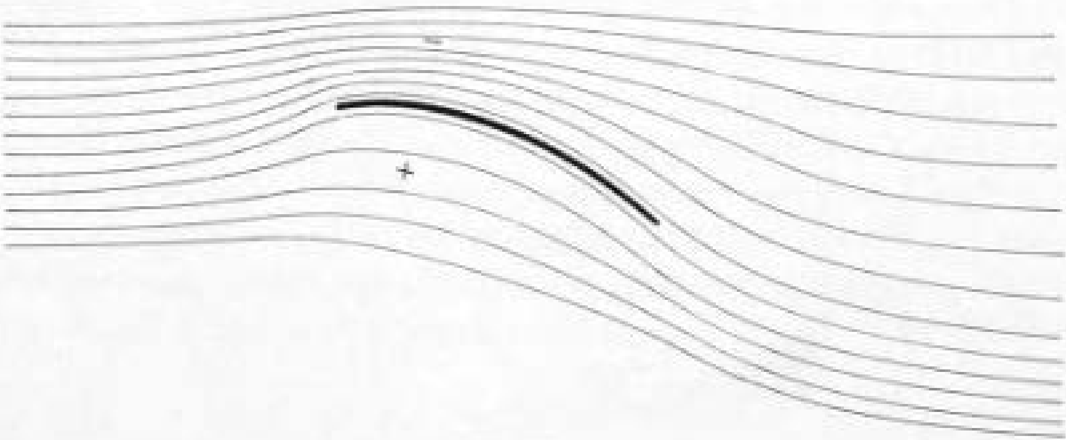
Fig. 10



To put it simply, on one side of the sail you have more air going through a narrower opening, increasing in velocity, and decreasing in pressure, while on the other side you have less air going through a wider gap, resulting in a decrease in velocity and an increase in pressure. The end result is a strong negative pressure or suction force on the lee side of the sail and moderate positive pressure on the windward side, both acting on the sail in the same direction (Fig. 11).

Fig. 11

Leeward side=negative pressure
Air is squeezed.
Velocity increases, pressure decreases.

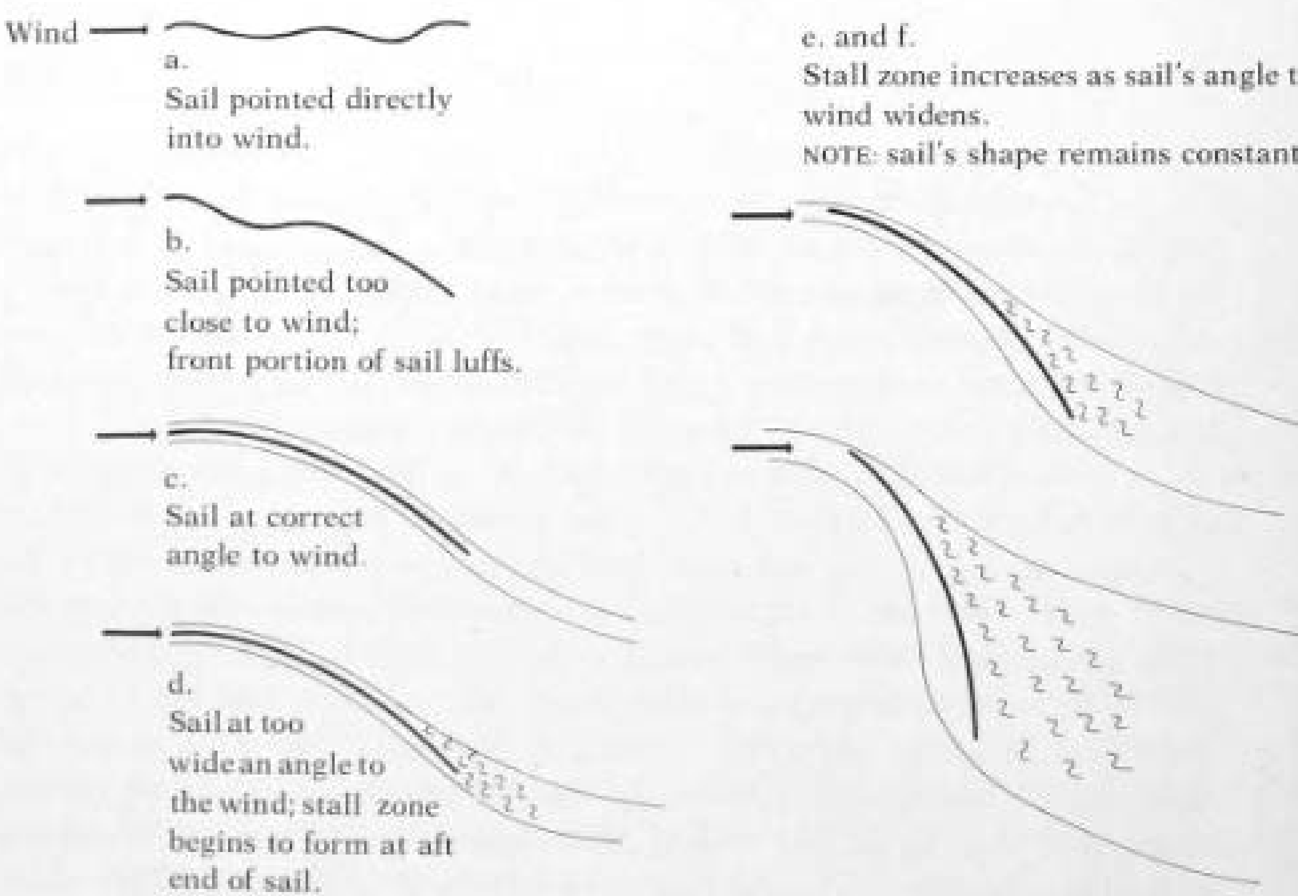


Windward side=positive pressure
Air spreads out.
Velocity decreases, pressure increases.

You now have a theoretical total force that consists of the combination of aerodynamic forces on both sides of the sail. But how, in practice, do you develop these forces? Basically, what you must do is establish a relationship between the sail shape and the wind (angle of attack) that allows the wind flow to both speed up and adhere to the convex curve of the sail most easily, thus developing maximum aerodynamic forces.

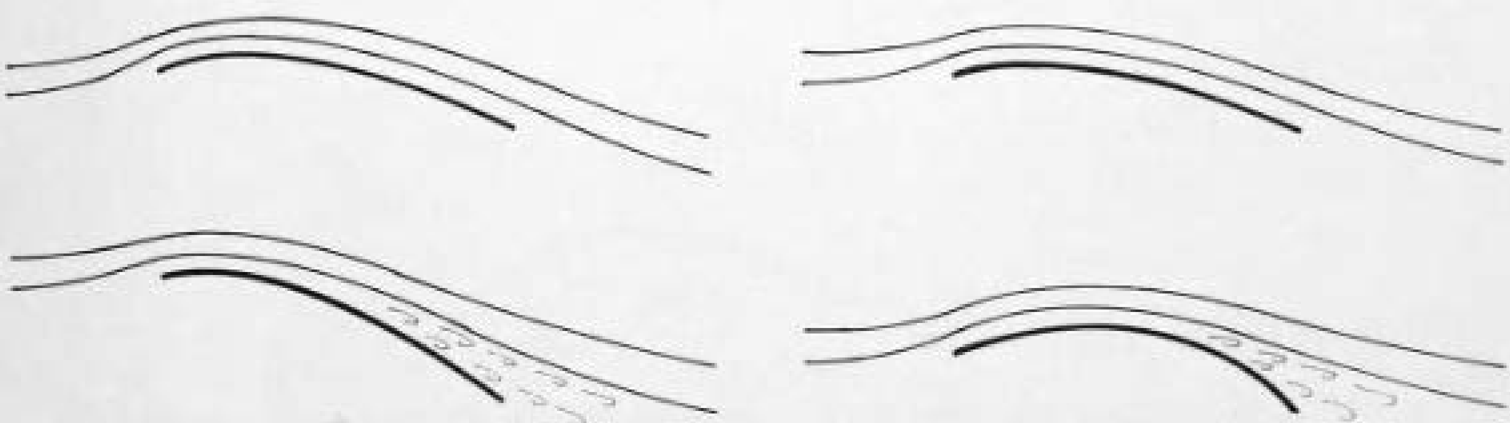
To achieve this, your sail must first of all have a curved shape. This is built in by the sailmaker, but it takes a certain amount of wind for the curvature to fill out. The sail must also be pointed at a certain angle to the wind. As you can see in Figure 12a, if the sail is pointed directly into the wind stream, the wind splits evenly on either side, there is no curvature, and no differential in pressure is obtained. The sail will flap like a flag in the breeze. However, the moment you angle the sail to the wind to just the right degree, two things happen: one, the sail fills away, taking its curved shape; and two, you get the natural phenomenon of the wind flow attaching to the lee side, clinging to the curved surface, and speeding up. This point is the critical angle of attack, and it is very precise. Beyond two or three degrees of the optimum angle, the aerodynamic forces deteriorate rapidly; if the sail is pointed too close into the wind, it will start to flag (luff); if it is at too wide an angle to the wind, the flow lines detach from the lee side of the sail (separation), and a stall zone consisting of haphazard eddies develops, reducing the aerodynamic forces. As the flow that develops the increase in velocity is interrupted in the separated area, velocity drops and the pressure begins to return to that of the free air stream; the low-pressure build-up is destroyed. Separation starts at the leech; this is because a sail's curvature will always cause the aft end of the sail to be at a greater angle to the wind than the leading edge. As the sail's angle of attack to the wind widens, the point of separation moves forward, leaving everything behind a stall zone.

Fig. 12
Sail at Different Angles of Attack



Not only must the leading edge of the sail be angled properly—to allow the air flow to pass smoothly onto the sail—but the flow must remain attached all along the sail. Thus, the sail must have the right amount of curvature all the way aft. If the curvature is too slight, the air flow will not bend out, and therefore you will not get the squeezing effect that causes the increase in velocity of flow (Fig. 13a). On the other hand, if the curve is too deep, the flow will not remain attached: an air flow will adhere to a curved surface only if the curved surface is not too divergent from the direction of the normal air flow (Fig. 13b). Thus, separation will also occur if the sail is too full. It's very important, therefore, not to have too little or too much curvature in the sail. Figure 12c shows the right amount of fullness as well as the correct angle of attack. How you manage this is discussed in detail in Chapter 5, Draft Control.

