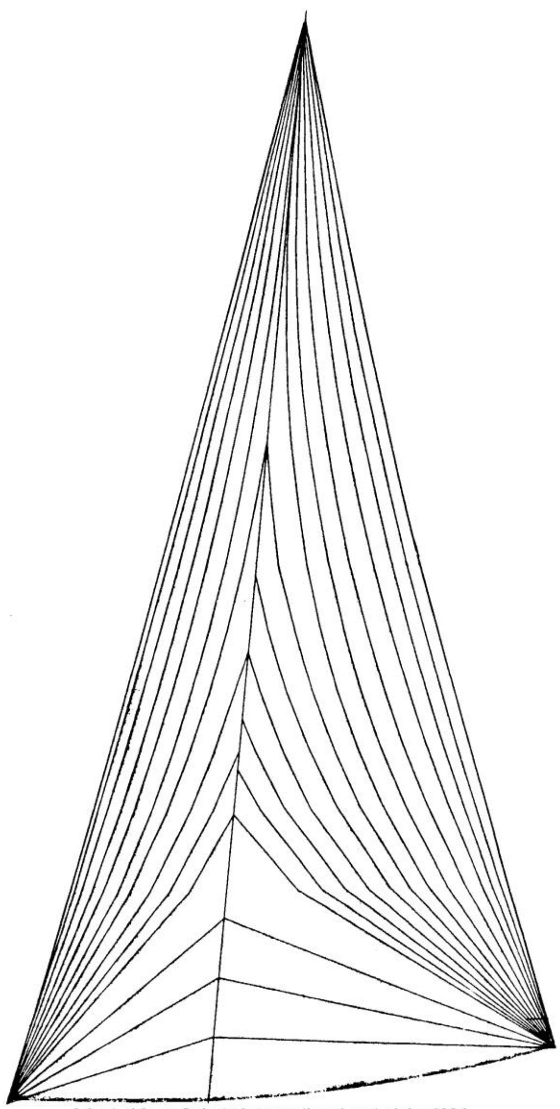
Contents

Introduction

This booklet describes a method of applying load bearing fibers ('strings') in a load path distribution to a sail blank. A typical load path is shown in **Figure 1**. This was adapted from some old Sobstad promotional literature and shows an indication of the direction of the maximum loads at different parts of the sail. It is important to recognize that each bit of the sail has loads pulling on it from all directions, not just those shown in the figure. Also, even these maximum load paths change with mast bend or jibstay sag, wind conditions, sheeting angles, twist adjustment, etc. In relation to sails for model yachts, these are relatively minor concerns. You don't have to match something like Figure 1 exactly. A reasonable distribution of threads top to bottom is all that really seems to matter.

Figure 1
A Typical Maximum Load Path Distribution



Adapted from Sobstad promotional material ~ 1994

You can make the sail blank as described in *Making Model Yacht Sails, Part 1* or you may purchase one from a sailmaker. (A sail blank is the basic sail without batten pockets, corner reinforcements, grommets, etc.) The final result will be the model yacht equivalent of the Ulmer-Kolius *Tape Drive®* sail. Having experimented with string sails for the last five years, I have concluded that they are most definitely not a breakthrough in model sailmaking, but that they do have certain advantages (most notably by giving the sail a greater wind range), albeit with a cost in time in making them and in durability for those who do not like sail maintenance.

When I started racing big boats as a kid, we had cotton sails. What a pain. They had to be very carefully dried whenever they got wet. Early on we got a set of sails made of a new material, Dacron! They were very fast and much easier to take care of, a big improvement. Later, when mylar / woven Dacron sail material came out, we found that our sails were lighter and held their shape better as the wind changed. Unfortunately the mylar began to peel off after a couple of years and the shape deteriorated almost as quickly as sails made from plain Dacron. A few years later, a major revolution began to take place. Sailmakers started to cut the panels in smaller and smaller pieces and to align them so that the stresses in the sail corresponded with the strongest axis of the sail material. About then Butch Ulmer came out with his *Tape Drive* concept where load bearing self adhesive Kevlar tapes were applied in a load path distribution on a relatively light sail seamed with simple broadseams. Sobstad used a similar concept *(Genesis®)* which they pioneered. Load bearing fibers were laminated between two tough layers of flexible plastic. "Garbage bag material" according to a local Sobstad rep.

I just had to try to duplicate the concept of orienting fibers along the sail's principal load paths. The Sobstad method did not seem practical, so I adapted Ulmer's approach to our scale. My first sails using this concept were made of Clear Micafilm with the load paths reinforced with 1/8 or ¼ inch mylar splicing tape (used for fixing audio tapes, e.g. Radio Shack #44-1128). They were reasonably effective, but it was very hard to get the tape stuck on properly without causing the sail to wrinkle. I also exhausted the local supply of the tape. After several false starts, I found that I could glue fine threads onto Micafilm with thinned Balsarite. This is a logical adhesive because it is made by the manufacturer of Micafilm to glue the film down. Balsarite is normally brushed onto the frame of the model aircraft and allowed to dry. The Micafilm covering material is then secured in place with heat, using a special 'covering iron'. Unfortunately, I found that using the glue in this way could cause wrinkles with just a slight mistake in the heat setting of the iron. So I just brush the thinned glue on and let it dry. Fortunately, it stays flexible for years. I began experimenting with this idea in 1991, making sails for a short lived Marblehead project. Load bearing Kevlar threads were glued to the 'fuzzy' side of clear Micafilm panels and the panels were then assembled. At the corners, where all the threads came together, I glued on little corner reinforcements of 0.015 inch sheet acetate with Devcon Plastic Welder. Although the reinforcements were small, their strength was quite amazing.

Because of the high aspect ratio of an M rig, these sails held their shape more effectively than those I saw on the competitor's boats. About this time the M was put on the back burner and I started making EC–12 sails. I quickly found that laminating the threads ('strings') to the fuzzy side of Micafilm eventually caused the sail to curl unacceptably, most likely from glue shrinkage. Although the thread adhesion is not nearly as good, I now glue the threads on the shiny side of the film.

The first sails were made of individual panels that had the threads already glued on. Later I found a way to allow the threads to cross the seams, making continuous load bearing elements from head to foot. The seams became much stronger now and do not creep with time. This booklet will show you the method to do this. As I made more and more string sails, I experimented with each sail and learned the hard way what works and what does not. I've tried making the glue thicker and thinner than the specification to follow. Either the sail was too stiff or the threads would come loose. I've used all sorts of materials for the strings: Kevlar, carbon fiber, Technora, Dacron and glass fiber. Dacron is very hard to work with because it stretches as it is applied, causing wrinkles. Technora is the best choice for flexibility and for fineness of the threads that can be used, but my only source for it comes from disassembling cordage. This is not an easy task. As you unbraid the rope, at a certain point the fibers become interwoven and further dividing the strand results in a lot of wastage. You can spend perhaps five to ten minutes preparing one thread. That translates to three to four hours just to prepare the strings. My favorite material for more than adequate strength, reasonably small size and ease of use is Kevlar bead thread, #001, (Gudebrod, Inc, Pottstown Pa., available at TSI, 1-800-426-9984).

There is no question that making string sails is a lot of work. I expect to spend six or more hours applying the threads to an EC-12 sail. Is it worth it? There is no single answer to this question. You must be reasonably skilled with your hands to consider making them. If you are 'all thumbs' the project will be an exercise in frustration. When I first used my string sails I found them very fast, but it was not clear whether the sail shape (which was new) or the strings were the cause. Recently Rod Carr, Sailmaker, has been making sails out of various weights of TRI-SPI (Dacron fibers laminated in a mylar sandwich) using my seam positions and using a duplicate set of sail blocks that I made for him. The shapes produced are similiar to mine, provided the block choice and luff allowances are the same. Although we have not yet had a chance to do controlled sail testing of string sails vs. those made of TRI-SPI, I currently think that in conditions suitable for the chosen weight of TRI-SPI, there is no major variation in the power produced. Perhaps the string sails are a little easier to read, but this is a minor point. The wind, however, rarely stays within the wind range of a given sail all day. Certainly you can change sails as the conditions change but, at least in our area, it's often not done. In addition, some courses have, by their nature, light spots in critical areas. Here string sails offer some advantage.

So a string sail can function as an all purpose A rig sail. It will hold its shape almost as well as a sail made of clear Micafilm alone in drifting conditions, yet when the wind comes up to maximum A rig weather the sail will still work essentially as well as one made for heavier air. Of course the potential advantage here is dependent on the typical winds on your pond. I don't recommend string sails for EC–12 B rigs. There is no need for the large wind range, and durability may be a problem. (Model yachts that use high aspect ratio sails, like Marbleheads, may find some benefit in using string sails for the B rig because of the higher vertical loads.)

Make no mistake: string sails are not a panacea. They are relatively fragile because of the base material used. They are susceptible to creases. Occasionally a few strings may come loose and need to be stuck back down again. This turns out to be rather easy. You can do it at the pond if necessary. I'll tell you how later. In spite of the negatives, Jerry Brower has used the 1994 string main that I made for him in over 85 regattas. (It's shown on the cover of *Optimizing the East Coast 12–Meter.*) This has been a fast sail. It has required occasional maintenance, mostly sticking one or two strings back down, but our recent sail photos show that the sail shape today is essentially the same as when it was new. If you are willing to spend the time and effort to learn to apply the strings, and to learn how to take care of string sails, you may want to use the methods outlined in this booklet to convert a sail blank into a string sail.

I should mention that I may have found a solution to many of the problems related to string sails. As of September '97, I have made only four test sails by this new method, but the results so far are quite encouraging. The 'threads' on this sail are individual filaments of linear Kevlar yarn that is not interwoven. The very small individual fibers (0.3 mils diameter, about 1/10 the size of a hair) fan out from the corners, giving the appearance of a North *3DL®* sail. The layout of the threads is more modern too. Some of them start at the clew and fan out all along the luff, while others run from head to clew and from head to tack. Because the fibers are so small, much less glue is needed, and the glue is water thin. The total thickness of the sail including the threads has gone from about 8 to 9 mils to about 4 mils. This helps light air shape. There may be less drag, but this is of unknown significance. The first test sails seem reasonably fast, but long term durability is not yet known. Nonetheless, at this point we see none of the minor degradation with time that we have come to expect with string sails. You will find a brief description of the method I currently use to make what we decided to call 'filament sails' in the appendix.

A further word about the appendix: several of the articles were originally written for our club newsletter, *The Waterlines*, or as a part of *Optimizing the EC–12*. I have included them here because I thought that they would be useful. Their focus is primarily on the EC–12, but the material may be adapted to other classes.

> A Warning: You may have already gathered from the cartoon on the cover that there is potential danger of fire or explosion in making these sails with the materials and solvents suggested. In addition to these risks, the solvents used are proven health hazards. Toluene, for example, is a known liver and brain toxin. Consider the risks before you decide to proceed. Use adequate ventilation and consider the use of an appropriate respirator. Be ever cognizant of the risk of fire, too.

Getting Started

Photo 1

Some of the things that you will need are shown above. The most convenient work surface is your sail board. If you have not already made one, there is an article in the appendix on laying out the sail plan on the board. Here, a nearly finished sail is suspended above the board, pinned to blocks. There is more on this to follow. The strings are glued to the sail blank (shiny side to prevent curling) with thinned Balsarite. Use the original formula, No. 6000.

The glue recipe, by weight:

- 175 grams Balsarite (original formula, No. 6000, by Coverite)
- 100 grams toluene (toluol)
- 100 grams xylene (xylol)

The xylene is added to slow the drying of the glue. You may substitute the same weight of toluene if you wish. A good quality one inch modeler's brush is required, like the sort used to dope model airplanes. Get one at the hobby store. A cheap brush will push the threads out of position when you apply the final glue coat. In the background, note the pieces of ¾ inch thick Styrofoam. These are placed under the suspended sail to support it where the threads are being applied.

Note: Jeff Proulx and I are now experimenting with thinned Sig Stix-It instead of Balsarite. It may not shrink as much with age, allowing the threads to be applied to the fuzzy side of the material for better adhesion.

Photo 2

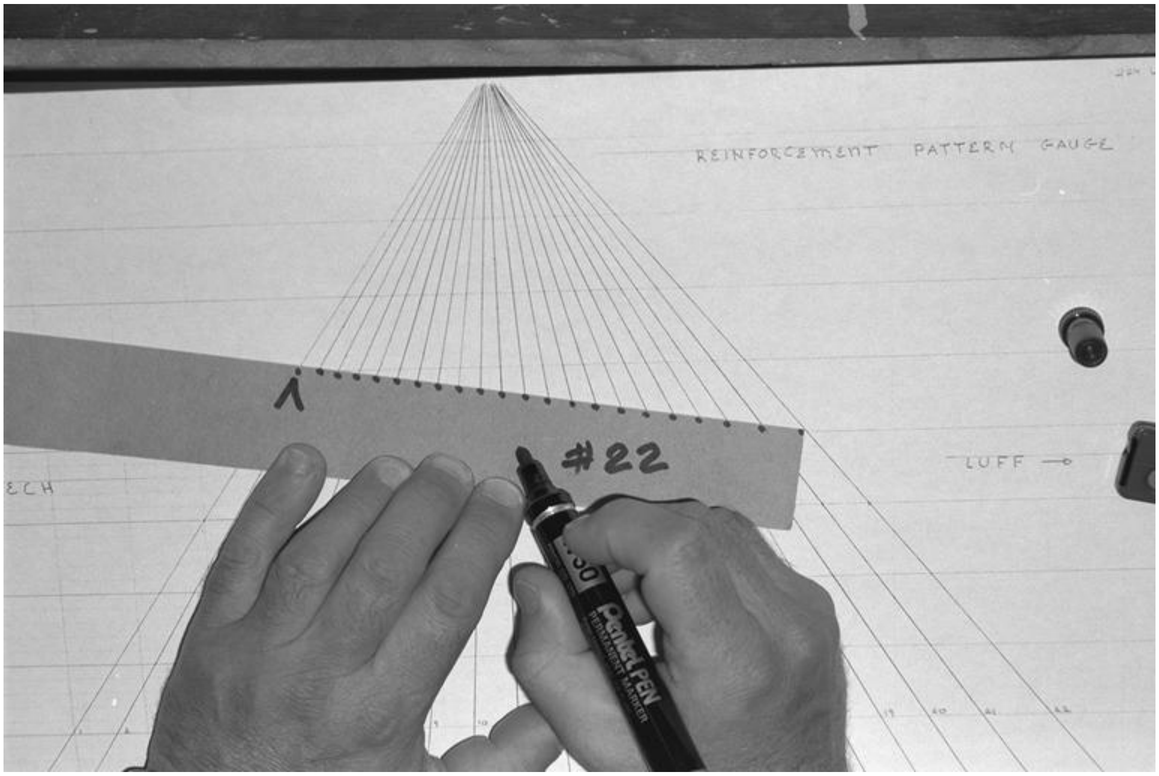
To help the threads bond to the shiny side of the clear Micafilm substrate, gently wipe the surface with steel wool and toluene. Don't scrub too hard or you will wrinkle the sail.

Note: if you are planning to apply strings throughout the sail, rather than just at the corners, the sail blank should made with the shiny side of the panels all facing one side of the sail, rather than alternating shiny - fuzzy, shiny - fuzzy, and so on. This means that the actual seam will bond the shiny side of the material to the fuzzy side. See page 23 in *Part 1* for more details on how to assure a good bond. Because the strings will greatly strengthen the seam, 1/8 inch sailmaker's tape can be used instead of the conventional ¼ inch tape. I find that it's easier to make fair seams with the 1/8 inch tape. Sewing the seams is unnecessary and not recommended. The stitching will just interfere with the application of the strings.

A word about sail material choices: Clear Micafilm (#2505, 65 inches, or #2605, 15 feet) is currently the best choice for string sails. It's available through Tower Hobbies (1-800-637-4989). An alternate, if you can find it, is Bainbridge Test 505.

Using other materials, such as Pearly White Micafilm, one of the various colored Micafilms, TRI-SPI 40 or heavier, is not advised. I found that such sails were not responsive in very light winds. The top seam might not pop across after a tack. They were no worse in this respect than non-reinforced sails, but by using heavy fabric, you give up the principal advantage of string sails, that of a large wind range.

