Chapter 4

Sailmaking

The hallmark of the small-boat sailor is self-sufficiency. Most of us try our hand at cabinet work or other interior 'improvements', install instruments and repair rigging. Some even find the time and energy to build their own boats. Yet we are usually content to leave sailmaking to the professionals, regarding it as some sort of a cross between a black art, with hidden secrets handed down from one generation of craftsmen to the next, and a high-tech industry requiring specialist skills and precision equipment. This is to some extent true. Sailmaking is engineering with cloth, and it takes an experienced commercial loft to produce a good suit of racing or high performance sails, or large ones of any sort; and generally speaking only the professionals have the necessary floor space and facilities for handling large areas of cloth, and machines that can work with heavy materials. But there's nothing particularly difficult about making sails for a dinghy or a small cruising boat, and more often than not it proves to be a very interesting and satisfying enterprise for the amateur. Besides saving money, it helps him to appreciate more fully the functioning of the rig as he watches his own handiwork drive the boat.

Sailcloth

There are two vital ingredients in a successful sail: what it's made of, and how it's made. The sailmaker's contribution is to transform lifeless rolls of flat cloth into living, responsive sails, designed for maximum performance and reliable service. But even the most skilled craftsman can't make good sails from poor cloth or material of the wrong type. That may sound obvious, but the current pace of technological development, not to mention a certain amount of advertising hype, has led to some confusion over just what material is the most suitable, and bargains of uncertain origin have all too often led to disappointment and wasted time. It pays to play safe by selecting a brand-named cloth from one of the leading manufacturers, and making certain that its specifications are suited to the shape, cut and duties of the sail it will become, and the conditions under which it will be used. Cost, though important, should be a secondary consideration.

The number of different cloths on the market runs into hundreds, but

they can be grouped under three main categories: polyesters, nylon, and the various laminates. Each has a different form of construction and physical properties that govern its performance and may affect its suitability for any particular type of panel arrangement or working conditions. The first two are woven fabrics, and as such are by far the most widely used in yachting and best suited to amateur sailmaking, while the highly specialised and much more expensive laminates are generally reserved for racing boats, large cruising craft and board sails.

Woven cloth is constructed of warp and fill (or weft) yarns, interlaced at right angles to each other along the length and width of the fabric respectively. (Think of warp as a rope and it's easier to remember which is which.) Loads that are parallel to the warp or to the fill cause only slight elongation of the yarns, but those that are not produce considerable bias distortion at 45° – diagonal stretch – which increases with the strength of the load. This spoils the original optimum shape of the sail, with a corresponding loss of efficiency. On the other hand, a certain amount of stretch can be more of a help than a hindrance for cruising. When used intentionally, for example in tensioning the luff to draw cloth from other parts of the sail and pull the draft forward (and provided that other areas such as the clew are reinforced against unwanted distortion and wrinkles), a cruising sail becomes more versatile.

Besides being heavy, unwieldy and prone to rot, sails made from natural fibres such as flax and cotton used to stretch permanently out of shape in a hard blow. This didn't matter very much on a square-rigged ship, but fore-and-aft sails needed recutting every so often to regain any semblance of their original performance. These materials are only used nowadays in preference to synthetic fabrics where authenticity is the prime consideration.

Polyester

Polyester yarn, on which much of today's sailcloth is based, was developed in the 1940s and 1950s by ICI Fibres in Britain, where it is known as Terylene®, and by DuPont in America, under the tradename Dacron®. There are half a dozen other manufacturers of polyester cloth in other parts of the world, each with their own name for it.

The choice of characteristics in a cloth starts with the yarn, which is formed from bundles of continuous extruded filaments of a plastic polymer. First its thickness and hence its weight (a figure expressed in 'decitex', the metric equivalent of denier) is selected for the warp and fill, which are usually different from one another. Each thread is made up of a specific number of filaments – typically 6000 to 8000 – twisted together, and whose count will affect the fabric's performance. In addition, the yarns themselves may be twisted, and two or more can be plied together, further affecting the properties of the finished fabric. Stretch along the cloth also depends on the degree

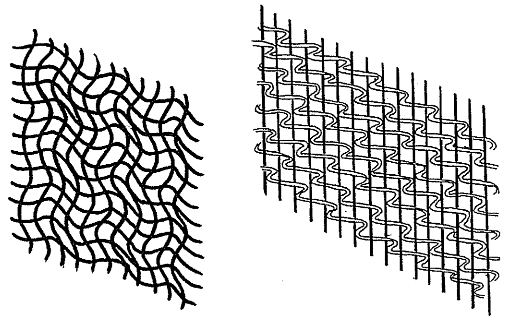


Fig 4.1 Crimp, the corrugated shape which the warp and fill yarns are forced to adopt as they go over and under one another in the loom. The relative amounts of crimp directly affect the bias characteristics of the cloth. *Left:* Balanced weave, warp fill yarns have equal amounts of crimp. *Right:* Vertical yarns are straight for minimum stretch in this direction, with crimp restricted to the crossing yarns.

to which the fill yarn distorts the warp as it goes over and under it in the loom, and vice versa. The resulting corrugated shape which the warp and to a lesser extent the fill yarns are forced to adopt is known as the 'crimp' (Fig 4.1). Their tensioning has to be precisely controlled during the weaving, since the relative amounts of crimp directly affect the all-important bias stretch.

In high aspect ratio sails, such as tall and narrow blade jibs and mainsails with long luffs and short feet, most of the stress is imposed down the leech, so its fabric needs to resist this with low-stretch, high-decitex fill yarns with the minimum of crimp. Such a sail will usually be cross-cut, so as to align the fill from head to foot. Bias stretch is less important, because the central area of the sail is comparatively small and not under high stress, and the fullness here can be controlled by using mast bend and Cunningham controls. In low aspect ratio sails, however, such as overlapping genoas, the large central area is under more stress than the leech, so bias stretch is reduced by using a more balanced construction with heavier decitex warps and crimping the fill yarns, making the fabric more suitable for vertical or radial panel layouts.

Newly woven material, known at this stage as 'greige' cloth (a term derived from the old French word for raw silk), is then scoured to remove the size that was applied to the warp yarn to lubricate it during the weaving. If dying is required, this is when it is done. Next the greige is impregnated with melamine and other resins chemically similar to it to act as a filler, together with an ultra-violet inhibitor to help protect it from the degrading effect of sunlight. When heated, the yarns shrink and bulk up, the filler becoming as one with them, reducing the movement between them and producing an altogether stronger, tighter and more stable weave. Some cloths are further stabilised by depositing a thin film of resin on the surface of the fabric to produce a particularly firm finish. The more resin that is added, the stiffer and

more stable the cloth becomes – and the more prone to damage, as the resin can break down with hard use. Intricate control of the yarn tensions is again essential at this stage, for it continues to affect the characteristics of the cloth until, once the heating process has locked up the crimp, they become permanent. This is important for stretch recovery, because it gives the fabric a 'memory', so that it always wants to regain the precise shape of the weave.

Heat setting is also the key to its ultimate durability, since in chemically bonding the filler to the polyester it becomes part of the fibre structure. A sail made from a firmly finished, stable cloth, will set well and hold its shape, but tends to be stiff and crackly, and doesn't suit every application. For example una-rigged dinghies, such as the Finn and Laser, need greater bias stretch for the wide range of mast bend over which the same sail has to operate. Cruising yachtsmen generally prefer a soft finish because it also furls well and is easier to stow. Finally the cloth is 'calendered', being pressed through heated rollers under tons of pressure to flatten the weave and consolidate its structure by sealing the interstices between the yarns. This reduces the porosity of the fabric, glazes its surface and makes it feel smoother to the touch – the 'hand', as it's known. The selvedges are then trimmed to conform to the standardised 36 in (92 cm) or 54 in (137 cm) widths, and heat sealed.

Nylon

Originally a DuPont tradename, nylon has long since become a generic term. It is a thermoplastic polymer similar to polyester, extruded and drawn in the same manner, but woven into a cloth with very different characteristics. It is no accident that nylon is universally used for spinnakers, whose requirements are totally different from those of fore-and-aft sails. Weight is of prime importance, because as well as the problem of carrying it so high up above the deck, a spinnaker depends on the wind to keep it full and maintain its shape, being fixed only at head and tack. The lighter the sail, the less wind is needed to fill it and the more efficient it will be; and the lower its porosity, the more it will remain pressurised at low windspeeds, especially when the pole is squared off and the apparent wind angle increases. So light airs and general purpose spinnakers are specially coated to reduce their porosity to zero. (The heavier yarns and tighter construction used for racing reachers and heavy weather runners, or for very large spinnakers, make such a coating unnecessary.)

Since the dimensions of a spinnaker are not determined by a mast and boom, stretch has to be accepted and controlled, rather than minimised or eliminated as in the case of fore-and-aft sails. Most sail nylon is warp orientated, but because it stretches so much more than polyester it is better able to absorb the energy from the frequent shock loads as a spinnaker collapses and refills. It also has good tear strength and resistance to abrasion, but is weakened by exposure to sunlight to a much greater degree than polyester.

Polyester laminates

Laminated fabrics have very little in common with their woven counterparts. The problems of crimp and bias stretch have been solved by laying straight yarns in the required direction and not weaving them at all. Instead they are held in tension and bonded to one or two thin plies of polyester film (usually DuPont Mylar®) which has the same strength in all directions. This forms a composite warp- or weft-strong sandwich, its resistance to stretch without any crimping being entirely due to the stretch resistance of the particular yarn used and the orientation of the fibres.

Another fundamental difference between laminates and woven cloths is that the former are able to operate much closer to their tensile strength limits, because of their low stretch right up to almost the point of failure, whereas for safety reasons woven cloths have to be used well down their tensile strength curves to give a suitable stretch performance. Laminates therefore offer clear advantages in weight savings, particularly aloft. On the other hand they have lower safety margins and leave less room for error, with an increased chance of catastrophic failure if the sail is used outside its recommended operational limit, besides being more susceptible to wear and tear.

Polyester was the first of these reinforcement materials and is still the most widely used on account of its good all-round performance and comparatively low cost, although all laminates are more expensive than woven fabrics. Moreover, the Mylar® itself is not so highly resistant to bending and flexing as polyester yarn, and therefore needs protection and careful handling, with loosely woven taffetas (uncalendered cloth) often being included in the sandwich to provide extra strength and longevity. And because of the inert nature of the film surface, complex chemical systems are needed to bond it. Overall, because of the high cost of laminates and with certain exceptions their shorter working life, their share of the sailcloth market remains limited.

Kevlar®

The search for materials with less stretch and greater strength than polyester led to the development of a range of so-called exotic yarns and their laminates. Best known of these is Kevlar®, DuPont's tradename for their golden coloured aramid. Not only is it 2½ times stronger for the same weight as polyester, so that sails made from it can be much lighter, but more importantly its resistance to stretch is some five times greater, and its high dimensional stability means that it will not 'creep' and permanently deform during extended periods of high load. Small wonder, then, that Kevlar® was considered revolutionary when it was introduced by Hood in 1972, first as a woven cloth and later as a Mylar® laminate.

Unfortunately, however, Kevlar® is also considerably less durable than polyester, due to its poor flex-and-bend performance – the ability to retain its strength after repeated folding or flogging – which makes it unreliable and totally unpredictable in terms of fatigue failure. Added to this is its high cost, poor resistance to abrasion, and an exceptionally high rate of UV degradation, losing around three-quarters of its strength after only four months of exposure to sunlight. Technora®, a similar aramid sailcloth made by the Japanese company Teijin, is dyed black to improve its UV resistance, and has a slightly better abrasion resistance, but it costs more than Kevlar® and is inclined to 'creep' (stretch permanently).

Spectra®

Much more durable (and even more expensive) are two recently developed polyethylene yarns, Spectra® from Allied Signal and Dyneema® from the Dutch company DSM. They withstand abrasion, stress flexing and UV exposure better than Kevlar®, and result in a fabric that is 40% stronger, one-third lighter and three times more stretch resistant than Kevlar®. Size for size, a Spectra® rope is as strong as steel – and floats. Unfortunately, however, these yarns are unsuitable for racing because of excessive creep, with sails quickly losing their designed shapes. But they are capable of handling the massive loads found in the sails of large cruising yachts where cloth strength, durability and weight aloft are more important than either cost or the last fraction of performance. They cannot be tightly woven in the way that polyester can, due to their slippery nature, nor can they be heated to shrink and tighten the weave, because of their low melting point. So they are used in the form of structural scrims and laminated to Mylar®. (A scrim is an open-weave fabric with measurable spaces between the yarns. Two Mylar® films encasing a scrim actually touch each other in these spaces, bonding the yarns very securely.)

Alternatively, in order to avoid Mylar's® shortcomings, they are inserted as minimally twisted yarns between two layers of woven polyester. One side is a heavy decitex, tight weave for the low-stretch property that Mylar® would have provided, the other a taffeta scrim of polyester as a backing to hold the polyethylene yarns in place. The process, termed warp insertion, gives substantial weight savings with great strength and stretch resistance, yet the cloth remains pliable for easy handling and roller reefing, and has the potential to last as long as conventional polyester fabric.

Carbon

Carbon fibres have been used, with varying degrees of success, in top level racing such as the 12 metre campaigns for the America's Cup. They have an extremely high ability to resist stretch, which is why they are used to reinforce epoxy composite spars and hulls, but they are so brittle that if you try to fold one in your fingers it will snap almost immediately. So sails incorporating carbon are fragile, to say the least, and require such careful handling as to make them totally impractical for everyday use.

Vectran®

This is the latest super-yarn to arrive on the sailing scene, produced by Hoechst-Celanese. Spun from a liquid crystal polymer, it has the low-stretch performance of Kevlar®, better flex and abrasion resistance, UV properties similar to those of polyester, but the highest cost of all the performance fibres. Unlike polyester, however, it doesn't creep. For racing sails, it is applied in the form of a stabilising diagonal grid across a Kevlar® warp and fill, sandwiched between Mylar® film and a base fabric of woven polyester. In a further technological advance, Hood Textiles have succeeded in interweaving Vectran® yarn with a high-tenacity polyester to produce a much softer and more durable material than the laminate, and one that can be used for roller furling sails. Although costing considerably more than straight polyester, sails made from woven Vectran® hold their shape better, besides being lighter and stronger. It may well prove to be the ultimate cruising sailcloth – for the time being, at any rate.

Choosing the cloth

The amateur sailmaker would be well advised to steer clear of laminates and exotic fabrics. Most of them are not only unsuitable for the small cruising boats and knockabout dinghies whose sails he would be capable of making, but they are difficult if not impossible to buy in short lengths and awkward to sew. Besides this, their high cost can make mistakes very expensive. Better to choose an ordinary woven polyester with a reasonably close, tight weave that won't distort badly under load. Try pulling the cloth at 45° to the threadline. It should have a certain amount of give, but feel stable and secure, and the resulting crease should largely disappear after the tension is released. If it doesn't, or if the weave feels coarse and tends to open up, give it an extra tug to see what happens. If you're not sure what finish you are looking for, it's a good idea to compare the cloths used on one or two boats similar to yours. (This doesn't, of course, apply to nylon. There are seldom any problems with spinnaker cloth, provided you select the right weight, but it might be worth blowing or sucking through it to check its porosity. A lightweight nylon shouldn't be porous at all.)

Another test is to repeatedly twist and crumple it in your hand and see whether it crazes. (Lowell North used to tie a sample to his car radio aerial and observe the results of violent fluttering after some fast journeys between home and office.) The cloth may appear to be well enough finished, but if it was poorly woven in the first place, its initial stability may only be temporary, performing well at first but deteriorating rapidly with use. With too firm and harsh a finish, a sail will be difficult to fold and prone to damage. Too soft, and despite being aesthetically pleasant to handle and easy to fold and stow, it will be unlikely to last more than a season or two of hard sailing without becoming baggy.

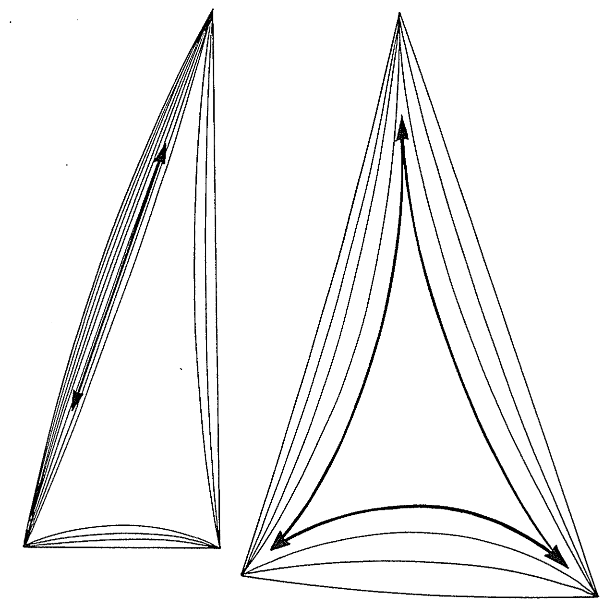


Fig 4.2 Sail stress distribution. In the high aspect ratio mainsail *(left)*, the catenary lines show the major load paths lined up with the leech. In the low aspect ratio genoa. *(right)*, the loads are spread throughout the sail.

The dimensions of a sail largely determine the distribution of the stresses within it, and hence the most suitable form of construction and finish for the cloth. Using computerised stress mapping to determine the direction of the loads, weaves can be tailored to suit the way in which the cloth will be used by varying the relative size, spacing and crimp of the warp and fill yarns, and by orienting them in the appropriate direction when the sail panels are cut.

The key factor is aspect ratio, as we saw earlier. In the high aspect ratio mainsail we looked at, or a No 3 jib, short on the foot and long on the luff, the primary loads are lined up head to clew along the leech, with comparatively moderate forces acting on the bias in the middle of the sail (Fig 4.2). This calls for an *un*balanced cloth construction, with low-stretch high-strength yarns tightly woven with little or no crimp, into a high density, low-decitex warp. Tight separation, further stabilised by heavy resination, means that as the fabric ages its stretch properties will change very little, allowing the sail to maintain its designed shape over a wide range of working conditions.

At the other end of the scale is our low aspect ratio genoa, whose sheet lead virtually bisects the angle of the clew. The loads are more evenly distributed, fanning out radially from clew and tack towards the head and requiring good stretch resistance in both fill and bias directions. This is achieved by using a balanced construction, with warp and fill yarns of similar decitex and count, and only light resination. Peak directional performance is deliberately compromised by crimping so as to increase bias stability, the shared crimp creating more contact surface between the yarns, which in turn mechanically reduces bias movement. These balanced cloths, with their even stress response, are also well suited to gaff and other four-sided sails, and in the lighter weights make good jibs for dinghies with short, wide foretriangles.