Fig. 13
How the Wind Flow Is Affected by the Sail



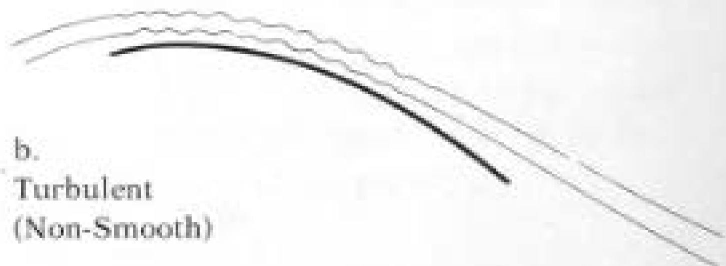
a. At Different Angles of Attack (Shape Constant)

b. With Different Amounts of Curvature (Angle of Attack Constant)

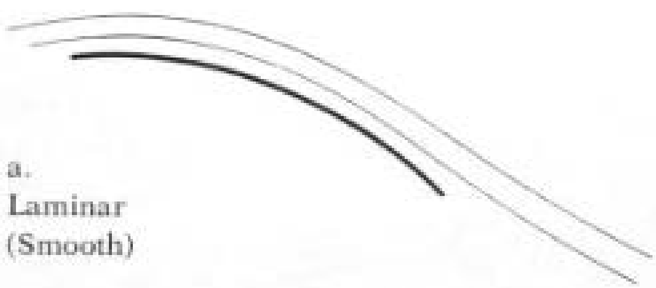
Do not confuse the words "separation" and "turbulence." (See Fig. 14.) The attached flow on the lee side of a sail can be either laminar (smooth) or turbulent (non-smooth), or a combination of both; sometimes, turbulent flow is purposely induced as it will adhere to an irregular surface better than laminar flow. In either case, whether the flow is smooth or turbulent, if it remains attached, the highest aerodynamic forces can be developed and this is exactly what you're aiming for in any windward sailing. Therefore, the sail must be angled to just the right degree—no more and no less, and the sail must not be too full or too flat.

Fig. 14
Types of Flow

Attached flow on the lee side can be either laminar (smooth) or turbulent (non-smooth).
Both produce effective forces; in fact, the turbulent flow is sometimes more desirable, as it will adhere to a rougher surface.



b.
Turbulent
(Non-Smooth)



a.
Laminar
(Smooth)

SAIL-FORCE STRENGTH

Now we have seen how the pressures on the sail are developed theoretically and practically. But how do these pressures work on the sail, how strong are they, and how are they translated into forward motion of the boat?

In the first place, air pressures are real and measurable. Take the low-pressure area, for example. At sea level there is a constant pressure of 14.7 pounds per square inch or 2,116 pounds per square foot. If the faster flow on the lee side of the sail drops the pressure to 2,112 pounds per square foot, you have an average negative force of 4 pounds per square foot acting on your sail. If your sail area is 500 square feet, you have a force of 2,000 pounds on the lee side, "pulling" or "sucking" the boat forward. As we have seen, this suction force is the major component of the total force acting on the sail.

There is also a positive force on the windward side of the sail. Assume that this averages 2 pounds per square foot. Add this to the 4 pounds per square foot of negative pressure on the leeward side. Regardless of the positive and negative signs, both forces are working in the same direction. There is an average force of 6 pounds per square foot or a total force of 3,000 pounds working on the entire sail (Fig. 15).

Fig. 15

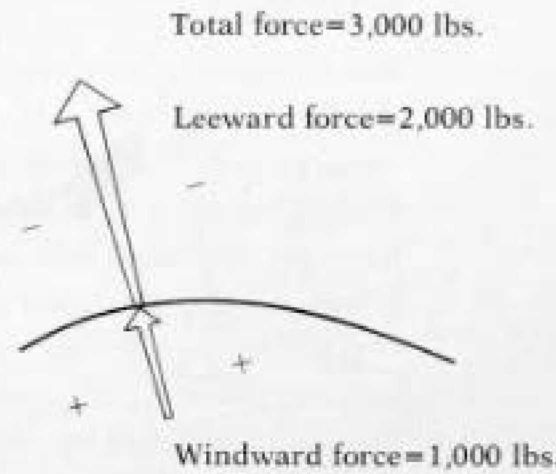
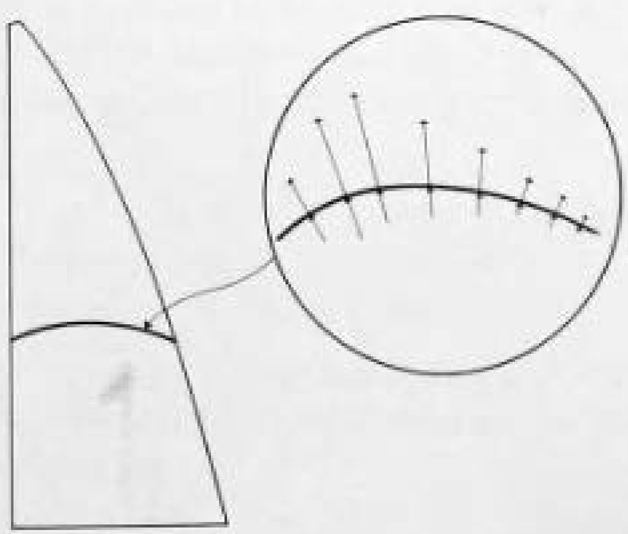


Fig. 16
Local Sail Forces at One Level of the Sail from Fore to Aft



These are only average figures because, in actuality, the pressures are different at each point on the sail. Remember that the lee flow increases in velocity as it approaches the deepest point of the curve—with a corresponding increase in force; after the deepest point, the velocity of flow slows down until, at the trailing edge, it is near the speed of the free air stream. The forces here are negligible. Figure 16 shows the varying strengths of the individual forces on the sail at one level from fore to aft. But that's not all: you also get different pressures at different heights on the sail, since the velocity of flow increases with height above water—as the air is less and less affected by the surface friction of the water. This is called the *wind velocity gradient*. Also, the fullness of the sail can vary at different heights and this too varies the pressure.

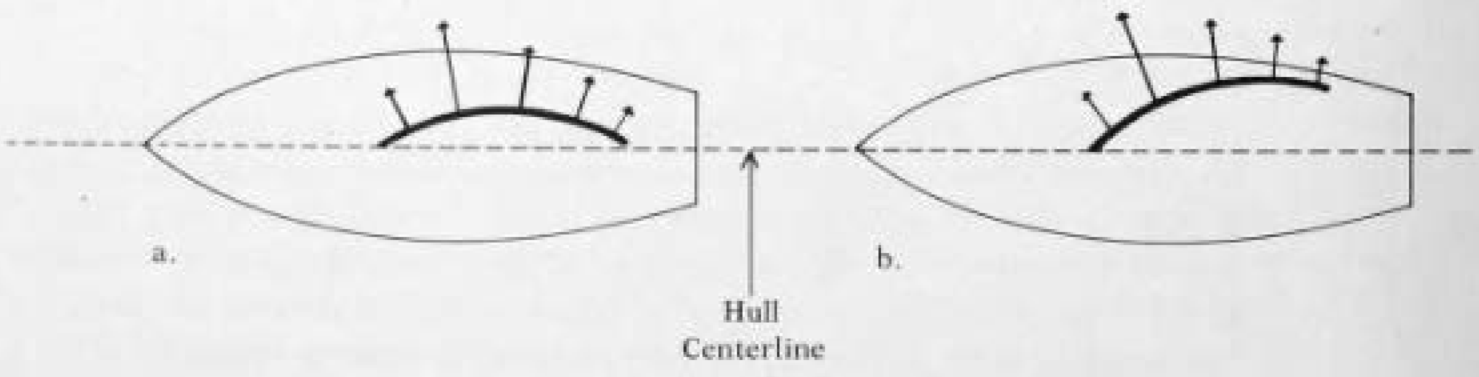
These individual pressures on each unit of sail area not only have strength, but, as you can see, each has direction as well: at every point in the sail, the force is perpendicular to the sail's surface.

The very strong forces in the forward third of the sail are also in the most forward direction. As you move back toward the middle of the sail, the forces grow weaker and they are not in as forward a direction; they contain a larger heeling component. As you move even farther aft, the heeling or sideward forces become more predominant. You may even get backward or drag forces because of the sail's adverse angle in this area. However, the forces are minimal at this point.

Of course, the directions of force (forward drive, heel, and drag) are only meaningful when you relate them to the boat. And then, the directions are modified by the angle at which the sail is trimmed in relation to the centerline of the boat. If you trim the sail outboard, all the forces will be in a more forward direction than if you trim the sail to the centerline (Fig. 17).

Fig. 17

The direction of the forces on the sail changes with changes in sail trim.

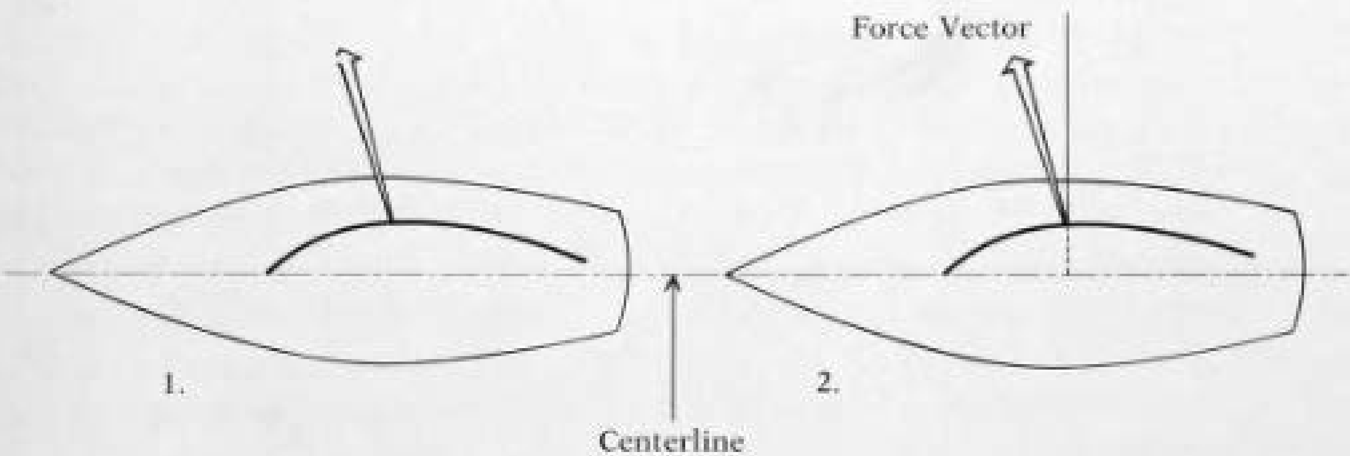


Finding the Components of Force

Each force on the sail can be broken down and diagrammed into its component parts to show how much forward drive, heel, or drag it contains. First, one draws a vector representing the strength of the pressure force over the unit of sail area (Aerodynamicists use vectors as illustrative simplifications. Vector lengths are arbitrary but proportionate.) (1)

