HARD SAILS

By Wally Ross

Probably everyone will agree that a significant part of the pleasure of sailing lies in talking about sailing. In that talk, however, agreement stops. There will probably never be a time when any two racing sailors will agree completely. Theories flow like wine, but confirmation of any one of them is rare. The proof of the pudding, of course, is success in racing, but so many factors contribute to the success of a champion that it is impossible accurately to analyze their relative importance. For example, no one can say with certainty the extent to which sails are responsible for a specific victory, but no one can deny that they are a vital factor.

The inability to assess precisely the relative effect and importance of boat, sails, weather, trim, tuning, etc., is one of the happy frustrations on which the sailor thrives. Take away the sailor's post mortems at the bar and you will have swelled the ranks of the golfers.

The uncertainty is infinitely compounded by the fact that each of the more general factors, boat, sails, weather, etc., is in itself a subject of substantial scope. Sails alone present an almost inexhaustible supply of material for speculation and debate. The location and amount of draft, the kind of material, the method of cutting and roping and a hundred other details affect the final product. To the racing skipper, whose principal aim is winning, many of these factors are of interest as topics of debate, but to the sailmaker, whose job is to produce winning sails for a variety of skippers on a variety of boats, all of them are vital. The sailmaker must attempt to find working answers to all of the many problems presented, and his ability to do so is the measure of his success.

The fact that some of the problems do not lend themselves to precise mathematical solution does not justify reliance solely upon trial and error. Synthetic materials are highly stable, a property which makes it possible to determine in advance the shape they will assume with any given cut. True, the advance determination may not be absolutely perfect. in terms of inches of draft or belly at a given point in the sail, but it will be very close and also highly accurate in terms of the relative draft to be found at one part of the sail as compared with another or in one sail as compared with another. Thus, if careful records are kept, realistic and useful tests of performance can be made, and the causes of success or failure more clearly understood.

Of course, measuring and producing a sail of given shape is only part of the task. Of much greater importance is determining the optimum shape. Most racing skippers are generally aware of the forces which drive a boat to weather. Briefly, the wind flowing along the sail produces a pressure differential between the leeward and weather sides. This differential results not only from an increase in pressure on the weather side, but also, and in the view of many, more significantly from a decrease in pressure on the leeward side. The decreased pressure on the leeward side is greatly affected by the action of the jib, which if properly cut and trimmed can add substantially to the total force produced.

The force produced by the pressure differential on a close hauled boat acts largely to leeward, causing heeling, and slightly forward, causing motion. In addition, the air passing along the sail is impeded by friction, producing a force acting astern, usually called drag. These forces will be discussed in more detail, but it is obvious that the optimum shape is one which produces the greatest forward force with the smallest heeling force and drag.

Although some important modifications in the shape of a sail are made by adjusting the tack seam and leech seams, the shape is principally controlled by the amount of curvature, known as roach, which is cut on the luff and foot. If a sail were cut without foot and luff roaches it would be stretched tightly between the mast and boom over its entire surface and assume the shape of a barn door. The roach is the source of the extra cloth which allows the sail to belly to leeward. That roach can be carefully measured and controlled and, of course, controlling the roach controls the shape and set of a sail. For that reason, careful measurement and painstaking workmanship are of vital importance at the cutting stage of sail construction.

Every step, however, is important. Naturally the selection of the material is the first step. Egyptian cotton was introduced about 1850 and for nearly a century following, sailmakers and sailors had grown used to the variations and ramifications of cotton. Suddenly, within a few short years, three new synthetic sailcloths were introduced. First Nylon, then Orlon, and Dacron.

The advent of one synthetic sailcloth forced changes in both sailmaking and handling, but three compounded the confusion. Nylon, because of its stretch, is still used primarily for spinnakers and other light sails. However, Dacron, the most stable of the synthetics, has now gained the widest acceptance for all other sails.

Paradoxically, Dacron has made sailmaking both easier and harder. With sails cut from cotton, small errors did not show up, as the cloth was mobile, and the shrinkage and stretch tended to nullify imperfections. However, the biggest handicap with cotton was the fact that it required a "breaking in" process which was not at all consistent, and made it impossible either to duplicate a sail, or have it set **exactly** as designed.

Dacron corrected this problem with its stability but, in turn, created new problems, of which the foremost is the fact that this stability made precision methods of design and cutting mandatory. Small errors in cutting do show up and remain in the sail, making Dacron very sensitive to small changes in design. On the credit side, Dacron's stability makes "breaking in" unnecessary. A Dacron sail can be tested or raced immediately upon completion.

Dacron, therefore, has a combination of assets making it an ideal sailcloth. First, its stability permits draft calculations to much finer tolerances, which justifies more time spent in detailed designs. Secondly, the shape of the Dacron sail will remain constant for a long period of time. This is a very important point, as it is the shape of the sail that is the #1 factor with which we are concerned. Once the correct shape is attained, the finer tolerances and more detailed designs also allow the highest detail of duplication.

The third big asset is the smooth surface. This cuts down surface friction, which is definitely a drag or negative force. Surface friction is important in all airs, but it increases in importance as the wind increases. Anything that can be done to a sail to cut down its negative forces, or drag, will naturally make a sail faster.

Once the material is selected, the next step is the actual cutting of the sail. As mentioned before, the shape of the sail is attained through the luff and foot roaches of the main, and the luff roach of a jib. Therefore, the resultant shape would depend on the shape and depth of these luff roaches.