Photo 3

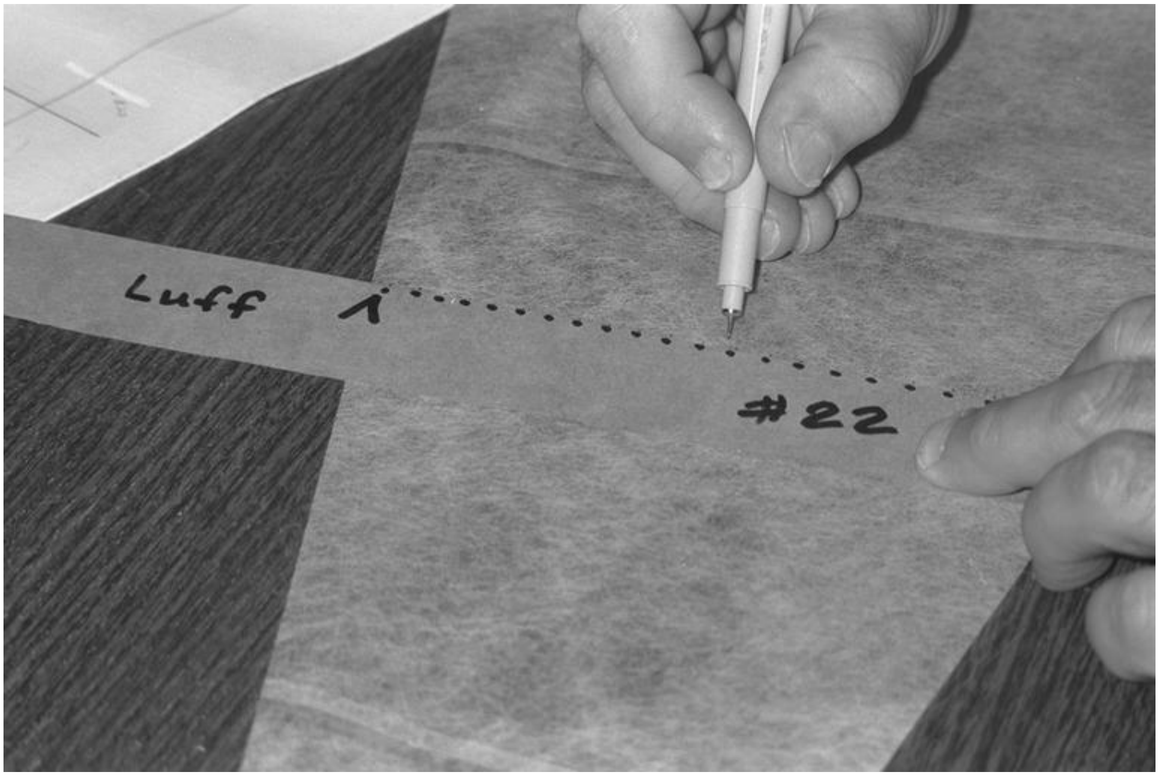


Making a string positioning guide:

On an 11 by 14 inch sheet of graph paper, draw lines radiating from a point at the top of the sheet to points spaced about ¾ inch apart on the bottom of the sheet. Number each line for later reference. Twenty-five lines are more than enough. This sheet is labeled 'reinforcement pattern gauge' in the photo.

Measure the chord at about one third down from the top of the sail and mark this length (shown with a ^ symbol above) on a strip of paper. Position the paper strip over the radiating lines corresponding to the number of strings you are planning to use for the sail and mark the positions. EC–12 mains work well with 18 to 23 threads and EC–12 jibs with 16 to 19 threads. More is not necessarily better, as the head can become too stiff. By angling the paper strip as shown, you can make the spacing of the threads gradually tighter as you approach the leech. Don't overdo this as there still are substantial loads near the luff.

Photo 4

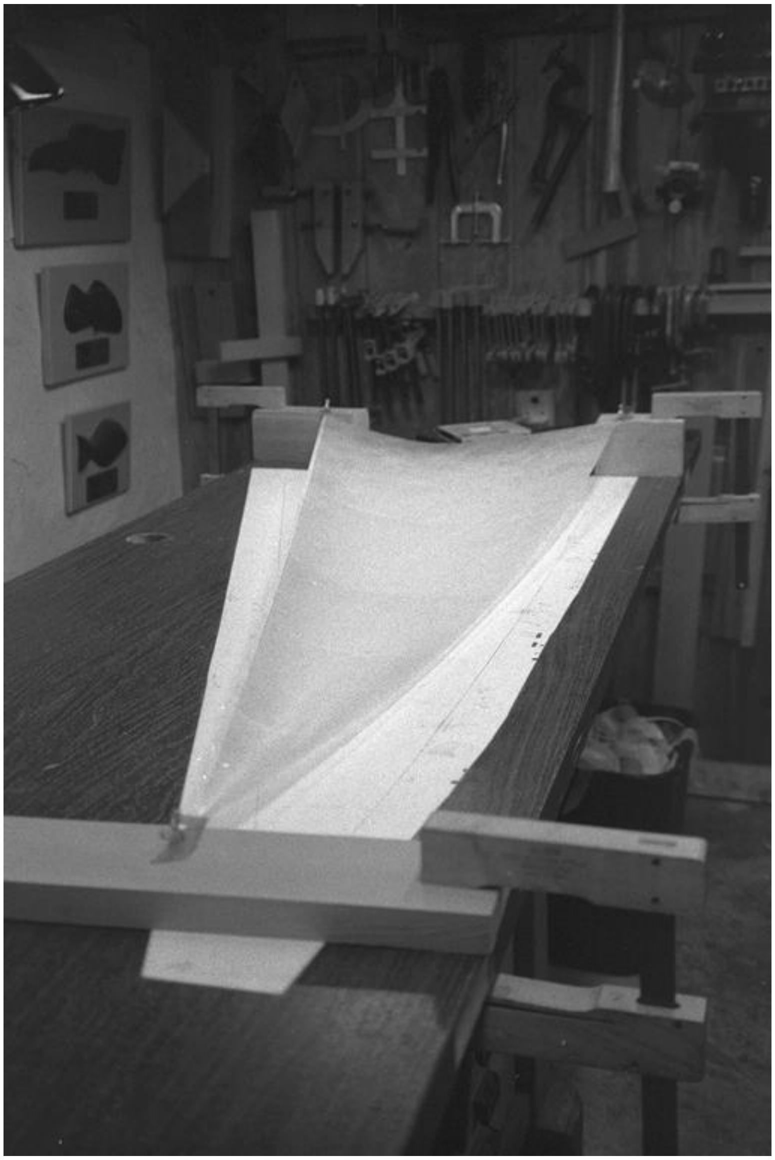


Transfer the marks on the paper strip to the sail with a felt tip marker. The marks for the threads at the luff and the leech should be about 1/8 inch from the edge of the material. Notice that there is no hem at the leech. It is not necessary. There is also no luff pocket in this particular sail because it's a main that will not use a jackline. A hem at the luff is not needed here either. (The option of a jackline, which would require a luff pocket, is discussed in Part I. Jibs also have a pocket at the luff.)

Now make another paper strip to mark the string location about two thirds down from the head. You should not need other location marks. Extras will just be confusing later.

Supporting The Sail Blank

Photo 5

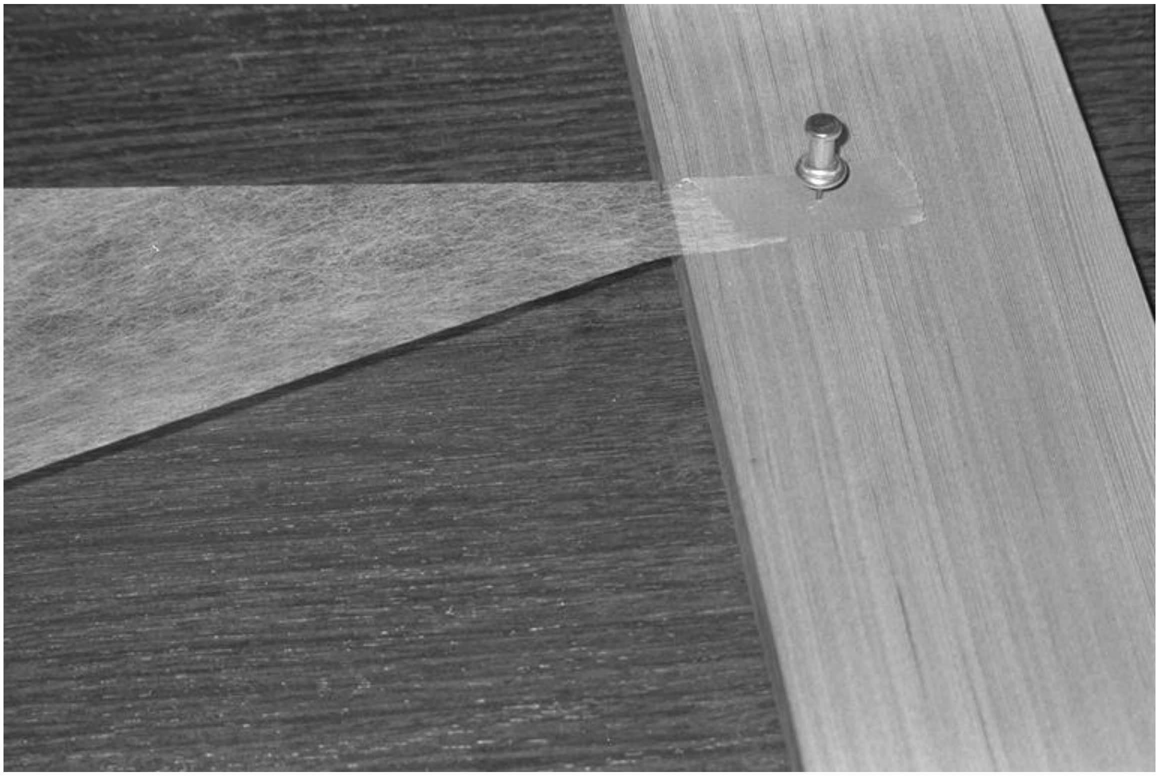


If you are applying strings throughout the whole sail, rather than just at the corners, the sail must be supported so that it hangs freely, as shown above. If you don’t do this, some of the strings will end up too tight, ruining your sail. Remember, shiny side up, to avoid later curling at the leech.

Here, a variety of wood blocks have been clamped to the working surface (an old hollow core door). The sail is pinned to the blocks, which are then positioned to get the right tension. The sail should not touch the work surface, and the leech should be rather loose. (You want the sail ‘relaxed’ as you apply the threads.

If you are just planning to apply strings to the corners, the sail does not need to be suspended. All that is necessary is to stick the corner to a small sheet of cardboard sprayed with 3M Artist’s Adhesive (No. 6065) while the strings are being positioned.

Photo 6



This photo shows in more detail how the head is temporarily pinned to the block (about 1 inch high) that supports it. Notice the small tab of fabric that projects beyond the final dimensions of the sail. A couple of pieces of masking tape stiffen the tab so that the push pin will not tear out.

Photo 7

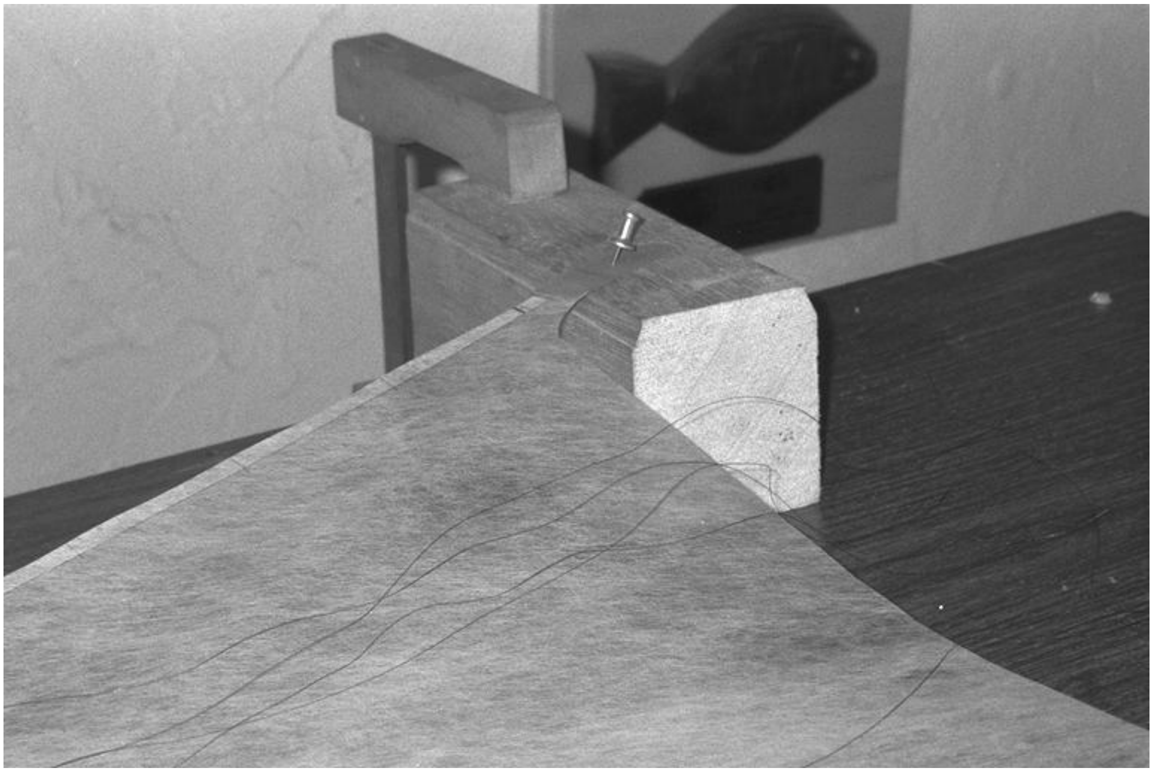
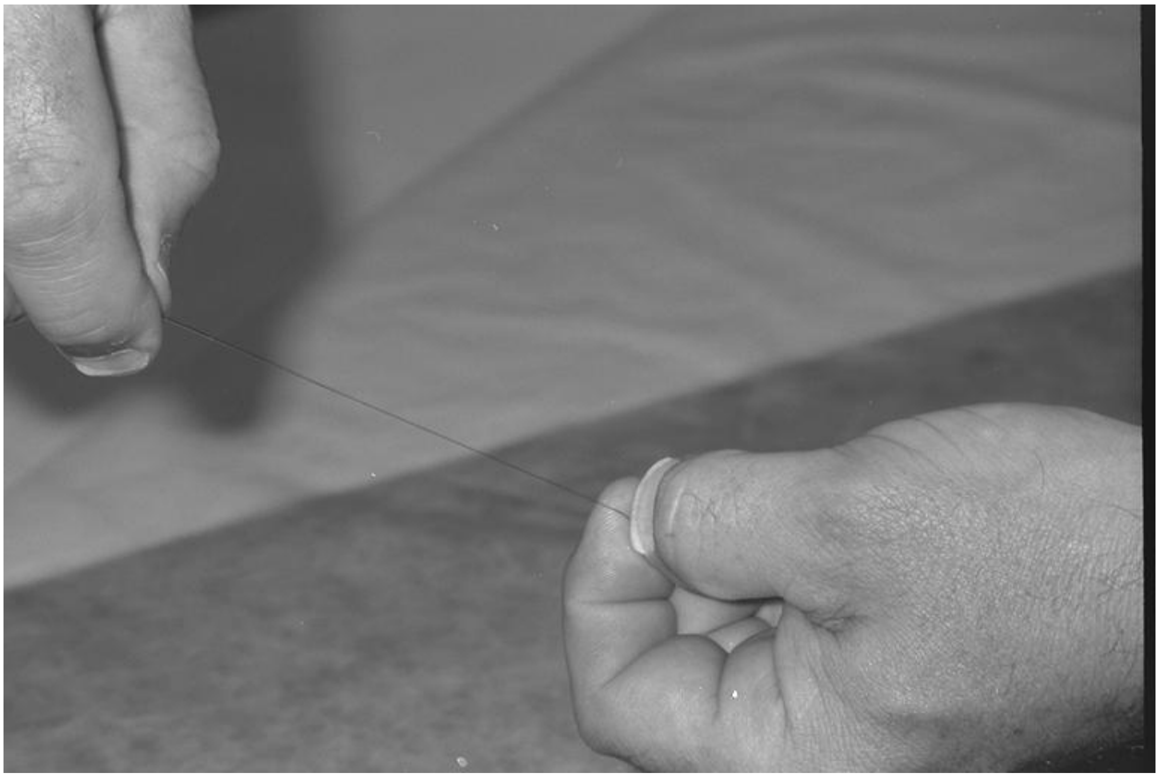


Photo 7 shows how the tack is supported, in this case for a jib. Note the luff pocket for the jibstay at the upper left. You can also see five strings draped along the sail, prior to their being glued in position. Support the clew in a similar manner.