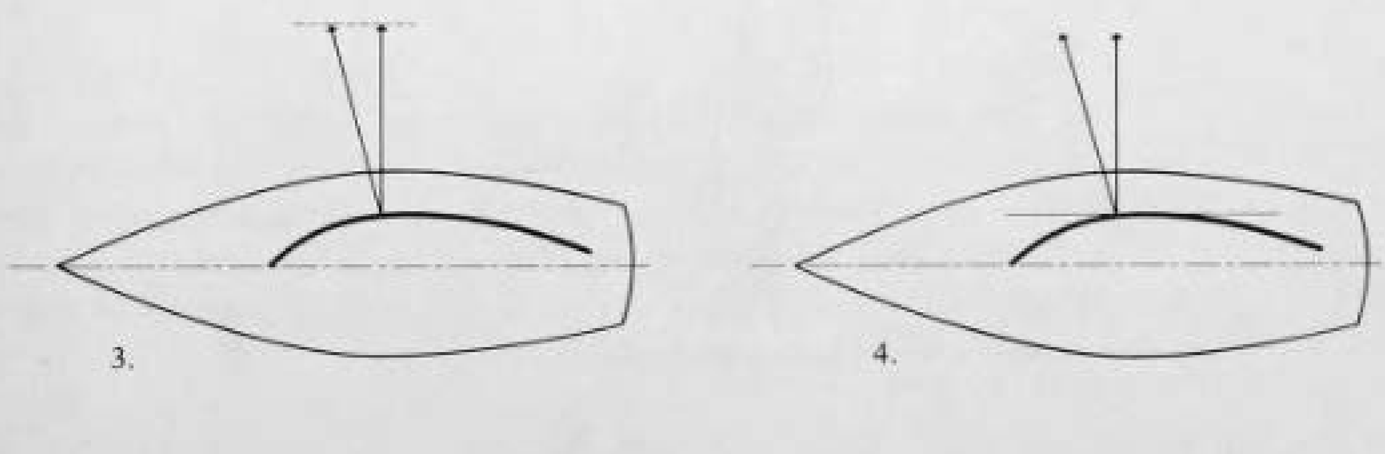
Then, from the point on the sail where the vector originates, a line is drawn perpendicular to the centerline. This line will represent heel (2).

Fig. 18

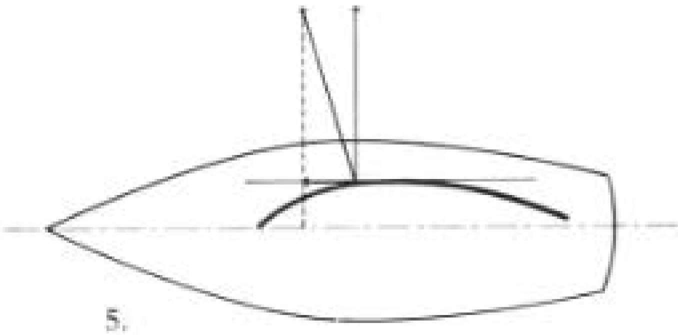


To find out how long the heel line should be, draw a line parallel to the centerline from the tip of the force vector, to the perpendicular; where they intersect, the heel line ends (3).

To find the amount of forward drive, a line is drawn parallel to the centerline and passing through the point on the sail where the vector originates (4).

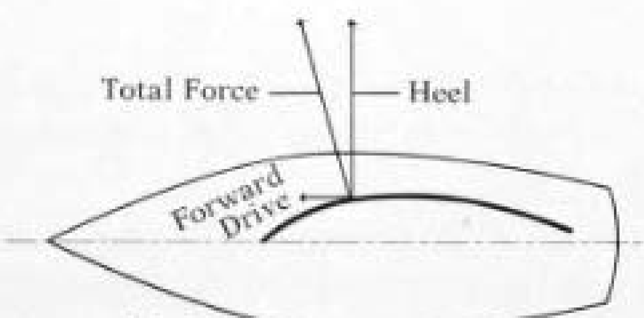


To find its length, a perpendicular line is drawn from the centerline to the tip of the vector; the drive vector ends where the perpendicular intersects the parallel line (5).

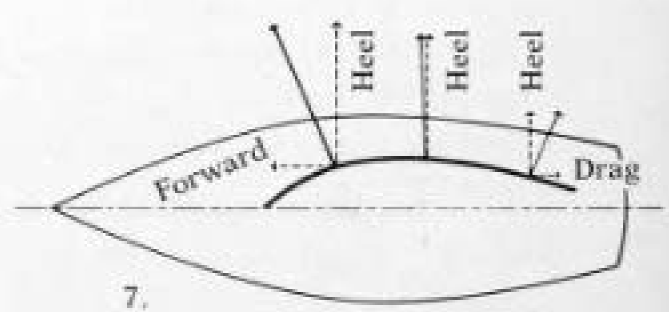


5.

Finally, one cleans up the drawing so that only the three vectors are left, representing the forward drive component, heel component, and total force. (If the force vector goes aft, one simply reverses this procedure. The same procedure is also applied to the forces on the windward side of the sail.) (6,7)



6.



7.

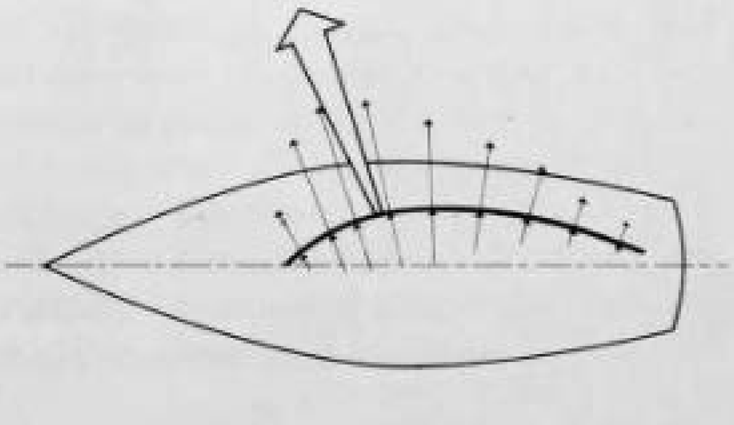
By analyzing the sail forces from fore to aft in this way, you can get a very good idea in what direction the different forces act and what relative strength they have. You can see, for example, that the most efficient part of the sail is the forward portion. That is why it is important not to let your sail luff even slightly, unless, of course, you are overpowered in heavy air and need to carry a luff to keep the boat on its feet.

Total Sail Force

Given all these different forces acting on different parts of the sail in different directions, how do you find the strength and direction of the *total* force? Obviously, the strength of the total force will be the sum of the strengths of all the individual forces on both sides of the sail that act in the same direction (whether windward or leeward, all forces are perpendicular to the sail's surface). But the direction of the total force has to be calculated by weighting the direction of the individual forces according to the strength of each. Since the forward forces are also the strongest forces, they will predominate. Therefore, the total force will have a slightly forward direction, unlike the individual force that is perpendicular to the sail's surface. The total force can be diagrammed into its component parts in the same way the individual forces were plotted. For the sake of clarity and simplification, wherever possible from now on individual forces will not be drawn; instead, the total force vector will be used to indicate sail force (Fig. 19).

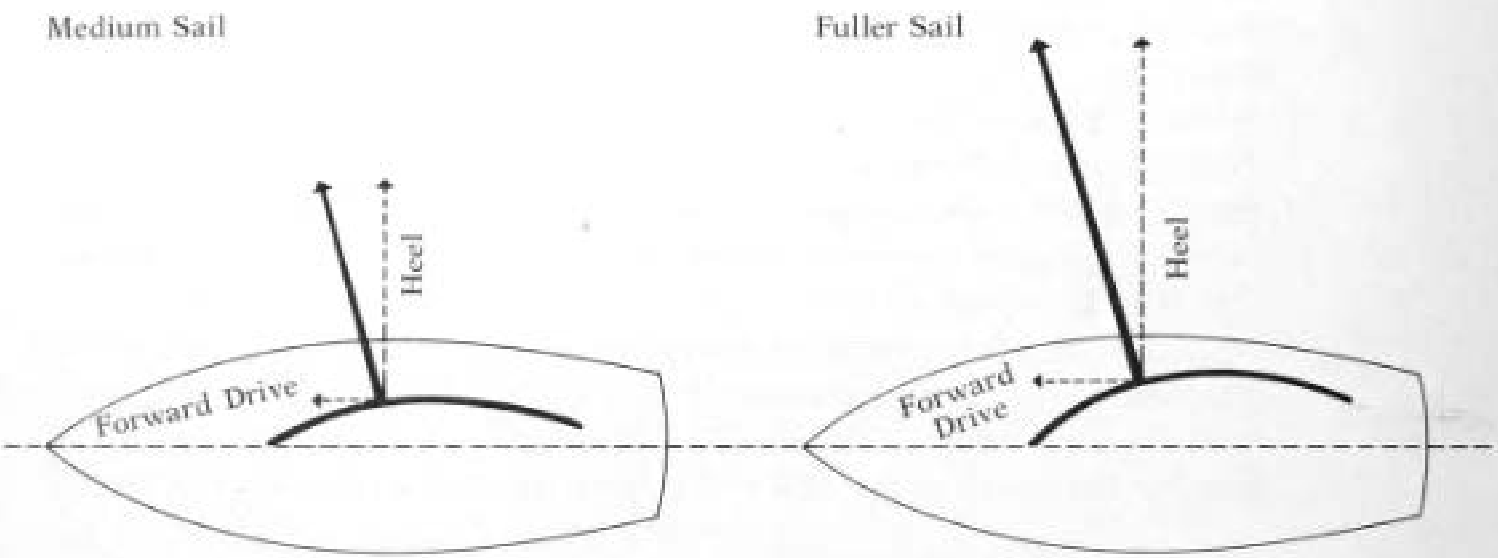
As you can see, most of the force acting on the sail is in a sideward direction when going to windward. The sideward component will usually be many times greater than the forward component. As a result, when you increase the power of the sail to get more forward driving force, you also

Fig. 19
The total-force vector represents the total of windward and leeward vectors.



get a great deal more heeling force. (See Fig. 20.) Crew weight and hull stability are the major counterbalances to this, and set the limit to how powerful a sail you can carry. Obviously, this limit doesn't apply to light air, where you're not in danger of being overpowered, which is why, over the years, fuller sails in light air and flatter sails in heavy air have become standard.