In between the two, there are a number of general purpose fabrics using high tenacity yarns in a moderately unbalanced construction, with the fill tending to be slightly the stronger threadline. Tightness of weave and the amount of resination is varied according to the bias stability required in terms of stretch and the ability to return to normal after repeated elongations. The more unbalanced the construction, the greater is the tendency for the sail to develop a tight leech after some use, whereas with the more evenly balanced 'blade' cloths, the draft tends to stay forward with an open leech. These are excellent for mainsails with modest aspect ratios, particularly those with short battens; in the lighter weights for dinghy mainsails; and on cat-rigged boats and those with fractional sailplans featuring a long-boomed main and a small non-overlapping jib.

If the budget allows, it is always worth paying a bit extra for material from a well known company such as Bainbridge or Hayward, with the dependability that such names ensure. Hayward*, incidentally, are one of the few manufacturers from whom you can directly obtain small lengths, the majority supplying only their account customers, the professional lofts and wholesalers. You would be unlikely to find any of the big lofts willing to sell you a bolt end of cloth, since they can hardly be expected to encourage amateur competition. But if Hayward don't happen to have what you want, or a small length proves too expensive, it would be worth approaching one of the smaller sailmakers who might have some leftovers on his hands, or asking around the general chandlery firms.

Estimating the yardage

The most common widths of polyester are 36 in and 54 in, with 54 in for virtually all the laminates, and 41 in or 54 in for spinnaker nylon. There is no need to allow for stretch in polyester when estimating the quantity you will need for each sail. But to be on the safe side, it is as well to make the luff in particular an inch or two shorter than the plans show, for there's nothing more frustrating than hoisting your new sail hard up to the halyard sheave, only to find that the luff is still slack.

To determine the area of a sail based on an approximately right-angled triangle, such as a Bermudan mainsail, assume that the sides are straight and multiply the height (luff) by half the base (foot) length. For a sail with no right-angle, such as a typical headsail, again assume its sides to be straight and draw a line from the clew to join the luff at 90°. The area will be the length of this line, times half the luff. For a four-sided sail, cut the outline shape into two triangles and add their areas together. It is difficult to determine the areas of the curved surfaces of a spinnaker, but fortunately nylon is reasonably inexpensive and you won't be wasting much cloth if you multiply the luff by the foot and take three-quarters of the result.

Dividing an area in square feet by nine gives the number in square yards and hence the length needed in a 36 in width; pro rata for 54 in cloth. To this figure must be added a substantial allowance for seam overlaps, tablings, reinforcement patches and reef points, and for roach. In America, where most of the cloth comes from, a yard run – on which the weight is based – has long been counted as 28½ in, the reason being that the cotton cloth for sailing ships was woven 28½ in wide, while its weight was measured per running yard. Using this figure, known as a 'sailmaker's yard', results in an apparent discrepancy of about 28%. To arrive at the length of cloth needed in this measure, you should add 50% for an averagely reinforced sail with a reasonable amount of roach, and anything up to 100% for a heavy weather sail with extra-strong reinforcements and multiple reef points. Use half these percentages if you want the answer in the ordinary English yards used by most British sailmakers. Just to complicate the matter of American weights still further, particularly as they apply to spinnaker cloth, the weight is quoted – for the benefit of owners demanding the lightest possible fabric – for the cloth as woven, before it is shrunk and finished. So although described as ½ oz, it may weigh as much as ¾ oz American or 1 oz per English yard. Cloth is also sold in metric lengths but English widths; in which case multiply the length by 1.3 to arrive at square yards and proceed as before.

Cloth weight

From one standpoint, the lighter the cloth the better, for not only is it easier to sew, but the sail will be easier to handle, set and stow, and will fill in light airs that would scarcely pull the creases out of a heavier one. Another factor to consider is weight aloft. A sail may not feel heavy to lift off the deck, but it can exert considerable leverage when set on a tall mast. A boat needs to be sailed as upright as possible, and minimising the weight of the rig helps reduce the overall heeling and pitching forces acting on it. Just as this is necessary on a high performance, highly tuned racer to enable the sails to work efficiently, so it is on a cruising boat in the interests of safety and comfort aboard.

However, by far the most important consideration in choosing the weight of the cloth is its resistance to stretch. Since for any given type of cloth, the

* Richard Hayward & Co, Tiverton, Devon EX16 5LL, England.

lighter it is the more readily it will stretch, the weight determines the effective range of winds in which the sail can be used. The minimum windspeed is that which is just sufficient to fill it to the designed shape; below this, it will simply sag under its own weight. The upper limit is reached when the sail, already reefed, needs to be taken down to avoid permanent distortion. Other factors relating to stretch are the area and profile of the sail, since this affects the wind pressure acting on it, and the size and type of boat. Clearly a heavy, beamy cruiser with a powerful righting moment will require stouter sails than a slim round-the-buoys racer of similar length.

Some boats carry more or less sail than the average, so it can be misleading to use sail area as a parameter in deciding on the optimum weight of cloth. Instead, waterline length, being a fair indication of the size of a yacht, is a better and more convenient yardstick to use for the working sails. The figure can be varied up or down if the boat is particularly light or heavy for her size, if possible making some allowance for the weather conditions she can be expected to meet and the way she is likely to be handled.

The mainsail cloth for a ketch or a yawl can in theory be a little lighter than a sloop's, being a bit smaller; but it's usually best to play safe and use the same weight, because it probably won't be reefed quite as often. Similarly, it makes sense for a mizzen, despite being even smaller, to be made of the same cloth, because except on boats with particularly broad and buoyant sterns, the chances are that it will be used in a gale long after the main has been taken down. Headsails are a different case, for although boat length again exerts an overall influence on their size and weight, there are obvious differences between masthead and fractional rigs, sloops and cutters. Generally speaking, the larger the headsail, the lighter its cloth can be, because the sooner it will be changed for a smaller one in freshening winds. The exception is a genoa, especially one with a large overlap. Since this is often left on to drive the boat after the main has been reefed right down, or in the case of a roller furling genoa, used part-rolled as the wind increases, it needs to be as heavy as a working headsail, or for the leech area of the roller sail to be made of heavier material than the luff.

Weight measurements

Although the American sailmaker's yard is currently the most commonly used measure of sailcloth weights, you are increasingly likely to find them expressed in grams per square metre as metrication becomes more widely adopted.

- To convert oz per sailmaker's yd into oz per English yard, multiply by 1.29 (divide for vice versa).

- To convert oz per sailmaker's yd to metric (gm per sq m), multiply by 43.74 (divide for vice versa).
- To convert oz per English yd to metric (gm per sq m), multiply by 33.91 (divide for vice versa).

Alternatively you may use this ready reckoner, whose figures are accurate enough for most purposes:

American	English	Metric	American	English	Metric
oz/sailmaker's yd	oz/sq yd	gm/sq m	oz/sailmaker's yd	oz/sq yd	gm/sq m
$\frac{1}{2}$	$\frac{3}{4}$	22	6	$7\frac{3}{4}$	263
1	$1\frac{1}{4}$	44	$6\frac{1}{2}$	$8\frac{1}{2}$	285
$1\frac{1}{2}$	2	66	7	9	306
2	$2\frac{1}{2}$	88	$7\frac{1}{2}$	$9\frac{1}{2}$	328
$2\frac{1}{2}$	3	110	8	$10\frac{1}{4}$	350
3	4	131	$8\frac{1}{2}$	11	372
$3\frac{1}{2}$	$4\frac{1}{2}$	153	9	$11\frac{1}{2}$	396
4	5	175	$9\frac{1}{2}$	$12\frac{1}{2}$	416
$4\frac{1}{2}$	$5\frac{3}{4}$	197	10	13	438
5	$6\frac{1}{2}$	219	$10\frac{1}{2}$	$13\frac{1}{2}$	460

No set of figures can serve as more than a rough guide to selecting the optimum cloth weight for any particular duty, because of the wide variety of qualities, types of construction and characteristics. It takes an expert to select the right cloths for a big boat or for serious racing, just as it does to make them. But fortunately it is far from being an exact science when it comes to the sort of sailmaking that can be undertaken by an amateur. The table on page 40 gives some typical figures, based on a general purpose single-ply polyester of moderately balanced construction. (A handy formula for determining the approximate weight of cloth needed for a working sail, expressed in ounces per sailmaker's yard, is to take the waterline length of the boat in feet and divide by five.) The choice is much simpler when it comes to spinnaker nylons: $\frac{3}{4}$ oz is sufficient for dinghies and small dayboats, while 1 oz is suitable for almost any other size of boat. Only on large offshore cruisers or for bullet-proof heavy weather spinnakers is it necessary to move up to the $1\frac{1}{2}$ or $2\frac{1}{4}$ oz cloths.

Suggested Polyester cloth weights in oz/sailmaker's yd They should be varied up or down if the boat is particularly heavy or light, or frequently sailed in strong winds or light airs.					
	Average dinghy	Small keel-boats and daysailers up to 20 ft	21–25 ft	26–30 ft	31–35 ft
Mainsail and working jib	3½–4	4½–5	5–6	5½–7	7–7½
Light genoa		3–4	3–4	3–4	3½–4½
General purpose genoa		4–4½	4–4½	4½–5	5–6
Furling genoa		4½	5	6	7
Storm sails		6	6½	8	9½

SAIL DESIGN

Nowadays many of us either have a computer in the household or have ready access to one, and even if we don't know how to work it, our children usually do. With so many sophisticated and skilful games that can be played on these magic boxes of tricks, it is easy to imagine that using one to help design a simple sail might be child's play too. In some ways it is. However, the software needed for three-dimensional computer aided design is so complex and expensive, and requires so much expertise to be used effectively, that the use of CAD is mostly confined to the major lofts.

The much simplified 2D programs and instructions available with this book have been specially written for the amateur sailmaker or small loft interested in taking a look at this branch of technology. Nevertheless it is important, before setting out on any such course, to understand the basic principles of sail design and the methods of lofting that served sailmakers long before the computer age – and in many cases still do. Familiarity with the manual process not only helps us to appreciate just how much the computer can do to help, but total commitment to electronics without this background knowledge can sometimes lead to misinterpretation of the computer's instructions, and also – as in navigation – might one day leave us high and dry if it should malfunction.

Details of the rig, showing the profile and dimensions of each sail, will have been drawn by the boat designer. Besides aiming for an aesthetically pleasing appearance, and observing any class or international measurement

rules that might apply, he will have integrated the underwater shape of the hull with the sail area needed for a fair performance in light airs, adequate stability in heavier weather without the need for inconveniently early reefing, and a comfortably balanced helm. His sailplan is certainly useful for estimating the quantities of cloth required, but it is only a two-dimensional diagram and doesn't pretend to represent the flying shapes of the sails, least of all the spinnaker. The sailmaker has to make a construction plan for each of them, indicating how the individual panels are to be cut to give the right amount of built-in shape where it is needed, taking account not only of the type and weight of cloth to be used, but of its likely stretch under freshening winds, the effects of mast bend and forestay sag, and of the tensions applied to the edge curves along the luff and foot. Factors such as these are fed into a computer to form an integral part of the CAD program, but the manual design process relies entirely on rule of thumb methods that have been derived from decades of practice.

Spinnakers are the exception. They are extremely sophisticated sails, as difficult to design as they are to set and control, compared with other forms of headsail. For much of the time the wind blows across them from luff to leech, but they lack the jib's straight luff and flat leech, and both the tack and the clew have to be continuously adjustable. Only when the wind is blowing from 10–15° either side of dead astern can the spinnaker act as a simple wind-blocker to drag the boat downwind – and then only when either it is badly set and stalled, or when the mainsail is lowered. To remain stable under those conditions it needs lift from a full head, but this makes the luff all the more likely to curl in and collapse the sail as soon as the boat is brought on to a reach. Properly set, with the mainsail drawing, the two sails together act as an aerofoil, the spinnaker deflecting most of its airflow sideways into the lee of the main. Very little of it spills out under the foot, so flying a spinnaker high for the sake of lift is just giving away power.

The amateur can make a basic old-fashioned parachute spinnaker by unpicking an old sail and copying its panels, bearing in mind that it will probably have stretched out of shape, or by guessing at the curvature of its centre seam; but even if he gets it right, the result will be disappointing compared to any of the modern cuts. It's not as if the eventual spherical shape can be marked out on the loft floor. Spinnaker design nowadays involves so many variables and complex mathematical calculations that it requires a computer to process them, so we will confine this section on manual design to fore-and-aft sails.

If you want to make a replacement for a worn-out mainsail and don't have a drawing of it, a straightforward method of obtaining the outline measurements, assuming you have access to the boat and the mast is stepped, is to top up the boom to its working position and send a tape aloft on a halyard, or a length of rope which you measure afterwards. Ease it a little way down from the headsheaves to allow for stretch – say 250 mm on a 500–750 mm in luff. It's even worth hoisting the mainsail, if you can, to check whether it can still be set without the tack and clew being pulled past the black band markings on the mast and boom that apply when racing, and if the sail is particularly old and dilapidated, making sure there is still a safe margin of travel before neither the headboard nor the clew become chock-a-blocked at their sheave. You can do the same sort of thing with a headsail, but if it overlaps the mast, remember to lead the tape outside the shrouds.

Alternatively, you can measure the old sail. Lay it out flat, spike the head and pull the other corners out with a tackle until the edge reinforcements appear to be stretched out to their working tensions, balancing these as best you can to ensure that the sail isn't distorted in one direction or another. You will need to take the diagonal as well as the peripheral lengths. Using a piece of string pulled taut between the corners, you can then measure off the edge curves, allowing for a small degree of deformation that will have occurred over the years, notably along the luff and leech. Needless to say, if you are lucky enough to have a large enough clean wooden floor to work on, you can loft the new sail right there simply by tracing the old one and making the necessary allowances including the hems, known as 'tablings'.

Should you decide, in the interests of performance, to increase the sail area, it would be worth taking the precaution of checking the centre of effort of the rig before and after your proposed modifications, using the procedure shown in Fig 2.16. Giving the mainsail a larger roach, for example, without some corresponding alteration in headsail area or mast rake, might result in excessive weather helm. Conversely, if the boat has always been a bit hard-mouthed, even with the mainsail flattened as much as possible, straightening the leech or taking a few centimetres off the foot would probably move the CE forward enough to put matters right.

More difficult to guess at, lacking the experienced eye of a professional sailmaker or unless you know the boat particularly well, is how much too full a sail may have become due to permanent stretch in the cloth, even if it isn't obviously baggy. The following procedures take out a lot of the guesswork in deciding on how much fullness should be built into the new sail, whereabouts to position it, and how to draw the curves that produce it.

As we saw in Chapter 2 there are two methods, usually combined with one another, for introducing draft into what would otherwise be a flat area of cloth (Fig 2.12). The first is to give the luff or the foot a convex curvature, so that by tensioning it along a straight spar, or gathering it up a headstay, surplus material is forced into the body of the sail. (The converse principle is used to compensate for forestay sag by giving the upper part of a headsail a hollowed luff which straightens under tension and drags the adjacent cloth with it.) The other is the technique of broadseaming, in which one or sometimes both edges of the panels are cut in a convex curve for part of their

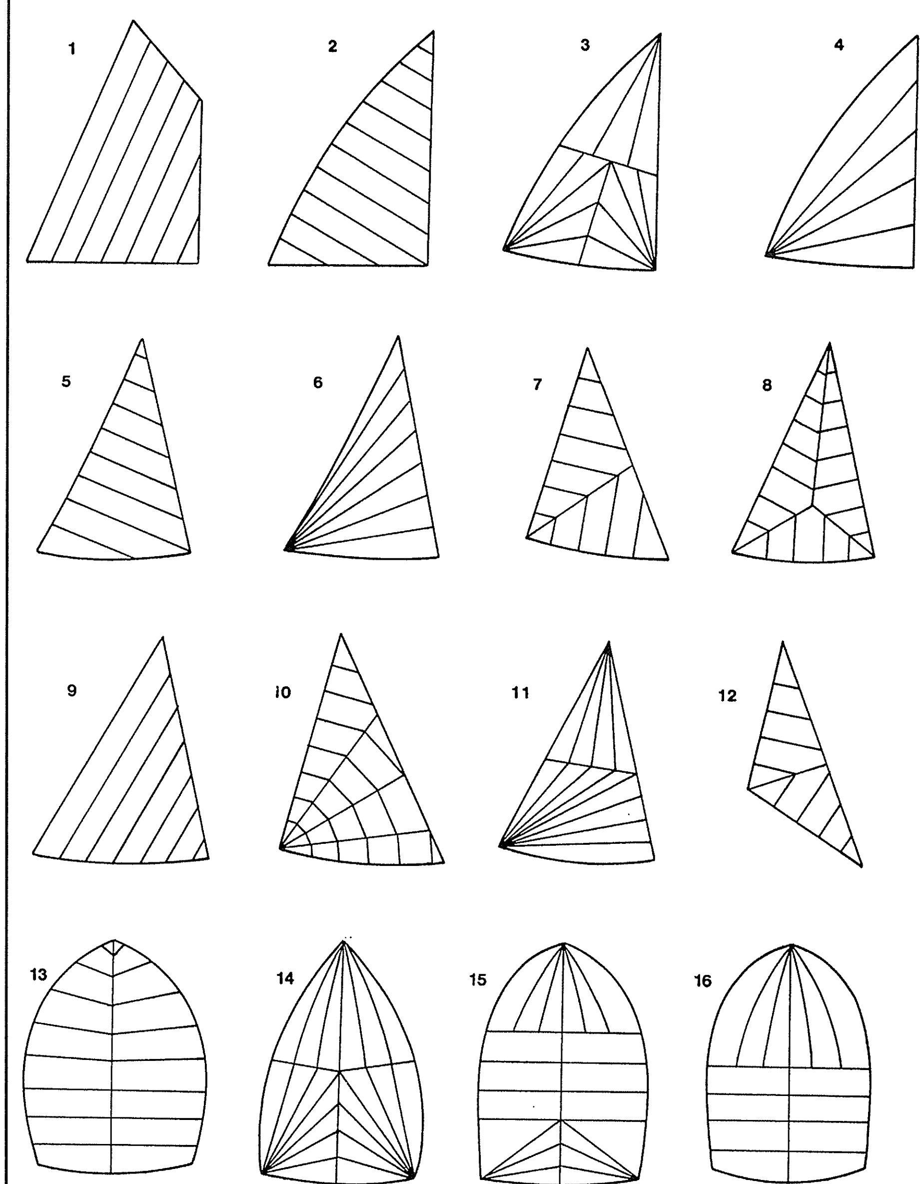


Fig 4.3 Typical cloth layouts. *Mainsails:* 1 Vertical cut. 2 Cross-cut. 3 Starcut. 4 Radial cut. *Headsails:* 5 Cross-cut. 6 Radial cut. 7 Mitred. 8 Triple mitred. 9 Vertical cut. 10 Spider web. 11 Bi-radial. 12 Yankee. *Spinnakers:* 13 Horizontal. 14 Starcut. 15 Tri-radial. 16 Radial head.

length, so that when they are sewn to adjacent panels, the sail assumes a moulded three-dimensional shape. How much of either method to use depends on the specifications of the cloth, the depth of camber required and its positioning, and the cut – the manner in which the panels are to be laid out (Fig 4.3).