Preparing The Strings

Photo 8



If you are using the Kevlar beading thread mentioned in the introduction (available from TSI, 1-800-426-9984) you will find that it has a natural curl as it comes off the spool. This can be largely removed by pulling the thread between your thumbnail and finger. (Be careful not to cut your finger by pulling too hard.)

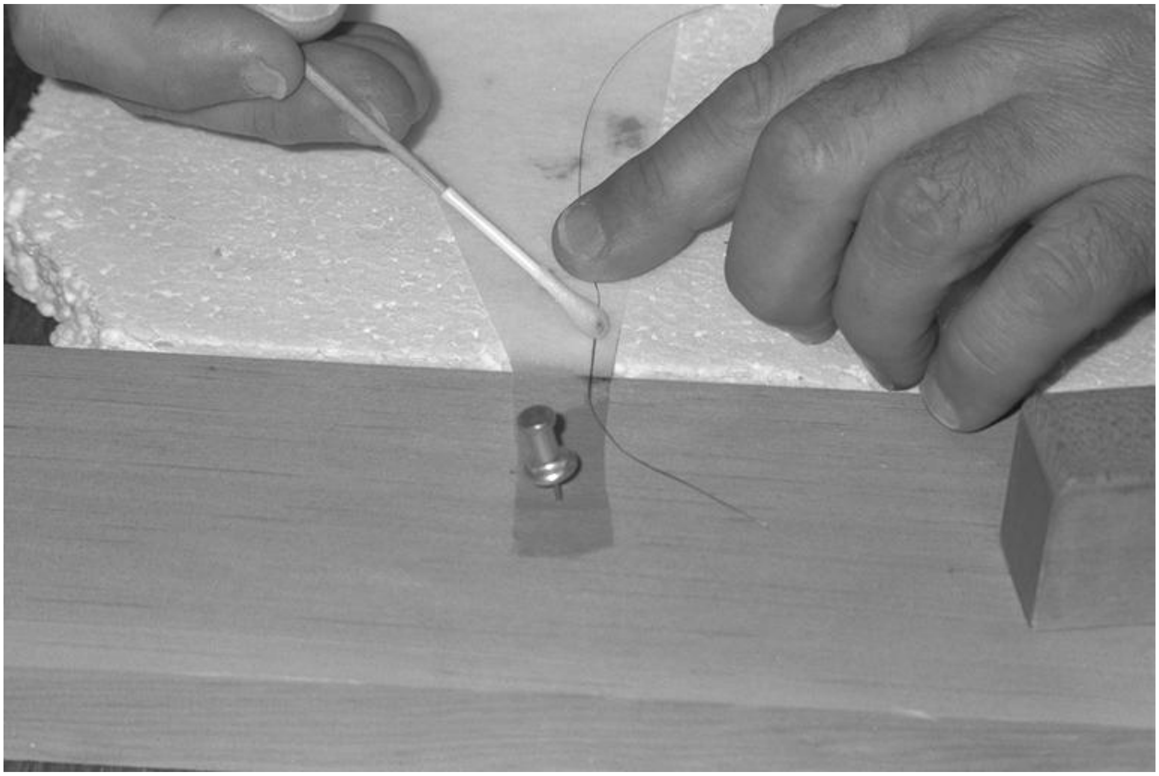
Instead of beading thread, other materials may be used, each of which have their own peculiarities. Most that I have tried come from 'reverse manufacturing' various materials. With difficulty, carbon fiber tow can be separated into small strands, but it is very hard to maintain a constant thickness.

Linear fiberglass laminate material makes reasonable strings. It has about 3 times the stretch of Kevlar, but it's still strong enough. (The overly strong Kevlar can cause a washboard effect on the sail if not applied with care.) Like the rest of these alternate materials, the individual bands of the linear fiberglass must be removed from the stabilizing cross strips, then split into half, and half again, and maybe half again etc. There always is some interweaving of the individual filaments, so this becomes a tricky job, with a lot of wastage.

If you don't mind a lot of work separating filaments, Technora salvaged from the core of a scrap of hi-tech marine line is a reasonable choice. You just keep separating the core into smaller and smaller parts, but eventually you will run into interwoven filaments. At that point, you usually still need to separate each strand into four parts. (Don't just skip this last step or your sail will look as if you glued rope on it.) The individual strings should be no larger than the finest sewing thread. Smaller is better. Except for the work involved, Technora makes a very nice material, because it is very supple and lies flat on the sail with ease. It's also incredibly strong.

Applying The Strings

Photo 9



Here the first string is secured at the head, about 1/8 inch from the luff. The glue (described in the introduction) is applied with a Q-tip stuck on the end of a bamboo skewer. It gives better control than a brush. Only a half inch of string is stuck down at this point.

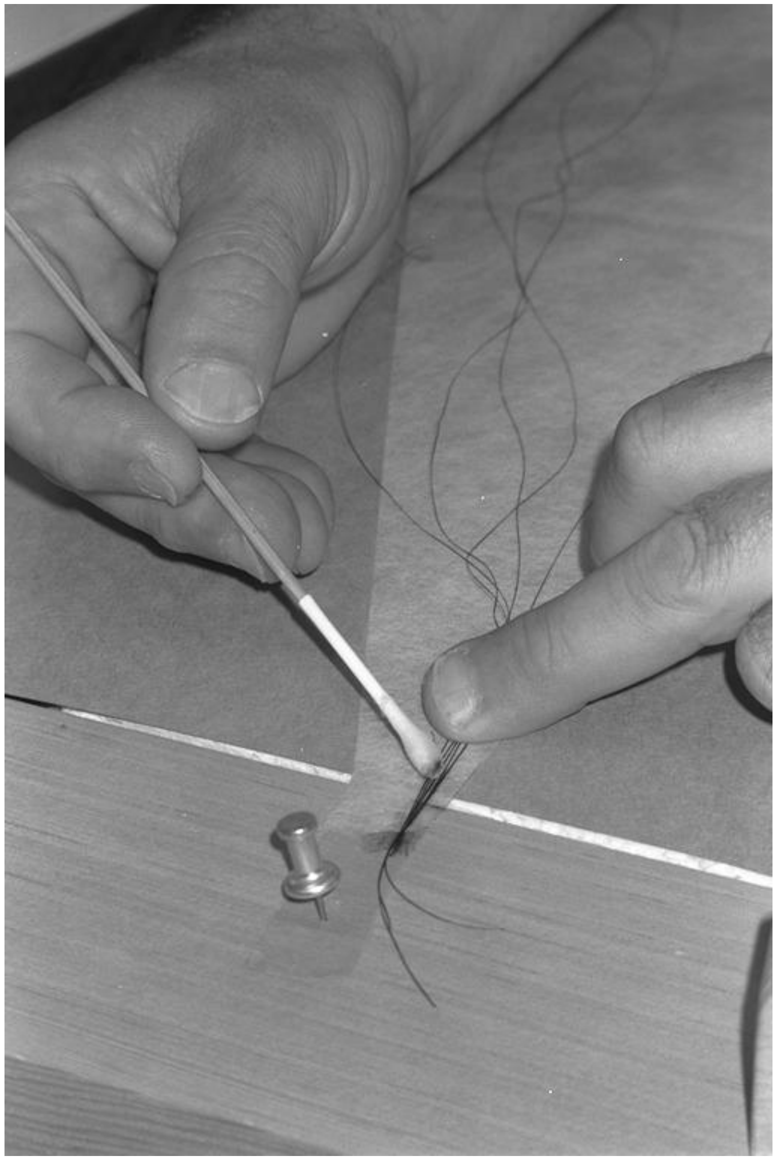
Be sure to start applying the strings at the luff, not the leech. When I worked from leech to luff, I found that there was much more of a tendency of the leech to curl. Also, the strings must be applied sequentially to avoid a washboard sail.

Warning: unless you want to look like the fellow in the cartoon on the cover, always be aware of fire hazards when using this very volatile and potentially dangerous glue. Make sure that you have plenty of ventilation.

Photo 10

To save time, speed the drying of the glue with a hair dryer set on low. Be sure to test the dryer on a scrap of sail material first to make sure that it will not cause shrinkage. Here I am holding the thread down as the glue dries. Again, be aware of the potential danger from fire or explosion. Use adequate ventilation and assure yourself that the hairdryer is in good repair.

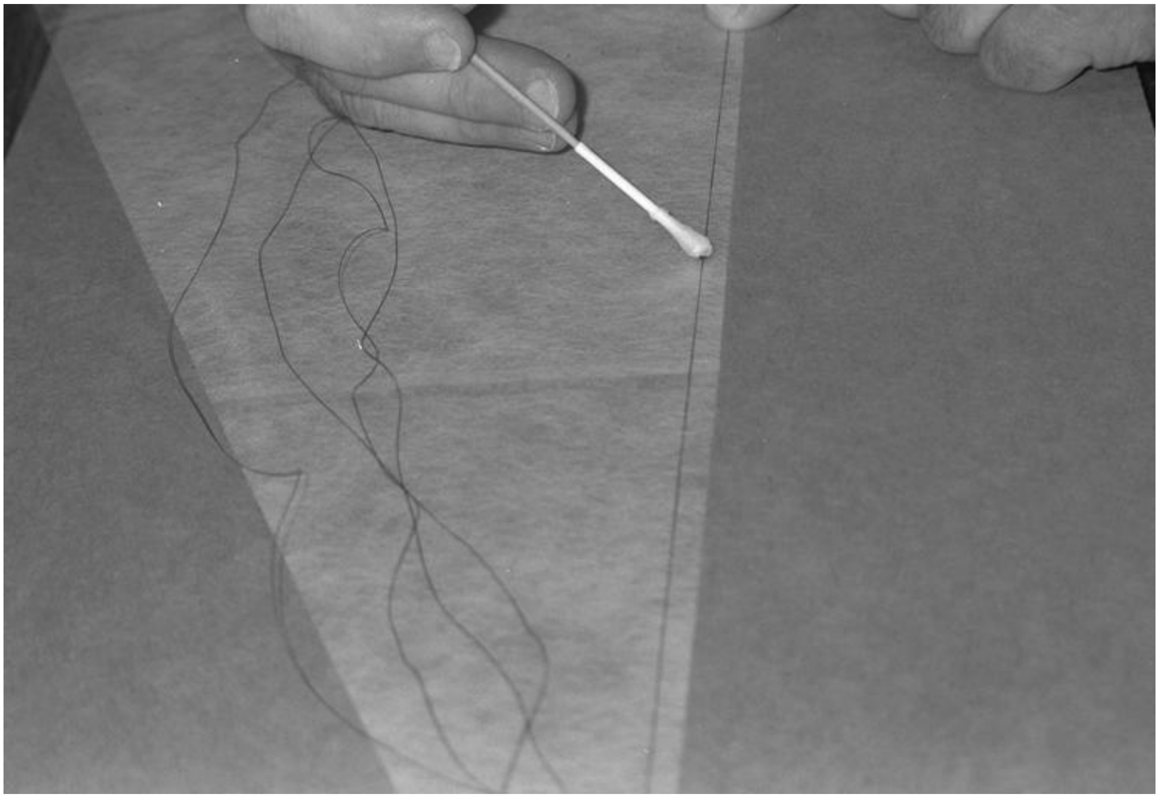
Photo 11



Rather than working on only one string at a time, work in groups of five. Here, the first five threads are being glued at the head. This way you can glue a portion of one string down, then move to the next while the glue is drying. This is important. If you try to stick down too much of a thread at one time, it's very easy to apply inadvertent tension to it. The result will be a dramatic hard spot in the sail at that point.

Always apply the strings sequentially, luff to leech. If you skip a spot and later fill in the threads, you will cause a wave in the foil shape. This happens because the non-reinforced sail stretches a little. The strings stop this stretch. So you don't want to apply them in a haphazard fashion.

Photo 12



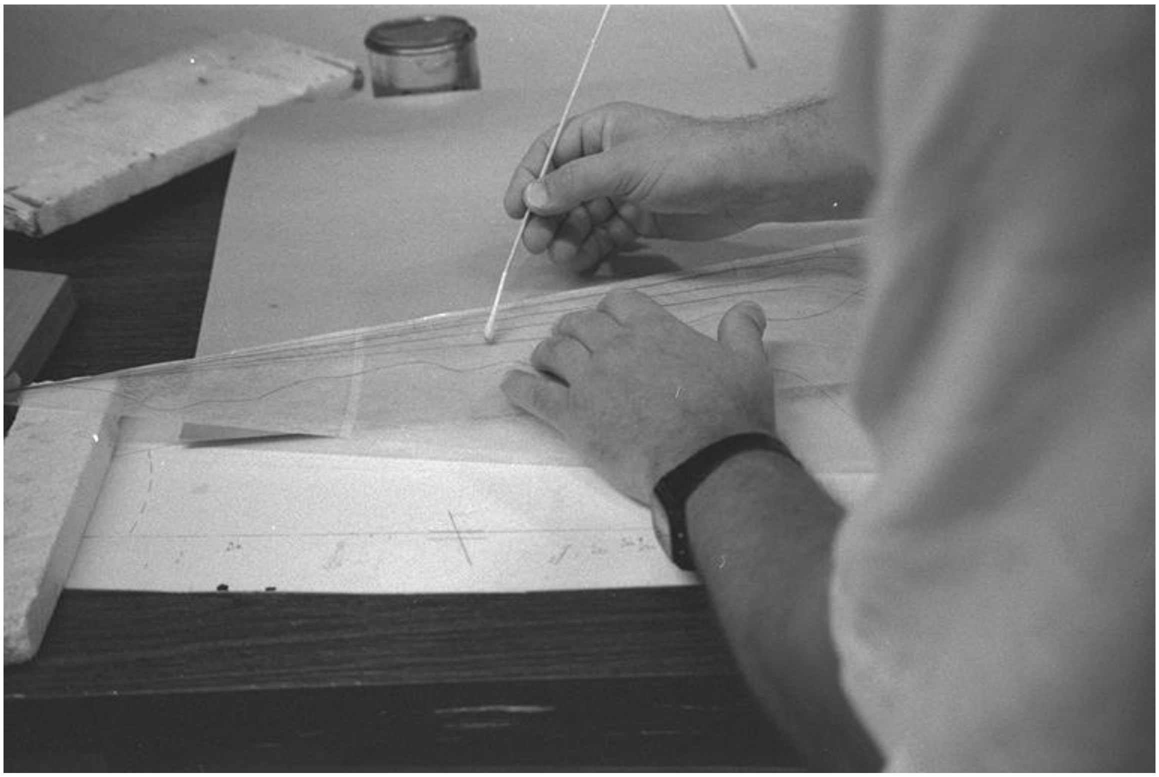
Here, I have started to glue down the first string along the leech. I have placed a small section of cardboard under the sail and blocked it with some foam wedges so that it just supports the sail in its proper shape where I will apply the threads. Later, as you work on other portions of the sail, the cardboard is repositioned. The idea is to avoid stretching the sail locally as you apply the strings.

The thread is positioned with your index finger, under no tension whatsoever, and the glue is dabbed on with the Q-tip. If you wish, you can ‘spot weld’ the thread in place first. This assures that it is not under tension. You can then apply a little more glue. Later, glue will be applied to the whole sail, so you only need to make sure that the thread is held in position at this point. Too much glue will make the sail stiff.