Fig. 20



How Sail Force Moves the Boat

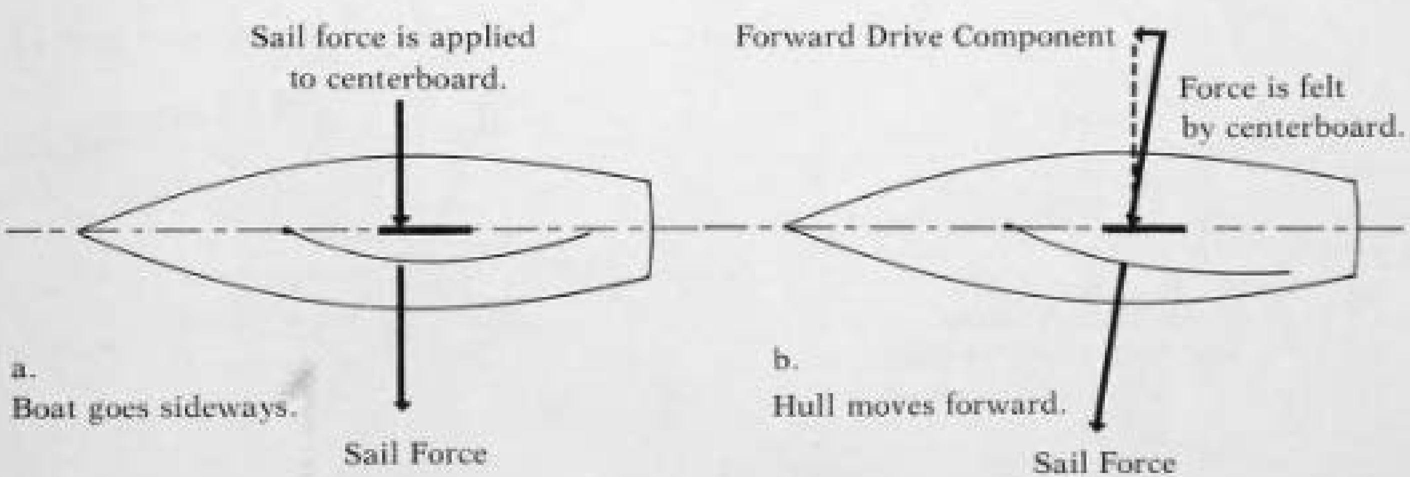
Now we have a total force acting on the sail in a general direction. How is this force on the sail translated into forward movement of the hull?

First, the direction of the total force will be almost directly perpendicular to the sail's axis or chord—the imaginary line drawn from luff to leech at any one height. Now, if, as in Figure 21a, the chord of the sail is directly parallel to the centerline of the hull, you can see that the main force is almost completely to the side. The lateral plane of the boat (its hull and centerboard or keel) will resist these sideward forces, but the steady perpendicular thrust pushes the boat slowly sideward. The boat "crabs" slowly to leeward as the keel or centerboard resists the side thrust of the sail.

If you angle the sail just a little so that the sail force is in a slightly more forward direction, the boat will immediately move forward (Fig. 21b). The reason behind this rather puzzling phenomenon is simple: the lateral plane resists sideward movement to such a degree that forward movement is the course of least resistance. You can see this happen quite commonly in everyday life: take a mop. If you push straight down on the handle, the mop won't go anywhere. The moment you angle the handle even slightly, the mop slides across the floor easily. (The mop can give you another graphic example of a sailing principle: the more slippery the mop, the faster it moves. The same applies to a boat's hull—if it is encrusted with barnacles, for example, it is a lot harder to move than a sleek, slippery hull would be.)

This explains how a boat, with most of the force to the side when

Fig. 21



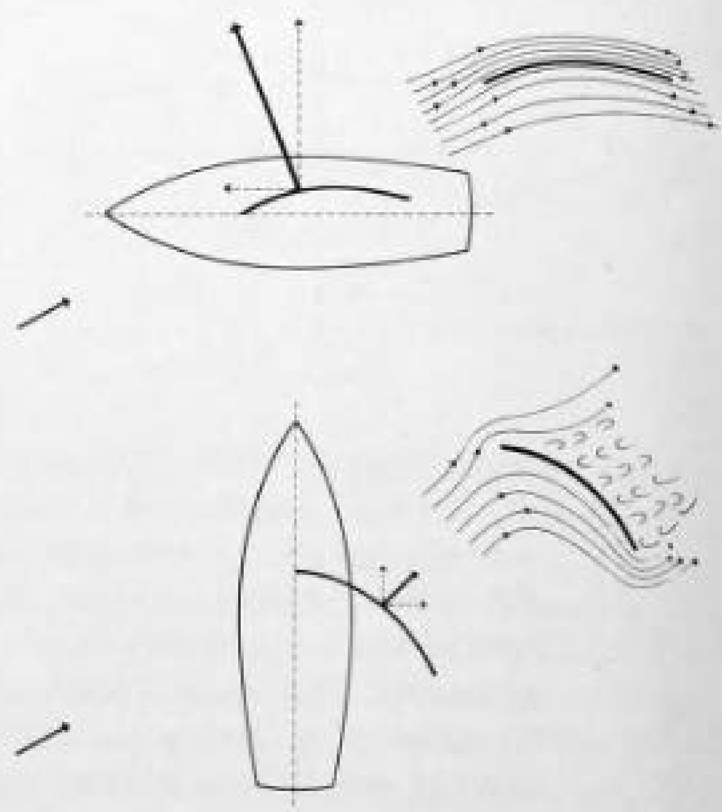
a.
Boat goes sideways.

b.
Hull moves forward.

the sail is close-hauled, moves to windward. As you go farther and farther off the wind—and the sail is angled more and more out from the centerline—more of the force is in a forward direction, and there is less and less side or heeling force, until, when you are heading dead downwind, all the force is in a forward direction—that is, in the same direction as the hull is moving. This would seem to be the most efficient and, therefore, the fastest point of sailing—all the forces are pushing you in the direction in which you want to go. However, like almost everything else in the theoretical part of sailing, things are not that simple. In fact, in average wind conditions, you may go faster to windward than downwind. One reason is that in going to windward, the total force on the sail is developed from aerodynamic flow and is very much stronger than the force resulting from the simple drag of the sail to the wind on a run. Another reason is the difference in *apparent-wind* velocity. This is the wind the sails "feel," which is indicated by the telltales. It is a combination of the true-wind velocity and boat speed. When you are heading into the wind, boat speed is added to the true-wind speed, resulting in a greater velocity of flow over the sail, thus producing greater forces. However, downwind, the fact that the boat is moving in the same direction as the wind decreases the apparent-wind velocity over the sail. Boat speed is subtracted from the true-wind velocity; the velocity of the apparent wind operating on the sail is less than the true-wind speed, and the already weaker total force is weakened even further. (See Fig. 27 for a detailed explanation of apparent wind.)

Thus, going to windward, the stronger sail force at a poorer angle produces more forward drive than sailing off the wind with the weaker force at a more favorable angle (Fig. 22).

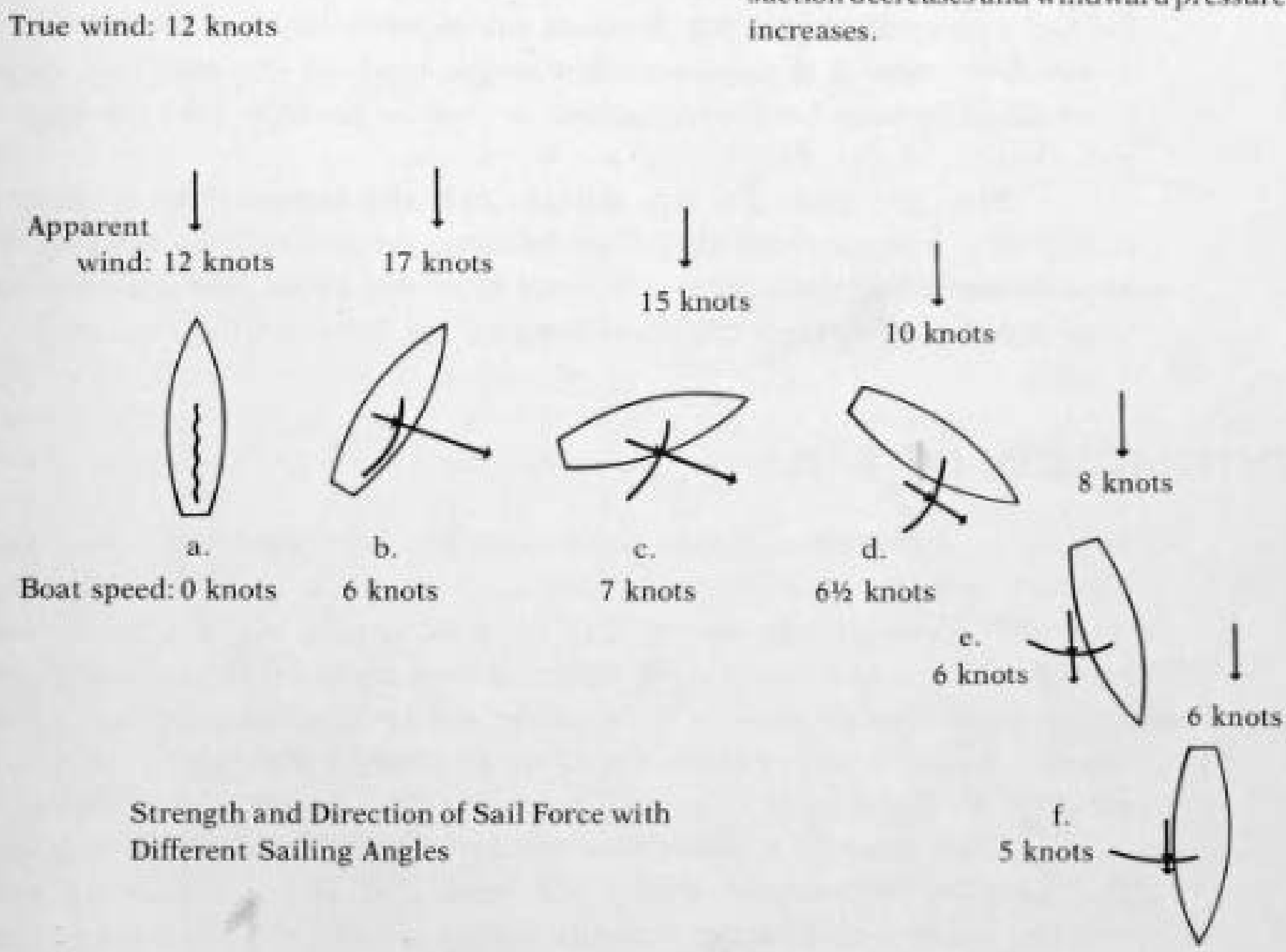
Fig. 22



a.
True wind: 12 knots
Apparent wind: 17 knots

b.
True wind: 12 knots
Apparent wind: 9 knots

Fig. 23
As the boat rotates under the sail onto a reaching angle, the forces are less to the side and gradually more forward—which is the favorable direction. In addition, as the reaching angle widens, leeward suction decreases and windward pressure increases.



Strength and Direction of Sail Force with Different Sailing Angles

Examine Figure 23 to see what happens as you head off the wind: as the boat goes from a windward point of sailing to a close reach, the sail remains trimmed to approximately the same angle of attack to the apparent wind as when going to windward. In other words, the sail remains in basically the same position in relation to the wind, but the hull rotates underneath it. Most of the driving power is still developed by aerodynamic forces on the lee side of the sail, where attached flow is maintained. However, as you go farther off the wind to keep the proper angle of attack, the sail has to be angled more and more to the centerline until, on a broad reach with the wind coming from well aft, it is no longer possible; the shrouds prevent the sail from going any farther. Thus, you can no longer achieve the proper angle of attack, and the flow on the lee side begins to break down. Finally, on a run with the wind directly astern, the force is almost entirely derived from the weaker pressure on the windward side; the sail simply blocks the air. Because the negative force on the lee side is so much stronger, it is important that as you head off the wind you make every effort to keep lee flow attached as long as possible (see Chapter 6, Sail Trim).