The vertical cut, with the seams running up-and-down parallel with the leech, was the accepted pattern in former times when sails were made without any roach, and is still used for the sake of authenticity on many traditional boats, whose sails are usually made of a soft cloth, and where the panels and their warp threads were lined up with the leech in order to minimise stretch on its unsupported edge. The mitre cut, with the upper section having its cloths perpendicular to the leech, and joined along a diagonal seam to a lower section with its cloths square to the foot, was developed for headsails in an attempt to control and limit stretch in either direction. However it is seldom seen nowadays except on stormsails, where it has the advantage of having no seams striking an edge. A third alternative was the Scotch cut, which was the same as the mitre except that its cloths lay parallel to the leech and foot.

With the development of more stable fabrics, bias problems on the foot and leech have largely disappeared. The horizontal or cross-cut is currently by far the most widely used for cruising sails, with seams running roughly parallel with the airflow and the fill yarns bearing the brunt of the luff and leech loads. Lastly there are the various radial and multi-radial cuts for high-performance sails, in which the warp yarns are aligned with the stresses that fan out from each corner. The problem that these complex patterns pose for the amateur is how to shape the panels so as to put the requisite amount of draft in the right place. A computer, fed with a sophisticated program, is about the only alternative to a lot of inspired guesswork.

Draft is readily induced in a loosely woven fabric by bias elongation and needs little or no help from broadseaming, whose purpose in that case is to position the draft and to shape the entry profile, whereas a stiff and stable cloth, designed to resist bias stretch, can make good use of broadseaming to give it belly, especially on cross-cut sails where seams run more or less parallel with the chord, and on vertically cut gaff, lug or sprit mainsails. It is rather less effective on some other cuts whose seams strike an edge at too shallow an angle.

In this instance, we are going to make a suit of sails for a typical 23 ft Bermudan rigged dayboat or small cruiser, compromising between a softly finished cloth that furls well, and a hard finish that sets well, by using a medium-finished 5 oz polyester for main and jib, both of them cross-cut. The length of the seam tapers will define the draft points, each seam starting to widen at the point where maximum fullness is required, and opening out further as it approaches the luff. Excessive tapering near the after end would hook it to windward like an over-tweaked leechline, so less broadseaming is

used in this area so as to produce a flattish exit from which the airstream can run off cleanly. Too flat, and the leech will become structurally unstable and flutter, unless it is supported by long or full battens.

There are no hard and fast numerical rules governing a sail's camber – the maximum depth in relation to its straight-line chord length between luff and leech – or whereabouts this should be placed. But there are some useful guidelines that can serve as substitutes for experience. A camber ratio of 15–16% can be considered to be very full and so powerful that it is only suitable for light weather and reaching, while at the other end of the scale 5–6% will give very little drive until the wind really pipes up. So a good compromise that is generally adopted for cruising sails is to make them moderately flat at around 12% and to rely on edge tensioning or mast bend to reduce power in strong winds. On a mainsail the point of maximum designed draft halfway up the sail is best positioned no more than 35–40% back from the luff, because in a fresh breeze it will blow aft to around 50% as it assumes its flying shape, and around a third of the way up from the foot. For high pointing, a jib needs a finer entry, with the airflow at the exit from the slot streaming off parallel to the lee side of the mainsail, so the designed draft point can safely be brought back as far as 40–45% from the luff. For the sake of simplicity in cutting the sail panels, and especially in amateur sailmaking, the depth of the sail is best kept to a constant proportion of the chord length near the foot. This results in there being very little actual draft towards the head, but it doesn't matter very much in cruising, because the top part of the sail does comparatively little work, tending to heel the boat almost as much as it drives it. Professional sailmakers looking for the last ounce of competitive power will increase the draft in the upper regions of the sail. But it will flap if there is too much shape in it, with any sag in the headstay only adding to the fullness.

In order to put some actual values on seam tapers and edge curves, let us assume that the boat looks something like the one on page 90, a fractionally rigged 23 footer with a small self-tacking jib (but cross-cut for our purposes, leaving the complexity of radial panelling to the professionals).

We will take the mainsail as having a foot length of 3.3 m, a roach projecting 300 mm beyond the straight line between head and clew and about halfway up it, and an 8.7 m luff*. Incidentally, when you come to draw a sail full size, always allow for some stretch in the luff when the halyard is swigged up, amounting to 25 mm per 2 m of length – that would make it about 100 mm on this one. To end up with the 12% camber we are aiming for, we will need a minimum of 20 mm of luff round per metre of length, say 170 mm in this case. Its widest part should be located about 3 m above the tack, taper-

* Although cloth weights and lengths are mostly expressed in imperial units, metric measurements are invariably used in sailmaking, for convenience in percentaging and proportioning.

ing off in a convex curve towards the bottom of the sail, and upwards to a point about two-thirds of the way to the head. From here the luff can be made *slightly* hollow to help keep this part of the sail flat, but it should run straight up if the mast is designed to be bent in action (by about 180 mm in this case) and the luff round doubled to compensate for the draft that will then be absorbed. Foot round should amount to some 25 mm per metre of length, so call it 100 mm at its widest point, positioned about 1.25 m back from the tack and curving off smoothly in both directions, but not hollowed.

Seam tapers

The roundings are combined with a series of broadseams at the luff, starting with the one striking nearest the tack, and which in this case are parallel-sided until they reach a point about two-thirds of the way forward from the leech. They then widen progressively towards the luff, their angle of taper depending on the type of cloth. A ratio of 1:60 will be about right for this sail, using a medium-firm cloth. So a 1 mm increase in seam width will be needed for every 60 mm of length, giving a nominal 12 mm seam that opens to about 18 mm at the luff, except for the tack seam, or the lowest luff seam, whose taper angle should be doubled to 1:30. Proceeding up the luff, taper every seam for the initial one-third of the way towards the head – their width will be decreasing anyway as they become shorter – then start reducing the draft by tapering every other seam for the next third, before reverting to all-normal seams on the upper part of the sail which is to be kept flat.

Edge curves

Broadseam (Fig 4.4) can if necessary be put into headsails, but generally speaking they are best cut fairly flat, extensive broadseaming being mostly reserved for large jibs and overlapping genoas. All headsail shapes are, however, affected by forestay sag, which by itself will induce a certain amount of camber and has to be allowed for in the edge curvatures. The jib we are to make has a luff of 8.2 m, so aiming at a 12% camber, the lower part of the luff need only be given a convex rounding of about 20 mm at its maximum, changing to 25 mm of concavity in the upper half where the effects of sag will be most pronounced. These are in fact such shallow curves that taking the easy option, and cutting a small short-chorded jib such as this with a straight luff, will not greatly affect its draft. It is advisable, on the other hand, to give the leech some hollow, amounting to around 15 mm per metre at the midpoint, or about 120 mm in this case. Not only will it ensure a clean exit, but the hollow leech will stand better than a straight one. The allowance for foot rounding can be taken as 25 mm per metre, the same as for the mainsail, which works out at 70 mm on this jib, although without a boom it won't have the

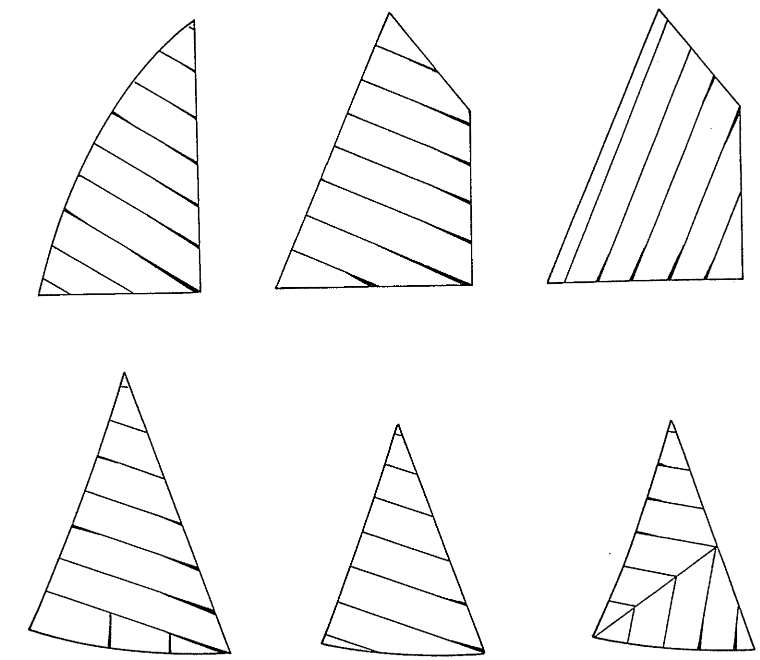


Fig 4.4 Broadseaming. Like dressmakers' darts, tapered seams introduce draft into what would otherwise be a flat sail until its curved edges are tensioned. Tapers can also be used to support the foot round in boomless sails such as a cross-cut genoa, and to produce additional draft in fixed-footed gaff sails.

same effect, just adding some area and matching the profile of the deck.

Similar principles are applied in different ways to other shapes and cuts of sail. There are so many variations that it takes a specialist book to describe them all in detail. A gunter mainsail, for instance, is usually treated in the same way as a Bermudan, ignoring the kink where the yard joins the mast, whereas on another frequently encountered example, a four-sided sail such as a gaff, lug or sprit mainsail having its cloths laid parallel to the leech, the seams are broadened in the region of both the head and the foot. They should start at around 7.5% down from the gaff, with a nominal 12 mm seam opening out to 18 mm at the head. Nearing the bottom of a boomed sail, a rather larger taper runs from a point some 15% up from the foot, broadening from 12 mm to about 25 mm. If the sail is boomless and doesn't have a boltrope to help support its foot, the requisite draft in the lower areas is provided by doubling the degree of bottom broadseaming, with the tapers originating a quarter of the way up from the foot, and opening out to about 50 mm. Head rounding should amount to 25 mm per metre, with the apex halfway along it; luff round 25 mm per 1300 mm one-third up from the tack; boomed foot round 25 mm per metre and one-third aft of the tack; and

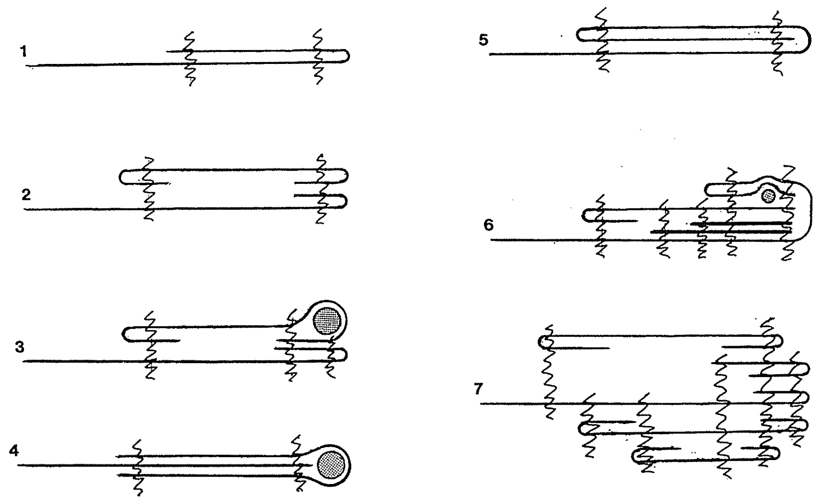


Fig 4.5 1 Sail edge hotknifed and folded over. 2 Traditional cut tabling. 3 Cut tabling carrying luff rope. 4 Luff rope in tape. 5 Rolled tabling. 6 Rolled tabling with internal patches and leech cord. 7 Cut tabling with one upper and two lower patches.

anything up to three times that depth of curvature if the sail is loose-footed without a boltrope.

Returning to our design for the 23 footer, the accessory items can now be pencilled in, starting with the reinforcement patches at the corners of each sail (see page 170). These form an essential part of the sail structure, dispersing the high corner stresses into the body panels and along the hems, known as tablings, that are used to finish the edges (see Fig 4.5). It is very important that these tablings are made correctly, because they affect the way a sail sets. Too flimsy and it will flap; too stiff and it won't stretch with the body of the sail which will be liable to end up with a loose belly. On the leeches, allow an extra 30 mm of cloth which will be folded over and sewn down to form their tablings, with the leech lines inside. This simple process can only be used where the cloths meet the edge at right angles, allowing the threadlines on the sail and the tabling to run in the same direction and both to stretch in the same way. At other angles the weaves won't match and wrinkles would form under tension, so either the tabling must be cut off and resewn, or replaced by 30–40 mm wide polyester webbing tape folded and sewn round the edges of the sail. But to avoid a hooked leech, its a good idea to stretch the cloth and fit the tabling untensioned, so that the stretch in the leech will match that of the adjacent cloth when there's wind in the sail. The same tape in wider form can be used to form a tough pocket or channel for the mainsail footrope and for both the luff ropes when these are fitted.

Batten pockets are also subject to high loadings and need to be carefully

fitted. On this particular mainsail, four battens divide the leech into five roughly equal sections. Battens must be long enough to avoid any risk of a hinged leech, so the general rule is for each one to be three times as long as the depth of roach it is supporting. On a cross-cut sail they are laid parallel to the cloths, except for the bottom one, which has to be in line with the foot, so that it can be taken in with the reef.

Finally there are the two rows of reef points to be positioned, in the form of eyelets on diamond-shaped patches, spaced at 50 cm intervals (30 cm on a small dayboat) and running in straight lines parallel to the foot. The rings or cringles at either end, sewn on to heavily reinforced patches, should be raised about 10 cm above the line of points (15 cm on larger boats) to ensure that they, and not the reef points, take most of the strain, which can be considerable, because a reefed sail is effectively loose-footed. The height of the first reef above the boom should be calculated to reduce the sail area by roughly one-third, and the second reef then placed about the same distance above it.

These and all the other design calculations can be done for you automatically by a computer.

Computer aided design (CAD)

This section is a short one, since it has only to serve as an introduction to the Sailmaster CAD programs that are available with this book. These are contained, along with a step-by-step tutorial, on a 3½ in floppy disk which you can obtain free of charge by sending off the form at the back of the book. The disk will automatically install the software in the computer, allowing you to view or to print out the full documentation, or any part of it, simply by pressing the appropriate keys.

The function of the programs is to design mainsails, genoas and spinnakers, guided by your input figures and using traditional 2D techniques. The end product will be a set of co-ordinates from which the sail panels can be drawn and cut out on the loft floor. The values quoted in the tutorial are those for the 23 footer we are using as an example, but the programs can be used for virtually any size or shape of sail, and whatever design curves you produce can be stored on disk and recalled whenever you need them.

The limitations of these simple programs are that they don't include radially cut mainsails and jibs, which require more complex detailing, nor can they drive a plotter or a cutter such as are used by all the big commercial lofts; and they do not try to predict the 3D flying shape of the sail. It takes a suite of far more sophisticated (and hence expensive) programs to model the many combinations of mast bend, forestay sag and the sail deformation from wind pressure and tensioning of the rig controls, and to produce competitive high-performance sails. Even then, the resulting panel shapes are not always developable – that is to say, they cannot always be laid out on a flat roll of sailcloth.

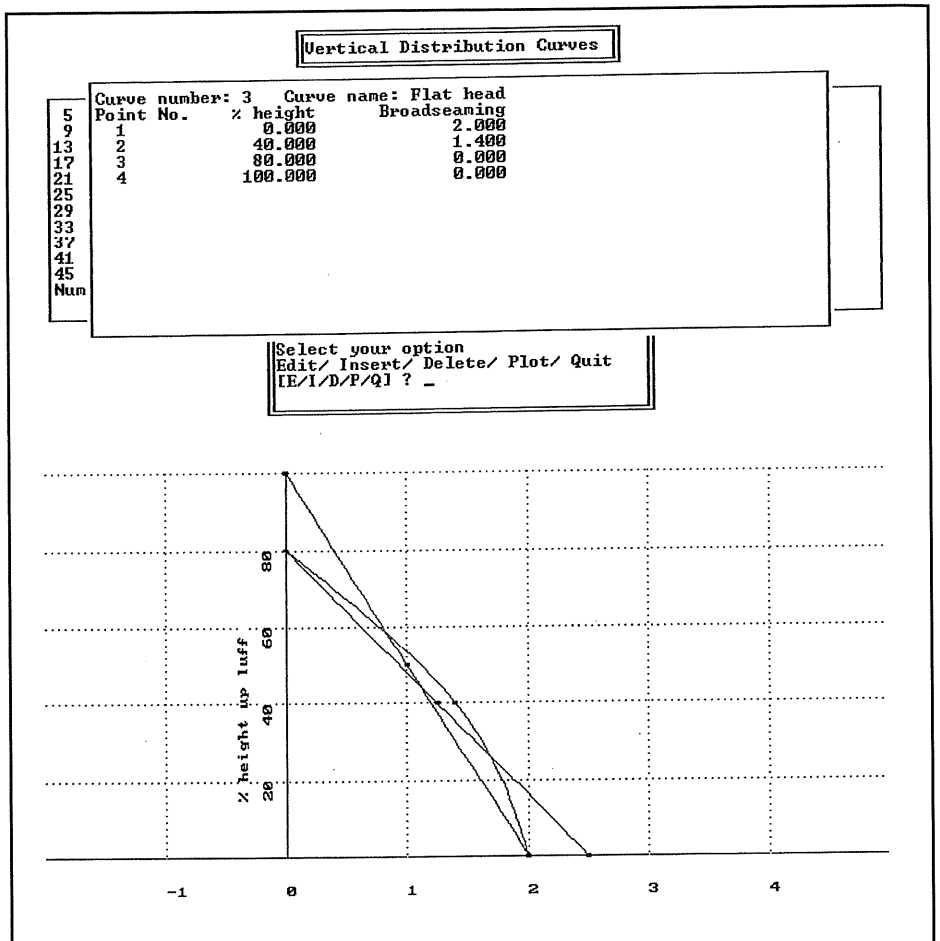


Fig 4.6

(Try wrapping a sheet of paper round a football without getting any creases in it.) It takes experience, expertise and the right equipment to make proper use of a professional 3D program, but the 2D versions we are looking at here will help an amateur, even a novice, to design a perfectly satisfactory suit of cruising sails for his boat.