Surface friction is a property of the sailcloth itself, but the other forces of a sail (forward drive, heeling action, and some of the drag) result from the shape. The objective, therefore, is to produce luff and foot roaches that will produce a shape in the sail with the maximum percentage of forward drive, and the minimum percentage of heeling action and drag.

The shape of the sails, therefore, is concerned with the resultant forces, and apparent wind. As an example, if a mainsail had 60% forward drive, 20% heeling action, and 20% drag, it would have to be faster than a sail with, say, 40% forward drive, 30% heeling action, and 30% drag. Since the resultant forces are obtained from a pressure differential from windward to leeward of the sail, which is in turn created by the maximum differences in velocities between a windward to leeward flow, the effect of the jib is a major consideration. The maximum optimum effect is also a function of the shape and trim of both mainsail and jib.

The actual plotting of a sail for these forces starts with the apparent wind angle. As the boat speed increases, the apparent wind goes further and further forward. Therefore, the apparent wind depends on the pointing angle of the boat in relation to the true wind, the boat speed, and the wind velocity. The apparent wind angle is less than the true wind angle but the velocity of the apparent wind is greater.

The shape and resultant forces of the jib are purely dependent on the apparent wind angle, whereas the shape and resultant forces of the main depends on the apparent wind angle, plus the increased flow from the jib. Therefore, for a given apparent wind angle the shape of the sail can then be drawn so that the fullness of the sail forward will not be so great that it will luff. The remainder of the cross sections can be drawn with the maximum curvature, consistent with keeping the resultant forces acting in a forward direction. Higher cross sections of the sail have a freer flow than the compound curves that are attained near the boom, particularly near the tack. Because the sail is attached to the boom, it is impossible to have all the forces positive near the foot, particularly near the leech. This is the main reason why a sail cannot be made with 100% forward drive force. The "twist" of the mainsail also affects the percentage of forward drive and will be discussed later.

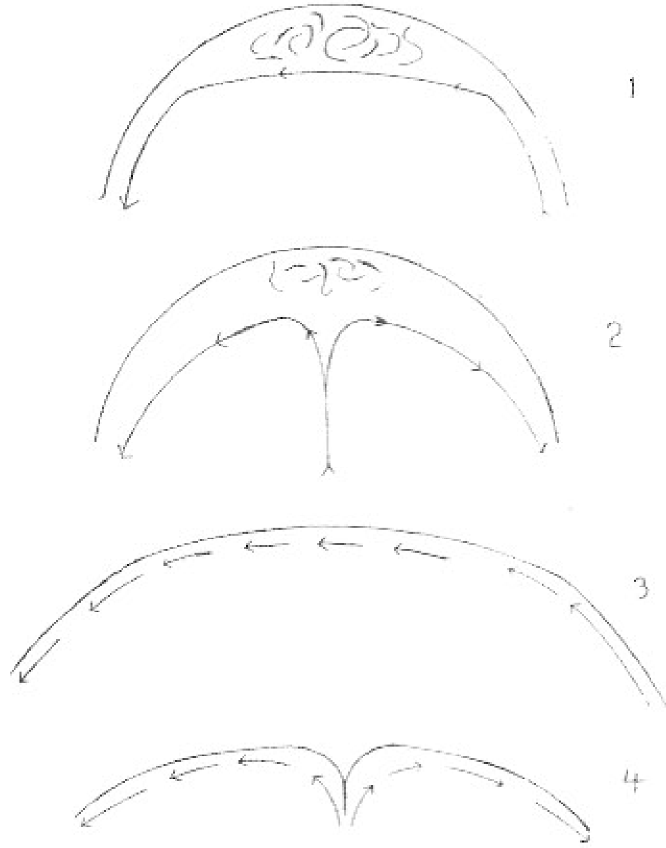


Diagram No. 1

After the draft roaches are plotted, the sail is then laid out on the floor and cut. From this point on, until the sail is finished, workmanship plays an extremely important part in making the sail come out as designed. While on the floor, the sail has to be marked so that it can be sewed together with all seams perfectly parallel, and the overlap of cloths exact. The placement of the headboard, seam adjustments on the leech, and the roping are all critical, and directly affect the final product. The design is made to very fine tolerances; poor workmanship can ruin it.

The roping is an extremely critical point. The rope is not put on evenly, but is hand sewed on with increased tension near the tack, and with decreased tension near the head and clew. This is accomplished by marking the bolt rope to the sail. If the bolt rope were put on evenly, the draft would be higher and further aft in the sail than designed, so that the bolt rope serves the purpose of holding the draft where it is intended to be. Very small differences, even 1 or 2 millimeters, in the marking of the bolt rope to the sail can change the placement of draft. This is the reason why the mechanics, or benchmen, who do the roping are very highly skilled and require years of experience to do this job correctly.

The shapes and functions of spinnakers are in a state of rapid change. Many of the early experimentations were done on single luff spinnakers. The parachute spinnaker of today is a relatively newer type of sail in comparison to the standard mainsails and headsails.

Gradually, information has been attained through the explanation and proof of theories, experimentation, and constant testing of new ideas. In analyzing the older

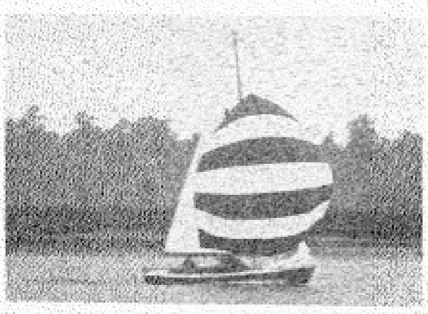
BILL COX'S past record in other classes shows him to be one of the finest sailors of our time. His skill was demonstrated during 1956 when he won his District Lightning Championships with three straight 1sts, then continued on to win the Lightning Internationals by 18 points with three 1sts in five starts. We are indeed proud that Bill's choice for his sails has been Scientific Dacrons by HARD.