Thus, in Figure 23, you can see that the fastest point of sailing is generally a beam reach (Fig. 23c) because the sail still maintains good aerodynamic flow, the force is at a more favorable angle, and the apparent wind is still strong, therefore developing strong forces on the sail.

INTERACTION OF SAILS

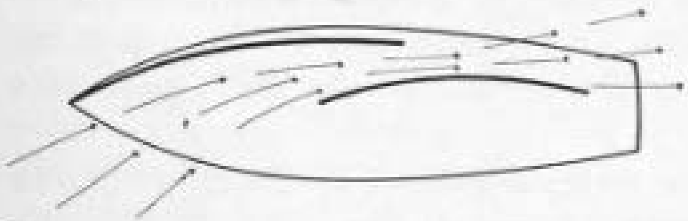
So far, the explanation of how sails work has been confined to one sail. Now we will see what happens when a jib or genoa is added to the rig.

We have already shown that air flow speeds up in a constricted area. Look back at Figure 8b, where the convex curve on the lee side of the sail creates a narrow channel between the sail and the free air stream, thus causing the air mass to accelerate. This produces a decrease in pressure, which is the major force in moving the boat to windward.

When you add a genoa that overlaps the lee side of the mainsail, the most widely accepted theory has been that you introduce an even stronger leeward side barrier than the free air stream; there is more squeezing of the air between the after portion of the genoa and the convex, lee surface of the mainsail, and the result is a greater decrease of pressure. This constricted area is known as the "slot" and the phenomenon is described as the "slot effect."

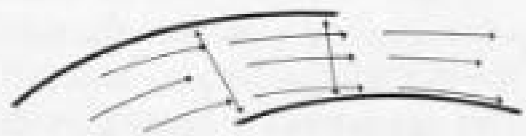
If the main and genoa are too close, the main will luff or become backwinded (Fig. 24b), reducing its drive. If these sails are too far apart, there is no constriction, and the air flow does not attain the maximum increase in flow velocity (Fig. 24c). However, when the main and genoa are properly trimmed, the slot operates effectively (Fig. 24a), and air flow

Fig. 24



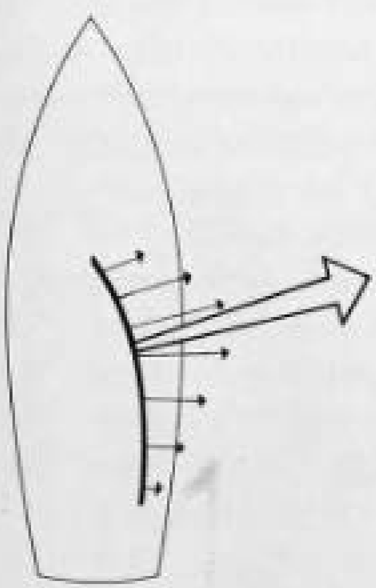
a.
Correct Slot—Just Enough Squeezing

b.
Slot Too Closed—Too Much Squeezing

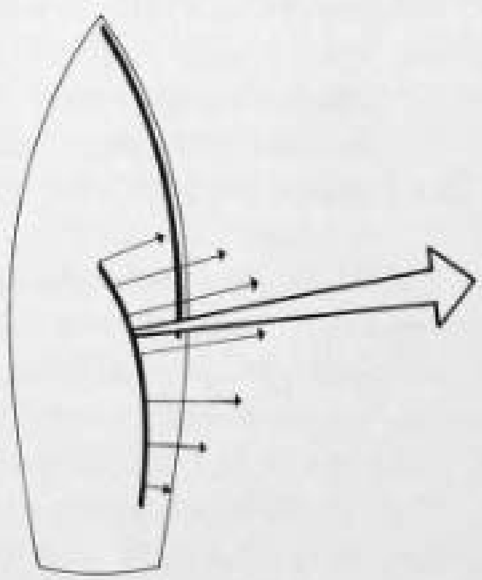


c.
Slot Too Open—Not Enough Squeezing

Fig. 25



a.
Without Headsail



b.
With Headsail

from the windward side of the genoa adds even more speed to the flow on the lee side of the main, thus altering the forces developed by the mainsail. Comparing Figures 25a and 25b, you will see that the changes in flow velocity in the area of the overlap cause the forces on the forward part of the main to change in strength and direction.

On small boats with working jibs, there is no overlap at all, but the jib redirects the air flow toward the mainsail in the same way, although to a lesser extent. This also increases the flow velocity over the lee side of the main and augments the forces. The photographs in Chapter 1 show this quite graphically.*

In addition to increasing the forces developed by the mainsail, the jib and genoa obviously create driving forces of their own. In fact, the genoa, which can be trimmed more outboard near the rail of the boat, provides a force with more forward direction than the main. The forces acting on the genoa and the forces acting on the main are combined into one total force acting on the boat's centerboard or keel to produce forward motion.

By now you should have a basic understanding of the theory behind your sails and how sail force is developed, how it is translated into forward movement, what happens on different points of sailing, and, in a general way, how sail shape and trim affect your boat speed. Virtually all the remaining chapters will be devoted to showing you how to put this theory into practice and how to use it to get the most out of your boat and sails. The first step toward this goal is having the right sails for your boat and for your particular needs, and so we will begin with a discussion of sail design.

*See Figure 148 for the latest explanations of aerodynamicists concerning the slot effect.

Chapter 8

Sail Handling

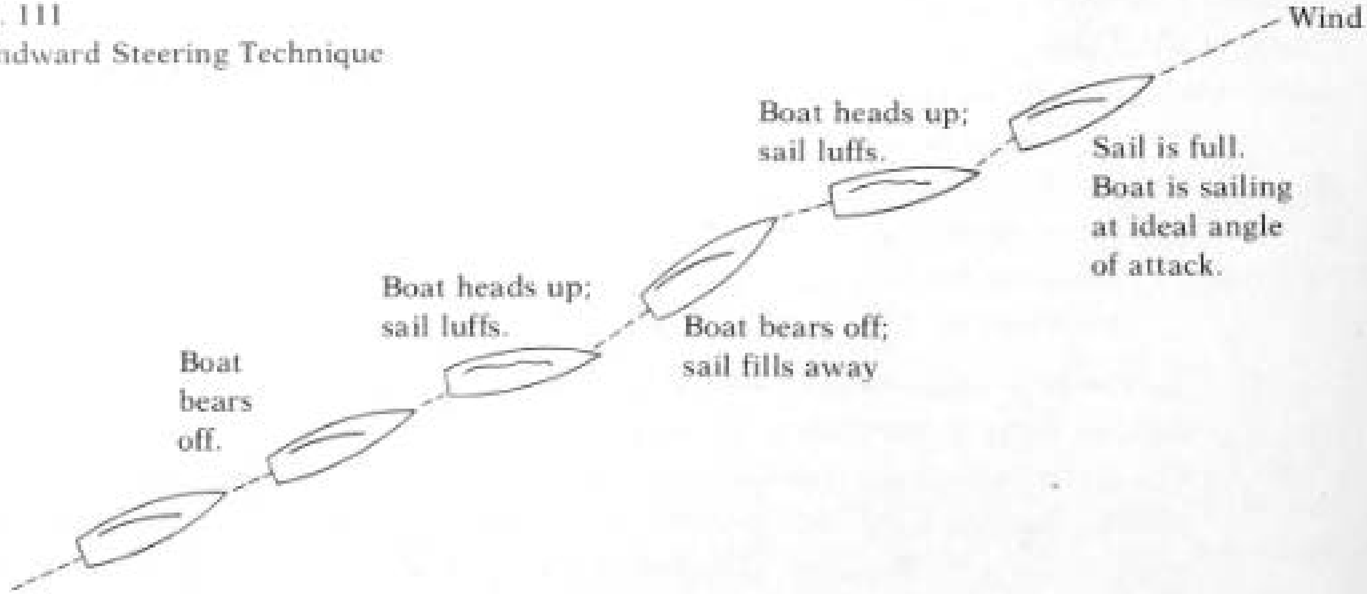
To the new sailor the myriad adjustments, wind conditions, and sea conditions form a seemingly infinite number of possible combinations with the odds stacked against his ever finding the correct combination of adjustments. Surprisingly, the problem is simpler than it seems, because there are general guidelines for different wind conditions that are universal, with few exceptions. These guidelines reduce the number of combinations to only a few and work for a cruising boat or a one design with only a difference in the degree of trim.

First, a review of general sailing techniques and considerations is in order. Proper upwind steering technique is essential to attain good boat speed. The normal starting point for the beginner is to set the trim angle of the sails and steer the boat to the edge of the luff. Slight wind variations will cause the angle of attack to change. You must steer to these changes—that is, steer to keep the angle of attack constant. One way to learn how to do this is to steer a long scalloping course with the sails luffing slightly at the peaks of the scallops (Fig. 111). When the sails just break (luff), steer the boat gently away until the sails fill; gradually head up the boat until the luff just breaks, and again head away. With experience, the steering corrections used in this technique can be refined until they are barely perceptible and allow the boat to be continually sailed within the 2- to 3-degree range of the best angle of attack. The best skippers can steer to the edge without breaking a luff for long periods of time, but it takes the utmost concentration.

You also have to know how to deal with heeling. Sometimes, if you have a flat-bottomed or shallow-draft hull, you can use heeling to your advantage. In lighter air, you can reduce wetted surface and, therefore, hull drag by inducing a slight heel. This also helps the sails to fill out by gravity.

But your main concern with heeling will be in heavier airs, and to deal with it, you have to understand it. A boat, like a pendulum, has a cer-

Fig. 111
Windward Steering Technique



tain amount of righting ability. A keel boat will always right itself; a centerboarder will, but only up to a certain point. The boat will fight to right itself, but when a critical point of heel is reached, everything changes. This usually occurs at an angle of from 25 to 30 degrees. The efficiency of the hull underbody deteriorates rapidly. The boat's righting force is decreased, and it becomes difficult to steer. The steeper angle of heel causes the sail to luff; the luffing increases drag, slows the boat down further, and you will heel even more.

Here are the ways heel can be countered:

1. Get your crew hiking as far to windward as allowed. The bigger your crew, the more power you can have in your sails.
2. Ease the traveler to get more of the force in a forward direction.
3. Ease the sheet to allow more twist in the leech. With less leech control the leech falls off to leeward; the sail is then a straighter line from luff to leech. This flattens the sail aloft, which is desirable: any side forces on the sail up high are going to have a proportionately greater heeling effect because of the leverage they will have from height. Use mast bend up high if you have a flexible mast.
4. Reef the sail (this again principally removes the side forces from the upper part of the rig).
5. Change to a smaller sail.