Vertical distribution curves

The first part concerns the amount of broadseaming to be used and where to place it. A set of vertical distribution curves are drawn on the computer screen (Fig 4.6), starting with a straight line from the foot to the head of the sail. This would give it the same draft all the way up and would make the head too full for most purposes. So in order to have no broadseaming above a certain height, say 70%, the top of the line is moved down to that point. Then

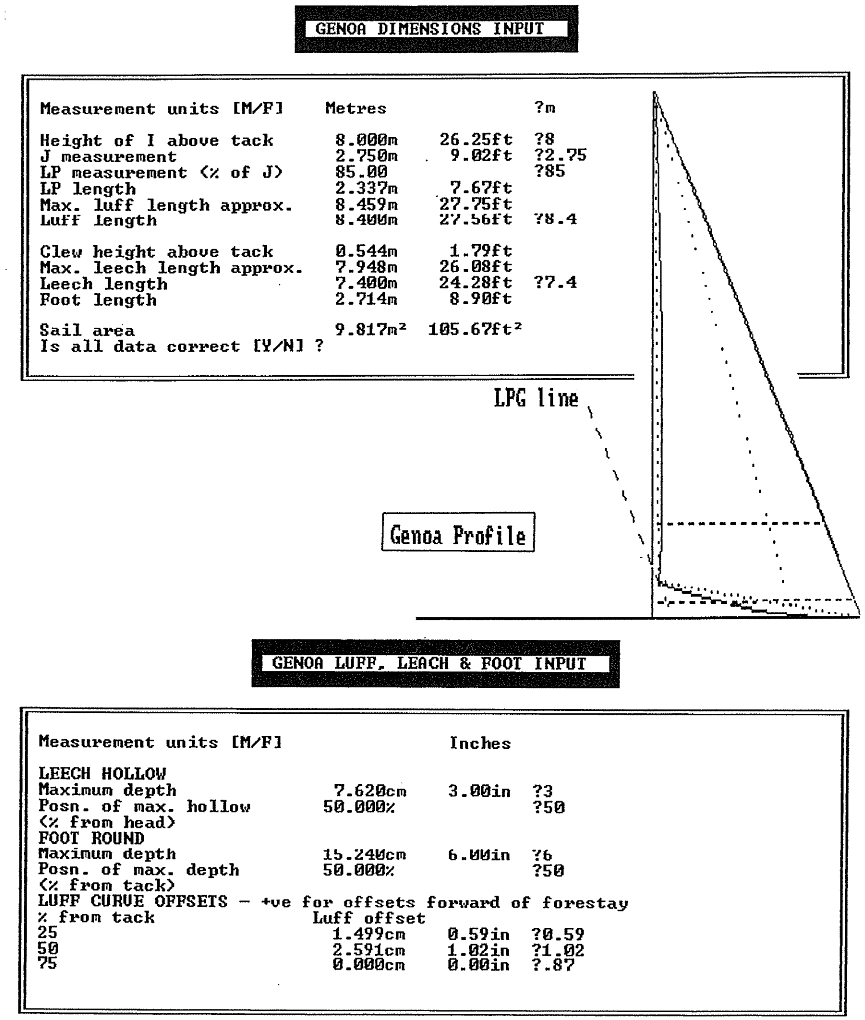
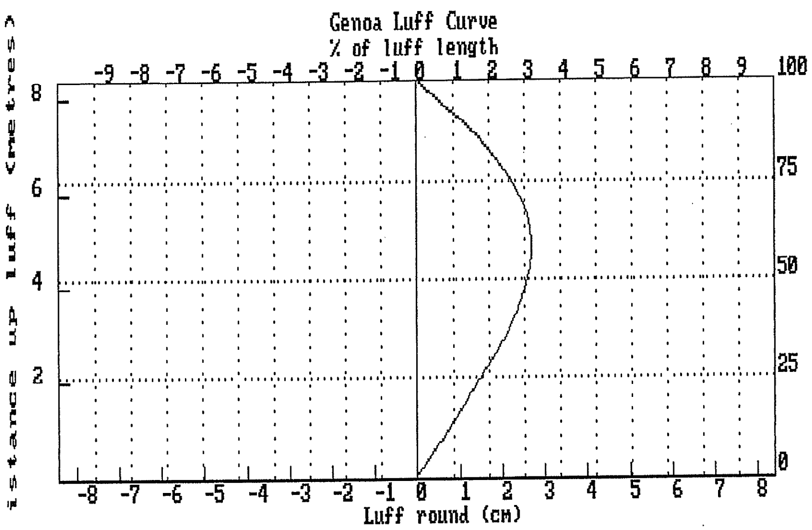


Fig 4.7a

suppose, for example, that the boat has rather a wide jib-sheeting angle, due to the spread of the shrouds, but you want to flatten the middle of the foot to improve windward ability. All you do is insert an extra point on the curve and move it around to give the necessary fullness. As you do so, all the other points on the curve automatically change position to maintain a fair shape. Half a dozen of these VDC curves will usually cover all your sail designs, and a table of figures showing the amounts of broadseaming, either as offsets or as percentages of each seam, can then be called up on to the screen.



GENOA BROADSEAMING DATA INPUT

```
Measurement units [M/F]     Centimetres
Standard VDC curve              3    Flat head and foot        ?3
Total amount of broadseamin 5.000cm    1.97in  ?5
Apply VDC curve to luff or leaCh [F/C] Leech                   ?
Enter broadseam camber position as % from luff :
% from head              Camber position
  0                         35.000             ?35
 25                         35.000             ?35
 50                         35.000             ?35
 75                         35.000             ?35
100                         35.000             ?35
Is all data correct [Y/N] ?
```

GENOA CONSTRUCTION DATA INPUT

```
Measurement units [M/F]     Centimetres
Cloth width                 120.000cm    47.24in ?120
Seaming allowance             3.000cm     1.18in ?3
Luff tabling                 -2.500cm    -0.98in ?-2.5
Leech tabling                 0.000cm     0.00in ?
Foot tabling                  0.000cm     0.00in ?
Height of 1st seam up luff   30.000cm    11.81in ?30
Cloth type :               ? Dacron
Comments                   ? Sailmaster demo headsail
                           ?
                           ?
```

Fig 4.7b

Designing the jib

The next step is to design the jib. Start by typing in the outline dimensions (Fig 4.7a). You can set up the basic foretriangle shape by entering the length of the forestay above the tack fitting, known as the 'I' measurement, and the distance 'J' from the tack to the fore side of the mast, followed by the jib overlap. This is the 'LP' (longest perpendicular of headsail, in other words the distance from the clew to the luff) expressed as a percentage of 'J'. On our self-tacker we will set this at 85%, so that the leech is sure to clear the mast, provided the clew is not located too high off the deck. (It is not yet positioned, so it can still slide along the LP line.) Follow this with the actual luff length of the sail and the screen will display the area of the sail, calculated on the assumption that its edges are straight. Finally, the clew needs to be fixed along the LP line, either by entering its height above the tack fitting, or its leech length. This completes the first page of data entry.

Next come the leech hollow, foot round and luff curves (Fig 4.7b). The leech hollow is entered first, expressed in terms of its maximum depth and its position as a percentage of leech length, followed by the greatest depth of foot round and its position measured from the tack. The luff curve is then defined by entering the offsets at several positions along the luff, using a positive value for an offset forward of the forestay and a negative one aft of it, remembering that the greater the luff round the less the necessary broadseaming, as both increase the draft of the sail.

The computer will then ask you which of the VDC curves is to be used to locate the broadseaming and the size of it; whether it is to be applied to the luff or the leech (as in this case), and the point where the maximum value occurs, as a percentage of chord length at various heights. (It is constant on this sail.)

Having so far designed the sail without regard for panel width, this must now be entered so that the program can lay out the seams so as to make the best possible use of the cloth and minimise wastage. The computer will therefore request the allowances for seaming and for the tablings, taking account of whether the cloth is to be folded or taped (or both), and whether a boltrope will be fitted internally. Finally you will be asked for the height of the first seam, since this will act as the reference point for positioning all the others, and is also the lowest one to which broadseaming can be applied. The computer can now perform all the necessary design calculations, print out a summary of the input data for you to check before it files them, and produce a drawing of the sail, together with the dimensions of each panel to be marked out on the cutting table.

Designing the mainsail

The procedure for designing the mainsail is similar. As with the jib, the first screen defines the basic dimensions: 'P', the mainsail luff length; 'E', the foot length; 'HB', the width of the headboard; and the boom droop, in degrees (none in our case). The computer then wants to know the length and the amount of 'poke' of the battens – the amount by which each extends beyond the straight leech line, measured as a percentage of 'E', to support the roach. This is followed by the foot round, as before, and then the luff curve. This has to take account of mast bend, which is designated as occurring at 50% of 'P', so that by altering the bend at half height, you change the amount of bend along the entire mast. It is an arbitrary figure which the spar maker can usually advise on. For this boat we are estimating a bend of 180 mm, entering 75% of this at 25% and again at 75% of 'P'.

The section on broadseaming works in exactly the same way as it did in the jib program, and so does the section on cloth width and tablings, except that an additional page asks you for details of the finishing, such as the positions of the Cunningham hole, reef points and the ends of the batten pockets, all of which will be shown on the cutting sheet for the appropriate panel.

Shaping spinnakers

The last of the three programs is a particularly versatile tool that enables you to design star-cut, tri-radial, radial-clew and cross-cut spinnakers (Figs 4.8 and 4.9a and b), and is therefore rather more complex than the others, as you might expect. The example we are using here is a good general-purpose sail for a cruising boat, with a radial head to absorb the loadings in that region, and horizontal panels in the lower half that allow it to develop a moderately deep belly for running, but to be kept flat enough to remain reasonably stable, and to reach with the apparent wind on the beam in light conditions. Being symmetrical (unlike a single luffed cruising chute or genniker, which is more of a lightweight genoa than a spinnaker), this sail is designed as if it were folded in half, so that the two leeches coincide. When the edges are pulled taut, the only remaining fullness is due to the shaping of the seams.

To begin with, you enter the basic 'I' and 'J' dimensions, as with the jib. From these, the maximum recommended luff and width and minimum girth values are calculated and displayed. You then enter the sizes you want, as a percentage of those limits. We will accept the full luff and width dimensions, and 85% of the maximum foot. As soon as you input these figures, the computer works out the resulting area and shows it on the screen.