Reinforcing the corners only: light air sails do not need strings reinforcing the entire sail. Just terminate the strings beyond say six to eight inches from the corner. As an alternative, you can use conventional layered patches of sail material at the tack and clew. However to preserve the fullness that you have built into the head of the sail, strings are very effective. They are strong in the major direction of the loads, yet allow the needed flexibility.

The ‘string head’ can also be used on medium - heavy air sails made of TRI-SPI 40 or 50 to preserve a nice shape at the top of the sail. These materials do not need reinforcement in the body of the sail, but conventional head patches make the top so stiff that not much camber can be induced here.

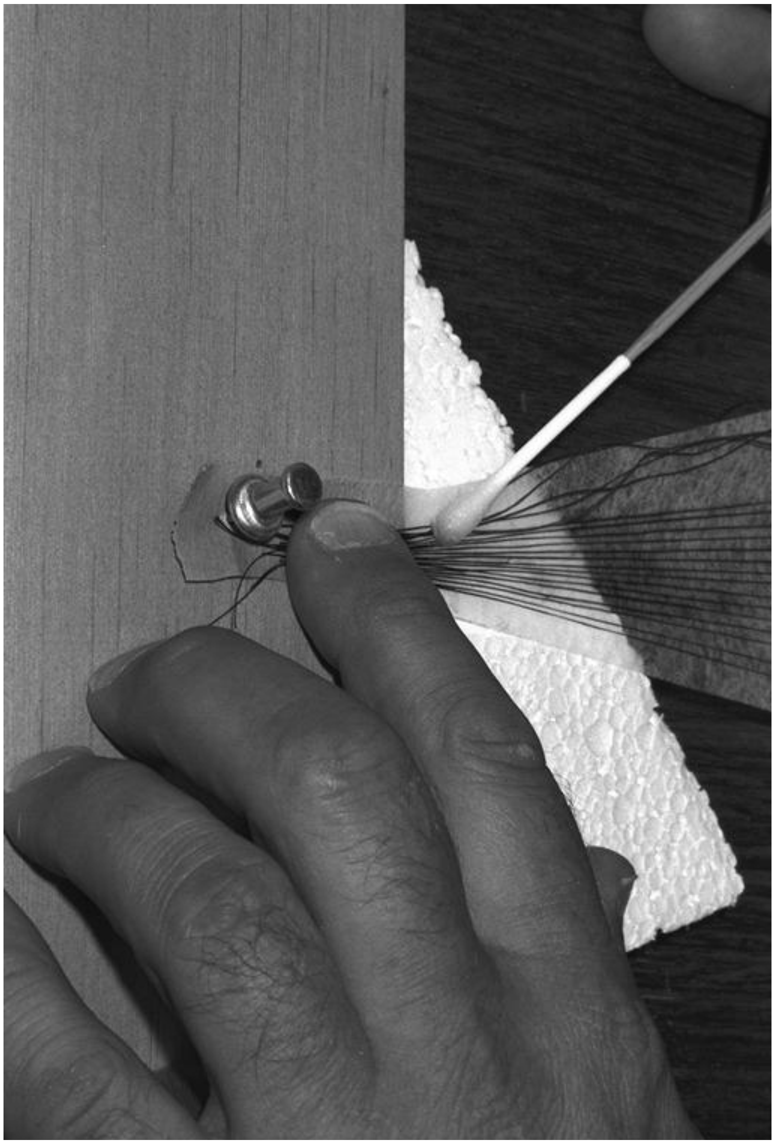
Photo 13



In this photo, we're back to working on a jib. You can see the luff pocket and the first seam. Here, work on the first group of five threads is underway. Note the piece of thin cardboard that is being used to support the front of the sail so that it will not be stretched as the threads are applied. I have glued the first three strings down for a distance of about 10 to 12 inches from the head, and am now gluing the fourth string. Although the reference marks for placing the strings are not visible here, I am using them to guide the spacing.

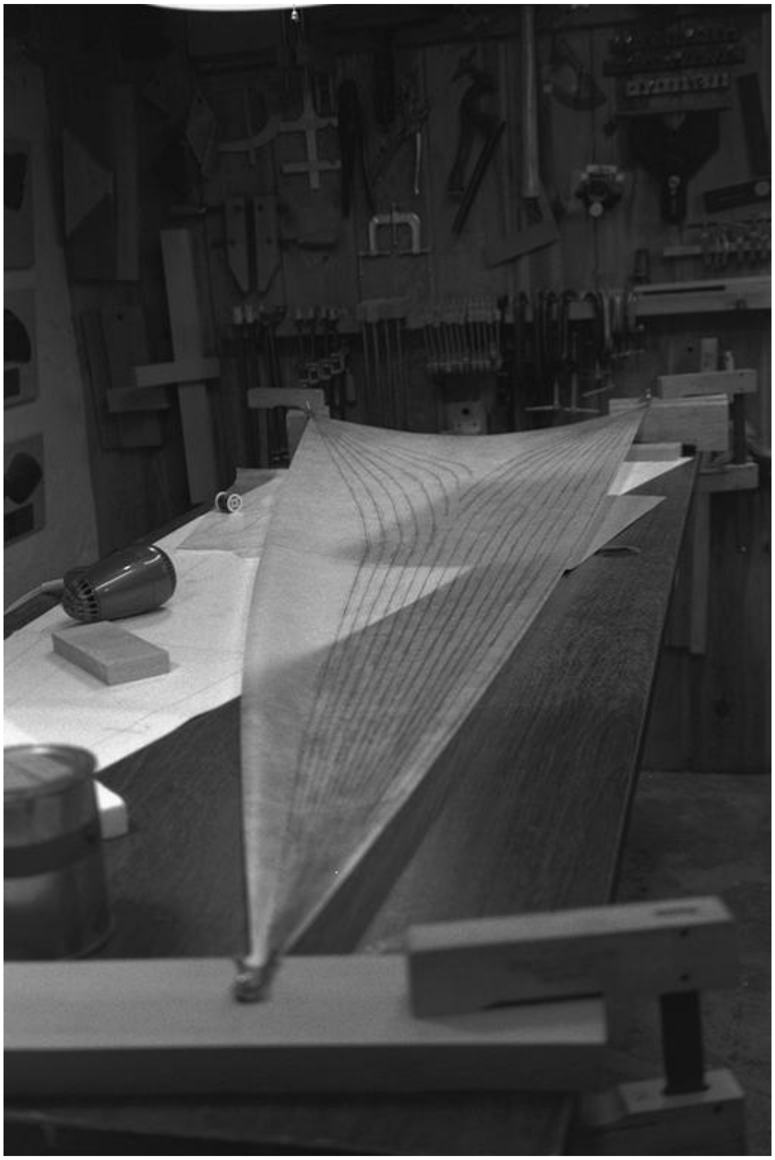
You don't want to glue more than about a foot of string down at a time or you will risk getting it too tight. Remember, no tension. Also, be sure that previously applied glue is dry before you again start to work on a string. Using the hair dryer on low will speed things up. (Shield the strings that are not stuck down with your hand so they don't blow around and tangle.)

Photo 14



Here, three sets of five threads have already been applied from the head to the tack or clew of the sail. The last set of five is being stuck down at the head. (This sail will have 20 threads radiating from the head.) With practice, it's possible to glue two or three threads to the head at once, as shown here. The small foam block supports the sail as this is done.

Photo 15



About three quarters of the threads, starting at the luff, are positioned at this point. Roughly half the threads terminate at the tack and the other half terminate at the clew. The threads from the head begin to arc towards their respective corners about two thirds the way down the sail. The threads are tacked down in these arcs 'freehand', by positioning the string with the Q Tip as it is glued. Use the previous thread as well as the position marks for a guide.

To adequately reinforce the tack and clew, additional threads are tacked down at these corners and then positioned following the general pattern of the other threads. As shown in the photo, these secondary strings do not extend to the head.

If you like, you may use a slightly different thread distribution. The latest ads from the big sail lofts make good sources of ideas. However I think that you will find that the skill with which you apply the threads is way more important than minor changes in their position.

Final Gluing

Photo 16

All the threads have been tacked in place and the sail has been removed from the blocks holding it above the work surface. A single coat of sail glue is then applied in the following way.

Divide the sail into four or five imaginary panels. Paint alternate panels, excluding a small area around each corners (head, tack, and clew) and let the glue dry. This helps to prevent the threads from shifting while the glue hardens. Use the hair dryer too.

Warning: make sure you have adequate ventilation and that the hair dryer is in good repair or you could cause a 'significant' explosion and fire!

When the glue is dry on the first set of the imaginary alternating panels, go back and paint the rest. If, with experience, you find that the threads frequently come loose along the leech, you can apply an extra coat of glue in that area.

Finishing The Headboard

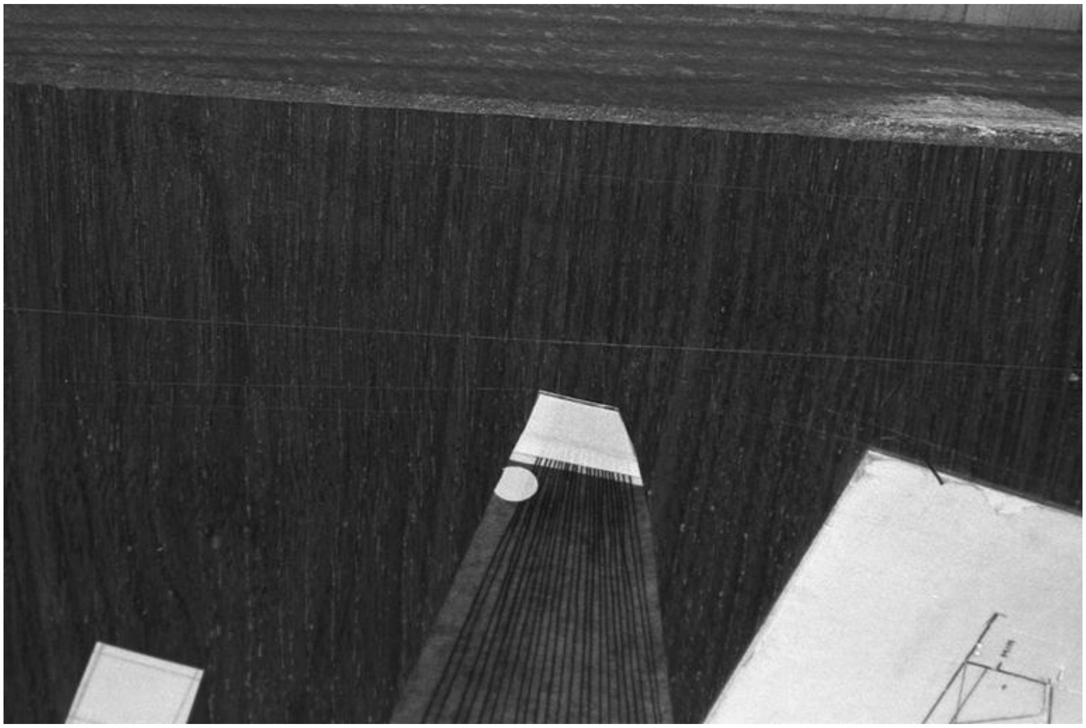
Photo 17

Now that all the threads are finally glued to the sail, the little tabs on the corners are cut off, leaving the sail at its final dimensions. At this point we need to evenly transfer the load on all the threads to the corner reinforcements. Here's how:

Let's begin at the top of the sail. Stick the head, thread side up, to a small piece of cardboard sprayed with artist's adhesive as shown above. Cut off a 3/8 inch strip of .015 sheet acetate (the kind used for model aircraft windshields) and bend up a corner so it can be positioned with pliers. This will become the headboard. Evenly coat the plastic with *Devcon* Plastic Welder, mixed per the instructions. (Do not substitute epoxy! It's too brittle. Use only the *Devcon* Plastic Welder.) Position the headboard, then gently squish out the extra glue with a pencil eraser. Don't overdo it or the bond may fail. Let the glue harden at least eight hours before trimming the plastic to the final size.

Notice that in this photo of a main, the threads start back from the luff perhaps 1/8 inch. This will allow a notch to be cut here to clear the knuckle of the headboard hinge. Mains with a significant amount of camber at the head require some sort of headboard hinge in order to set properly. There is more on this subject in the appendix, as well as in *Optimizing the EC-12*.

Photo 18



Once the sheet acetate is glued in place and trimmed, cover it with small pieces of ‘stickyback’ (sailmaker’s patching and repair material). You could use spinnaker repair tape instead. Do not use *MonoKote* trim material, as it will come loose after several years.

In this photo of a main, the cutout for the knuckle of the headboard hinge has not yet been made. The small circular reinforcement below the headboard marks the lower margin of the cutout, and is there to stiffen the luff in that area. Notice that this main does not have a luff pocket for a jackline. If it did have a pocket, it would stop at the circular reinforcement, because the jackline must be secured below the hinge.

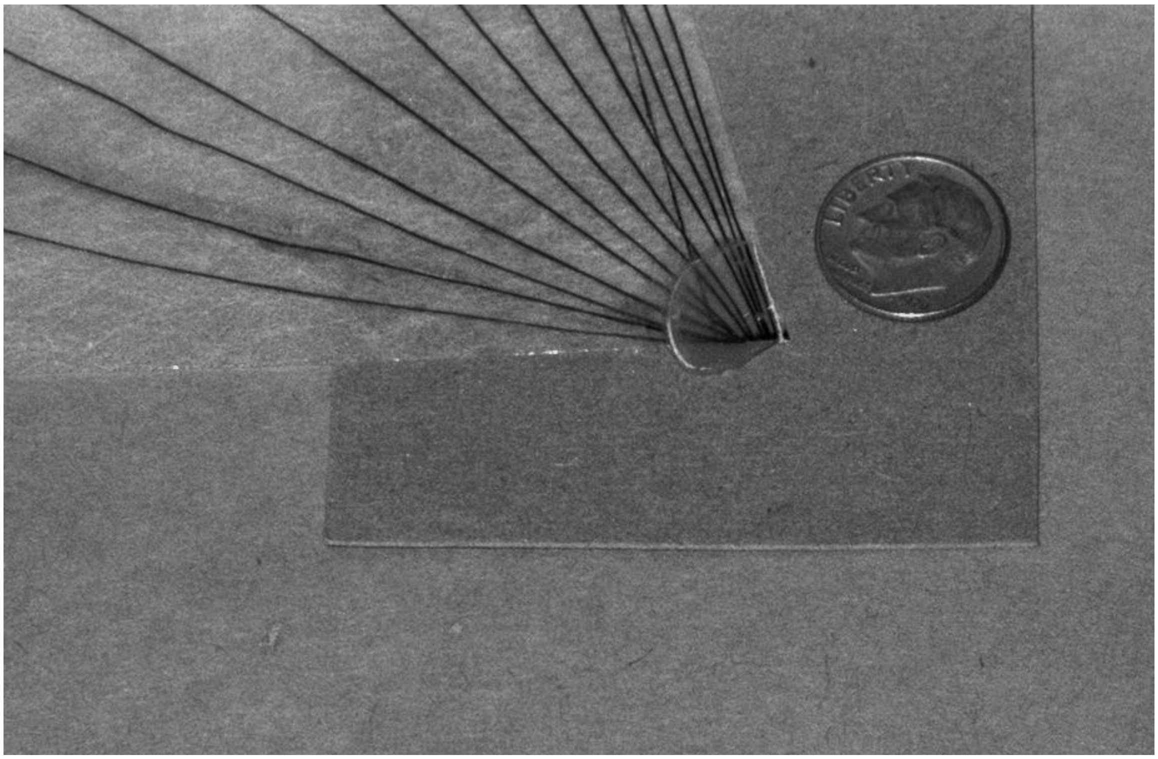
The photo also shows how close the strings are to each other at the head. They essentially touch as they exit out the top. This headboard is about 5/8 inch across at the top. Although the EC-12 rule allows a ¾ inch headboard, more is not better. It forces the very top of the sail flat, which can subtly distort the shape below. This is especially true as the head of the sail is made fuller. Some may be concerned about the infinitesimal loss of sail area (in relation to the total) but I think that better overall sail shape is far more important than an extra square inch of area.