Bill Cox leading fleet in the Internationals.

Photo—courtesy COURIER-EXPRESS

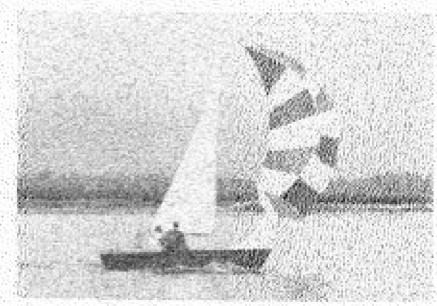
SCIENTIFIC Dacron sails by HARD are made by (a) plotting ideal cross sections for maximum percentage of forward drive combined with minimum percentages of heeling action and drag; (b) then translating those cross sections into the construction of your sail. While these methods do take longer, you get a more faithful reproduction of ideal cross sections—hence a "faster" sail.

The *New* Taper-panelled, All-Purpose, Spherical by Hard



Bob Crane's "Jimlin" — Winner of the Deep South Regatta in Savannah with three straight 1sts; and 3rd in the Mid-winters.

After the three races in Savannah, the two tune up races and the five races of the Mid-winters in St. Pete, Bob Crane reported the results of the new spinnaker as follows:



1. Outside of "freak conditions", at least 2 to 3 boats were passed on each leeward leg, whereas no boat passed him.
2. Spinnaker had an extremely high reaching angle—and could be carried above beam wind when most other spinnakers were not used.
3. Complete combination effect. Spinnaker pulled away from other boats on dead leeward legs in both heavy and very light conditions, in addition to the faster speed on reaches.
4. Ease of handling—spinnaker stayed full with minimum of handling and had a high resistance to collapsing.

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Wallace C. Ross, President — *John Snedeker, Secretary* — *Peter Paige, Vice-President* studies, together with the new information developed this winter, there are three conclusions that can be stated with reasonable assurance.

First, the flow of air in a spinnaker goes from luff to leech in any reaching angle, and from the center of the spinnaker to both leeches on a dead run, whereas relatively little wind escapes off the foot.

Secondly, a very full cut spinnaker is not the most ideal shape even for leeward work, as there is a turbulence (a section that might be called almost "dead air") at the deepest point. This air is not rapidly replaced, thus decreasing any forces acting on the surface of the spinnaker in that area.

Third, as a result of this "pocket", air moving across the spinnaker from luff to leech has a tendency to take a "short cut" and bypass the deepest point located generally in the upper third of the spinnaker.

In some of the testing done on the flow of air through holes cut in spinnakers, the result has been that very little air flowed through the holes until they were made quite large.

This effect is caused by this short cut of flow and the resultant "pocket", together with the direction of the flow across the spinnaker.

As in the case of the mainsail and jib, the most effective spinnaker would have the cross sections similar in shape from head to foot. The foot, however, is flatter than the upper section of most spinnakers so the desired effect would be to flatten the upper part of the spinnaker to a similar shape but held to a point where the valuable lift component is not destroyed. This would decrease the turbulence and cause a greater flow of air across the spinnaker, increasing the resultant forces acting on the surface.

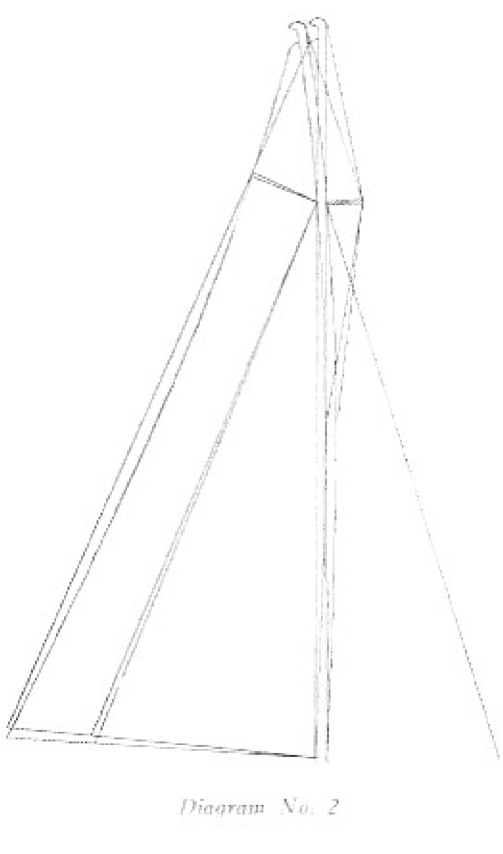

Diagram No. 2

Also, under proper construction, another valuable asset can be created. On a leeward leg, when the wind is extremely light, the flow of air "splitting" out at the center, combined with the weight of the cloth, allows a "center collapsing" action—a condition that will take place when the wind is not strong enough to fill out any full sized spinnaker. This center-collapsing action shrinks the size of the spinnakers **in the center only**, leaving the leeches exposed and drawing. This action gives the spinnaker working area even in extremely light air and then will fill out readily if the wind increases, with no change in trim. These assets in leeward work, plus the flatter cut which is valuable for maximum performance in reaching, give the spinnaker a full combination effect for both reaching and running in both light and heavy airs.