The critical curve in the design is the one running down the adjoining centrelines of the two halves – the mitre curve – as the more pronounced this is, the fuller the sail will be. It is defined at 20, 40, 60 and 80% distances from the head down an imaginary straight centre seam to the foot, the offsets at those points being themselves expressed as percentages of the length of that head-to-foot line. Traditionally the offset at the 40% level is the one used to specify the overall fullness of the curve, leaving the other three, *expressed as percentages of the first one*, to describe the shape of the curve. (Sounds rather


```
SPINNAKER DIMENSIONS INPUT

Measurement units [M/F]    Metres                 ?m

I measurement               8.000m    26.25ft  ?8
J measurement               2.750m     9.02ft  ?2.75
JC measurement              2.750m     9.02ft  ?2.75
SL (% of MXSL)              8.036m    26.37ft  100.00%   ?100
SMW (% of MXSMW)            4.950m    16.24ft  100.00%   ?100
SF (% of SMW)               4.207m    13.80ft   85.00%   ?85

MXSL                        8.036m    26.37ft
MXSMW                       4.950m    16.24ft
MinSMG                      3.156m    10.35ft
SPIN                       22.321sq.m240.26sq.ft
Area                       32.156sq.m346.12sq.ft

Is all data correct [Y/N] ?
```

```
SPINNAKER 2-D MITRE INPUT

Aspect ratio [I/JC]          2.909
Standard mitre length        8.438m     27.68ft

Standard HMPC               12.182
Use standard HMPC [Y/N] ?n

HMPC                         1.013m     3.32ft    12.00%

TMPC                         0.608m     1.99ft    60.00%
FMPC                         0.962m     3.16ft    95.00%
BMPC                         0.759m     2.49ft    75.00%

Head curve type             N                    ?
[Natural. Quadratic. Double or Gradient]
Head mitre angle            20.4514
Is all data correct [Y/N] ? _
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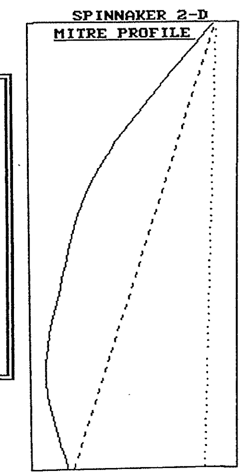


Fig 4.8

complicated, but that's the way it's always been done, and it works well.) Since you need a moderately flat sail for a good, all-round spinnaker, you should select a 12% offset at the 40% level, 60% *of that value* (ie 24%) at the top point, with 95% and 57% at the lower ones respectively. When all this data has been typed in, the profile of the sail appears, as if by magic, on the screen.

By defining the all-important mitre curve and the width of the spinnaker, you have already done most of the design work on its radial head panels. The only information the computer still lacks is how far down the sail the radials are to extend, so this is now entered as a percentage of the luff length – 40% in this case – measured along the mitre curve. Next, input the cloth width (60 in) and seaming allowance (20 mm) – such a mixture of metric and Imperial units is commonplace in sailmaking. This is followed by the number of panels you wish to fit across each width of cloth, whether you want an odd or even number of head gores and how wide you want those adjacent to the leech – the wing gores – to be as a percentage of the main gores. If you have

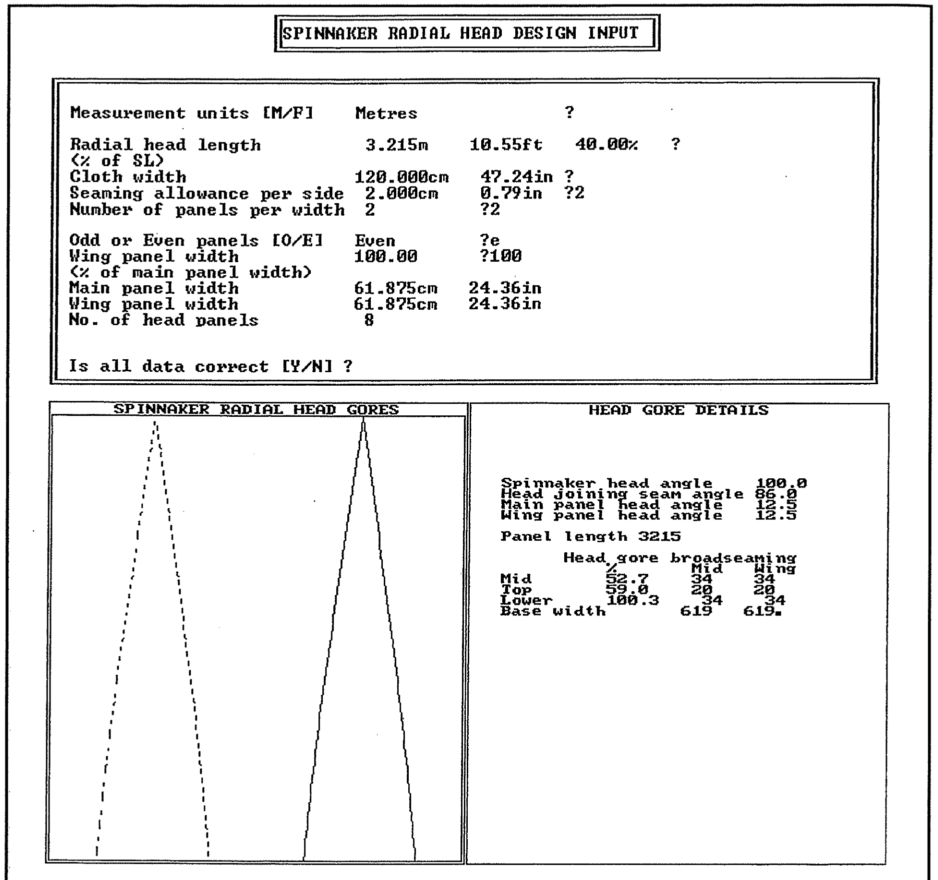


Fig 4.9a

no particular figure in mind, you can simply ask for 'Large', to make best use of the cloth, or 'Small' if you are more concerned with appearance. The main gores are all identical, resulting in circular arc sections in the head of the sail, although this may be modified by broadseaming at their bottoms. In response to your input, the screen now displays a drawing of a head panel beside a wing panel, accompanied by a set of data indicating the head angle of the complete sail and of the main and wing panels; the head seam angle between the base and side of a main panel; the panel length; and the extent of the broadseaming, tabulated as horizontal offsets.

Moving down the sail, a similar procedure is followed for the cross panels, which are then automatically added to the screen picture, together with a note of the foot aspect ratio. The computer assumes that you intend these panels to lie square to the mitre curve, but if you want to change the angle, for example to ensure that the threadline follows the leech more closely, or to alter the amount or shape of the broadseaming on the bottom of any

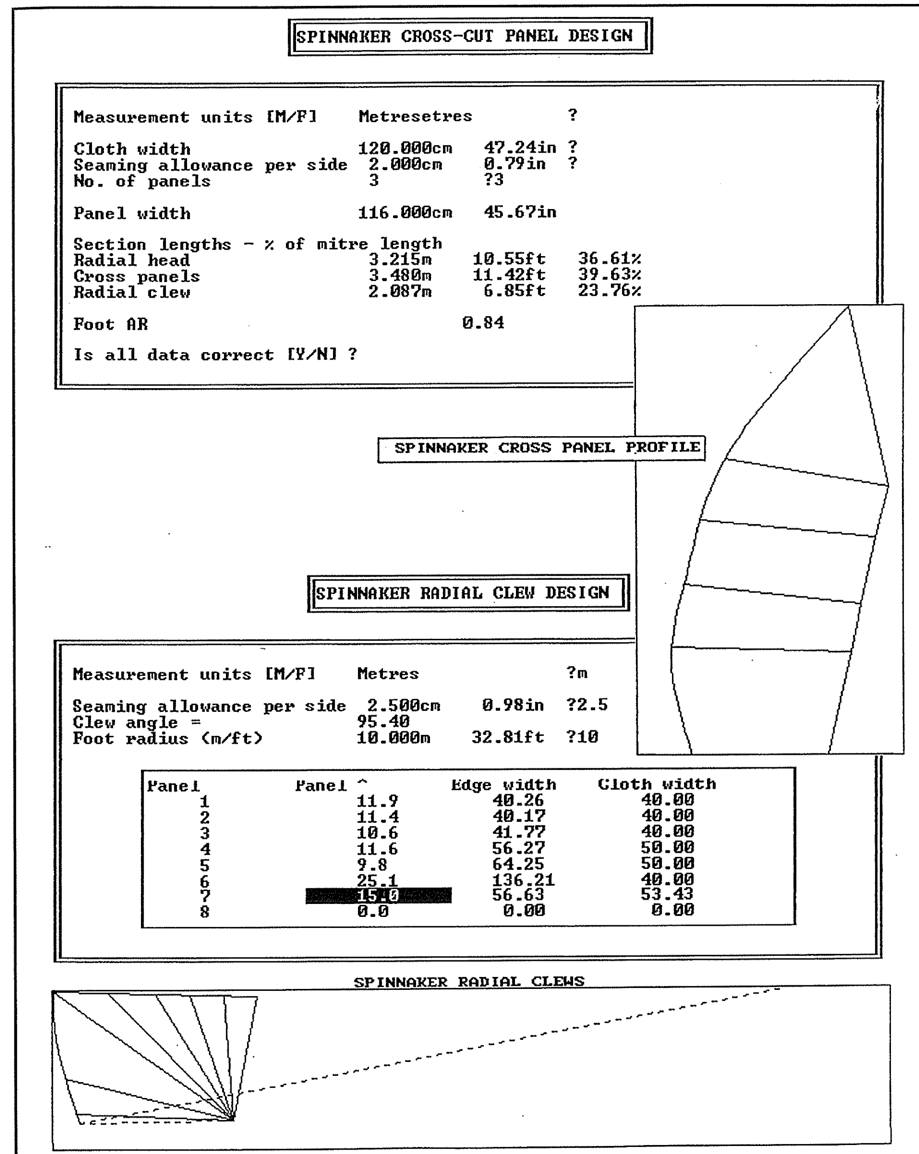


Fig 4.9b

particular panel, you can modify each seam individually. The further away from the centreline that the cross panel remains parallel-sided, and the tighter the curve that is applied to the broadseaming, the more elliptical the sail will be. You also have the option of altering the shape of the leech if you don't like the look of it, by entering plus or minus offsets at 20, 40, 60 and 80% of its height. The program then draws a fair curve through the new points, if necessary modifying the clew height to match the required luff length, and then displays both the old and the new leeches side by side, noting the change in sail area. The cross panels on our sail continue on down to the foot, but there is a further section of the program for the design of the radial clew panels that feature on some styles of spinnaker.

The computer has infinite patience! If at any stage you have second thoughts about the panel shapes or dimensions, or the seaming allowances, you can go back and alter your figures until you are satisfied with the final result. An output menu will then display or print out all the input data and the intermediate calculations, followed by the sheets detailing the offsets for the radial main head and wing panels, the number of panels required and the seaming allowance, together with a set of figures for the broadseaming on each panel. Similar tables of offsets are produced for the cross panels, and for the radial clew panels too, when these form part of the design.

These and far more detailed explanations and instructions are given in the tutorial that accompanies the programs. And all this on one small floppy disk.

Turning designs into sails

The first thing you will need, in addition to a generous measure of determination, is plenty of space in which to work on the sails and around them. This means finding a covered, flat area that will accommodate the largest sail, preferably with a wooden floor, so that the cloths can be laid out and held in place with awls or 'prickers'. It is sometimes possible to borrow a room in the village hall or other local amenity for the purpose, but if it comes down to commandeering your living room and there is some objection to leaving holes in the floor, thumb tacks or map pins make smaller marks and 4–5 lb (1.8–2.3 kg) weights, if you can get hold of some, leave none at all. These alternatives are fine for marking the edge curves, but prickers are better at taking the strain at the corners of the sail. If space is limited, the sail can be folded and worked on a bit at a time, but to begin with the full area of floor will be required for lofting, since this consists of drawing out the design life size on the floor, working from the scale drawings, tables of offsets, or cut sheets. It won't become essential again until the sail has been sewn together, although the more space you have the better.

Part of it can be used to house a bench. Except when he is on hands and knees lofting and laying out, a sailmaker mostly sits and sews. An ordinary kitchen chair will do if you intend only to make the occasional small sail, but a proper sailmaker's bench is a lot more comfortable and does wonders for the ergonomics of the operation. For unlike a workbench that you stand at, a sailmaker's bench is for sitting on. It needs to be just high enough to allow your lap to be level with the floor, and about 6 ft (1.8 m) long, with all the tools and spools of twine grouped within easy reach to your right (for right-handers). It should have a raised back to prevent things from falling off, with a loose seat pad so that you can slide to and fro on it. Such a bench has to be stout and stable, but basically it's a simple piece of furniture that is easily made and soon pays for itself many times over. A small portable workbench and vice will also come in handy.

The tools

For the lofting process you will need the following:

- Half a dozen prickers for designating the end points.
- Cheap screwdrivers, with their blades sharpened to a point, are an economical substitute for traditional sail prickers.
- A piece of chalk and a reel of twine. This is stretched tightly between the prickers, and the peripheries of the sail are established by chalking the twine, pulling it up and letting it snap back, leaving a fine white line on the floor.
- A 5 m locking steel tape and a 12 in rule.
- A 15 m linen tape, or a roll of $^{3}/_{4}$ in polyester webbing, which is laid curved on the floor as a guide for drawing the luff, foot and leech roundings, a process known traditionally as 'throwing the tape'. The long, flexible wooden or grp splines used by boatbuilders, sprung into curves against aluminium pushpins, are a better alternative to tape, because they make it easier to draw a fair curve. A few lengths of plastic curtain rail make a good substitute.

Now for the sailmaker's tools. The one crucial piece of equipment is a sewing machine. An ordinary domestic model can be used on fairly lightweight synthetic materials, provided it can do the zig-zag stitching which is necessary to distribute the stress in each seam over a reasonably wide area. Such a machine can cope satisfactorily with up to four layers of the 4–5 oz cloth we will be using. But for more layers or heavier cloth, a second-hand industrial machine with a wider throat and more power, or one of the portable semi-industrial types, such as the Reed Sailmaker or the Necchi 512, designed to be carried aboard large cruising boats, would be a wise investment.

The rest are hand tools, foremost among which is a leather sewing palm (Fig 4.10), an indispensable item for any sailmaker ashore or afloat and a particularly personal piece of kit, because after it has been wetted and worked for a bit, it moulds itself to the hand and becomes comfortable to wear for long periods. It is used for pushing the needle through the cloth, in the manner of a dressmaker's thimble, except that this has a metal eye set in the palm, with indentations to take the head of the needle. It comes in two types. A seaming palm, as its name implies, is for all the day-to-day sewing of seams, tablings and patches and is in constant use during sailmaking. The other is a roping palm, used primarily for sewing on boltropes. This is heavy work

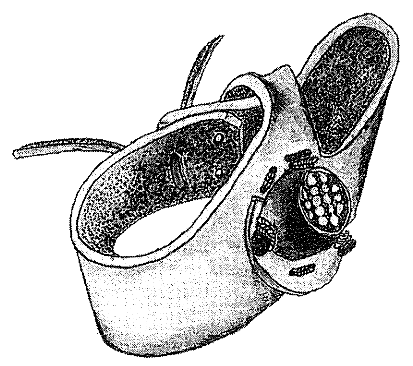


Fig 4.10 The leather seaming palm used for most hand-sewing work.

requiring stout needles, so it has larger indentations in a deeper set needle guard, and a protective piece built up around the thumb hole to allow the thread to be wrapped round it and pulled tight. However, the amateur may find it somewhat clumsy compared with a sewing palm, and if boltropes or very heavy cloth do not figure largely in the work, he can invariably manage without one. Both types are made in left- as well as right-handed versions.

Next, some sailmaker's needles. These are triangular in section, with their corners rounded so that the needle separates the yarns as it is passed through the cloth, instead of cutting them. They are graded by numbers conforming to the standard wire gauge, the size to be used depending on the weight of cloth being sewn and hence the weight of thread. They are not expensive, so it pays to have a good range, with some spares. For small yacht sails such as ours, with cloth in the 4–6 oz range, you will need No 17 and 18 needles – three or four of each in case of breakage or bending – some 19s (the smallest made) and a packet of household darning needles for nylon and other light cloth or for detail finishing, and a couple of 16s for multiple thicknesses and heavy cloths. The larger the needle the easier it is to thread and to hold, but the bigger the hole it makes in the cloth, so resist the temptation to use a 16 when an 18 is heavy enough and will make a neater job.

The corresponding sizes of hand seaming twine, which is made of spun polyester, are a 5-strand No 40 for most of the work and a 3-strand No 20 for the spinnaker and any other light cloth. It comes on small spools, ready waxed. (There are equivalent machine threads, which are identified by a variety of numbering systems. Choose the thread to suit the needle(s) on your machine.) It's a good idea to blunt the point of one of your 17s to use for roping, so that it will pass more easily between the strands of the rope without penetrating them and getting stuck. The other needles should be kept sharp with a fine stone, all of them oiled regularly or smeared with Vaseline and stored in an airtight container to prevent them from rusting.

Finally there are the various tools for cutting, stretching and flattening the cloth (see Figs 4.11a and 4.11b):

- A really sharp knife. The type doesn't matter – it can be a sheath or clasp knife, or one from the kitchen – but it should have a vee-ground blade, kept razor sharp, clean and oiled.

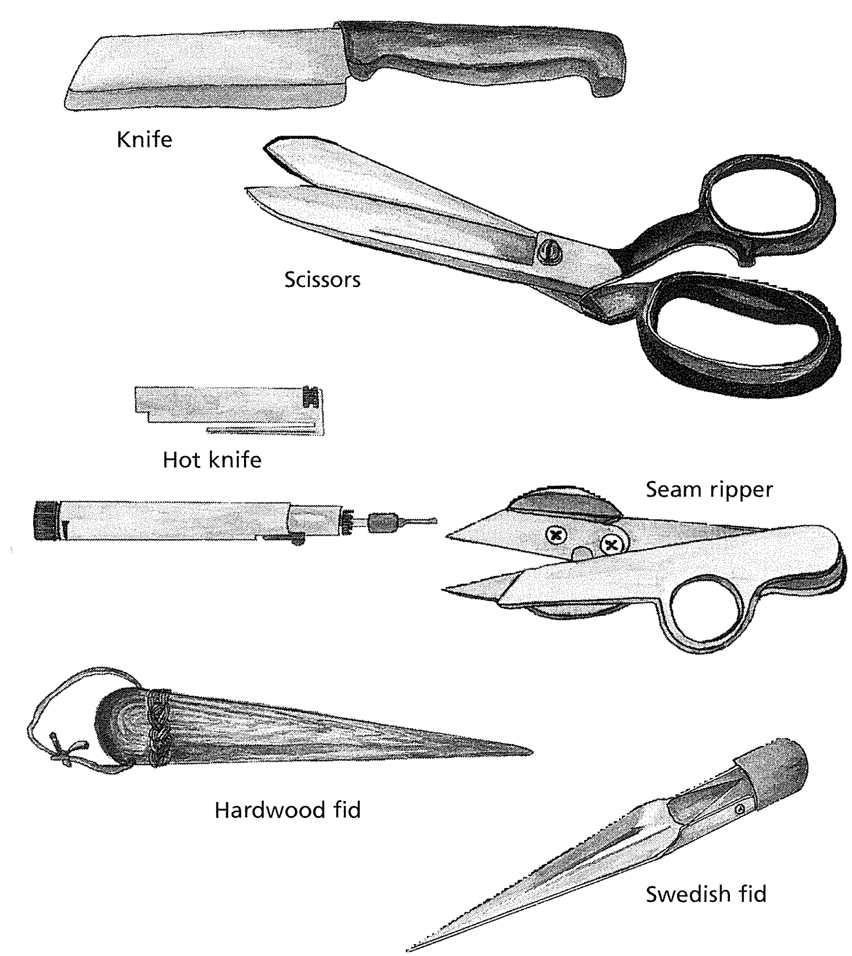


Fig 4.11a The sailmaker's hand tools.

- A good pair of large dressmaking scissors.
- A bevel-edged soldering iron or hotknife for cutting and sealing the raw edges of synthetic cloth, and preventing twine and rope ends from fraying. (The process produces acrid fumes, so make certain there is adequate ventilation.) You will also need a piece of aluminium, plastics laminate or stainless steel as a backing plate against which to do the cutting.
- A dressmaker's seam ripper; it is much faster and surer than a knife for removing stitching.
- Two or three fids of different sizes. A fid is a tapered hardwood spike, used for opening the lay of a rope when making a splice, stretching cringles before setting in the metal rings, opening up holes in cloth, and with a few turns of thread wrapped round it, for heaving up on stitches. There is also