At this point, no hole for the attachment to the hinged headboard has been made. This is done later, as the sail is fitted to the rig. If the headboard is not attached in the correct position, the sail will not set properly, often exhibiting strange wiggles in the foil shape at the head.

Attaching the headboard to the headboard hinge: fix the luff to the mast by the method of your choice, and secure the clew to the boom. Clamp the headboard to the headboard hinge with a strong spring clamp. Move the headboard back and forth to find its natural position where the sail sets properly. (A common mistake is placing the head too far aft.) Drill through the center of the headboard and through the headboard hinge, then sew the two together with three or four wraps of sailmaker’s thread or similar material. Use CA on the knot, but be sure that the headboard is free to pivot slightly on the hinge so that it ‘auto aligns’ with the loads while sailing. (There is more on this subject in the appendix.)

Finishing The Tack And Clew

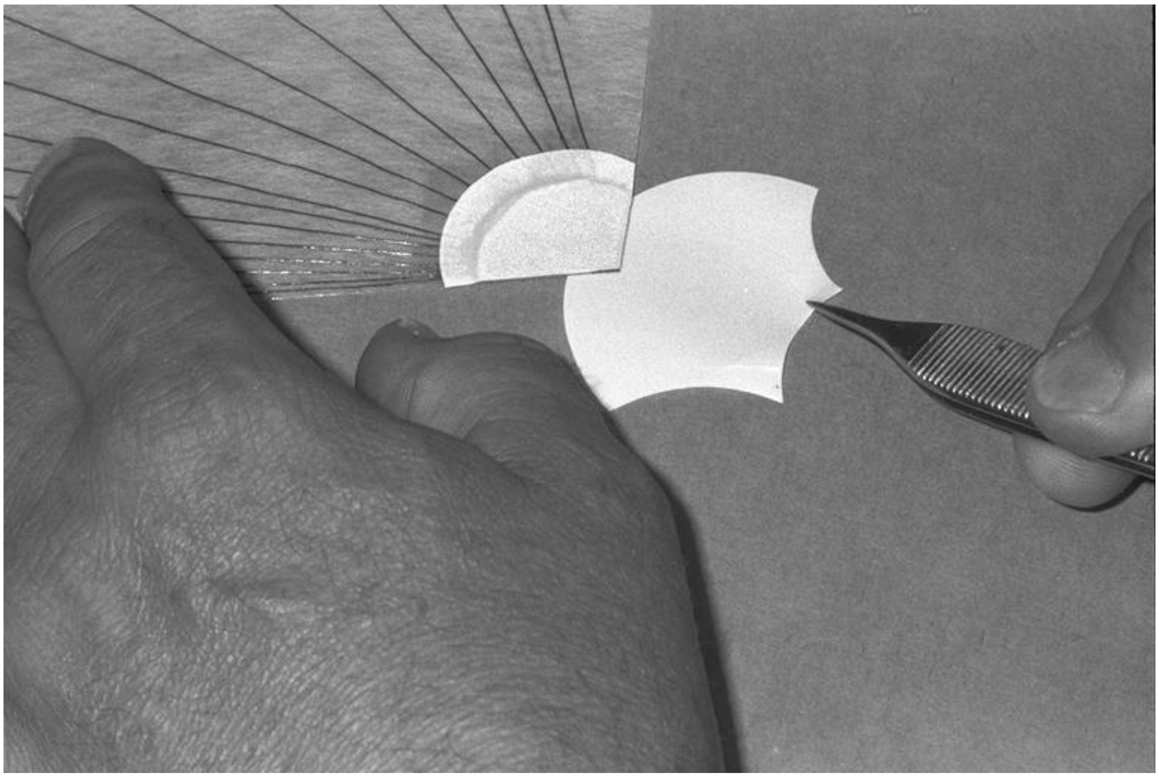
Photo 19



This photo shows the corner reinforcement at the tack of a jib. The tack of a main with a luff pocket would be made the same way. The sheet acetate reinforcement is attached in the same way as was done at the head. Although the small quarter circle of plastic has a radius of only about 3/8 inch, the result is amazingly strong. If done properly it’s way in excess of working loads, as are the other corner attachments made this way.

As was done on the head, the tack is reinforced with stickyback. Here, the patch must wrap around the front of the pocket to prevent the jibstay from sawing through the luff pocket.

Photo 20



Here the clew is being finished. A quarter circle of sheet acetate (about ¾ inch radius) has already been glued to the threads with *Devcon* Plastic Welder. It has already been covered by a slightly larger patch of stickyback. The photo shows the patch for the remaining side of the clew being positioned. It's placed sticky side up under the clew so that it appears concentric. Burnish the area gently, then cut off the excess material with a razor knife. The radius of the largest patch does not need to be any more than 1 ¼ inches. The threads take all the load, so larger patches are superfluous.

Photo 21

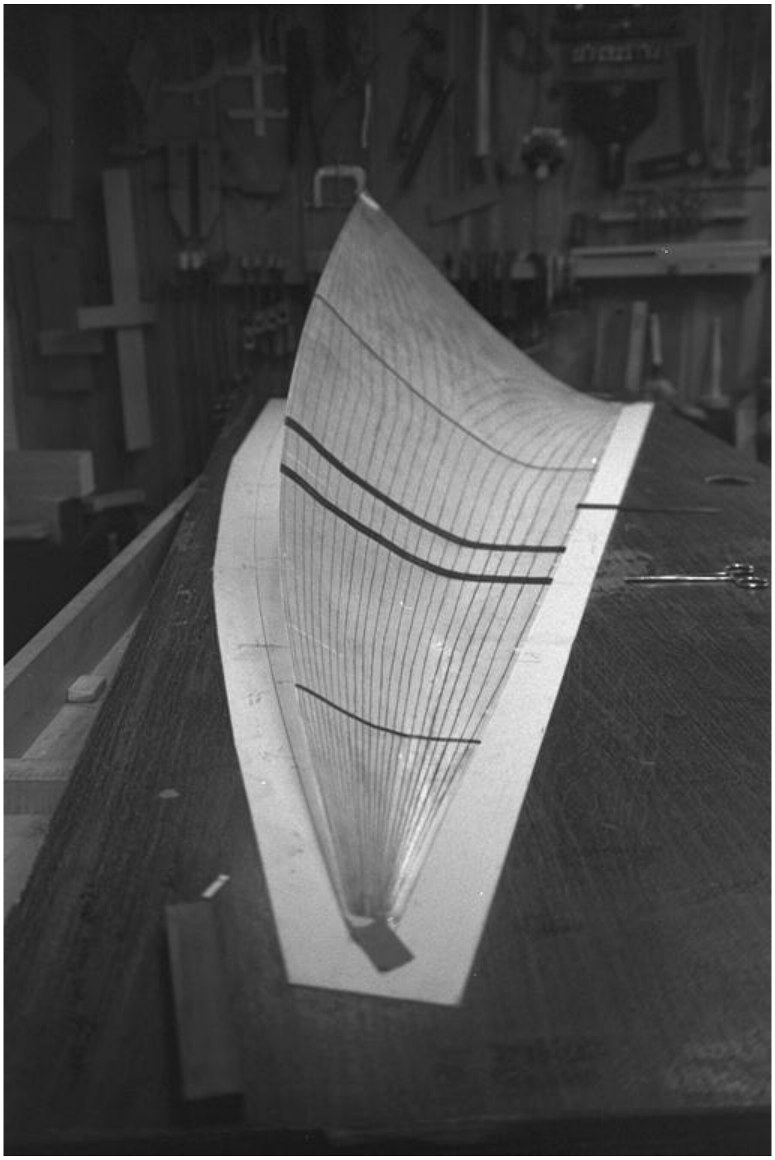
Photo 21 illustrates how to make the holes in the corner reinforcements. Metal islets are not necessary. Just heat an eighteen gauge brad with a torch and melt the holes as shown. I have never had one of these fail. If it were to happen I would regard it as a nice safety feature, in the same way as ‘D’ rings on full size jibs are sewn on in such a way that they may fail before the body of the sail fails.

The hole for the tack is placed as reasonably close to the luff as possible to keep a fair sail shape at the foot. (As shown in the photo, about 1/8 inch back from the edge is reasonable.) I place the hole in the clew patch up ¼ inch from the foot and 1/8 inch ahead of the leech.

Also, be careful with the torch. It would be only too easy to melt a big hole in your sail at this point!

Measuring The Luff Curve

Photo 22



Here the mainsail has been finished. Draft stripes have been inked on with a permanent marker, and battens made of small strips of *MonoKote* have been applied. Because of the relatively small roach, EC–12 string sails do not benefit from typical stiff battens. Sails for classes that allow large roaches will require battens. I usually make them from sheet acetate and just stick them on with sailmaker's tape. (There is more on the subject in the Questions and Answers article in the appendix.)

Before you mount the sail on the rig, be sure to measure the luff curve (for the main) or luff allowance (for the jib) as described in Part I. Here, the head and tack have been taped down to the 'luff line' with a bare minimum of tension. (Rod Carr actually standardizes this by attaching a four ounce weight via a string and pulley to the tack.)

The clew has been supported so that the luff of the sail is tangent to the board, and the distance that the luff projects ahead of the luff line is noted. Write this number on the head of the sail for future reference.

Ready To Sail

Photo 23

Here is the finished sail, which was used on the winning boat at the 1996 EC–12 National Championship Regatta. (That made the 10th win for Kelly Martin, which indicates that the sail probably did not have much to do with the win. In 1997, Kelly won again for the 11th time. Congratulations, Kelly.)

Photo analysis of this sail gave the following values (based on a slightly different photo):

Main: Kelly's A21		Date: 8-96	Twist: 18
BST:	MB: 0?	MPH: 2	Location: Surprise Lake
Stripe	**Camber**	**Corrected Camber**	**Draft Position**
Top	11.2%	11.4%	47.8%
Mid	11.1%	11.4%	42.3%
Bottom	9.7%	10.3%	39.9%
Percent Camber Increase at Head: 9.8%			

Note: ‘corrected camber’ is the camber corrected for camera angle.

Kelly and I were reasonably happy with these results. Since then, we have experimented with more extreme camber distributions for both the main and the jib, but found that such sails can be rather unforgiving.

Appendix

Smoking around open glue can. (Before)

Smoking around open glue can. (After)

Laying Out A Sail Board

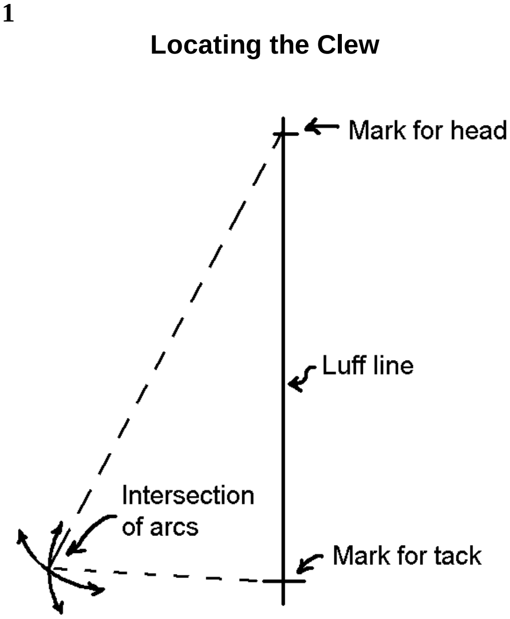
This article was written for the Seattle Model Yacht Club newsletter and therefore focuses on the EC–12. Nonetheless, the principles should be applicable to other classes.

In order to dimension model yacht sails, most sailmakers rely on a ‘sail board’. It’s just a flat board of some type with the outline of the sail on it. Many regatta measurement committees also use some type of board when checking sail dimensions. As an aside, checking sails this way is probably accurate enough for the purpose, but there is the potential for a small error when measuring EC-12 sails. This is because there is no tolerance associated with the girth stations on the leech, only the length of the girth dimension itself. The position of the line is exactly specified in relation to a line from head to clew. But the head to clew line has a tolerance in length as well as position, based on how you choose to use the basic tolerances in the luff and foot. So the exact locations of the girth stations on the leech will depend on these choices. A very minor point, but if they question your girth measurements at the next regatta, give them a hard time and insist that they properly and exactly locate the girth stations. That should be good for a laugh!

When I made my sail board, I discovered that I had forgotten some of my grade school geometry. I didn’t quite remember how to erect a perpendicular or bisect a line. Sure, I could have just used a tape measure to get the sail board sort of right, but it would most likely not be very accurate. Here is one way to lay out a sail board to a higher degree of precision and get a little geometry refresher, like I did.

The board itself should be dimensionally stable. No wet sheets of thin plywood. An old hollow core door or perhaps a sheet of MDF (medium density fiberboard) will work. Instead of laying out directly on the wood, I like to glue sheets of mat board (from the artist’s supply house) to the board with contact cement. It’s easier to draw on and it’s easier on the razor blades or X-Acto knives used to cut the sails too.

Figure 1



You will need a long straight edge that is really straight, a tape measure and also trammel points or the homemade equivalent. Fancy ones are relatively expensive, but you can get simple ones that slip onto any standard yardstick. Micro Mark, (ph 1-800-225-1066) has a set for about six dollars, #14302. If you are not familiar with trammel points, consider that they work like a giant compass, with the points positioned by sliding them on a long beam rather than having them attached to hinged legs. Remember your old grade school geometry teacher at the black board using his/her large compass that had chalk for points? We’re back to the same thing here!

Begin by drawing a straight line 4 or 5 inches from one long edge of the board. Using the tape measure, mark off the luff dimension. Even though your sails may have curved luffs, the ‘luff line’ on the board should be dead straight. This is done so that this line can be used as a reference for marking your desired luff allowance (for the jib) or luff curve (for the main). The line is also used for measuring the luff curve or allowance you ended up with, once the sail is built.

Carefully set the trammel points (with a pencil holder in place of one of the needle points) to the foot dimension and strike an arc from the bottom mark on your luff line (the tack) to the area about the clew. Reset the trammel points to the specified dimension from the clew to the top-forward corner of the head, and strike an arc from your top mark on the luff line so that it crosses the arc you drew from the tack. For EC-12 sails, note that this arc originates at the front corner of the headboard, not the aft corner. The intersection of the two arcs is the point of the clew. See **Figure 1**. Now draw lines from the head and tack marks on the luff line to this point.

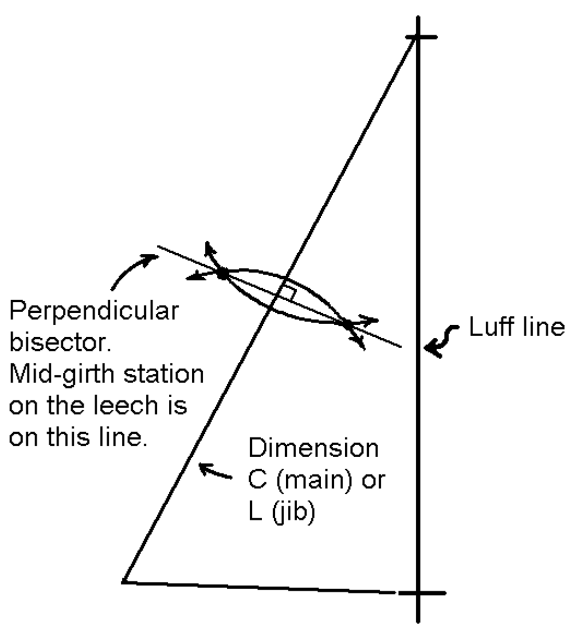
After you swing the arc from the head, reset the trammel points to the maximum foot round dimension and strike an arc from the head well across the middle of the foot. To finish off the foot, you need to find the point on the arc just drawn that is equidistant between the tack and the clew. For accuracy, do this with the trammel points. Set them for a distance somewhat greater than half the foot dimension. Strike two new arcs across the previously drawn arc at the foot, one from the tack and one from the clew. These two new arcs should intersect at two points, one above and one below the first arc. Connect these two points. Now the point where this new line crosses the first arc is the point of maximum foot round. Draw a curved line through this point, the tack and the clew, using a constant thickness batten as a spline. (Hold the batten down with weights of some sort while you draw the line.) This defines the foot of the sail.