As a boat heels, there can be a major change in the balance of the helm. The increased wind velocity, which causes the heel, will force the draft farther aft in the sail, thus moving the center of effort aft, increasing the windward helm. You should look to draft controls to balance the helm as wind changes. Sail trim affects helm as well. Weather helm will decrease as the sails are trimmed out and increase when they are trimmed in. In pivoting centerboarders, lowering centerboard position will increase weather helm and raising it will decrease weather helm.

SPECIFIC WIND RANGES

For each wind speed we will discuss the proper adjustments to be made when sailing to windward. As the true-wind velocity increases, there are changes in the boat's performance. The amount of adjustment necessary to maintain optimum performance will vary from boat to boat, so only general guidelines will be discussed.

Drifter: 0–2 Knots

Very low wind velocities are not steady but usually come in puffs. Because of this, the hull will have very low forward speed. When a zephyr hits, the sail forces will be much greater than the lateral resistance of the hull (because it has no speed), and the hull will slide sideways. In this unsteady condition, it is important to have the boom trimmed well out until the boat gains speed. After attaining this initial momentum, you can sheet the boom nearer the centerline. You should have a medium amount of draft in the sails and keep a slight twist in the leech. Most boats have lee helm in these circumstances, and so if you have a centerboard, put it far forward. Try to induce a heel both to decrease wetted surface and keep the shape in the sails through gravity. Do not let the sails slat. Minimum hull resistance, medium-to-full, loosely sheeted sails, and a good telltale are most important in a drifter.

Light Wind: 2–5 Knots

Generally in these conditions boat speed is quite high compared to wind speed. Since the boat speed is faster, leeway will be less (boat speed increases lateral resistance) and the boat can support all the side force that can be created with the sails. With this little wind, it is important to develop all the power you can; so the boom should be trimmed to the farthest inboard point (the centerline) and the leech should be relatively tight. (Midships travelers will need to be pulled to weather until the end of the boom is centerlined.) Jib fairleads should be at their farthest point inboard, but the sheet should be free and the leech and foot should form easy curves. Maximum draft should be used. In this condition you may even be able to get the draft as full as 18 per cent. Be sure draft is at least 40 per cent aft in the jib and about halfway back in the main. The heads of the sails should be quite full; ease the outhaul and trim the sheet slightly to get the smoothest possible shape. Again, lee helm may be a problem. If it is, induce a slight heel, reduce wetted surface and hull resistance, and put the centerboard forward to get proper helm balance. Excessive helm in these conditions will cause a great deal of drag. Finally, in order to obtain maximum sail forces, the boat should be sailed below the luff—that is, close to the stalling point for the sails.

Light-to-Moderate Wind: 5–9 Knots

These conditions are very similar to the conditions described above, except that sail forces will get rather large and the boat will begin to heel. Crew weight will be needed to balance the boat. Most boats will reach maximum efficiency in this range, and boat speed will be very high in relation to true-wind speed, narrowing the apparent-wind angle. The sails should be flatter and twist reduced. The main traveler should remain close to centerline until the boat has reached maximum heel and the crew is fully hiking; at this point the traveler should be eased if necessary to keep the boat on its feet. The jib athwartship trim should correspondingly be eased and the jib sheet tightened to reduce twist and draft. Moderate draft, about 15 per cent, should be used, and since weather helm begins to increase, the centerboard should be moved slightly aft to balance the helm. Finally, the boat should be sailed to the luff and feathered through heavier puffs: that is, when a puff hits, head the boat higher into the wind, so that the sail is on the verge of a luff. This will prevent excess heeling. This technique can be combined with the scallop steering technique illustrated in Figure 111, so that the peak of the scallops corresponds to the wind gusts.

Moderate Wind: 9–13 Knots

For most boats, this is a very critical range, where you reach and go beyond the heeling angle at which the boat sails well. The maximum heeling angle to maintain optimum performance on most cruising boats is recommended by the yacht designer, and varies from 18 to 32 degrees. Most lightweight centerboard one designs should be sailed relatively flat at all times; 2 to 12 degrees being the maximum heel angle allowed. In the lower wind speeds (9–10 knots) a boat will not heel excessively, but in the upper range a smaller boat might be overpowered. Maximum crew weight and hiking ability are needed to hold centerboarders flat.

At the bottom of this range, begin to let the main twist by loosening the leech and easing the traveler. Draft should be reduced slightly. You will have to exert moderate luff tension to keep draft at the proper place. The jib draft should be reduced slightly, but the slot should remain narrow and the jib twisted. This can be done by moving the fairlead outboard and slightly aft and trimming the sheet tighter.

Once heel affects speed, do everything you can to reduce side force and improve forward drive. The traveler should be eased and the twist increased (by easing mainsheet tension) until the boat can be sailed on an even keel. Mainsail draft should be reduced. The draft should be kept from moving aft.

At this time the slot should be opened to relieve backwind on the main by moving the jib or genoa fairlead outboard. Jibsheet tension should be increased to keep twist constant. The draft in the jib should be kept forward through luff tension. The helm should be carefully balanced: move the centerboard slightly aft to decrease the rising weather helm.

In this wind condition the boat should be feathered through the puffs on the edge of a luff. With proper trimming the boat will point very high and the main will break into a luff slightly before the jib. However, only in the stronger puff should the sails be allowed to luff.

Moderate-to-Heavy: 13–18 Knots

Excessive heeling is the biggest problem. In this wind range the boat should be kept on her feet and driving by easing the traveler and opening the slot.

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Moderate-to-Heavy: 13–18 Knots

Excessive heeling is the biggest problem. In this wind range the boat should be kept on her feet and driving by easing the traveler and opening the slot.

The best way to reduce heeling force is to reduce the side force up high by increasing twist. The amount of twist will depend on the sea condition. The traveler and jib fairlead should be moved outboard. Jib draft should be reduced by increasing sheet tension. Weather helm will get worse, and so the centerboard should be moved farther aft; make every attempt to reduce the helm, especially in a cruising boat.

Finally, point high, carry more luff than before, but try to drive the boat whenever possible. Again, the main should break first, but probably it will be necessary to carry a constant backwind. If pointing ability is bad, increase twist by easing the mainsheet and pulling the traveler slightly inboard to compensate, thus keeping the same trim angle (Fig. 112).

Heavy Wind: 18–25 Knots

Windward ability is greatly decreased on most boats. This is the point at which larger boats begin reefing. Any sail force in the top of the sails is useless. Since no more side force can be used, every attempt should be made to reduce rig drag by snugging extra lines close to the mast and doing anything else you can to get rid of extra windage aloft. Maximizing the forward driving components is your main concern. Most travelers are eased to their outboard limits in these conditions. Usually a moderate amount of twist in the main and especially the jib will be helpful. Even more luff tension is needed to keep the draft from moving aft. The jib should always be kept driving. The main may become almost useless, but try to keep it trimmed so that the batten area is just firm enough so that it doesn't flog. Weather helm will progressively increase, and every step should be made to reduce it. Steer the boat to keep it upright. Some sailors suggest that you steer to a constant angle of heel. Try to anticipate the puffs by heading up slightly as they hit so that you won't be knocked down. On the new IOR cruisers (with small mains and large genoas) the correct procedure is to let the mainsail luff in strong gusts, so that the boat will remain on her feet and the helm will remain balanced.

Very Heavy Wind: Over 25 Knots

At some point, however, the side force will overwhelm the righting force of the hull, and it will become very difficult to sail any boat upright. Alleviating

Fig. 112
Relationship of Mainsheet Tension and Traveler Position to Leech Twist

a. Tight Leech—the traveler is outboard and the sheet tight; there is very little twist.

b. Loose Leech—the traveler is moved toward center and the mainsheet eased; there is increased twist.
Note that the leech setting is almost identical in the upper half of both mains, but from the mid-leech down (b) curves inboard to the center traveler setting, while (a) goes down straighter to the outboard point.

these problems on a keel boat is the fundamental reason behind reefing (see Chapter 14). This is the best solution, since the well-shaped smaller sail can be used at maximum power without overpowering the hull and causing excessive heeling.

On most one designs, reefing is not allowed. The only alternative is to reduce draft to a minimum (using the flattest mainsail available), and ease the traveler, to maintain helm control. Open the slot and try to keep the jib full and driving. It is important to carry a lot of twist since excess twist allows the sail to luff high, which is, in effect, a form of reefing. With a flexible mast, make the top of the main a flat board by having the mast bend high. All the problems discussed in the previous wind range are magnified. Again, the boat should be steered to stay on her feet, using every lull to drive her to the highest possible forward speed.

CHOP AND WAVES

Most sailors find that racing in light air with chop is the most difficult condition in which to do well. First, boat speed is greatly reduced due to the added resistance to the hull's movement created by chop and waves. Second, the fore and aft pitching motion caused by the waves, called hobbyhorsing, causes the apparent wind at the top of the mast to continually change direction, first luffing and then stalling the sail. When boat speed is reduced, the entire vertical apparent-wind structure is changed; it is important to correlate sail twist to sea conditions.

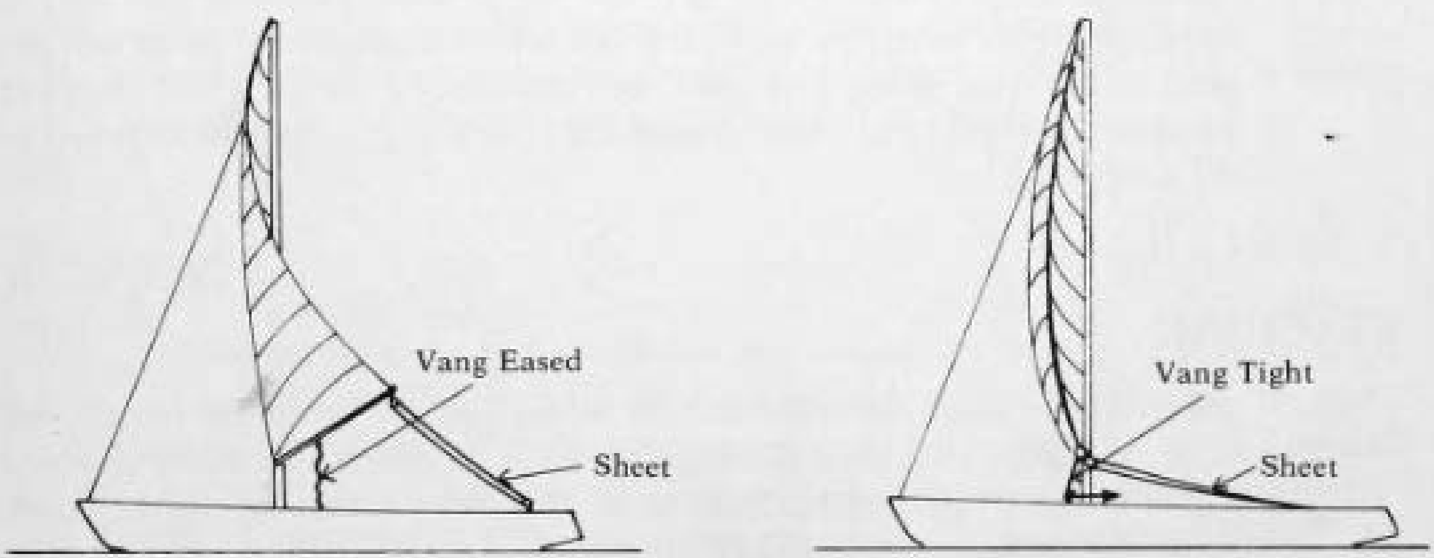
In light air it is best to ease the traveler somewhat, open the slot, and ease the sheets. Try to keep the draft full in the top of the sail without causing a tight leech. If the chop conditions are severe, trim the traveler more to the centerline and ease the sheet a good bit to compensate and keep the right angle of trim. A large amount of twist in severe chop will often significantly increase speed and pointing ability. Finally, it is most important to drive a boat through chop and to steer to miss the bigger waves.