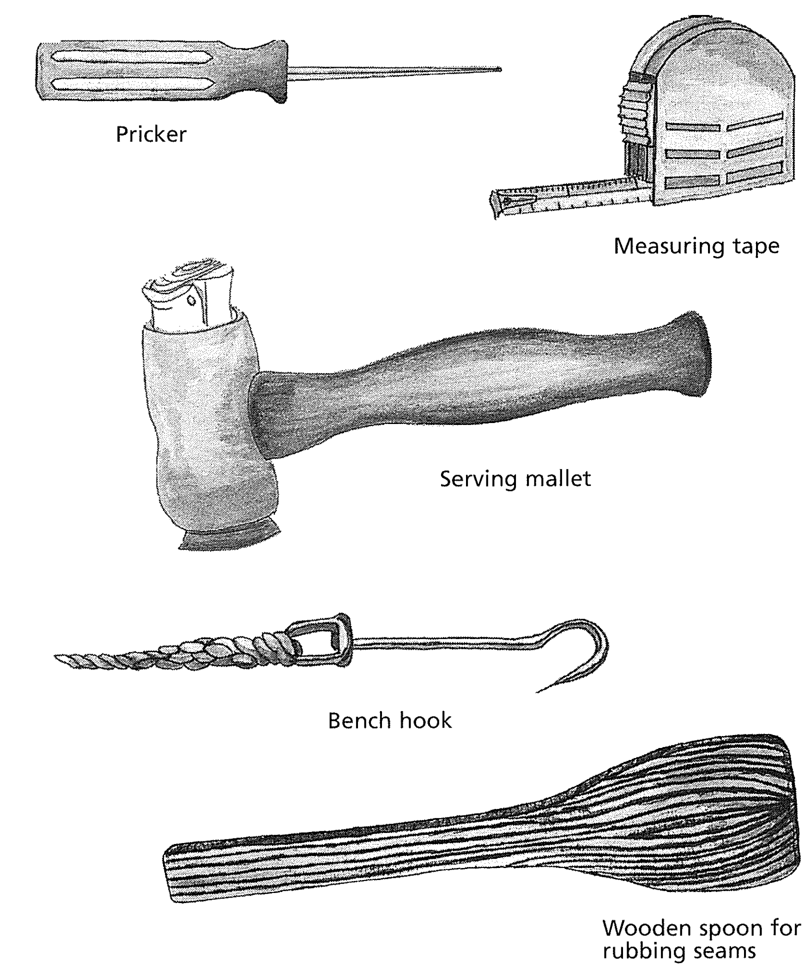


Fig 4.11b The saimaker's hand tools (continued).

a useful variant called a Swedish fid, which is made of steel and shaped like a gardener's trowel. This makes it easier to tuck in the strands of a laid rope when splicing it.

- A selection of eyelet punches and dies for two or three sizes of rings and turnovers.
- A light ballpeen hammer and a rawhide or wooden serving mallet.
- Pliers, for pulling needles through stubborn cloth and heaving tight on seizings.
- A bench hook. This is a steel hook with a swivel spliced to a lanyard. The sharp point is stuck into the cloth and the lanyard is tied away to one side

to tension the work against the pull of the needle. It effectively provides the sailmaker with an extra hand and makes sewing easier and neater.

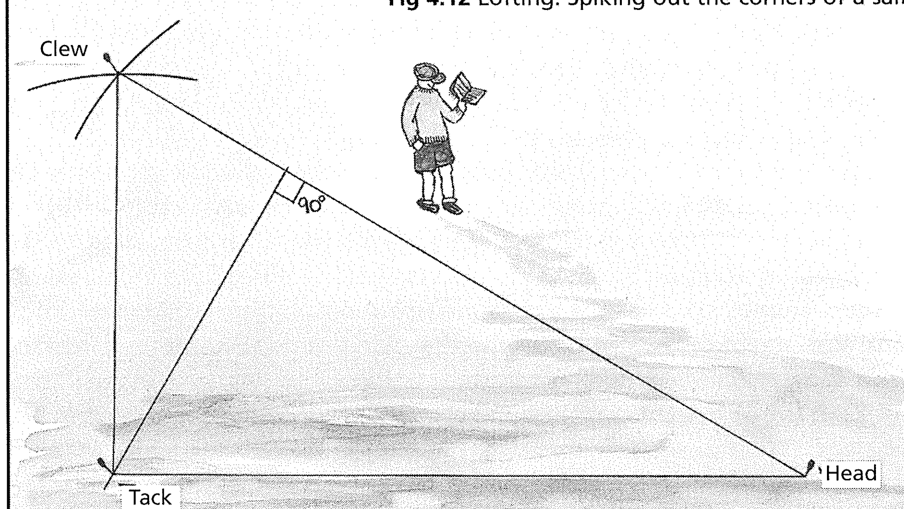
- A seam rubber for creasing the cloth and smoothing the stitches. A short-handled wooden spoon will do both jobs nicely, but you can use the rounded back of a knife or the blunt edge of a pair of scissors for creasing.

LOFTING, LAYING OUT AND CUTTING

Working from the measurements on the design plan, begin by spiking out the corners of each sail full size on the floor (Fig 4.12). Start at the tack by driving in the first pricker, followed by another to locate the head (assume for the moment that it is pointy – the headboard can be drawn in later) allowing for the stretch we can expect in the luff. From there, using a piece of twine as a trammel, scribe an arc in pencil on the floor roughly where you expect the clew will be. Repeat the procedure with the twine tied to the tack pricker. Where the arcs intersect, push in the definitive clew pricker, and stretch the twine tightly round all three, half-hitching it at each corner. Then simply chalk it and twang it to produce the basic outline of the sail.

The next step is to draw in the true line of the sail edges, with their respective roundings. Scaling the amounts of curvature off the design drawing, or working from the tables of offsets, transfer these measurements to the floor at the mid- and quarter-points, or at closer intervals if possible. Then sketch in the profiles, following the line of the tape arranged in a fair curve, or use thumb tacks and string to give a rough indication of the shape before free-handing it. A more surefire alternative is to draw along a spline, sprung

Fig 4.12 Lofting. Spiking out the corners of a sail.



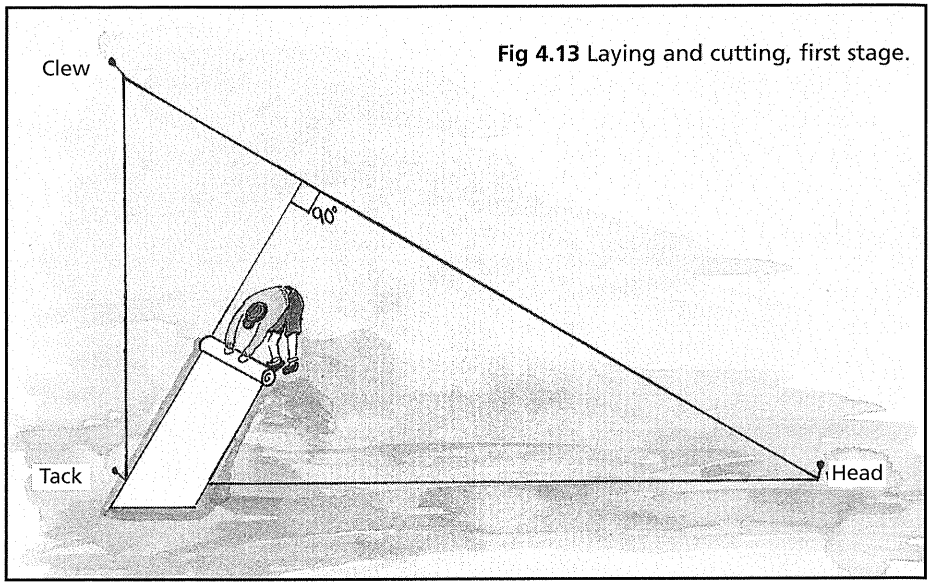


Fig 4.13 Laying and cutting, first stage.

against pushpins at the key points or held down with weights. Whichever method you use, check the fairness of the curve for any bumps or flatspots by lying down on the floor and eyeballing it. Finally, draw a dotted line round the outside of the sail where tablings are to be formed, and at a distance out according to their depth and type. This will only apply to the leeches in our case, since we propose using webbing tape on the other edges.

Now for the actual laying and cutting. Draw a seam line perpendicular to the leech – or to the straight-line edge of it, to be precise – down to the tack. Unroll the cloth so that its lower edge lies along the tack seam line and slightly overlaps the dotted line at either end (Fig 4.13). This is to allow for the subsequent broadseaming at the luff, which may shorten it a little, and in case one cloth should creep over another during the sewing. Then pin it down to the floor and cut it with the hotknife, using a backing plate to reflect the heat and save tattooing the floor.

Next, draw a sewing guide line parallel to its upper selvedge and about 15 mm down to allow for the seam overlap (the rule-of-thumb is 1 mm for every 10 gm/sq m of cloth weight). Even though the edges are heat sealed, they can still fray in time, so the professionals usually allow an additional 5 mm and turn them under, so that the needle will pass through three thicknesses of cloth. It is sound practice, albeit somewhat fiddly and by no means essential. Where broadseaming is to be introduced, allow the line to fall away in a smooth curve as it approaches the luff so as to produce the appropriate taper (see page 146) and draw a new sewing guide parallel to it. Then lay another cloth, starting at the luff, with the bolt turned round so that the slanting edge lies neatly along it. Number each panel on its forward end as you go along,

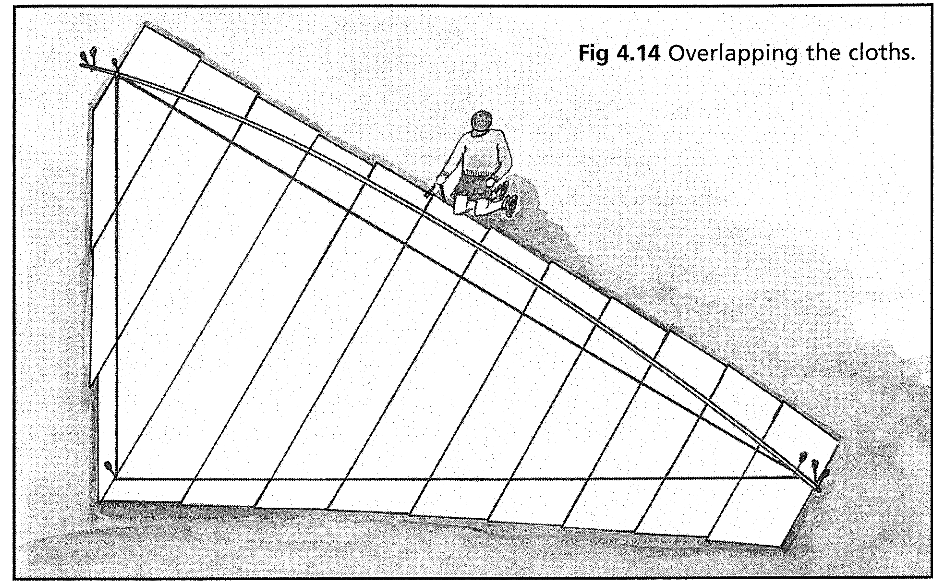


Fig 4.14 Overlapping the cloths.

and put strike-up marks – short pencil lines – at intervals across the real seams. When these come to be sewn, the two halves of each mark can then be lined up to ensure that the seam is sewn exactly as laid. Continue the procedure up the sail to the head, followed by the area under the tack seam – but with the upper edges of these panels and their sewing guides placed *under* the preceding cloth, so that all the seams overlap in the same direction (Fig 4.14). Finally, starting with the top panel, lift it and, without turning it over or around, lay it on the next one below. Lift both of these and lay them on the next panel and so on until they are all piled on one another, the top one being the first to be sewn. This may all sound a bit pernickety, but it saves getting into a muddle later.

Joining up and rubbing down

The novice sailmaker will do well to stick the cloths together with double-sided tape, to make sure they are correctly positioned before being sewn. Take the top pair of cloths off the pile; tape up the whole length of the first seam, leaving the paper backing on the upper side of the tape; roll away the upper panel and working from the leech towards the luff, unroll it along the sew-to line, including the broadseaming, aligning the strike-up marks and removing the backing paper as you go along. When you have reached the luff, check that the seam is fair and free of kinks and wrinkles. If you are not happy with it, take it apart, correct the faults and stick it together again.

Having read the instruction book for your machine and tried some test pieces on scrap material, there will be two adjustments you may have to make.

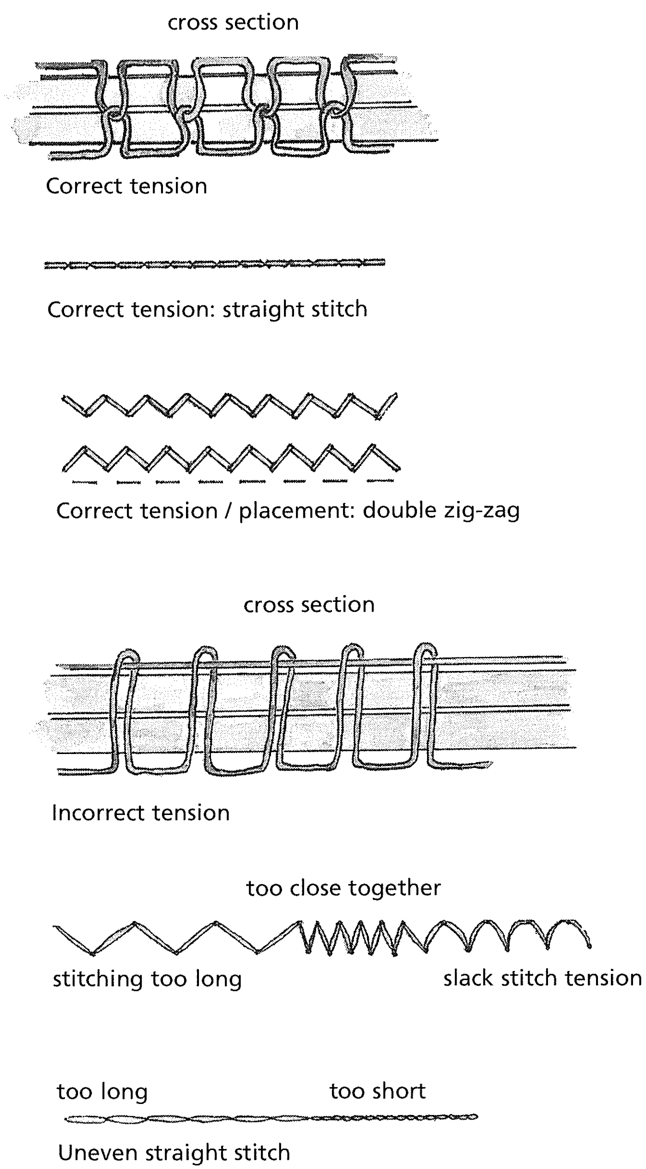


Fig 4.15 Adjusting the sewing machine tensions.

The first is the tension (Fig 4.15), which regulates where the interlocking occurs in the cloths; it should be somewhere in the middle of the sandwich, rather than on top or underneath it. The other is the stitch length. For most seams, 4–5 mm looks about right, with the zig-zags at right-angles to one

another, but where a rope is to be attached, increase the length to 6–8 mm. Where you are using sticky tape, it is as well to keep a can of silicon spray handy, as the needle may tend to get clogged.

Now you can safely run the first line of stitching, keeping it close to the edge of the upper cloth (say 3 mm from it), with the leech facing away from you and leading first into the sewing machine. Working like this, with the first cloth on top of the second and to your left, and with each subsequent cloth being added from the right, ensures that only a single cloth at a time has to pass under the arm of the machine, instead of a bunch that might get jammed. Turn the cloths over and sew a line of stitching along the other edge of the seam, from luff to leech this time. Continue the routine until all the cloths are sewn together, and then lay the sail back on the floor and pricker it down above the outline markings, pulling it out firmly to remove any wrinkles, but not stretching it.

At this stage you give the sail its final shaping. Check and correct any discrepancies that may have occurred during the sticking and sewing, making sure that the edge curves are fair and agree with the design profile, and then mark and bend over the tablings where these are called for, crease them with the seam rubber (together with the patches which we'll come to in a moment) and sew them down. Don't forget to run the leechline (3 mm braided) and make sure it doesn't get caught up in the sewing. It will be attached to the headboard, emerge through a small eyelet near the clew and be secured to a mini cleat sewn to the sail. Some sailmakers like to run over the lines of stitching with the rubber to smooth them, and to finish them off by painting them on both sides with one of the proprietary sealers which penetrate and bind the stitching together as they dry.

Hand-sewing and the stitches

Although as much of the sail as possible will be stitched on the machine, there are bound to be some parts of the work that have to be done by hand, either because it is too heavy, with too many layers of cloth (such as patches) for the machine to handle, too intricate for it, or inaccessible to it. You probably won't be able to match the dexterity and precision of a professional, but strength and an acceptable standard of neatness are quite easily achieved, provided you are patient and don't try to rush the job.

Most hand-sewing is done from above the cloth, rather than struggling to turn the work over with every stitch and push the needle through from the other side. This is the principle followed in flat seaming, the most widely used method of hand sewing panels, tablings and patches. Sit with the work across your lap and sew from bottom right to top left (Fig 4.16), with the bench hook caught in the cloth and tied off to the right, and the left hand tensioning the cloth against it. (Vice versa for left-handers.) Nudge the head of the

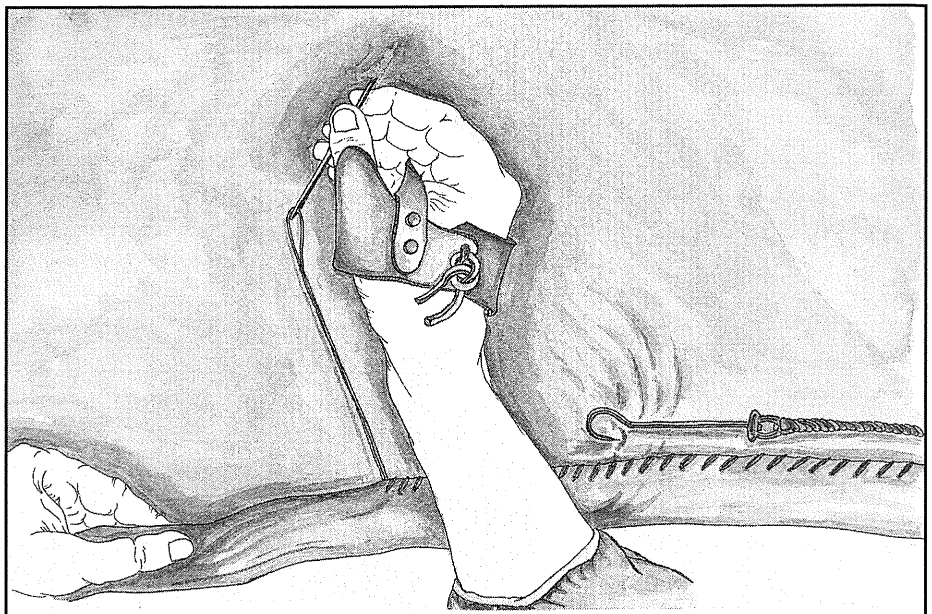


Fig 4.16 Sit with the work across your lap and sew from bottom right to top left.

needle into the recessed eye of the seaming palm and hold it there with the ring or forefinger while your thumb and index finger grip it firmly near the point (Fig 4.17), rotating the needle slightly anti-clockwise as you sew, in order to counteract the tendency for the thread to untwist itself as it is drawn through the cloth. Don't knot the tail end of the twine because it will probably chafe away. Instead, leave about ½ in (1 cm) of it sticking out from the cloth and anchor it by oversewing with the next few stitches.

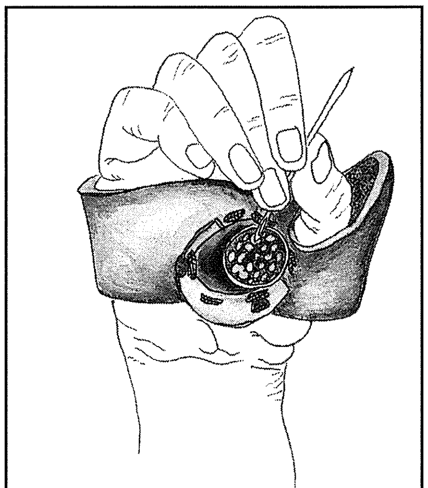


Fig 4.17 Holding the needle.

When flat seaming, always use the twine doubled, and start off with a length sufficient to reach from the work to your extended needle hand. Push the needle down through and then up again, all in one movement, taking care not to sew through more than the two layers of the seam. Space the stitches at 5 mm intervals (closer on light nylon) along the pencilled guideline as regularly as you can, pulling them just tight enough to sink slightly into the cloth without actually puckering it, and

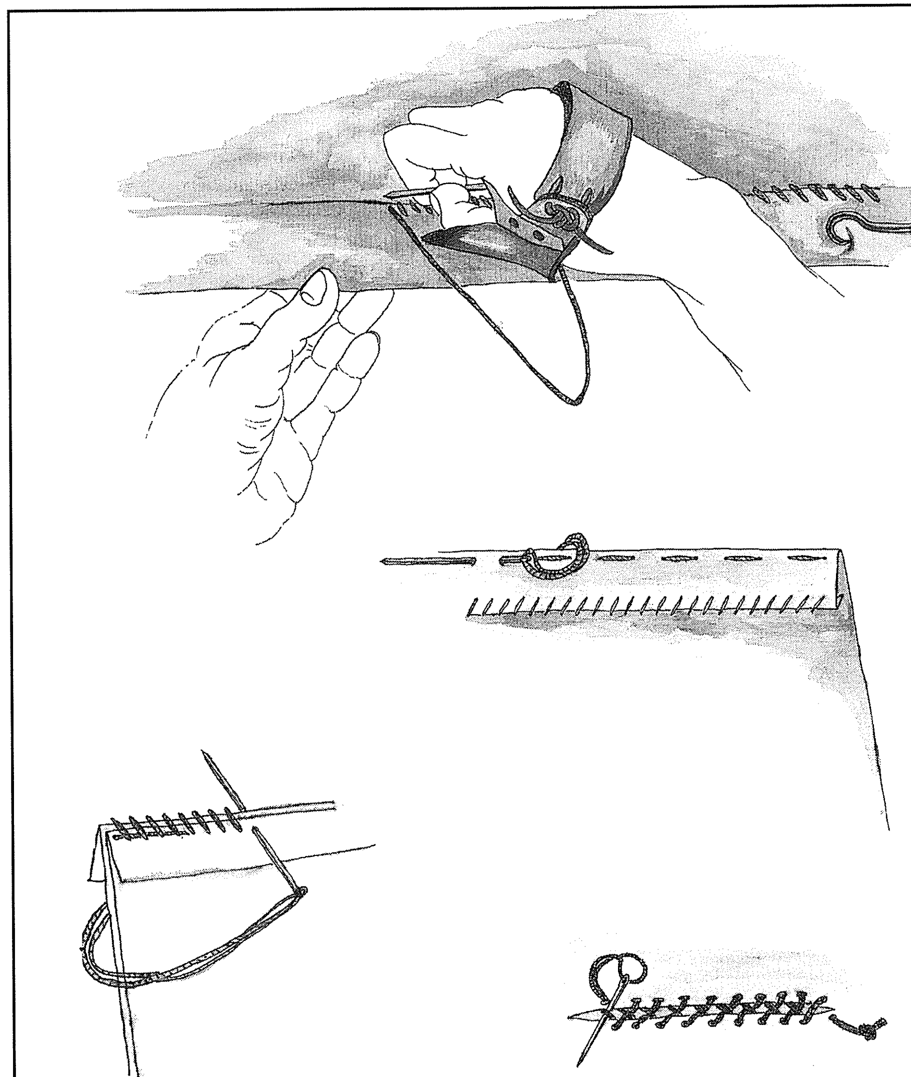


Fig 4.18 Hand-sewing stitches. *Top:* Sticking stitch. *Centre:* Running stitch. *Lower*

shifting the bench hook along as you proceed. At the end of the row, anchor the thread by passing the needle under the last few stitches and taking a final tuck under the cloth.

Next in the sewing repertoire is the sticking stitch (Fig 4.18), which can be used for tacking cloths together, instead of sticky-taping them (see below), so that they won't slide around on one another while you are trying to sew them; or to secure a luff wire to a headsail that is to be set flying, by sewing as closely as possible to the inboard side of it. (You can do this on the machine by using a piping foot.) With the needle facing away from you and pointing *along* the seam, pass it through the cloth at an angle, advance a short distance on the underside and bring it up through again. Another method of tacking is to use a running stitch, which is similar to the sticking stitch except that the needle goes through the work at right-angles, so that all the progress along the seam is made above and below it, instead of inside it. In practice, there's not a lot to choose between them if your sewing isn't particularly precise, but the running stitch tends to be the stronger.

Finally, for a row of stitches along a seam that is only visible from one side, eg when over-sewing the edge of a sail where two cloths have already been joined together, such as on a turned tabling or at the end of a batten pocket, the round stitch is simple and quick. For this it is best to work from left to right. With the bench hook pulling from your right, push the needle upwards and slightly away from you through the work, and repeat at close intervals.

Patches and pockets

Patches (Fig 4.19) are an integral and vital part of a sail's structural system and must be fitted wherever localised stresses will occur, notably at the corners, where they are sewn on together with any tablings that run through the patch. And as with the tablings, it is essential to cut the patches so that their warp and fill match that of the sail as nearly as possible. A considerable variety of sizes, shapes and styles can be used, depending on your aesthetic taste and personal preference, the material used and the time you are prepared to spend applying them. Some are a lot more decorative and elaborate than others, but their common purpose is to transfer the loads progressively into the body panels and along the tablings.

This is done by making each patch from several different-sized layers of cloth, their outer perimeters matching that of the sail corner, their inner ones following the chosen pattern in a series of steps. These should be no closer than about 2½ cm apart on a daysailer, 5 cm on a small cruising boat. The largest layer should be at least an inch long for every foot of sail edge (2½ cm in 30 cm) and with not less than two layers on either side of it – preferably three on our mainsail, and four or more on a big blue-water sail. Make each patch about 12 mm oversize all round, so that its edges can be turned under.