Now for the girth measurements. There has been some confusion about exactly where these are located on an EC-12 sail plan. The method below will duplicate the standard girth station locations on the leech as shown in the current AMYA EC-12 rule (as of this writing). There may be more on this topic available as a separate document available from the Class Secretary.

Begin by erecting a perpendicular bisector of the line from head to clew. See **Figure 2**. The mid-girth station will be somewhere along this bisector. Set the trammel points to a distance moderately greater than one half the head to clew dimension and strike arcs from the top-forward corner of the head and then from the clew. The perpendicular bisector is just a straight line drawn through the two points where the arcs intersect.

Figure 2

Finding the Mid-girth Station on the Leech



To find the ¼ and ¾ girth stations, erect perpendicular bisectors of each half of the very same line used above. The stations will be on these bisectors. Finish locating the girth points by setting the trammel points to the exact girth dimension, then begin sliding one point of the trammel in along the bisector until the other trammel point just touches the nearest point on the luff as you sweep an arc. (Replace the pencil with a needle point here for greater accuracy.) The 'aft' trammel point now marks the location of the girth station on the leech. Mark the locations of the trammel points by pushing them into the mat board, then draw a line through the two point marks, extending past the luff and the leech.

Although a curved line marking the leech will not be used in the final dimensioning of the sail, it is helpful to have an idea of the shape of the sail when planning your cutting allowances. Mark off the dimension chosen for the top of the headboard (no more than ¾ inch for EC–12 sails) perpendicular to the luff line. Use a spline and weights to define the leech as was done for the foot round.

Here is one method of accurately determining the final shape of the leech on the sail itself:

Finish the luff and place the sail on the board with the forward edges of the head and tack just touching the luff line. With dividers, measure the distance that the luff is forward (mains) or aft (jibs) of the luff line and add or subtract this distance as appropriate at the other end of the girth line. Mark these locations and use a spline with weights to mark the true luff curve. Cut (or hem) the leech to the desired line.

Finally, cut the foot round with reference to the line on the board. Even relatively opaque fabrics should allow the line to show through enough to let you see where the line should be. It is best to cut the leech first, as doing so may slightly change the way the sail lies over the foot round line on the board.

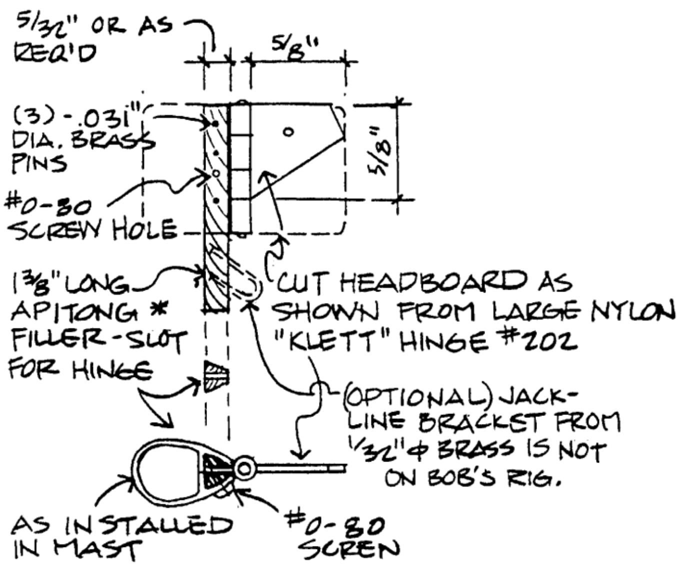
LR 7-20-97

The Hinged Headboard Attachment

(This article was taken from *Optimizing the EC–12*.) The headboard on most full size boats pivots. Why shouldn't we want the same? The use of the pivoting mast crane mandates the use of some variation of the fitting shown in **Figures 1** and **2**. I suspect that there has not been a lot of interest in headboard attachment fittings to date because most EC–12 sails (as well sails made for other classes) are quite flat at the head. Hinging the headboard does not help a flat sail shape that much. However with the sails made using the ideas in these two sailmaking booklets (which suggest increasing the camber at the head) the sail will not set properly if this fitting is not used.

Figure 1

The Hinged Headboard Attachment

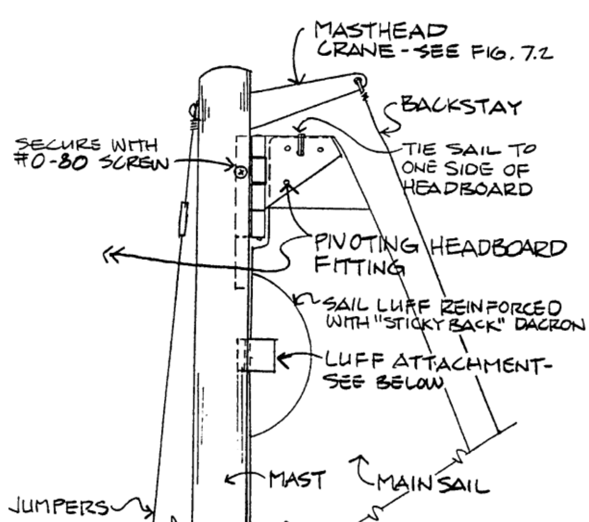


The effect of not having the fitting can be easily demonstrated. You simply push the headboard to the centerline and watch what happens to the sail. Typically, a big crease will appear, descending vertically from the head. The foil shape at the head starts to look like a "W", not the shape of speed.

We make the fitting from a Goldberg large Klett hinge (#202). The wood portion is pinned on with 0.031 inch diameter brass rod. Do not rely on glue alone, as this is a highly loaded fitting. When we wish to use a jackline, the wood is extended about one half inch below the hinge. A small U shaped attachment point from 0.031 rod is installed in this area. (This is more than strong enough. We proof tested it to over 35 pounds downward load.)

Figure 2

Headboard Fitting Installed



After fine tuning the fit of the headboard attachment fitting by filing off its forward edge, position it in the mast groove and secure it with a single #0-80 screw. Check for interference with the pivoting mast crane if installed. You should be able to depress the aft end of the crane a little below horizontal.

Attaching the headboard of the sail to the fitting is critical. Many strange sail shape problems can be solved by repositioning the attachment point. First, the headboard must be cut away slightly to give clearance for the knuckle of the hinge. Clamp the sail to the hinge and adjust the position so that the luff does not pull against its attachments to the mast. Drill thorough the grommet and the hinge leaf while they are clamped together. Use a small drill bit (say 0.040 inches) to help keep the headboard in the proper place. (A large hole allows too much slop.)

As the hinge loads up under sail it will deflect downward slightly. Also, the headboard will try to find its natural alignment. This will not occur if the sail is glued to the hinge. We tie the sail on with three or four wraps of sailmaker's Dacron tread, or perhaps Spectra. Be sure to secure the knot with CA, but check to see that the headboard can rotate slightly on the hinge to allow it to align itself under load.

Why Does My Top Draft Stripe Look Like A 'W'?

Of course you would like to have all the draft stripes represent nice fair curves, but often a significant kink will appear in the middle of the top draft stripe and sometimes even in the second stripe. (See **Figure 1**.) What causes this and how do you get rid of it?

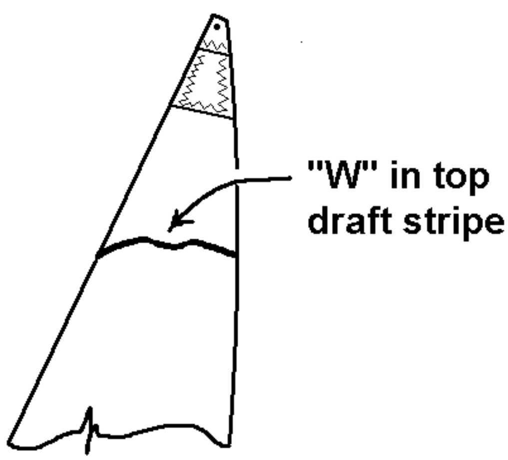
It turns out that there are a number of potential causes.

- The head reinforcement may be too stiff to bend to the curvature induced by the first seam.
- The head reinforcement may be flexible enough, but it doesn't evenly distribute the load down into the upper part of the sail.
- The luff pocket may have a kink, or there may be a sewing defect (like an over tensioned stitch).
- Even a very flexible head may not allow the amount of curvature that was planned for the top part of the sail.
- The headboard may be misaligned.

Notice that all but one of these items are the responsibility of the sailmaker. From the sailmaker's point of view, eliminating the 'w' is surprisingly hard because it's fundamentally a materials problem. The available fabrics used in the head are unfortunately too stiff for the strength they give.

Figure 1

The 'W', Or Kink In Top Draft Stripe



Let's discuss the causes of the 'w' one at a time. The most common head reinforcement seen on model yacht sails is the layering of material in a stepwise fashion. If you draw a small draft stripe near the bottom of the head patch, you will see that it bends little if at all in response to the wind. If the patch were not there, the sail would have curvature all the way to the very top, sort of like a cone. To see an exaggerated example of what happens when the top of this cone gets squished flat by the head patch, set your boat up in the wind and squeeze the top part of the sail between two straight sticks. A large 'w' should develop, descending below the sticks.

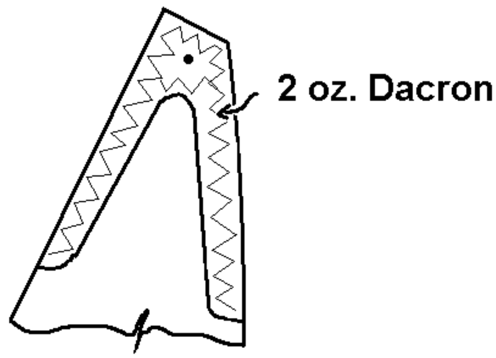
The culprit here is not the stiffness of the individual pieces of material but the consequence of the total thickness of the head of the sail. If you make a beam twice as thick, it becomes four times as stiff. So even if you use just one doubling patch of the same weight material, the strength is doubled, but the stiffness is four times higher. (Sewing effectively turns the two layers into one.) Most sailmakers use heavier materials for the head patch which exaggerates the stiffness even more. There is no easy solution here except to make the top of the sail quite flat so as to minimize any distortion. This is what most sailmakers do.

In an attempt to avoid the problems above yet retain the simplicity of the sewn head, Rod Carr experimented with head patches shaped as shown in **Figure 2**. They seemed to work fairly well in very light air, but as soon as the wind picked up a little, the dreaded 'w' or some other sort of deformity would appear! This method of reinforcement was just not able to uniformly transmit the loads from the halyard down into the top part of the sail. A look at the shape of the reinforcement should tell you why. Rod has since abandoned this type of head construction for most of his racing sails.

Sewing model sails consistently may seem like an easy task, but just a single over-tensioned stitch can produce a significant defect in the flying shape. Maybe the needle becomes gummy, or maybe just a fraction too much load is placed on the sail as it is guided through the machine. It's also possible to fold the luff pocket so that it has a slight kink. If the kink points forward, excessive load will be placed on the sail at that point and a wrinkle or crease may result.

To determine the location of the defect, whether in the head patch or on the luff, consider the 'w' as a form of overbend wrinkle which is formed from excessive loading. (I call these 'overload wrinkles'. You may also see them elsewhere on a highly loaded sail.) The path of the wrinkle will point to the region of overload.

Figure 2
One Type Of Head Reinforcement



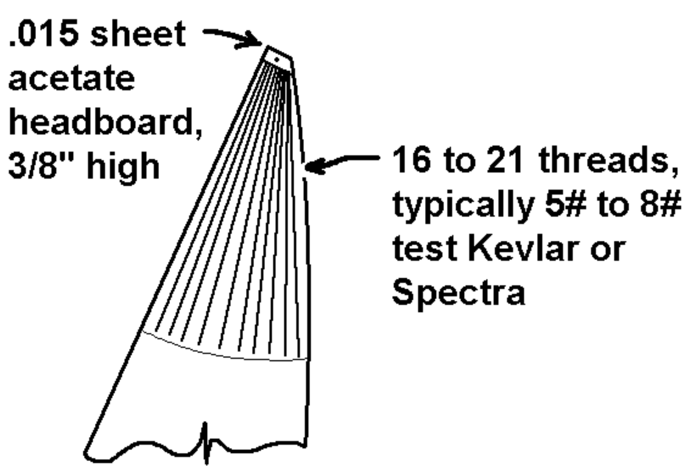
Up to a certain point, I have been able to eliminate the 'w' using a different but unfortunately time consuming method of reinforcing the head (as described in this booklet). The head is reinforced with a series of fine threads that radiate from the headboard. The sheet acetate headboard itself is glued to the threads with *Devcon* Plastic Welder. See **Figure 3**. You might think that this headboard is not strong enough, but I have used this method on quite a few sails since 1992 and have not had a failure. If one were to fail I would regard it as protective. For example, the sheet attachment on a full size jenny is sewn on such that the 'dee' ring is supposed to pull off before the sail is wrecked. (Some lucky guy then gets to drag the sail below and sew the ring back on!)

Rod has recently found a variation of this method that allows him to make a 'string head' fairly quickly, and he now uses it on some of his racing sails. The improvement in the resulting sail shape has been quite significant.

Nonetheless, there still is a maximum amount of curvature that you can effectively induce in the top of the sail and yet not have the middle of the sail too full. (Why you would want to do this was covered in *Part 1*.) If you try to broadseam in too much curvature right at the top, the sail will just not hold out and again something like the 'w' will appear.

Figure 3

The 'String Head'



As a consumer, there is not much you can do about some of the problems noted above, but there is one potential cause of the 'w' that is under your control. Sails that are made with more fullness at the head need to have the headboard aligned with the chord at the top of the sail. This means that mainsails should have a good pivoting headboard. To see what happens if the headboard doesn't pivot properly, set the boat up in the wind and push the headboard to the centerline. Typically, the 'w' will appear.

Jibs present a slightly different problem. If you position the grommet near the aft end of the headboard hoping to support the high leech loads, you will find that the headboard has a tendency to center, again producing a ‘w’. On the other hand, if you put the grommet too far forward on the headboard, the aft end will torque down, and the leech will loose some support. Sails with string heads should have the grommet placed directly under the imaginary intersection point of all the threads.

Incidentally, since the headboard is a miniature version of that overly stiff head patch, I have begun to concentrate all the threads close to the luff so that the headboard can be smaller than the standard ¾ inch allowed by the EC-12 rule. This helps get a better shape. The minute amount of sail area given up is not important in my opinion, but I know many skippers just have to have every little bit of sail area allowed.

Filament Sails

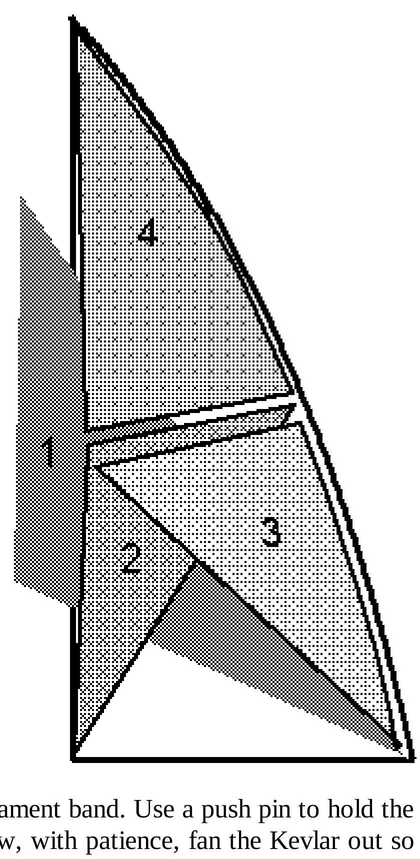
This article will describe what may be moderate improvement over ‘string sails’. I am currently working on methods of reinforcing the sail not with discrete threads or strings, but with individual filaments, fanned out all over the sail. I have only made four or five such sails, but after use for one sailing season, they seem to be effective. At a minimum, there is less need for maintenance.