In heavy air, waves slow the boat considerably. To gain speed, the most immediate answer to the problem is to ease the traveler, increase twist, and drive the boat through the seaway. This usually works in moderate conditions, but with increasing wind velocity the traveler will be eased so far that adequate pointing ability is lost. When this occurs in heavy seas, each wave will knock the bow farther to leeward, making it difficult to steer or keep the boat pointing. Many times this condition can be corrected by tightening the sheet, decreasing twist, and moving the traveler outboard to give the boat a better windward helm. Keep the slot open and the jib full. It is important in these conditions to sail the waves: point the boat up in the troughs (where it is a little calmer) and off on the crests. This technique is important for one designs, but is less effective and harder to accomplish as a boat gets larger.

OFFWIND SAIL HANDLING

Sail handling and sailing techniques on a reach or run are entirely different from those used for upwind sailing. Not only is there more variance between the direction of the true wind and the direction of the apparent wind, but offwind sail control is handled by different equipment from that used for upwind trim. Since the traveler width is limited to the beam of the boat, the vang and the sheet have to be used to control sail trim angle. On a one design, unless the vang is secured first, when the sheet is released the boom will lift, the leech will fall off, and twist will increase. The boom vang must be used to keep the boom down and control sail twist (Fig. 113).

Fig. 113
Boom Vang Plus Sheet Control Twist and Angle of Attack



a. With the vang eased, the sheet has to hold the boom both aft and down. Since the angle of downward pull the sheet can exert is small, the boom can lift easily, producing excess twist. Without a vang, the boom has to be overtrimmed to keep the head of the sail full, but the bottom of the sail is then stalled.

b. With the vang secured, the upper portion of the sail will be at the same angle of attack, as in (a), but the lower portion will be fuller and not stalled, as in (a). The vang controls the entire leech; the sheet only controls the fore and aft position of the boom.

The correct angle of attack for upwind sailing is maintained by steering to the luff; when reaching, it is normal to steer to the course and play the sheet to the luff to keep the sail at the proper angle of attack. Jam cleats should not be used offwind on small boats, since you should be constantly trimming the sails.

Sail trim techniques differ radically for close reaching, reaching, and running.

CLOSE REACHING

For a cruising boat, close reaching creates a special problem and requires specific sail combinations; these problems will be discussed further in Chapters 9, 10, and 11. One designs, because of the types of courses used in racing, rarely encounter close reaching, but in most cases combining upwind and reaching techniques by using the vang, sheet, and traveler produces good results. Generally, it is necessary to steer to the luff (holding the proper angle of attack) in the minor wind shifts, changing sail trim in the larger shifts to obtain best performance. The amount of twist will depend on the wind speed, and it will be controlled by the vang. Get the vang set first. Then play the sheet to keep the boat flat and the sail trimmed to the proper angle.

REACHING

On a broader reach, the sails should be trimmed to get maximum driving force: the angle should be such that the sails are always trimmed closer to a stall than to a luff. Use maximum draft. The main outhaul should be eased; there should be no mast bend; the Cunningham should be released. The amount of twist, set by the vang, is critical: one technique is to apply the vang to reduce the twist until the sail luffs evenly from top to bottom, like a jib.

In planing conditions, constant trimming of the sail is necessary to keep sail forces at a maximum. Acceleration and deceleration of the boat as it goes on and off a plane causes the apparent wind to change direction radically: the increasing boat speed in relation to the true wind causes the apparent wind to move forward suddenly; therefore, it is important to trim in the sails as the boat accelerates onto a plane. When you come off the plane, the situation is reversed, and the sails should be slowly eased.

Fore and aft hull trim on smaller boats is very important on reaches. At slow speeds crew weight should be forward to reduce wetted surface; when planing, the hull should be balanced farther aft. At all times, the hull should be kept flat and not be allowed to heel, except in light air. Weather helm will be a problem and can be relieved by raising the centerboard until excess side-slipping occurs. This also reduces wetted surface.

With one designs that rely solely on working jibs when reaching, it is important to move the jib fairlead to the rail in order to reduce excessive twist and form a better jib shape.

BROACHING

Broaching occurs when a sudden strong puff adds excess side forces to the sails that were properly trimmed for the pre-puff velocity. Keeping the boat "on its feet" is most important, and the quickest solution is to ease the vang and mainsheet immediately to reduce the sudden side force. This is mostly a problem with a spinnaker and is covered in Chapter 9.

RUNNING

When running, the main is stalled and nothing can normally be done to improve the situation. In most cases, maximum projected sail area, not draft, should be sought; but some curvature is needed to keep the leech firm and avoid an "S"-shaped sail, which occurs when the leech lays off to leeward. No twist should be allowed, since it reduces projected area: tighten the leech with the vang. In one designs, it is advisable to get the crew weight forward, pushing the bow down and so reducing wetted surface. Also, pull the centerboard all the way up. Last, in big and small boats alike, an old trick and a good one is to heel the boat to weather, thereby balancing the helm, getting the main higher up in the wind, and, sometimes, greatly increasing boat speed downwind. This also allows you to sail by the lee (Fig. 114).

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REACHING

On a broader reach, the sails should be trimmed to get maximum driving force: the angle should be such that the sails are always trimmed closer to a stall than to a luff. Use maximum draft. The main outhaul should be eased; there should be no mast bend; the Cunningham should be released. The amount of twist, set by the vang, is critical: one technique is to apply the vang to reduce the twist until the sail luffs evenly from top to bottom, like a jib.

In planing conditions, constant trimming of the sail is necessary to keep sail forces at a maximum. Acceleration and deceleration of the boat as it goes on and off a plane causes the apparent wind to change direction radically: the increasing boat speed in relation to the true wind causes the

Brushing, when combined with practice, will noticeably improve performance and reduce confusion. Start by holding a steady course parallel to the other boat (be sure you are in clear air and in the safe-leeward position). First trim both sails (headsail first) until they are just barely on the edge of luffing. Concentrate on steering fast while the boat settles down, and then decide whether or not the other boat is faster. Study the sail shapes and note how the boat "feels"; do the sails appear in accordance with general concepts, are they trimmed too tight, or does the boat have excessive weather helm? Try easing the main traveler so that there is a little difference in trim between main and jib or vice versa; trim the jib by changing athwartship fairlead position or by changing the sheet tension. Does the boat sail better by carrying a slight luff in the main or jib? Look behind at the wake; is the boat sailing a straight or snaky course? Is the boat heeled over too far, can it be sailed flatter, or is it too flat? Keep fussing and eventually your partner, the constant boat, will lose consistently and it will be your turn to be the constant.

ADJUSTMENTS ON THE RACE COURSE

On the race course, adjustments must be made to an ailing performer as fast as possible; time lost in diddling with adjustments and arbitrarily pulling on strings can never be recovered against top competitors. Brushing is a valuable tool and builds practical experience in proper "gut feel" diagnosis of ailing boat speed; but what if you don't know why the boat is not going? What string should you pull first? As with a color television set on the blink: which of the many knobs should be turned first? Standard practice indicates that main and jib twist are slightly more important than trim angle. Twist should be adjusted first. Balance comes next: does the boat have a noticeably bad helm? Last, the amount of draft and its position in the sails should be checked and adjusted. It is important to go around this cycle quickly, improving each major item and repeating the entire cycle until desired performance is obtained (Fig. 115).

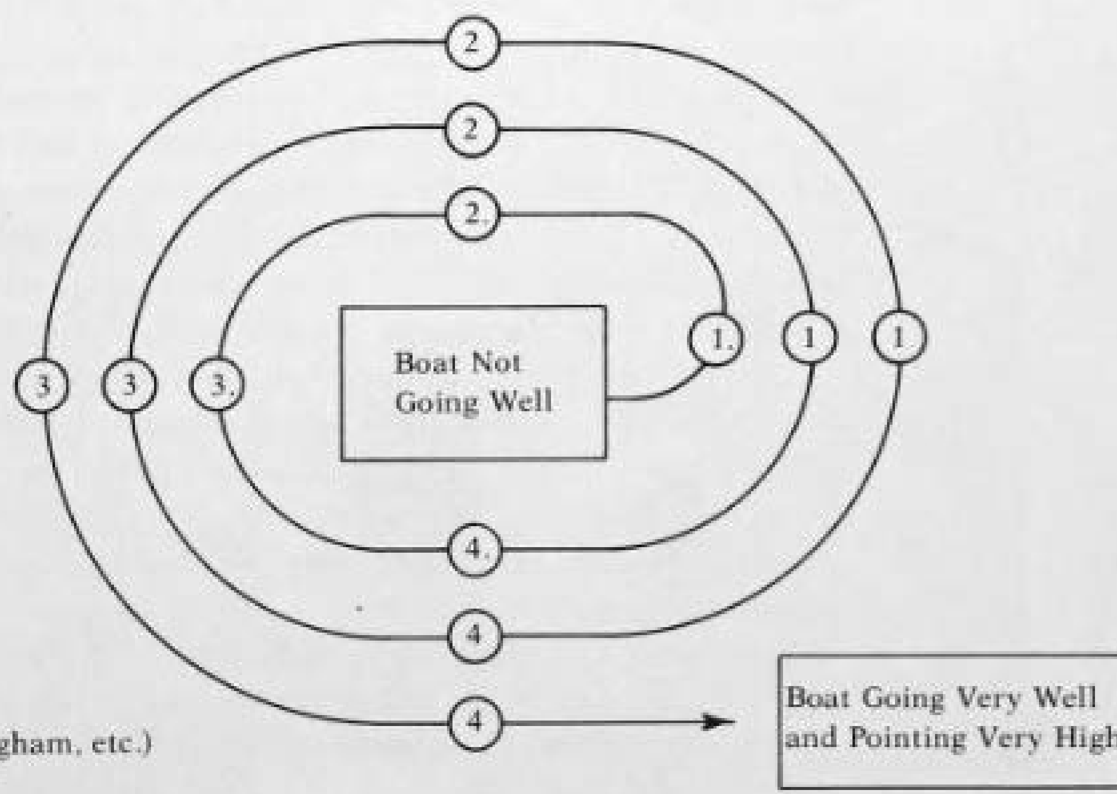
The following chart lists the major items of concern upwind and the primary and secondary adjustments which affect these items; coupled with Figure 115, a logical order of adjustment can be derived for most boats.