Opinions differ as to the best sequence for putting it all together. The simplest is to sew the largest one on first, and follow it with successively smaller layers. Some purists prefer each patch to extend into the sail less than the one outside it. A popular compromise is to start with the second largest layer, followed by the smaller ones, and finish by covering all of them with the largest. A further load-spreading precaution, if you have the time and patience, is to make each layer a different size from its partner on the opposite side of the sail. It is usually found convenient to sew the under patches on first, followed by the sail with its tabling, and then the top patches. With two, let alone three

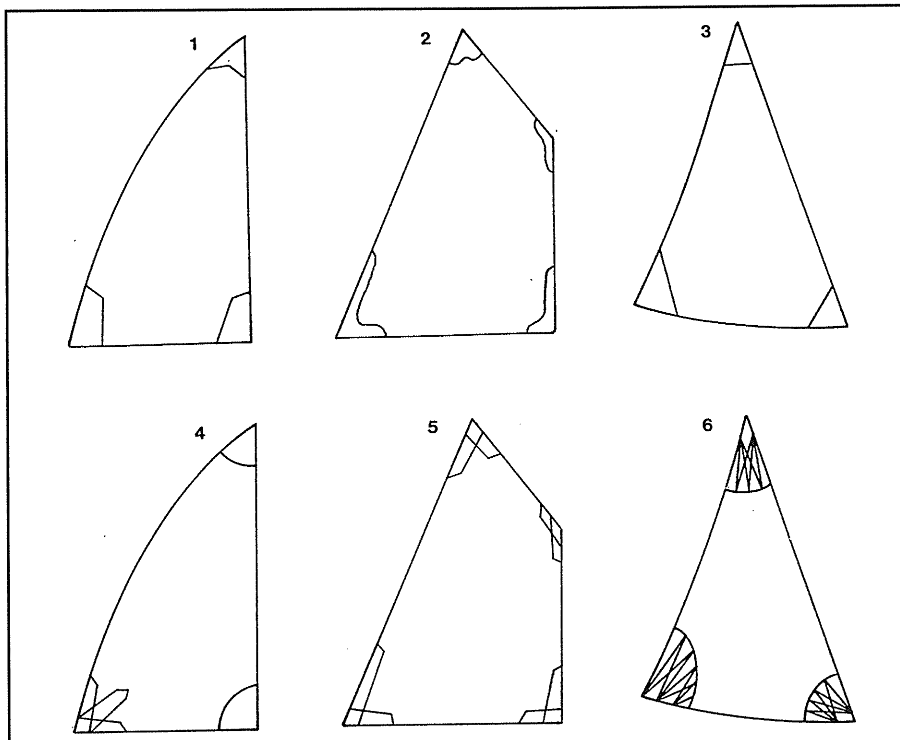


Fig 4.19 Patches. Some of the wide variety of shapes and styles that can be used to disperse the corner loads. Except on radial cuts, the cloth direction in the patches should match the weave of the sailcloth. 1 Rectangular tack and clew patches. 2 Fancy curved patches for a traditional boat. 3 Simple triangular patches. 4 Triple-finger clew patch. 5 Two-piece finger construction. 6 Radial stitching.

pieces of cloth either side of the sail, plus the tabling (or tape), hand-sewing will almost certainly be required if you don't have the luxury of an industrial machine.

Reef points, as positioned on your design plan, are constructed in similar fashion. The patches at the intermediate points, usually but not necessarily diamond shaped, are sewn either side of the sail, preferably with one slightly larger than its companion so that the stitching goes through different parts of the panel cloth. Each should have a sewn eyelet (see next page) at the centre of the diamond and a tie made up from line with a stopper knot on either side. The end patches, which take most of the strain, need to be multi-layered like those at the corners, with a heavy-duty ring worked into them.

Batten pockets (Fig 4.20) are also subjected to high stresses and must be carefully fitted. Cut the cloth for the pocket with the threadline running in the same direction as it does on the sail, and allow an additional 12 mm on all the edges so that they can be turned in when sewing. The pocket should

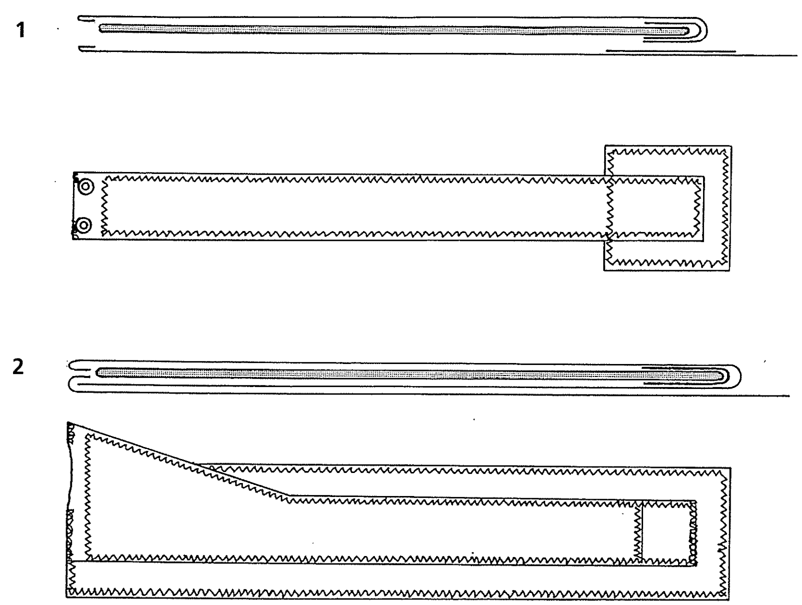


Fig 4.20 Batten pockets. 1 Simple construction, with end entrance secured with a tie cord or Velcro flap. 2 Heavy duty pocket, with angled entrance and elastic at forward end.

be large enough to accommodate the stitching as well as the batten itself, and reinforced with additional layers of cloth. Turn in a further 50 mm of cloth at the forward end, and either interpose an additional chafe patch between it and the sail – or better still, a full-length patch through which the sides of the pocket as well as the forward edge are then sewn. Finish off by round stitching both ends by hand. Some sailmakers also sew in a piece of elastic at the after end, to keep the batten pushed firmly against the leech so that it can't work loose and fall out. When sewing and oversewing the angled entrance, be careful to avoid the leech line, and should you be hand-sewing instead of machining, it's a good idea to insert a batten to prevent the needle from picking up the cloth of the pocket. Pockets for full-length battens are easily made from webbing tape, although its weave won't be consistent with that of the sail.

Eyelets, rings and thimbles

An eyelet, as its name implies, is a very small eye, in brass for most amateurs, stainless steel for those with the necessary press. It consists of an outer ring which is pushed through a criss-cross incision in the cloth, and a mating liner which is punched into position over it. Where more strength is required, as

on the reef points, the eyelet may be oversewn all round its periphery, before the liner is fitted to protect the stitching from chafe (Fig 4.21).

Eyes, which are best defined as large rings, are similarly worked into the luff and clew patches, and at the ends of each line of reef points. Their liners, known as thimbles, are then inserted and splayed out, using the appropriate punch. (Most large rings in production sails are of stainless steel and are hydraulically pressed, with no sewing: plain, but immensely strong.) Handworked rings are usually strengthened, especially the clew eye which is the most highly stressed, either by seizing to a pair of eyelets set further away from the edge of the sail so as to distribute the forces, or with one or two pieces of webbing running through the eye and sewn on in the general direction of the maximum tension.

A robust and traditional-looking alternative to a patched eye is a cringle (Fig 4.22). This is an external ring of rope, surrounding a brass or stainless thimble and attached to two eyelets in the sail.

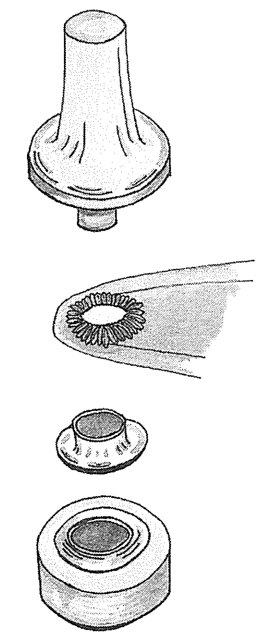


Fig 4.21 Fitting an eyelet.

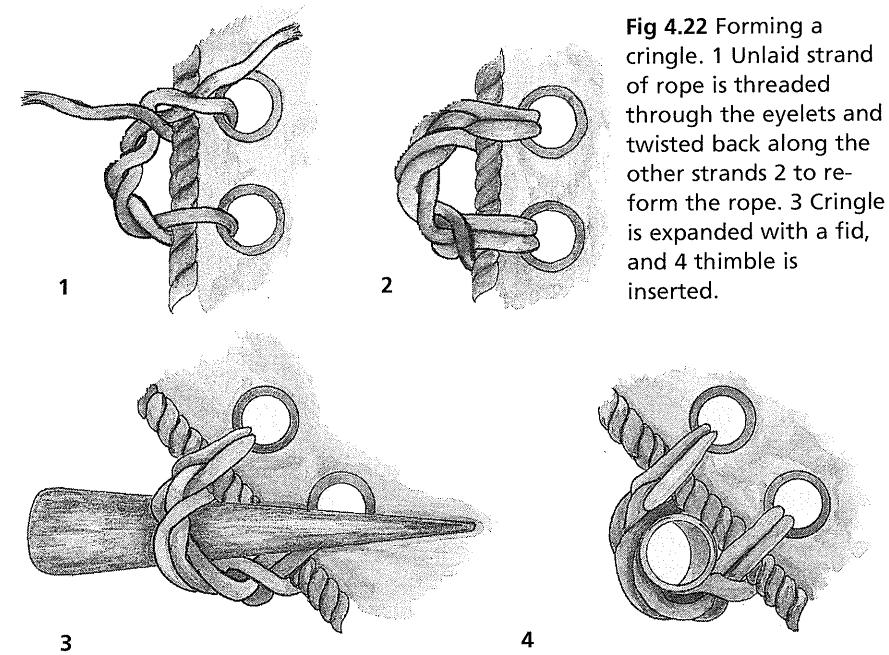


Fig 4.22 Forming a cringle. 1 Unlaid strand of rope is threaded through the eyelets and twisted back along the other strands 2 to re-form the rope. 3 Cringle is expanded with a fid, and 4 thimble is inserted.

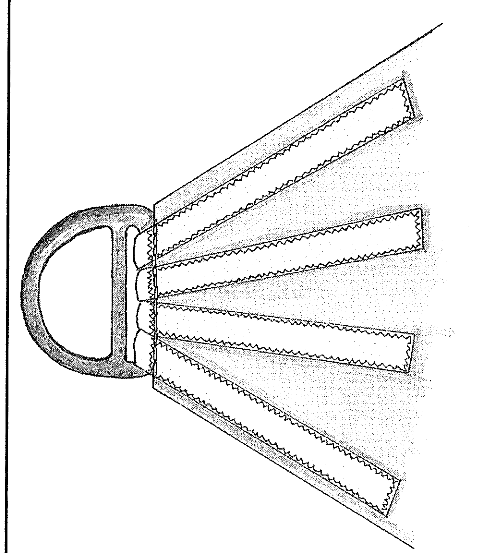


Fig 4.23 D-ring with crossbar.

To form a cringle, unlay a single strand of rope about four times as long as the circumference of the finished cringle. Thread it through one of the eyelets, leaving one end twice as long as the other, and twist them together again. Pass the longer end through the other eyelet, carefully and tightly twist it back along the others to re-form a three-strand rope, and tuck in the end as you would on a splice. The gap between the sail edge and the inside of the loop should be only *half* the finished diameter of the cringle. This is expanded by using a mallet to thump it down over a fid, which is then quickly removed before the cringle has time to shrink back, and the thimble is tapped into position.

Serving the same purpose as a patched eye or a cringle, is a stainless steel D-ring (Fig 4.23). This should be one of the types provided with a crossbar to prevent it capsizing under oblique loading. Several short lengths of webbing are passed through the ring under the crossbar, splayed out radially across the corner of the sail and sewn through to one another. By spreading the stress more evenly, this arrangement is stronger than a single large ring, though not as neat; more durable than a cringle; and easier to install than either of them. Its appearance is not to everyone's taste, but can be much improved by sewing on a leather gaiter as chafe protection.

Headboards, slides and ropework

Some blue-water voyagers prefer to fit a stout ring instead of a headboard, because these have been known to break under extreme conditions. But normally they are perfectly reliable, and act as a coat hanger in spreading the load at a Bermudan sail's skinniest corner. Made of plastics or anodised aluminium, they may either be fitted inside the sail between the top patches, pushed hard up into the pocket and sewn through pre-drilled holes; or mounted externally as a two-piece assembly, one on either side of the sail and its reinforcements, and sewn or riveted together. A large eye is then set in near the peak to accept the halyard shackle.

If you have opted for sail slides running in a track, rather than a boltrope held in a mast or foot groove, the best way to attach them is with webbing

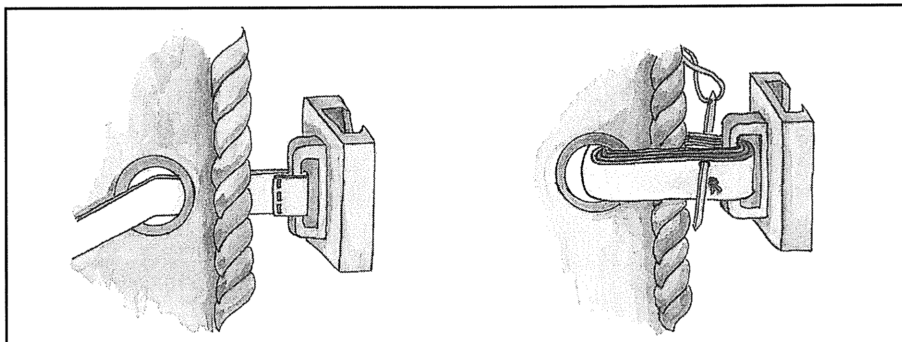


Fig 4.24 Attaching a mainsail slide with webbing tape. One end of the tape is sewn to the eye of the slide, the other end is passed several times through the sail eyelet and the slide, and all the parts of the tape are finally stitched through one another.

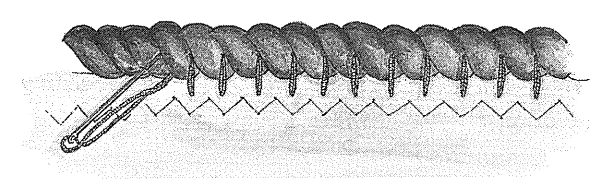


Fig 4.25 Fitting a boltrope.

tape (Fig 4.24), which is extremely hard wearing and doesn't chafe either the sail or the slides. One end of the tape is sewn to the eye of the slide, and the other passed through an eyelet in the reinforced edge of the sail and back through the slide. This is repeated three or four times, leaving enough play for the sail to swing from side to side, before the loose end is finally stitched through the six or eight parts. The sail eyelets should be placed at intervals of about a foot (30 cm) on a small sail (up to twice that on a large one), but kept far enough away from the nearest reef tack ring so that it can be pulled down past the accumulated luff slides to reach the tack hook.

There was a time when virtually all the edges of a sail were strengthened and finished by sewing them to a rope, known as a boltrope. Nowadays roping, except on traditionally rigged boats, is mostly confined to luffs and feet where they run in a grooved spar, jib luffs carried in the grooved headfoil spar used on roller reefing gear, and the occasional piece of decorative reinforcement round a clew. Wired luffs are usually still fitted to stormsails, but for everyday headsails the wire's resistance to bending makes them awkward to stow, wire splicing is labour intensive, and there is the constant threat of corrosion. So wire has been largely replaced by braided, pre-stretched polyester or low-stretch Kevlar® or Spectra® rope.

Pre-roped webbing tape is commercially available for roller headsails, with Teflon® woven in to reduce friction in the groove. However, the normal practice in making up an internal boltrope is to wrap a length of tape round the luff- or footrope, and to sew the two halves together as close to the rope as you can get. For sails of the size appropriate to a smallish cruising boat such as our 23 footer, 8 mm polyester rope and 50–75 mm tape will do nicely. If you are using the machine with a piping foot and it won't sew closely enough to the rope, lay in a light line instead and fish the rope through afterwards. Using this technique, you can also fish it around the corners, when two or more sides of the sail are to be roped, by cutting an access gap at the corner to fiddle the rope through, and sewing it up later. Alternatively, for a more traditional appearance, three-strand rope may be fitted externally. You do this by passing the needle around one strand and through the sail edge, repeating the process every strand's width further along the lay of the rope, taking great care that it doesn't twist and that both it and the sail are held taut (Fig 4.25). Nevertheless by far the simplest method for the amateur is to hand-sew the tape tightly round the rope with sticking stitches, and then to machine it to either side of the sail with two rows of zig-zag stitching. It should be finished off by tapering the ends of the rope into 'rats' tails', heat sealed with the iron.

Even though the rope is prestretched, it will probably elongate slightly under load, while the tape/sail combination will stretch quite a lot more. It is essential, however, that they remain in balance with one another. So before you start sewing, and whichever the method of attachment, each part should be hauled out, lying side by side to the sort of tension you expect from the halyard, using separate single-part tackles rigged to something solid at either end (such as a strongback across a door-way, or a tree through an open window). On a small to mid-sized sail, it is best to allow the rope to float freely inside the tabling, with just a stout multi-part seizing at the head and tack (and/or at tack and clew as the case may be). Leave several inches sticking out at each end, so that if wrinkles should appear when the tension is released, indicating that the rope is restraining the sail from developing its proper draft, it is a simple matter to cut and resew one seizing to give the sail a bit further to stretch. This procedure is not advisable, however, on any large sail, because the strain concentrated at its corners becomes very considerable in strong winds, and it would be potentially disastrous if a seizing were to pull away. So these boltropes need to be sewn in throughout their length, with the attendant care to avoid tensioning irregularities as the stitching proceeds.

Faults and remedies

Professional lofts usually have a test rig to check for faults in their sails, but apart from giving those you have made a preliminary examination by stringing them up horizontally in the garden, you can only do the job properly when they are set up on the boat and actually sailing. If possible, get someone else on the helm and look at the sails from a position ahead and to leeward.

The most common faults are creases. Some are impossible to avoid, particularly at the clew, and some will probably disappear after a few hours when the new cloth has settled down, so don't be in too much of a hurry to criticise your workmanship. Photograph the trouble spots, if you can, or memorise their locations, and mark them in pencil on the sail for future reference. Many of them occur because the clew, head and tack haven't been set up correctly, so try varying the halyard and outhaul tensions. You will probably be able to spot where seams or eyes have been incorrectly sewn, or where slides or hanks have been put on with uneven spacing between the sail and the spar or stay. A headboard eye not close enough to the luff or not directly below the fall of the halyard, or a headsail tack pennant out of line with the luff, will cause the sail to cant to one side and crease accordingly.