Because there are disturbances in air flow near the mast and rigging of a boat, and a blanketing effect to leeward of the main, it is advantageous to get as much of the spinnaker as far out to windward of the boat as possible. The spinnaker will thus work in a stronger, steadier air, and will function better. The flattened center will take area from the deep center and create a greater exposure, particularly in the "shoulders", causing the luff to stand further to windward in better air.

In all winds, except heavy airs, the maximum girth dimensions naturally are required for maximum area. However, the middle high girth dimension is more critical than the lower girth dimension. A spinnaker starts at a fixed point at the end of the spinnaker pole and continues its outward curve to windward, and then back to the head. A longer foot will not allow the spinnaker to set any further to windward, but along the free curve of the luff the maximum limitation in the girth dimensions will have considerable effect in getting the working area further into the better air to windward. Naturally, the maximum foot dimension is also desired for greater area, but we just wanted to point out that, of the two, the middle and upper girth dimensions are critical.

In the details of construction of a spinnaker, with the described effects, it has also become evident that perhaps the maximum control in the shape can be attained through totally horizontal construction. Thus the shape is controlled in the same direction as the flow of air across the spinnaker from luff to leech.

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So far we have discussed sail shapes without the introduction of outside variables. The variables of mast shape or trim can alter the shape and draft of the main and jib to a very large degree, and it is therefore important that they be discussed in detail.

First of all, let's consider the effect of the mast (Tuning is extremely important, and in some cases underestimated in its importance. However, tuning is mainly a function of the balance of the boat and helm, and is another separate study aside from our main subject.) We will, therefore, concern ourselves mainly with the profile of the mast.

The construction of a Lightning boom is quite rigid so that in most cases it will not bend.

We said earlier that the shape and draft of a sail is controlled by the luff and foot roaches—curvature cut in excess of the straight line luff and foot. We also pointed out that small variances in the draft and shape of these roaches creates variances in the draft and shape of the sail.

The same variances and decrease of controls is created by curvature of the mast. If the mast were bent to the same shape as the luff roach, the sail would, in effect, be the same as not cutting any luff roach in a sail for straight spars. However, I think we can safely say that the mast curvature never duplicates the exact curvature of the luff roach, thus creating an unbalance of tensions in the sail, usually resulting in some hard lines.

Lightnings were not designed for a controlled bend in the spar such as you would find, by comparison, in a Star. The **fully controlled** mast bend can be changed by movable step and deck partner, adjustable backstays, plus full control of the jibstay and headstay. A popular opinion is that a big bow, or bend, in the mast will flatten the sail. This is not entirely correct. The jibstay at the mast is a fixed point and the mast can take two **relatively** separate bends, one from the jibstay to the deck, or step, and the other from the jibstay up. The low bend from the jibstay down decreases the draft, whereas the high bend from the jibstay up effects mainly the leech of the sail, and quite often will produce a hard line in front of the battens, particularly the lower batten. The action of a bending mast is shown in diagram 2.

As the top of the mast falls aft, the measured leech dimension of 24′6″ between the head and the clew remains constant, but the aft bending will move this whole leech dimension downward so that the clew and the entire boom drops down to a lower position. As the leech area and boom drops down, the span of sail from the fixed point of the mast at the jibstay cannot move down to the lower position of the boom without producing increased tension on the inner span. In other words, the dimension of the leech remains at 24′6″ between the head and the clew, whereas the line between the jibstay and the boom parallel to the leech, will cover a span anywhere from ½″ to 2″ longer than the span with a straight mast. This change causes a hard spot or a line of unbalanced tension. Below the jibstay, with a smooth even bend, the different spans from the mast to boom parallel to the leech, are fairly proportionate to one another, so that there would be no severe unbalance but rather a gradual flattening as the mast bend increases.

We do not advocate mast bends in a Lightning because the duplication control decreases so greatly. If a sail were cut for a bent mast, the exact dimensions of the mast curve would have to be taken so that the cut of the sail would allow for the bend. The Dacron sail, being so sensitive, will set up differently with every variance in mast bend and in all probability no two mast bends would be identical. A straight stiff spar creates the maximum control so that if the sails are built identically, they can be set up on the boat more nearly identically, thus making reproduction a great deal easier. The features of the bending spar should be used only in self-defense, such as correcting a hard leech or flattening a sail that is too full, but at the first chance have the sail corrected, rather than sailing with a bending spar.

There can be some advantages in a flexible spar, particularly in widening the range of a sail. However, the reason it is not practical on a Lightning is that the advantages are only greater in a boat designed for a controlled bend, such as a Star, where bends up to 12″ can be created, and the sail has been cut to accommodate these bends. However, upon examination, it is harder to make good sails for the boats with bending spars than

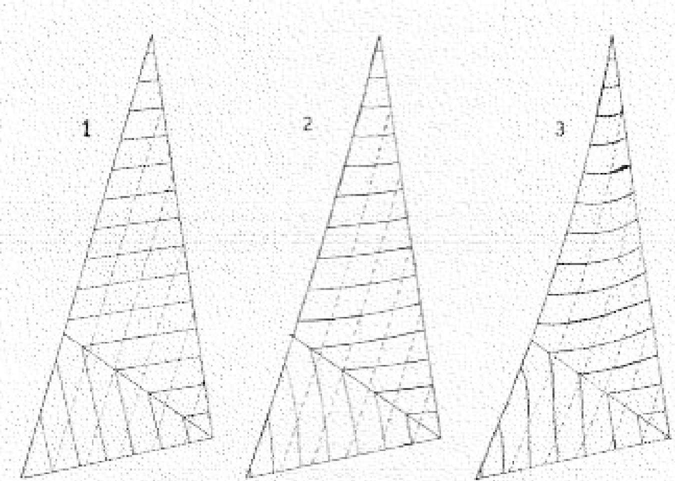

Diagram No. 3

for boats with a straight spar, simply because of the increase in variables. In many classes that have controlled bends, full adjustments are allowed during a race. However, it does require a full understanding of sails to make any proper changes.