Since *North Sails* came out with their 3DL® concept, I have wanted to try a similar reinforcement pattern on model sails. After a few attempts, I gave up the idea of molding the sail from one piece of material, but I kept looking for suitable filaments to use in place of the threads that I had been using. (It turns out that North does not really mold sails from a single sheet of material anyway.) Linear filaments without any interweaving would allow the type of reinforcement that I had in mind. I wanted one set of filaments to start at the clew, then fan out terminating up and down the luff. A second set would begin at the clew and fan out towards the center draft stripe. A third set would begin at the tack and also fan out towards the center draft stripe, while a fourth set would begin at the head and fan out to meet the threads from the tack and clew.

I finally found a material close to ideal when Maury Thoresen donated a section of fiber-optic cable. The sort that the telephone company uses. Inside the one inch diameter PVC jacket were about 10 smaller cables, about 3/16 inch diameter. Each of these was filled with a number of individual fiber-optic strands all bundled with a number of individual bands of Kevlar filament, about the diameter of lightweight string. And these filaments were interwoven just enough to keep them separate. They would fan out relatively easily.

Figure 1

Filament Distribution



Working with these individual filaments proved to be a challenge. They fly all over with the slightest air current. They can’t be cut with scissors. Straightening out a few filaments can result in the others becoming a tangled mess.

Instead of describing the early frustrations, I’ll describe my current method. It still leaves a lot to be desired, and it’s still evolving. Also, I don’t have an answer to the issue of the availability of these or similar filaments. But I think that it might be worthwhile reporting what I discovered in making these sails in case others want to experiment.

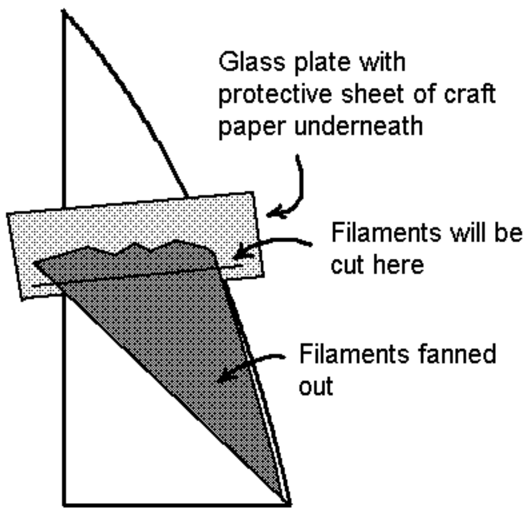
Start with a ‘sail blank’ as described in *Part 1*. You still need to clean the sail blank with toluene as before; however, it’s no longer necessary to support the sail above the work surface. Also, the sail glue for these sails is much thinner. The formula is:

- 40 parts Balsarite (Original Formula)
- 140 parts Toluene, by weight.

Begin applying the filaments by tying two overhand knots at the end of a piece of a Kevlar filament band. Use a push pin to hold the knot to the work surface just outside the very corner of the clew. Now, with patience, fan the Kevlar out so that it crosses the luff from about ¼ of the way up the luff to about ¾ up the luff. It takes practice. This is shown as area # 1 in **Figure 1**. Begin brushing the glue on at the clew and work slowly towards the luff. You should use a high quality ¾ or 1 inch modeler’s brush to avoid snagging the filaments. The glue should be water thin. Glue only about five or six inches at a time to avoid sticking the threads down under tension. Make no attempt to keep the filaments straight. Just push them apart with your fingers so that they go this way and that, but in the general direction of the luff. Before the glue dries, you can further fan out the fibers. Try to avoid bunching them up with the brush.

After the glue dries, place a glass plate under the luff, then cut off the filaments with a sharp razor blade. You cut right on the glass. It's an old modeler's trick.

Figure 2
Using A Glass Plate To Cut The Filaments



Now place the plate of glass on top of the sail as shown in **Figure 2**. Also, put a sheet of craft paper under the glass to protect the sail from the sharp edges of the glass. Again knot the end of a section of the Kevlar, pin it to the clew and fan the filaments out from luff to leech as shown in the figure. Manipulate them with your fingers, on the glass. Glue down in small increments as before. When you have glued to within a couple of inches of the glass plate, place a piece of paper over the filaments (to keep them in place) then cut them off, right through the paper, with a razor blade held against a spline. Remove the glass, smooth out the filaments and glue the ends down.

Now repeat the process with a band of filaments starting from the tack, corresponding to area #2 in **Figure 1**. When this is finished, do area #3, then #4. (For clarity, Figure 1 does not show the slight overlap between the filaments in area #4 and those in areas #2 and #3.) I found that two bands at the top caused the head to become a bit stiff, and were not necessary for strength. So just use one band at the head. With all the filaments in place, brush on a final coat of the special filament glue. Do this in segments as was described for string sails. If you inadvertently tension a few filaments, soften the glue with toluene and simply snip the filaments where they are too tight.

Finish the corners as shown in this booklet and you're done. I now find that although the frustration level can be high when the filaments don't behave, the whole process is much faster than applying individual threads.

I have now made several sets of sails using the methods above, and after one season of sailing, I think that they are slightly more sensitive in very light winds, and they need less maintenance. Speed differentials one way or the other in respect to string sails are not known at present.

String Sail Maintenance and Repair

String sails can be quite durable and long lived if properly cared for. However they do require the sort of maintenance that may not be for everyone. They do not tolerate long periods of flogging. It breaks down the Micafilm and causes the strings to come loose. Snags on docks or other boats can also pull the strings off. Fortunately a lose string is easy to repair, even right at the pond. All you need to do is brush on a bit of thinned sail glue. Either use the 'filament glue' formula (40 parts Balsarite and 140 parts toluene) or cut your string sail glue 50:50 with toluene. It's a lot easier to fix a lose string when it is first noticed rather than wait until a large section of the sail is delaminated.

Even apparently badly damaged string sails can be repaired and still remain competitive. At one EC–12 Nationals, the clew of one of Jerry Brower's jibs was literally torn off as the result of a 'contact'. It was hanging only by its strings. At the beach, the clew was roughly repositioned and covered with a patch of spinnaker repair tape so that the sail could still be used. At the shop, I removed the repair tape by soaking it with MEK (methyl ethyl ketone). and then used the methods described below to fix the damage. That same sail has since had two more seasons of use, including two more trips to the Nationals.

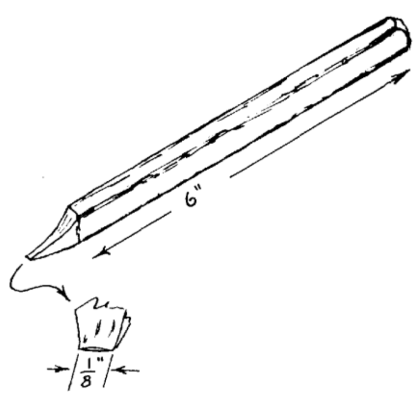
(The following is taken from the chapter on sails in *Optimizing the EC–12*)

Fixing Wrinkles

It's almost impossible to avoid wrinkles, even with careful sail handling. Each event adds a few more until the sail looks terrible. We have developed a homemade "crease eraser" that you hold like a pencil. See **Figure 5**. Place the crease over a piece of cardboard, such as the backing of a writing tablet. The crease must "tent up". Using an Optivisor or other magnifier (mandatory), gently rub the crease eraser along the crease. The radius along the working edge of the eraser is critical. It must bend the crease back the other way in order to remove it. If the edge is too dull it will not work, and if it's too sharp it will damage the sail. The sharpness of a dinner knife is about right. The tool must be applied exactly over the crease, or you will simply make another one. This is not a job to do after three cups of coffee. If you fix the creases after each regatta, you can keep ahead of the game. It takes a little time to fix a long crease. If you wait until your sails look like you slept in them, you will probably not have the energy to fix them.

Figure 5

The Crease Eraser



Fixing Tears

Sooner or later, you will have a major hole or tear to fix. First, remove any creases, as above, so they will not interfere with the repair. Spray a sheet of cardboard or art board with the 3M Artist's Adhesive (No.6065). The sheet will stay tacky for an entire sailing season if kept away from dust. Position the sail defect over the cardboard and brush the sail down as if you were applying wallpaper. The cardboard should adhere only to one sail panel. Do not cross a seam. After you think that you have the area around the defect stuck down in its original shape, brush the material towards the cut. You may find that the margins of the tear or puncture are stretched and will not lie flat. Cut these portions away with an X-Acto knife. You should not have to remove more than 1/32 to 1/16 inch of fabric. The sail panel under repair should now be perfectly flat, as if it were wallpaper. Make your own sail repair tape by applying ¼ inch double stick sailmaker's tape to the shiny side of clear Micafilm. Apply short sections of this custom repair tape with tweezers. If carefully done, even apparently badly damaged sails can be successfully repaired.

Questions and Answers

Thanks to Jeff Proulx and Paul Proefrock for sending their questions about *Part I* as well as other areas of sailmaking and for allowing me to use them here.

Q: How sensitive is the sail to the position of each seam? In playing with the camber prediction graphs from Part I, I found that I could smooth out the curve by moving the seams a bit.

A: It's not worth trying to nudge a seam up or down a quarter inch to get the camber prediction graph fair. In reality, such small changes don't affect much, if anything! I would challenge one to document the effect of moving the bottom seam a whole inch - - maybe two. There also is the question of where to measure the location of the seam. Should the reference point be the top, center, or the bottom edge?

Just mark the desired seam positions at the leech on your sail board, cut the bottom seam and broadseam. Then position that finished seam over your mark for the bottom seam and do the next one up, etc. You make the bottom one first, with plenty of extra material in the panels, because you may have to redo the seam by cutting it out and starting over. The long seams are harder, so do them first. Remember to cut the panels so that they project at least two or more inches beyond the final leech and luff dimensions. When all the seams are done, you then trim to an even margin all around the sail, say 1¼ inches oversize. Then lay out the luff. (If the trim margin is not the same on the luff and leech, you will miss your design luff curve.) When the luff is done, trim the leech and foot to the final dimensions.

By the way, not all my seams are parallel! It started as sort of a joke. The idea was that one could panel the sail as if it were a tiled drainage ditch in order to build in twist. The tiles are wedge shaped where they go around a corner. So I made the bottom two seams parallel to the leech, the top seam parallel to the luff, and the second being in between. I called it the "Drainage Ditch Cut", and some took it seriously. Really. (I don't think it makes any significant difference.)

Q: Why is the bottom panel so large on your sails?

Many dockside observers have suggested that I should use a seam near the foot of the sail instead of having such a large bottom panel. In turn, I ask why one would want a seam there. (Every seam is a chance to screw up!) The reply is often "well, everyone else does it".

To answer my own question, I would consider that you use seams to induce camber. So if you want a seam down low, then you want more camber down low. If the seam is low enough, you want camber that can't be removed by the outhaul. In theory, this can give you a speck of extra un-rated sail area.

So first look at your own sail photos. Ask yourself if you want more camber in the bottom panel, beyond what is induced by the outhaul setting. I have gradually convinced myself that big boat lessons can apply, if you are careful, to EC–12's. Take a look at how flat the bottom of the main is set on many 'grand prix' boats. Notice that many of the hottest boats now have loose footed mains. No "twist foot" whatsoever. Also consider vertical camber. Like a line from mid-foot to the head. Do you necessarily want a bend in this line near the foot?

Nonetheless, if you want a lower seam, go ahead. It will take you a long time, one way or the other, to do enough speed testing to decide if adding a single seam made any real difference. Of course to make an accurate judgement, you will have to adjust the seam above (because of seam interaction) so you are comparing only the change at the bottom of the sail, not the whole sail.

Q: How do you keep the correct mast bend (for the luff curve cut into the main) and still get adjustable jibstay sag? Is there something I can read on this subject?

A: This is a key issue, and it's covered in *"Optimizing The EC–12",* but not all in one place. It's sort of scattered all over. I'll try to do a quick summary here.

If you plan your main for a significant luff curve (in the terminology used in *Part 1*, 'measured luff curve' or MLC) there must always be a fair backstay tension to bend the mast to the correct shape. However, in light air you can minimize this required BST by hooking the lowers forward of the butt of the mast.

Many of the EC-12 mains that I have seen have what I would consider a large luff curve, typically a half inch or more, measured per the drawing on page 25 in *Part I*. Remember that the MLC is <u>not</u> the distance that the luff projects forward of the 'luff line' when the sail is flat on the bench. As you point out, this does limit the control your have over the jibstay tension. I think many sailmakers intend this to make tuning easier. You sort of forget about the jibstay tension. You tune the mast to suit the main and stop there.

For a while, I was cutting the main luff with zero or perhaps 1/16 inch luff curve (MLC). This meant that the jibstay could be very loose if you wanted it that way, and the luff allowance on the jib ('measured luff allowance' or MLA) could be correspondingly high. When the wind comes up, tightening the backstay will restore the jib to a good shape. At this time, your competitor's jib cut with little or no luff allowance (to match a main with a high MLC) will really suffer. To summarize, a low MLC on the main requires a high MLA on the jib and vice-versa.

However, there is one basic problem with the low MLC / high MLA approach. It's a fundamental rule of sailmaking that the greater the luff allowance, the narrower the wind range of the sail. So I am now back to using moderate luff allowances on the jib (say 6/32 of an inch for medium to high winds for the EC–12 A rig.)

Also, we found that when the main luff curve (MLC) was very low, the tension on the lowers had to be quite high. Typically 6#, but at times up to 9#. So I have gone back to a modest luff allowance, say ¼ inch, plus/minus 1/16. This way, the lower tension is less, and since we are tending towards a bit lower jib luff allowance, the slightly higher BST needed to bend the mast ¼ inch is not an issue.

Q: Do you have a good source for sailmaker's tape? The local "big sail maker" doesn't seem to want to sell any. Go figure.

A: The same thing happened to me, until I dropped the hint that we might buy a sail from him! Maybe you could tell him that it's a good way to help cycle his stock so he always has fresh tape. Outdated tape leads to all sorts of problems.

A good source, and the only one I know of for 1/8 inch sailmaker's tape, is Pop Up Mfg. (27 Emerson Ave, Amityville, NY, 11701). I use ¼ inch tape on non-reinforced sails, and 1/8 inch tape on 'string sails'. Remember, on non-reinforced sails stick the Micafilm 'shiny side to shiny side'.

If you are planning to sew seams, sailmaker's tape is a real pain since it gums up the needle, resulting in skipped stitches and puckered seams. You can clean the gum off with lighter fluid, but Rod Carr has another solution. He uses ordinary 1/8 inch 'Double Faced Basting Tape' from a fabric store. Like *Dritz* brand (N-101-8597). Set your zigzag stitch to bridge the tape. Unfortunately, the tape is thick (causing the seams to be a little stiff) and is not completely waterproof (meaning that the stitches should take all the load). Still, all considered, this is a very acceptable way to do it. Do not use this tape without sewing, as the seam may fail.

Q: I have some ¼ inch sailmaker's tape. How can I cut it down to 1/8 inch for use on string sails?

A: Use a balsa stripper to cut the tape to the width you want. (The one made by *Master Airscrew* is very nice, and cheap too.) You don't really need that much tape, so this should not be too hard.

Q: I want to use Figure 8 in Part 1 (showing various sail block choices) to design a sail. What do you think of selecting blocks so that the line on the graph is a 45 degree diagonal?

A: Let me be honest about what the charts really do. They only give a relative prediction of the camber that each seam will cause. The idea was just that you didn't want lot'sa camber, then a little, then a lot, or the opposite. Also note that the effect of the bottom seam can be swamped out by the outhaul setting.

You can't use that graph (or even the 'camber prediction' graph in the appendix of *Part 1*) to predict the actual camber values of your finished sail. (I have tried, unsuccessfully - - just too many variables, I think.) However, if you train your eye and document with photos, you can see relative changes in the sail as a result of block choices. For example the effect of using one block up at the top seam and one down at the second seam is fairly easily seen. Whether that change is good, bad, or indifferent can be difficult to determine!

Q: I used the methods described in Part 1, but my first sail is way too full. What could be wrong?