"UPWIND" SAIL-HANDLING CHART

A	*B*		*C*	*D*
Major sail-handling categories	*(breakdown)*		*Primary adjustments*	*Secondary adjustments*
I. TWIST	Headsail		1) Jib-sheet tension 2) Fairlead position (fore and aft)	1) Mast rake 2) Genoa-halyard tension (rope-luff genoa) 3) Cunningham tension (jerk string, OD)
	(SLOT) Mainsail		Mainsheet tension	1) High mast bend 2) Cunningham tension
II. TRIM ANGLE	Headsail		Fairlead position (athwartships)	Jibsheet tension
	(SLOT) Mainsail		Traveler	Mainsheet tension
III. HELM BALANCE	Centerboard boat		CB position (fore and aft) a. angle downward b. pin position	1) Mast rake 2) Fore-aft rig position 3) Twist of sails
	Keel boat		Trim-tab angle	4) Draft amount and position 5) Trim angle of sails
		Amount high	Jibsheet tension	1) Jibstay sag 2) Fairlead position (fore and aft) 3) Luff tension
	Headsail	Amount low	Fairlead position (fore and aft)	1) Jibsheet tension 2) Jibstay sag 3) Luff tension

IV. DRAFT		Fore-aft maximum position	Luff tension a) genoa-halyard tension b) Cunningham tension c) jerk-string tension	1) Jibsheet tension 2) Fairlead position 3) Jibstay sag
		Amount high	Mast bend (high)	1) Mainsheet tension (leech twist) 2) Cunningham tension
	Mainsail	Amount low	Outhaul	1) Mast bend (low 2) Cunningham tension
		Fore-aft maximum position	Cunningham	1) Mainsheet tension (leech tension) 2) Mast bend (high and low)

Fig. 115
Retrimming Cycle



Adjustment Order
1. Twist (Traveler)
2. Trim Angle (Sheet)
3. Helm Balance (Cunningham, etc.)
4. Sail Camber (Draft)

The above chart provides a logical means for deciding which of the myriad adjustments must be made to control the four major categories in sail handling: twist, trim angle, helm balance, and draft control. Using the chart, select the major category to be changed (column A) for either the mainsail or the jib or genoa (column B). Under the heading Primary adjustments (column C) is a listing of the adjustments which most directly control the major category. Secondary adjustments which may be necessary to get the ideal shape and trim are listed in column D.

Example: the trim angle for the mainsail is thought to be incorrect, too far inboard. To adjust this, look down column A to trim angle; then go across to B, the mainsail; continue across to C, for the primary adjustment: Traveler. When this is eased, the main will have a wider trim angle. This may be sufficient, or you may have to go to column D for a further, secondary adjustment to mainsheet tension because the slot relationship may also have changed and may require different mainsail twist. Therefore, you may have to make the secondary adjustment to mainsheet tension to get the shape and trim right.

Any adjustment may also have side effects which may not be desirable, and which will have to be countered by further adjustments. Once you have made your primary and secondary adjustments, to find out what damage you've done elsewhere check through columns C and D for the adjustment in other categories. For instance, mainsheet tension appears in column D under category 4—Draft—indicating that draft has been affected, and possibly has to be adjusted. Mainsheet tension also appears in category CQ1—Twist. Twist in the mainsail has been examined already, but twist in the headsail has not, and must be, because the slot relationship has changed. Thus, it is a cyclical process as shown in Figure 115.

This chart is laid out for sail control on one designs and cruising boats. Of course, some areas will not apply to both. Those adjustments which are only for one designs have been indicated by the initials OD. Avid sailors will find that the construction of a chart for their own boat is not only good winter homework, but could also reveal weaknesses in their sail-adjustments systems.

Figure 116 shows how different conditions require different settings, as outlined in the chart. On the opposite end of the spectrum, offwind, there are similar adjustments to be made to produce ideal shape and trim (Fig. 117).

Fig. 116
Upwind Trim Comparisons. The three Solings in Figure 120 were photographed at practically the same angle, allowing a comparison of sail shape and trim. The wind varies from light air in (a) to medium-to-light in (b) to medium air in (c). Notice that as the wind increases, the wind force drives the mainsail leech in each successive picture farther to leeward into more twist; the jib leech, however, is doing the opposite. There, the leech is cupping around more to windward, creating a fuller shape. The negative leech can drive air onto the main, causing it to luff. A more outboard setting of the jib would help, but luff tension pulling the draft forward would be the most important correction. Note that as the wind increases, the mainsail traveler has been eased from windward of center in (a) to quite a bit off to leeward in (c) to reduce side force or heel. It is interesting to see how much more of the upper part of the mast is visible in each successive picture as mainsail twist increases.

a.

b.

c.

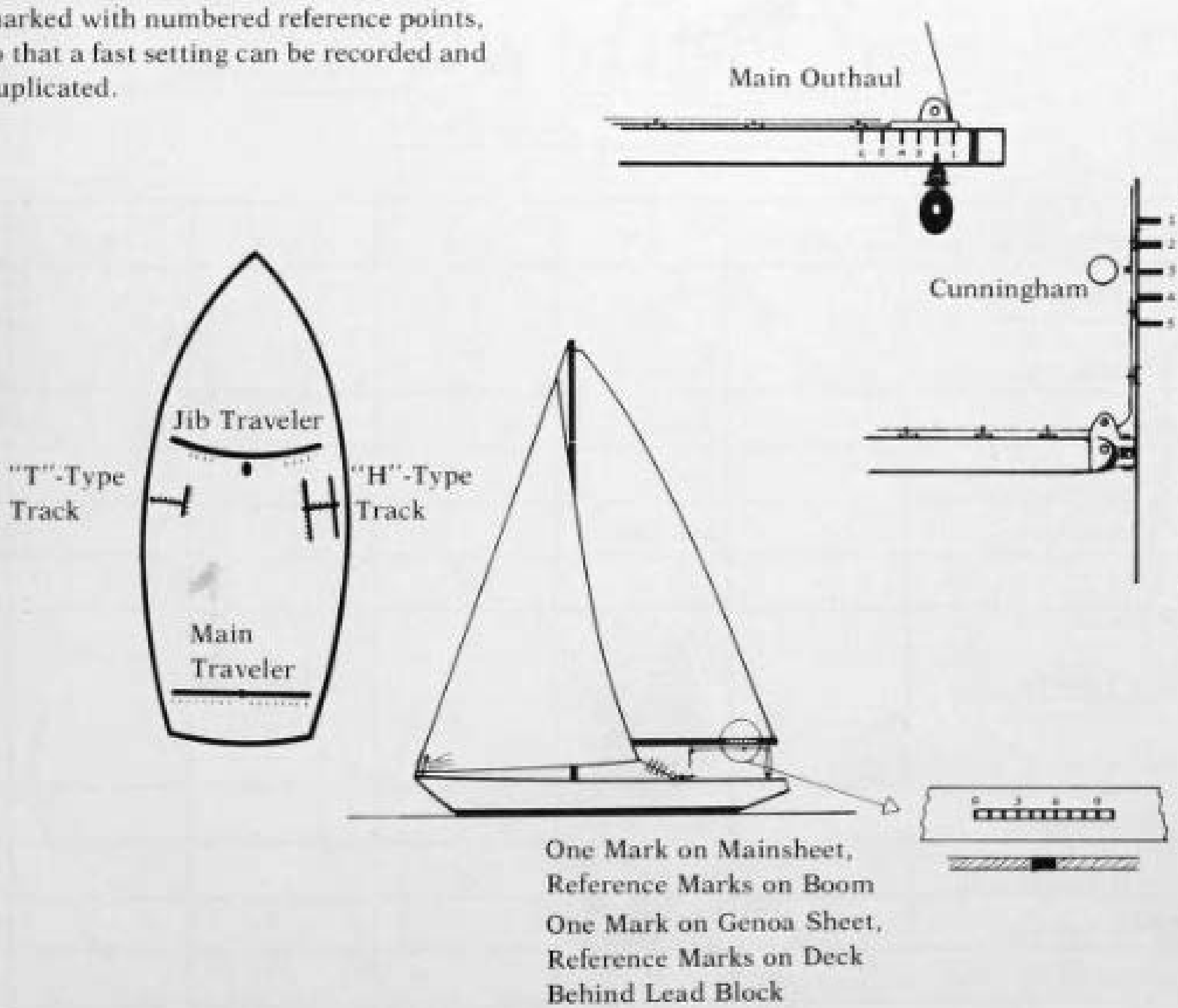
Fig. 117
Downwind Trim Comparisons. These two pictures show a striking contrast in twist control for both main and spinnaker. In (a) the main boom has no vang and the sheet does not have enough downward movement to control leech. The spinnaker has the pole too low, with the result that there is too little luff twist. The sheet is too far aft and, therefore, there is too much leech twist. In (b) the correct setting for main and spinnaker is shown. Note how the vang has made the main leech almost straight for reaching. The spinnaker pole is raised to the top of the track on the mast and the clew is set to the same height.

a.

b.

Many top sailors keep notebooks recording the adjustments for each improvement in performance during brushing, later to be cataloged for each wind and water condition. Like any cataloging system, later duplication of the adjustments made is only possible if the recording and filing system is good. Start by marking all adjustable controls: sheet lines, travelers, and so on; also mark the halyards, shrouds, and mast position. Add marks to the fore and aft jib and genoa deck-carriage positions, luff tension controls, foot tension controls (outhaul), and traveler controls (Fig. 118), so that when the boat gets moving really well in particular conditions, you can

Fig. 118
All draft control and trim points should be marked with numbered reference points, so that a fast setting can be recorded and duplicated.



record the trim positions and duplicate them next time you are in that situation (Fig. 119). Any number of marking methods can be used—for example, plastic tape or a magic marker—but do not get overly complicated, and remember that most rope stretches more when it is wet. A good system will eliminate guesswork after the start of a race, when concentration on steering and tactics is far more important. Always try to get to the starting area well before the warning gun, so that the boat can be preset to the expected conditions; also try brushing with a friend for a short period to assure that nothing is wrong. Most races are won through detailed preparation.

Fig. 119

Main and Genoa — Cruising Boat

Smooth Sea

Wind Speed in Knots	0-3	4-7	8-10	11-14	15-18	19-24
Main						
Traveler		On Centerline				
Sheet		At #8				
Outhaul		At #4				
Cunningham		Mark#6				
Genoa						
Halyard		9 in. Below Maximum				
Cunningham		Slack				
Fore and Aft Sheet Block		Hole #7				
Sheet Tension		Sheet Mark 2 in. Out of Block				
Inhaul		3 in. Inboard				