The jib is complicated by the fact that it is suspended on a sagging luff wire. Diagram #3 shows three different jibs.

The first drawing shows a straight luff wire, the second a slight sag in the luff wire, and the third a severe sag in the luff wire. As the luff wire sags aft, the sections of sail from the foot to the leech parallel with the luff wire also sag back, increasing the draft of the jib. There is a counter-force from the head to the clew and from the tack to the clew, in which any curve of the leech and foot under tension, tends to assume a straight line. Therefore, as excess draft is created from the sagging luff wire, instead of working back on the luff and foot also, it is held by the tension of the trim.

In the third drawing, with the maximum sag, the distance from luff to mid leech, and luff to mid foot, is shorter than with the luff wire tight, and the excess cloth just goes into excess draft working aft in the jib, generally just ahead of the battens, forming a hard leech. The obvious cure would be to have the jib luff tighter and tighter as the wind increases from very light air to prevent this condition.

Two points are important. First, to keep the luff as tight as possible. The halyard should be stainless steel wire and the end locked at the mast when raised. The tack should have a wire downhaul leading aft to a crank turnbuckle so that the downhaul can be tightened as the wind increases.

Secondly, many jibs made for medium or heavy air do not have maximum roach dimensions on the leech. The maximum roach will stand properly in light airs when the trim tensions are not great along the foot and leech. In the medium and heavier airs the excess roach creates an increased round that can be forced toward a straight line on the foot and leech under heavy trim tensions, thus creating an even harder leech than without the roach.

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The next important item effecting the efficiency of sails is the trim of the main, and bolt rope tensions. First of all, there has been controversy about how hard to pull the bolt ropes on a Dacron sail. This could be a hang-over from the cotton sails which were not supposed to be pulled out hard when new. However, since the Dacron sail does not need any breaking in, it can be set up and raced the first time it is used. The synthetic bolt ropes have some resiliency, more so than the Italian hemp used on cotton sails, and therefore do require a greater force to pull them out. The sail will be flattest with the bolt rope pulled out tight and added draft can be created by slackening the bolt ropes.

As a usual procedure in very light airs, **if a sail requires extra draft,** the outhaul can be eased about 1" and the downhaul raised 1" to 2". In light to medium air range, the draft can be flattened by tightening the bolt ropes as the wind increases. In all medium and heavy airs, the bolt rope should be pulled out as tight as possible to maximum dimensions. In spite of the extra strain required to pull most synthetic bolt ropes, there is very little chance any harm will be done by pulling hard in case the sail does not come out easily.

The tension of the bolt ropes also comes into play in the proper shape and trim of sails. Trim is a very complex subject and perhaps cannot be covered adequately in a short article. However, we will cover the most important points that have to be taken into consideration. The shape or draft of the sail is closely dependent on trim, so both points can be discussed together because of the close inter-relationship.

First of all, the following would be some of the important considerations in determining the shape and proper trim.

1. In very light air (0 to 2 knots) a slightly tight leech is sometimes advantageous. In this range, the wind is more "flexible" and not steady so that the usual rules of sail shape do change for the very light conditions. The proper shaped maximum draft is the most important consideration in this range.

2. As the wind increases over the very light air range, the leech should be in a flat plane with the least possible amount of negative force; i.e. curving back to weather.

3. The maximum resultant forces are created from the maximum pressure differential, in turn created by the greatest difference in velocity of flow between the windward and leeward sides of the sail. The most efficient sail would have maximum draft and yet have an angle of attack within the apparent wind angle.

4. The resultant forces within the apparent wind angle should have the maximum possible forward drive, and the least amount of heeling action and drag.

5. The efficiency of a sail increases if the shape or cross sections are similar from the foot to the head.

Each one of these points is generally restricted by another one of the points, which is why it can be complicated.

We also have to recognize two other factors that are important.

First: Most mainsails usually have what is referred to as a "twist" or "fall off" in the upper part of the sail. This causes the lower portion of the sail to have different cross sections than the upper part of the sail.

Second: The jib Venturi action can cause deviations from figures calculated from the drawn apparent wind

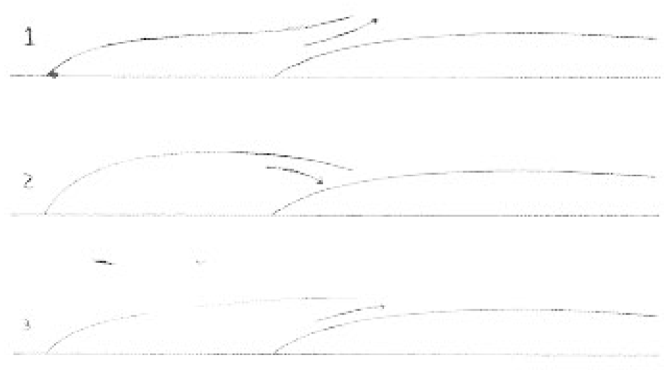

Diagram No. 3

angle, the effect, naturally, being on the leeward side of the mainsail. The change would be relatively small with the correct Venturi effect or even a decreased Venturi effect as caused by a slack leech on a jib. However, a tight leeched jib would have a very detrimental effect in changing the flow of air directly into the mainsail, closing the slot and causing the mainsail to luff. Too soft a leech is poor because it reduces the Venturi effect. A jib also has a higher angle of attack because of the absence of mast interference, and the luff of the jib is the only part of both sails that is working in the absolutely free apparent wind.