A: First, is the sail really too full? If you pull both tack and clew tight when checking at the bench (a very common mistake) the sail will appear to have a huge amount of camber. Ease the tension on the clew until the chord of the top seam is about 15 to 20 degrees off with respect to a line between the tack and clew. That is, you hold the sail as if the imaginary boom is horizontal, then ease an imaginary vang. Also, hold your hands such that a reasonably correct outhaul setting is simulated.

If your still are not sure, tape the sail to some sort of stick and hold it up in a gentle wind. (Be careful - - I've damaged a number of new sails this way when they got creased over the stick, or the tape came off and the sail flogged in the wind.)

Secondly, are the blocks dimensioned per the diagram? The blocks are based on a 'bevel angle' and a 'radius'. Could there have been an error in these values? The radius should be straightforward, but is the bevel angle correct? Verify this directly from your blocks, because your table saw gauge could be wrong. Are the blocks 'surface ground' to the correct angle? If you don't do this, and just use the blocks as they were cut with the saw blade, they will produce much more camber as compared to blocks that are surface ground.

Originally, my blocks were used right off the saw, and later I surface ground them to just flatten the subtle hollow cut by the blade. The result was that, for example, a block I called a '72-5' right from the saw became a '72-8' after I surface ground it. That is, I had to tilt the sanding disc to eight degrees to just clean up the '72-5' block, making it a '72-8'. If you are using the sticky block method, the blocks must be surface ground. The sail material will not properly follow a compound curve properly as you place the panel on the block.

Thirdly, before I used the 'sticky block' method I found that I could greatly change the camber produced by a block by gently pushing the fabric away from or towards the crown of the block. For example, you can perhaps double the curve induced by the low camber blocks by pulling the fabric away from the crown just before you stick the seam together. However, the sticky blocks should avoid this problem. Just make sure that you are putting the fabric down without tension or distortion.

Also, if you look at your sail before it is cut to the final dimensions, it will appear to have more camber than you planned. Temporarily marking the final dimensions of the luff and leech on the unfinished blank will give you a better idea of the final shape.

Q: Thanks for the tip on the sail blocks. I had tried to save time and just belt sanded the blocks. When I put them back on the jig and set up a sanding disc, I found that the angles were way off. I've fixed this and re-seamed my sail. It looks great. I am using TRI-SPI fabric. What do you think about not sewing the seams?

A: It's possible that there could be a long-term problem in not sewing TRI-SPI. Sailmaker's tape is very strong when loaded in sheer. But because it's a pressure sensitive adhesive (PSA), it may gradually come apart if there is a load that slowly tries to lift the tape. That may be the case inside each little square of TRI-SPI. That area is naturally depressed compared to the threads. So the little web is being deformed a small amount when it is pressed into the PSA. In time (like several years?) it might separate. It's just something to be aware of.

Q: By the way, I found that if you saturate seams with MEK (methyl ethyl ketone) you can take them apart and reuse the panels. Do you see any problems with this?

A: Good idea! If you use clear Micafilm for sail material, you need lots of MEK so that you don't accidentally stretch the material. (I've made that mistake, so If I can, I just cut the seam out.)

Q: What method do you use to determine batten placement for EC–12 sails? How do you make them?

A: Traditionally, battens are evenly spaced along the leech and are perpendicular to it. The EC–12 rule says that four battens are required for the main and jib battens are optional. When 'maxi-roach' sails were permitted, main battens may have served some purpose, but in my opinion that is not the case now.

Decide this for yourself by setting the boat up in the wind and checking the shape of the main without battens. If you made the seams properly and the sail material was not curled, the sail should look fine. Now stick some sheet acetate battens on with sailmaker's tape, and ask yourself if there is any improvement. (I never see any, unless the sail had a problem to begin with.)

If you really want to use battens, an easy way to make them is to apply sailmaker's tape to sheet acetate (0.015 inch) or sheet polycarbonate. Then cut the battens out and apply, making sure that the leech is not wrinkled when you stick them down.

If you don't want functional battens, you still want to comply with the EC–12 rule. It says that you must have main battens, but the material is unrestricted, and only a maximum length is specified. Not a minimum. To meet the rule requirement, I use strips of *MonoKote* self adhesive trim material as battens on the main. Nothing on the jib. Rod Carr is currently using rather long strips of 0.010 sheet polycarbonate for main battens. He is doing it not for shape, but to preserve the life of the sail, based on some tests where he taped the material to his car antenna. (Lowell North style!)

Nonetheless, I have had several of my older sails fail (rip!) right at the forward end of the batten when I didn't use a large enough patch of stickyback to protect this area. In terms of durability, the sail should never be allowed to flog enough to duplicate Rod's test. If you do use functional battens stuck on with sailmaker's tape (and I don't know why you really need them on a '12) make sure to use a good size patch (say ¾ inch diameter) covering the forward end of each batten.

Q: Should I use batten pockets?

Concerning batten pockets, sewn or otherwise, let me be bold and say 'don't do it'. Batten pockets are a very common cause of sail discontinuities. Some of this comes from the application of the pocket, and some comes from the batten itself.

Imagine a perfectly shaped sail with a batten pocket attached on one side, with no batten in it. Now put a batten in and note how the fabric now must go around the batten. This is a longer path than before, and the effect is the same as making a small tuck in the sail. A little tuck right at the leech is not a big problem, but think of what happens at the forward end of the batten. Here the little 'tuck' just stops. It's a discontinuity. You could taper the forward end of the batten to a point, but then, is the batten really doing anything? Pull it out and find out.

Here is another thought on battens. Some like to think that they create a flat exit on the sail and push the draft forward. Experiment with this while your boat is set up in the wind. Squeeze the back of the sail between two straight sticks and watch what happens. Typically the sail shape will be changed only in a small area around the sticks. So four battens will not change the whole shape of the sail. They will only affect it locally. Is this good or bad?

When there is a discrete change in the foil shape at the trailing edge, a vortex is created. (Watch a jet land when the humidity is high to see an extreme example of this.) An extra vortex that you don't need is just extra drag.

Q: I have problems with wrinkles radiating from the clew up towards the mast. How do I correct this?

A: Those wrinkles radiating towards the mast are called 'overbend wrinkles'. They indicate that in relation to the luff curve of your main, the middle of the mast is bent too far forward. It's overly bent. Furthermore, the overbend is located roughly where the wrinkles point. To fix this, you need to tighten the rigging that supplies the aft force in that area. On an EC–12, there are three separate controls that supply such aft force, each in a different area: the lower-lowers, the lowers, and the jumper struts.

Sometimes the cure is a bit more subtle. For example, if you have overbend wrinkles that point at the spreaders that will not go away even with very high lower tension, you may have the uppers set way too loose. Tightening them should solve the problem.

Q: How do I determine the correct luff curve for a main that I am making?

A: Here is a slightly different look at the problem, which was addressed in an earlier question. There is no 'correct' luff curve. Your choice should match the way you want to tune your mast. Once the luff curve is cut, your job is then to bend the mast to match. But each mast (with its rigging setup) will have only a limited range in which it can be bent.

The simplest option is to cut the luff curve, as described in *Part 1*, for a straight mast. The 'measured luff curve' (MLC) will be zero. This will allow you to set a very low jibstay tension for light air and still retain the proper mainsail shape without much fuss tuning the mast. As the wind gets stronger, you need more and more jibstay tension (which you set via the backstay). Because of the fractional rig on an EC–12, you then need higher and higher lower tensions. We have used up to 10 pounds tension on our lowers for mains with a zero MLC. However, in maximum A rig conditions we sometimes just couldn't keep the mast straight.

Another option is to use a large MLC, as do some commercial sailmakers. Say over ½ inch at mid luff. One claim for this sort of curve is that it automatically makes the main fuller as it is eased for a reach. This happens because as the main is eased, the mast becomes effectively more straight, becoming dead straight (in relation to the main luff) when the main is out 90 degrees.

The trade-off is that you are giving up projected area when running dead downwind. Curvature is nice, but I think projected area probably overrides when running. Also, with a large luff curve, the load path from the head to the tack no longer runs right along the luff. If the downhaul is a bit tight, this can cause a 'shelf' or bad deformity to form behind the luff when reaching or running.

Some commercial sailmakers might choose the high MLC option because tuning is easier. You just tighten the backstay until the mast bend matches the sail. Control of the jibstay tension is not really considered. It's much simpler for a newcomer to set his boat up this way.

My preference for EC–12 mains is a measured luff curve (MLC) of perhaps 3/16 to ¼ inch. This amount will allow backstay tensions down to the minimum that we use (¾ to 1 pound) and still achieve a proper mast bend. In this way, we do have control of the jibstay tension. That in turn allows us to cut a moderate luff allowance in the jib. The result is that adjusting the backstay will now allow the jib to set properly in light winds as well as strong. If you always need a moderate backstay tension to bend the mast to a high MLC, you can't always tune the jibstay sag to match the wind.

As the wind comes up, we apply more and more BST, based on our tables. (The backstay tension table is described in *Optimizing the EC–12*.) The mast then overbends, so we remove the overbend by tightening or repositioning the lowers, tightening the jumpers if necessary, then the lower-lowers. The lowers pull the mid portion of the mast aft based on how far aft they are located on the chainplates. Expect to spend a fair amount of time finding the right positions on the chainplate that result in the correct fore and aft mast bend, while at the same time keeping the mast straight laterally. (Some like to allow the mast tip to fall off a little to leeward.)

The MLC that you choose will determine (along with some other factors, like rig stiffness) where the lowers must be placed on the chainplates. For example, an EC–12 main with a 1/16 inch MLC might require that the lowers be placed two inches behind the butt of the mast, and that very high lower tensions be used in heavy winds. On the other hand, a main with a 5/16 inch MLC might require that the lowers be positioned directly aft of the main shrouds. You should now see why a close hole spacing on the chainplates is desirable. I like 3/16 inch on center.

Q: I understand how you can lap seams on a curve to get "belly" in a sail. From pictures in different books and articles, it looks as if you are curving one edge and not the other. What is the proper manner to broadseam?

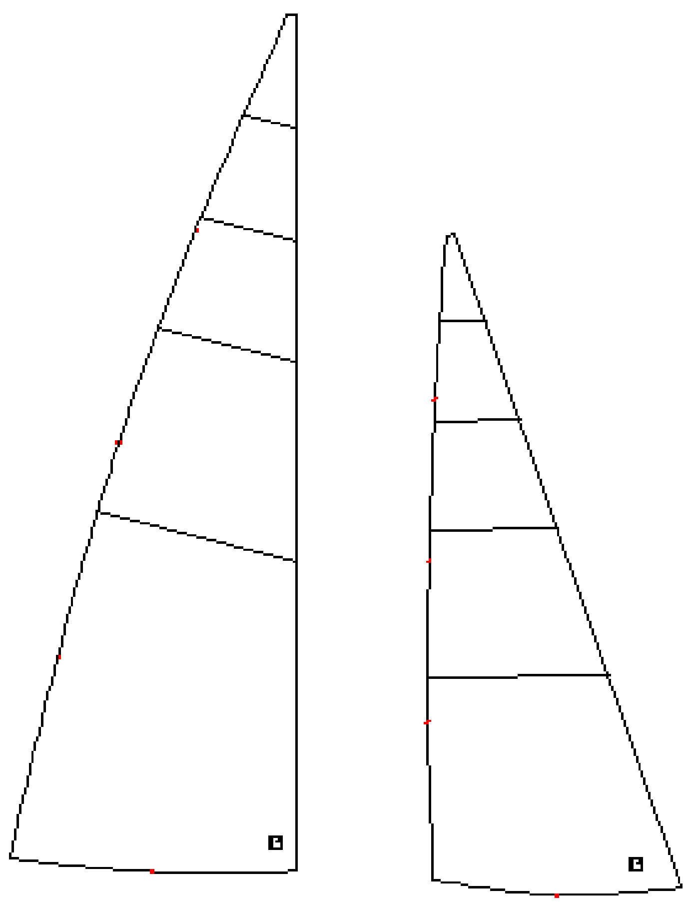
A: Traditionally, sailmakers made the broadseam by marking a curved line just inside one edge of a constant width panel, applying sailmaker's tape, then sticking the adjoining panel down along the line. The seam is then sewn. You could curve the edge of that second panel, but it would just be more work and not really affect the seam. This is the result of the very shallow curves that are used and the natural flexibility of the materials. Notice that the block system described in this booklet in effect curves both panel edges. Not a big deal one way or the other.

Q: When broadseaming sails, the amount of seam "overlap" determines the curvature and subsequent draft. This amount varies with the actual length of the seam and the amount of curvature. What is a typical amount?

A: A typical EC–12 main of mine might have ~0.1 inch broadseam at the bottom seam, and the top seam can have as little as, say, 0.02 inches. Yet these small amounts do produce a sail shape that has been effective. I think that trying to manually position panels to these small dimensions will very likely result in wavy seams. So knowing the actual amount of broadseaming is not required. It is predetermined by the block choice for that seam. (I did make an Excel worksheet that would compute the broadseam at each seam, but I didn't find any real use for it.)

Figure 1

Scale Diagram: EC–12 A Rig



Jeff Proulx, 10-98

Q: what do you think of using 3M Adhesive Tape to make my seams? I have also heard of people using Balsarite. Comments?

I would not recommend the sole use of Balsarite for seaming. If over-sewn, it might be ok. If you are not going to sew your seams, I would rely on real sailmaker's tape. It stays flexible and is designed for the purpose. (At present, the big lofts are spending lots of money trying to find a better tape that will allow them to dispense with sewing altogether.) If there is no sailmaker nearby that will sell tape, you can order it from Herman Berger (Pop Up Mfg.)

Q: Could you illustrate an "A" set of sails for an EC–12 showing where the seams are and how much broadseaming exists at the luff, leech and midpoint?

A: Jeff Proulx has kindly let me borrow a scale diagram (**Figure 1**) that he prepared with AutoCAD, based on the seam layout of one of the suits that I made for Jerry Brower. But specifying the broadseam in inches would suggest, wrongly, that the block system is not needed. For me, the actual amount of the broadseam is of no interest when you are actually making the sail. It's all in the blocks. They repeatedly and accurately do all this for you.

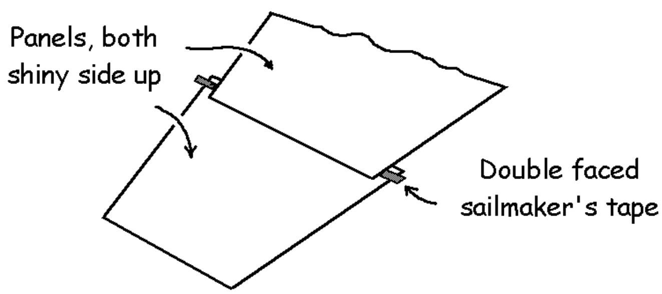
Q: I am not quite sure about the orientation of the panels when making string sails. Could you clarify?

A: If you are making conventional sails with Micafilm, not reinforced throughout with strings, the shiny side of one panel should be bonded to the shiny side of the adjoining panel. This is done because sailmaker's tape doesn't stick that well to the fuzzy side of the material, at least in the long term. The result is that when finished, the sail has alternating shiny and fuzzy panel surfaces on each side of the sail.

String sails however, have lots of fibers crossing the seam, so the strength of the tape bond is not as much of an issue. If you put strings on a conventionally paneled Micafilm sail, they would alternately cross shiny and fuzzy panels. Since strings glued to the fuzzy side can eventually curl the leech, this is not a good idea, at least when using Balsarite as the base for the sail glue.

Figure 2

Panel Orientation For String Sails



Therefore, the sail is made with the shiny surfaces of the panels facing all facing the same side of the sail. See **Figure 2**, compliments of Jeff Proulx.

In this situation, the seam bond will be shiny side to fuzzy side. As mentioned in *Part 1*, to help the sailmaker's tape bond to the fuzzy side, brush two coats of sail glue over the portion of the fuzzy surface that will be in contact with the tape. Let the glue dry completely before applying the tape.

(I am just now experimenting with *Stix-It*, made Sig Manufacturing, which may not cause curling. This might allow the fibers to be bonded to the fuzzy side, resulting in better adhesion. I do not know yet if this will work, so I am not recommending it.)

End