The first drawing shows a slack jib leech that has very little squeezing effect therefore producing very little increased acceleration on the leeward side of the main.

The second drawing shows a full, hard leeched jib causing the flow into the main which causes the main to luff and also decreases the flow of air in the "slot".

Drawing three shows the proper shaped flat leech resulting in the maximum squeezing effect causing increased acceleration of the air on the leeward side of the main without luffing the main.

The "twist" or "fall off" of the upper part of the mainsail can be the first step to lead into the full discussion of trim and shape of a main. In many cases the twist of the mainsail has been treated in the vein that nothing can be done about it. However, this is not true. Many top sailors have found the secret of trimming the mainsail toward the quarter and down hard as the wind increases. If the sail is trimmed to the center of the boat in heavy air, the sheet has to be eased slightly to avoid heeling action and drag forces caused by the leech curving in toward the center line, the decreased tension between the head and clew and results in the twist of the sail. Therefore, the first object would be to decrease the negative forces in the lower part of the sail and still eliminate as much of the twist as possible, particularly as the wind increases, so that all the cross sections will set as similar as possible by having the entire leech set in a "flat plane". It is important here to mention more can be done to eliminate the twist in medium and heavier airs when a strong tension on the sheet trim is required. A sail should not be trimmed hard in very light airs, but in those conditions the twist is not as great and not as much a deterrent factor. This is one example of why we mentioned that very light air conditions have to be treated differently.

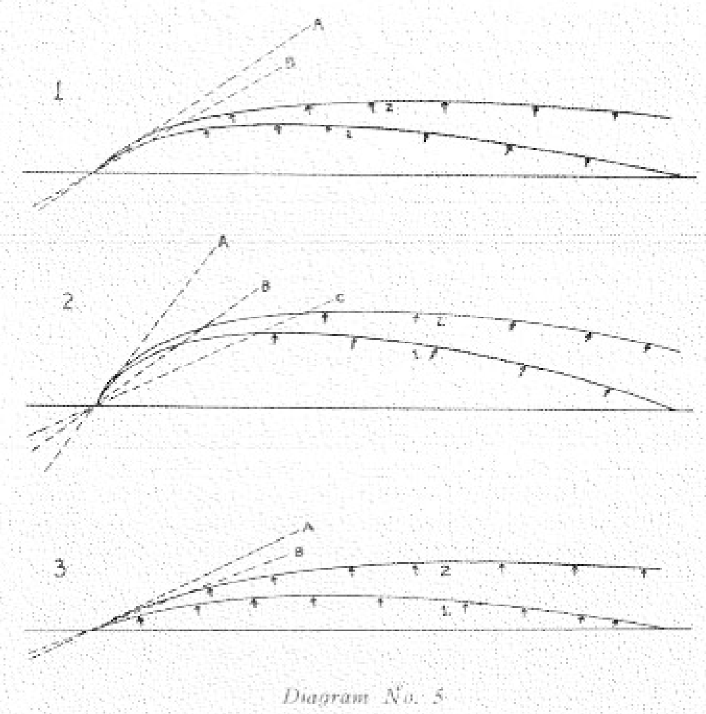

Diagram No. 5

Trying to describe trim with varying cross sections would naturally be very involved, which is the purpose of discussing it in terms of similar cross sections or the average cross section at the point of maximum draft. These are the cross sections that are shown in diagram #5.

We mentioned before that as the boat speed increases through the water, the apparent wind angle becomes more and more acute. Since changes in the wind and waves continually alter the boat speed, the apparent wind is continually changing, so that no boat will probably ever sail an entire windward leg with the same apparent wind angle. For this reason we have shown several different apparent wind angles in the diagrams to show what happens if sail shape, trim and apparent wind angles vary.

In the first diagram, the inner cross section (#1) shows this sail trimmed to apparent wind angle "A". The forward part would not luff as it is within the apparent wind angle, but being trimmed to the center of the boat (or to center line as shown in the diagram) the sail from about one-third of the way aft to the leech would have all negative forces. By trimming the sail off the quarter, a large percentage of the negative forces of heeling act on, and drag, are changed into forward drive. This is because the surface of the sail that was formerly aft of the perpendicular has been changed to a force forward of the perpendicular. The first cross section from apparent wind "A" would have approximately 30% forward drive 20% heeling action, and 50% drag. Whereas, the 2nd cross section would have almost 50% forward drive, about 15% heeling action, and 20% drag. This leaves a balance of 15% which is beyond the apparent wind angle and therefore will luff slightly. However, the sail is still more efficient as the resultant forces have a great percentage of forward drive, and the negative forces are at a much more favorable angle, only being curved very slightly toward the center line. (The drag forces would be proportionately increased as the angle of the leech curved toward the center line.) This is one possible explanation of why many sailors have found some sails to be at their fastest point when they barely start to luff near the mast.

Again, however, this is where shape is important. In this trim position, if the forward part of the sail were flattened slightly into a working area, it would further increase the percentage of forward drive.

Apparent wind angle "B" has the same effects, but it would also cut down the amount of forward drive in both cross sections, making the sail even less efficient.

The second diagram shows a shape that might conceivably be used in extremely light airs from drifting conditions to slightly above. In these conditions it is usually not possible to attain the highest pointing angle and the boat speed is at a minimum, thus opening the apparent wind angle very wide, sometimes as wide as apparent wind angle "A". If the breeze freshens slightly, the boat speed increases, the boat points higher, and the boat will be working nearer apparent wind angle "B". As it approaches maximum hull speed and maximum pointing angle, the sail will then be working in apparent wind angle "C".

It is necessary to have maximum draft to get a boat from a stopped position into motion, but as the boat increases its speed through the water, draft has to be decreased. Therefore, a very full sail of this shape has two bad features. First, its efficient range is limited to just the drifting conditions and very slightly above. Secondly, as the wind increases, the resultant forces of the sail cannot be improved radically by trimming the sail toward the quarter. In the apparent wind angles of "B" and "C", with increased boat speed, no matter where the sail is trimmed, a large percentage forward will luff, and a large percentage of the remaining sail will have resultant negative forces with only a small portion of the sail having a forward drive force. In heavier airs, this is the sail shape that could cause the boat, using a common expression, to "lay over and wallow".

The 3rd diagram would show shape and trim angles for heavy air. Cross section 2, trimmed toward the quarter, would have a majority of forward drive forces and its forward shape would remain within the apparent wind angle "A". As the boat speed increased to maximum, only a slight amount of the sail would luff forward, with the remainder of the sail still maintaining its greater percentage of forward drive forces. Cross section 1, trimmed to the center line of the boat, has a greater percentage of negative forces. It is also too far within the apparent wind angle.

There are two points about these cross sections that should be answered. First, when the sail should be trimmed near the center, and when the sail should be trimmed off the quarter. Second, how to trim off the quarter to attain similar cross sections with the flat plane leech.

First of all, in other classes boats with travelers, the traveler setting generally starts with the center of the boat in light air, to the furthest outboard athwartships position in heavy air. There is no exact setting that can be listed due to many variables. However, the diagrams show how the forces on the sails change through the various trim positions and, as mentioned before, the draft or shape can also be changed by slackening or tightening the bolt ropes.

Since a Lightning does not permit a traveler, the only possible mobility in the mainsheet trim can be attained through the Crosby mainsheet rig which starts at the boom, leads to a check block on one quarter, across the deck to another block on the other quarter, then back up to the boom and forward. When the sheet is pulled in hard, with this Crosby sheet trim, the boom can be pushed manually toward the quarter where it will stay. This is opposed to permanent center trims in which the boom will go toward the quarter only by slackening the sheet, thus decreasing over all control of shape.

The jib trim also changes slightly as the shape of the main varies and the trim of the main varies. An average starting point would be an 11° angle from the tack of the jib to the average of the fixed end and block of the sheet. In other words, a majority of small one design boats will trim at an approximate 11° angle. Experimentation is required varying from this 11° angle to maintain the greatest Venturi effect. The fore and aft placement should start at a line drawn from the luff of the jib about 3" above the mitre, bisecting the clew. This line is easier to attain with a single jib sheet than with the double sheet of the Lightning so that an average has to be taken between the two leads.

In addition to the spinnaker the trim of the mainsail on a leeward leg is also very important. On the wind the trim of the main sheet creates a tension from the head to clew, which holds the leech and roach of the sail in a firm position. In reaching and running, the main sheet is let off and therefore decreases its head to clew tension, allowing the leech to become slightly slack and form a slight "S" shape, as shown in diagram #6.

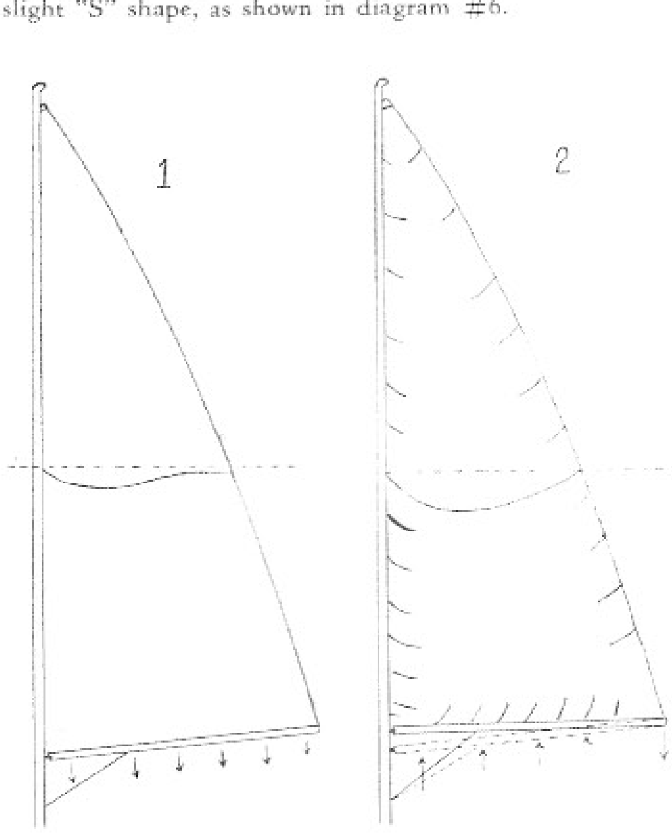

Diagram No. 6

The boom vang will maintain the leech slightly and help cure the situation. However, additional steps can be taken to further increase the efficiency of the mainsail for reaching and running. First of all, slackening the bolt rope of both luff and foot will add draft to the main, which will, in turn, partially relieve the "S" shape cross section. Generally it is difficult to change the clew position during a race without a special rig, but if it can be done, it is helpful.

Changing the luff tack position is considerably easier and very effective. If the boom is raised and locked anywhere from 3" to 6" above its normal position at the tack, it relaxes the luff tension and adds more draft in the forward part of the sail. Then, if the boom vang is tightened, the tack will not come down as it is in a locked position and all the pressure from the vang is transmitted in a downward action at the end of the boom, or at the clew. This hardens the leech of the mainsail allowing the remainder of the sail to have added draft and a resultant shape much faster for leeward work. These points should be taken in a gradual process from a close reach to a dead leeward leg. In other words, through these methods, the draft of the main would be increased by letting up the downhaul further and further as the boat approaches its downwind angle. If the bolt ropes were slackened too much on a close reach, the sail would be too full and the resultant forces in the aft part of the sail would be predominately negative.

On a broad reach, the mainsail is out far enough so that no angle of the surface of the sail would be in a negative force.

There is one other point that has an important bearing on the shape of the sail. This is the placement of the tack pin and the clew pin. If the bolt rope of the luff goes straight to the tack pin without breaking aft, and then straight out the boom to the clew pin, the resultant draft in the sail will take its full curvature and effect from the luff roach. If the tack pin is moved aft along the boom, the luff rope moves aft with the pin and the distance from the 1st slide above the tack to the cut luff roach decreases, as the change of angle of the bolt rope is approaching the cut draft in the luff. It is also quite evident that the tack angle has been increased, both factors decreasing the draft near the tack and decreasing the over all draft of the sail. If the tack pin is moved back severely, all the strain will be placed on the first slide above the tack pin so that the draft will originate at the slide, and the remainder of the draft from the slide up will be decreased. It also puts great added tension on this first slide causing hard lines from that point. If the tack pin is higher than the projected straight line of the foot bolt rope, the strain is created at the first slide on the foot behind the tack, and the same principle applies at the clew, causing an unbalance of tensions in the leech area.

The two measures of correction are either to measure the position of your tack pin when ordering sails, or change the position of the tack pin (or clew outhaul) after you receive the sail, so that the bolt rope remains in a straight line to the pins. If these "cut backs" are put in by the sailmaker, then the tack or clew pin should be left as measured.

The maximum distance between the tack and clew pins is very important and for most sails the tack pin should be about 1" aft of the face of the mast and ¾" up from the top of the boom. The outhaul pin should be approximately 1¼" above the top of the boom. On the standard

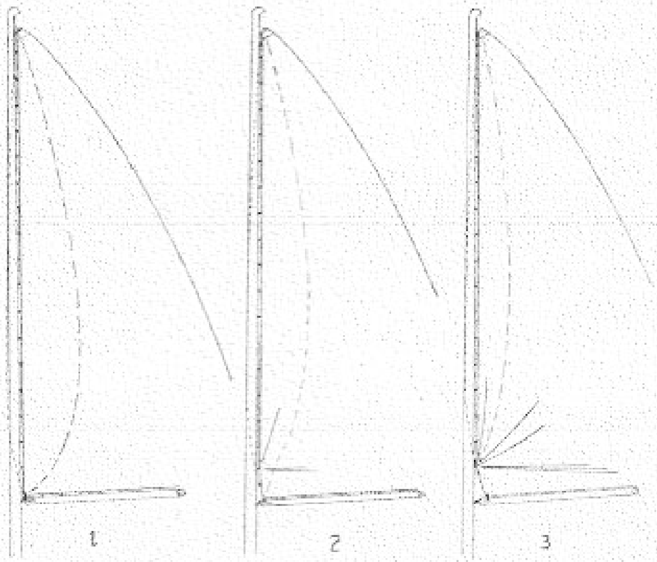

Diagram No. 7

outhaul fitting the pin is approximately ⅜" in from the aft end of the fitting. Therefore, if the end of the outhaul fitting goes to the very end of the boom the distance from the tack pin to the clew pin would be approximately 9'10-⅜". If the distance between pins is less, the tension on the bolt rope and tabling along the foot could be decreased so that the bolt rope would arc between slides. The slack tension could cause vertical lines in the foot at each slide. The above measurements are taken for the average sails but the important factors being here is that the sail will set smoothest when the tabling along the bolt rope is pulled smooth and taut.

The adjustable halyard lock and the downhaul allow more mobility on pin to pin measurements along the luff. For maximum luff tension the sail should be raised as high as possible without hitting the backstay and then pulled down on the downhaul to the black band.

In conclusion, we would like to stress that the information in this article is intended to serve as a starting point for your own experimentation. Two identical sails will only set up the same when both are put on the same boat, in the same wind, and sailed by the same skipper. From boat to boat there will be changes in the shape of the mast, the tension of the jibstay, the trim of the sheets, the touch at the helm, and over-all tuning. These require different adjustments from boat to boat before the fullest efficiency of the sail can be attained.

We recall a recent article by Carleton Mitchell in which he wrote the following:

> "Sailing is an endless challenge. Never can all the lessons be learned. The man who has crossed oceans makes discoveries whenever he drops the mooring for an afternoon sail. Each boat has her own ways, the combination of wind and tides is never quite the same, there are new messages in the sky and on the surface of the sea. A lifetime is all too short; you learn a little, and a little more, until finally by some standards you know a lot, and then you keep on learning until you discover the greatest lesson of all—how little you really know in relation to what there is to be learned."