There are a number of other common problems with leeches. A slack one shows up as a crease running down the forward ends of the battens, with the roach falling away to one side; or if only the aftermost few inches of roach are slack, this section may vibrate in the wind with the characteristic drumming noise known as 'motorboating', and which can usually be dampened out with a slight adjustment to the leech line. There's also the case of the permanently hooked leech so often to be found on old sails whose leech line has been permanently tensioned, causing the cloth to stretch inside the tabling. Any of these faults can usually be cured by judiciously tightening one seam between each batten. This involves unpicking the seam in the trouble area and resewing it as a broadseam, with a 5–10 mm taper at the leech, depending on the severity of the slackness, to remove the surplus cloth. Conversely a tight leech, assuming the leech line is slack and not hooking the leech to windward, will show up as a tight line between the after ends of the battens. It is easily remedied by unpicking the seams and letting them out a few millimetres.

Care and repair

Sails can go through hell in a single season of hard weather, but a yachtsman can minimise any damage they may sustain and prolong their life by proper handling, plus a spot of preventive maintenance from time to time, and by making immediate running repairs – homeward bounders, as they were called in the days of commercial sail. The old proverb 'a stitch in time' works well for sailors.

Deterioration of sails is usually caused by one or more of the following: flogging, mishandling, chafe, sunlight, salt and damp. Some you can't avoid entirely, but you can reduce the effects of those you can't duck.

It is not always appreciated that modern synthetic cloths, particularly those that are heavily resinated and firmly finished – let alone the laminates – are subject to work hardening. Like a sheet of metal that develops a crease and becomes brittle by being bent back and forth until it eventually fractures, the

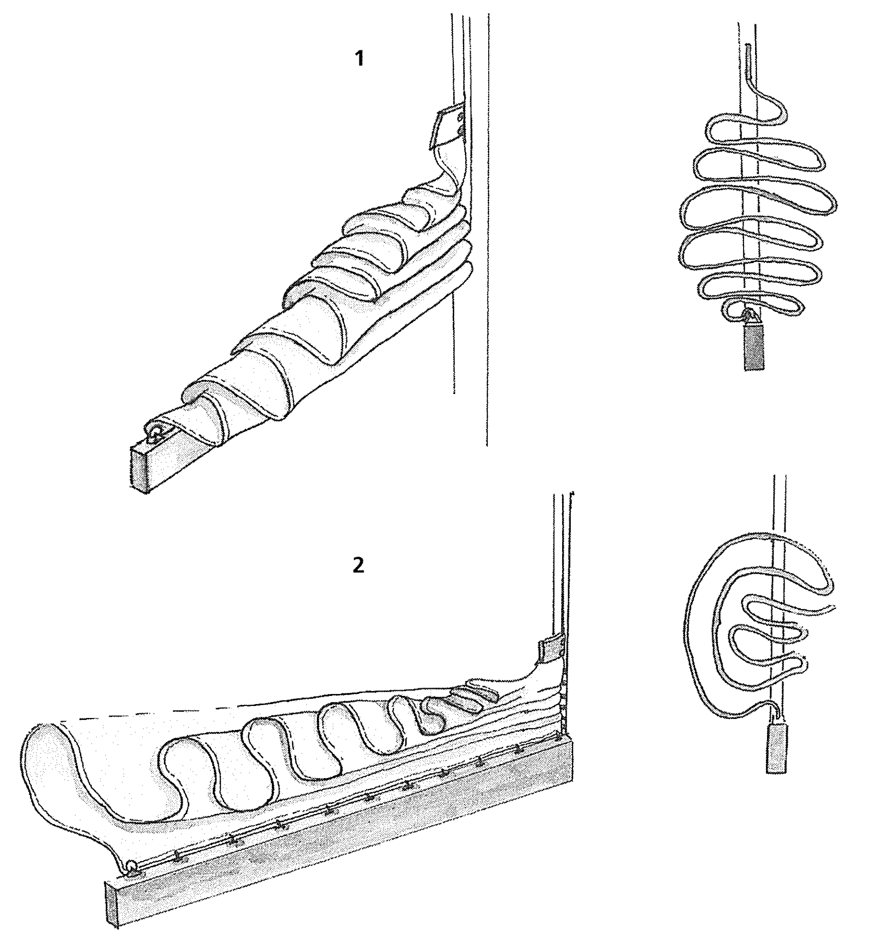


Fig 4.26 Two methods of stowing a mainsail. 1 Flaking it evenly on the boom, hauling the leech aft so as to avoid creasing it. 2 Pulling all the folds to one side and dumping them into the bunt before bundling the whole sausage round on top of the boom.

yarns in a sail are weakened if it is allowed to flog, leading to premature tearing. Flogging leeches are a common cause of this type of failure, with the breakdown usually occurring just forward of the leech tabling and clew patches. So before initial fluttering develops into full-blown flogging, slowly tighten the leech line until it is just snug enough to stop the movement. In the case of a jib with a slack leech that the line cannot control without hooking it excessively, try sheeting in a degree or two to dampen the oscillation. And avoid motoring into the wind at full speed for any length of time with the main up. When battens slat to and fro, they tend to damage the cloth where they hinge at the front of their pockets.

If you have to drag sails down, pull them by the luff, which is their strongest edge. Grabbing them by the leech is certain to stretch them. Flake the main tidily on the boom (Fig 4.26), folding bights in the sail as it is lowered and at the same time hauling the leech aft to avoid any creases. If luff slides are fitted, one should be in the centre of each fold, with an even bight lying on either side of it. An alternative method of furling, only really suitable for soft fabrics, is to pull all the folds of luff to one side as the sail comes down. Then haul the upper leech aft and work your way down it towards the clew, dumping each handful into the belly of sail and folding it into itself as you go along. Finally, with the sail gathered into a sausage, bundle it round on top of the boom and lash it just firmly enough to keep it in place. Always put a sail cover on a stowed main to protect it from sunlight, or dirt carried in rain which would otherwise collect in the folds and stain them, and from bird droppings.

Headsails should never be left lashed to the guard rail after a trip, but be carefully folded and bagged (Fig 4.27). Except with a very small sail, it takes two to do the job properly, one at either side pulling out the folds to avoid

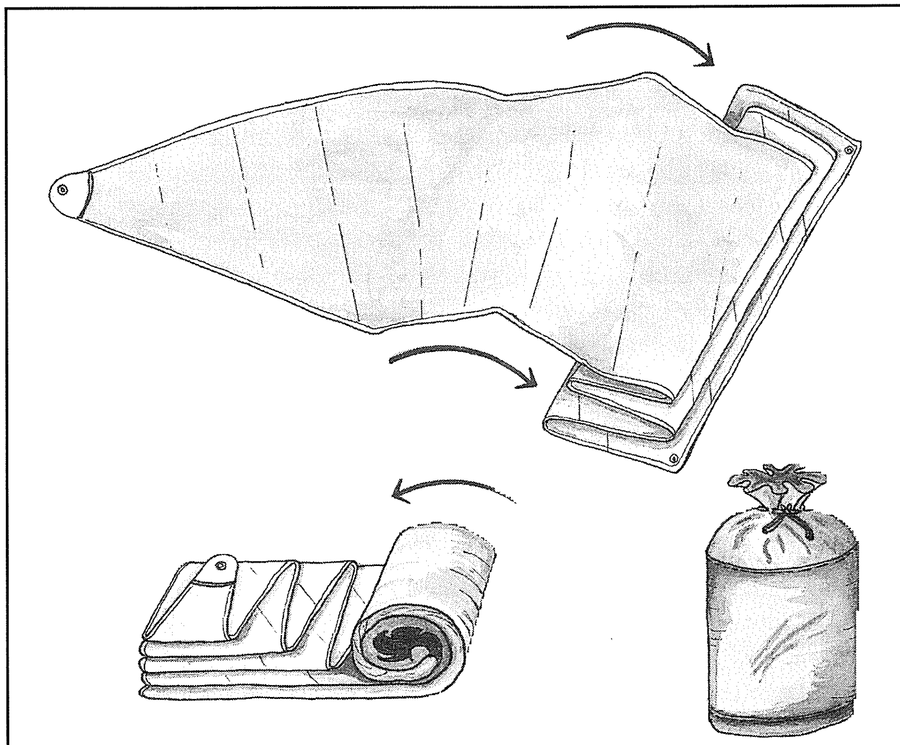


Fig 4.27 Folding a sail for bagging. Two people, one at the luff and the other at the leech, tension the sail between them to pull out the wrinkles while they flake it down. The bundle is then rolled up loosely and stowed in a slightly oversized bag.

creases and flaking them down on top of each other, starting at the foot. The whole package should then be rolled up loosely and put gently into a *large* bag, preferably three or four times the size of the rolled sail. Stuffing it down into a small bag creases the folds harshly and inevitably shortens the life of the sail. In the case of stiff, heavily resinated cloths (or laminates), the sail should be rolled up from the foot into a long sausage and stowed in a tubular bag. Nylon, on the other hand, doesn't crease much, so if the spinnaker is not kept stowed in a chute, it can be crammed into its turtle more or less any old how, provided the three corners are left accessible and clearly marked at the top of the bundle.

Whenever possible, dry the sails before they are covered or bagged, but don't be tempted to hoist them in a fresh breeze and allow them to flog. Better to lay them out on deck and tie them down while they dry out. If parts are wet with seawater, it's a good idea to rinse them out to prevent the salt from forming abrasive crystals, because these tend to cut into the cloth fibres and break down its finish. A rain shower makes a convenient alternative to a marina hosepipe; sailing in the rain is the most effective way of all to wash sails. If you get stains on them, scrub them with only a soft brush and soap or a mild detergent, so as to minimise wear on the stitching, and avoid using chemicals unless you can be sure of their effect. On the whole, they are best left to the professional cleaners. And at the end of the season, or whenever you need to dry off dinghy sails, hang them out ashore to air thoroughly, and support their weight by the luff acting as a clothes line.

The old bugbear of chafe is one that cannot be eliminated entirely, but you can avoid some of it and protect against the rest. Start by examining the sails inch by inch, if they are not new, for any signs of rubbing. Stitching and seams, and especially batten pockets, are vulnerable, as they are raised above the cloth surface. Danger spots to look for on the mainsail are where the topping lift has been allowed to rub against the leech, and wherever the body of the sail may have been in contact with shrouds, spreaders or lazyjacks. Chafe on a genoa is likely to occur while tacking, as it rolls around the spreaders, shrouds and rigging screws, and across the mast, being poked en route by stanchions, baby stay and sundry other projections. Headsails spend much of their time bellied out against the stanchions, guard rails or the pulpit; or sheeted in until they are up against a shroud or spreader on the weather side. In the case of new sails, hoist them and mark the locations of potential chafe areas as best you can.

Try to establish the cause of the chafing to see first whether it can be eliminated by re-siting any offending fittings. Apart from that, there are several protective measures that can be taken. First and foremost is to fit sacrificial patches to cover each critical area, either sewn flat on the sail, or folded in half and doubled around the foot and the leech to give protection to the edges as well as the sides of the sail. Leather gaiters can be hand-sewn round tack and clew corners where sheets are liable to damage them, and around the stitching of rings and cringles that can contact the mast, stays or shrouds. Short lengths of nylon webbing, which has a shiny finish and wears well, can be sewn to the outsides of batten pockets at potential trouble spots.

Next, go round the boat with a roll of pvc duct tape and wrap up all exposed cotter and ring pins and other sharp or protruding items – and the rigging screws too, if they are not fitted with plastic covers. The ends of spreaders must either be capped with plastic mouldings, or covered with pieces of white synthetic shag carpet with their edges stitched above and below each spreader. Parts of the shrouds themselves can be encased in split plastic hose, using the smallest size that will slide comfortably over the wire and revolve as the sail is dragged across it. (Most traditionalists prefer baggywrinkle, but in addition to increasing wind resistance it is liable to trap airborne dirt and other contaminants which can accelerate sail damage.) On a long running leg, it is worth rigging a preventer to hold the boom forward and down so that it doesn't pump up and down chafing the mainsail against the shrouds, in addition to its better known duty of guarding against an accidental gybe. It consists of a tackle attached about one-third of the boom's length from the mast and stretched across to the toe rail or to a pad eye just forward of the upper shroud, with its tail led to a cleat near the cockpit. Another obvious but often overlooked precaution is to avoid dragging an unbagged sail along a non-skid deck!

When examining the sails for signs of wear and tear, make sure all the stitching is in perfect condition. If any of it is suspect, push a fine spike under it, and if it has become weakened, it will come away quite easily. Watch out for panel seaming that has been worn by a batten on the *inside* of the pocket, where it is not immediately apparent.

While at sea, adhesive sail repair tape comes in handy for get-you-home patching of tears and holes in order to stop the damage spreading, but the sail should be darned or properly repaired at the first opportunity. For small holes, tears and burns up to about 12 mm, dressmaker's over-and-under darning is adequate, but for tacking back into position any longer tears, straight or L-shaped, always use a herringbone stitch (Fig 4.18). The easier alternative of bunching the two sides together with round stitching will stretch the surrounding cloth and cause wrinkles, besides standing proud and inviting chafe. In herringboning – there are several versions, this being the simplest – all the sewing is done from one side, and should be started in sound cloth well before the tear and finished some way past it. Double the twine and either knot the bitter end or take a clove hitch round the first stitch, and proceed from left to right. Push the needle down through the slit and up through the cloth on the other side. Then bring the thread across the slit and down through the near side, up through the slit, *across the previous stitch* and down again through the slit, up through the cloth on the far side, and so on, finishing with another clove hitch after passing the needle under several of the preceding stitches. Alternate long and short stitches help to distribute the load, and draw each one just tight enough to close the slit, but not so tight as to pucker the cloth.

For patching, try to find some material identical to the sail itself and align the weave direction. When working with a synthetic cloth such as polyester, you can dispense with hems and simply hotknife the edges of the tear and the patch. But if time allows, it makes a better job to turn those of the patch under. Crease the folds with a seam rubber, hold the patch in position with double-sided sticky tape, and either machine it zig-zag or hand-sew it with small, flat seam stitches. Where a tear crosses from one panel to the next and a small narrow patch will cover it, there's no need to worry about maintaining the integrity of the original seams. But if the damage requires a long, wide patch across more than one panel, it should be made from several pieces of cloth, machined together so as to reconstruct the original panel seams, before sewing it on to the sail. In the worst case scenario, with extensive damage running along a panel for much of its length, it will probably be as well to unpick and replace the entire panel, re-creating its edge curves and tapers, and re-using its tablings and other reinforcements. But this is likely to be a lengthy task best left to the winter lay-up. Rely meanwhile on your timely taping and patching to last the season.

Taking good care of your sails is, in some respects, just as important as maintaining your car, being able to repair them even more so. With a car, if you encounter a roadside fault you can't fix, you can at least go to a garage or telephone for help, whereas at sea you are very much on your own. Nevertheless sail problems are intrinsically easier to solve. They can usually be repaired sufficiently to get you home, instead of having to rely on an auxiliary engine. Even if they or their spars should sustain serious damage, they can be jury rigged, provided you have a clear understanding of how they work, the various configurations in which they can be set and controlled, and the way each can influence the handling of the boat.

I like to think that sailing is like riding a horse. When you are able to appreciate the reasons for its behaviour and can anticipate its reactions, it becomes, in a sense, an integral part of you. The more you can develop this intimacy, the greater the pleasure that sailing will give you.

Glossary

Aback A sail is aback when it is sheeted to windward and the wind comes on what should be its lee side.

Abaft nearer the stern than, further aft than, behind. As in abaft the mast.

Abeam At right angles to the fore-and-aft line of the boat.

About to go about is to tack through the wind – hence the command 'Ready about' to warn the crew.

Angle of incidence or **angle of attack.** The angle between the apparent wind and the chord of the sail.

Apparent wind The strength and direction of the wind as felt by the crew, being a combination of the true wind and the wind developed by the boat's own movement.

Aspect ratio The height of a sail (its luff length) in relation to its breadth.

Athwart Across, from side to side, as opposed to fore-and-aft.

Backstay A wire support leading aft from the mast to restrain it from falling forward.

Backwind One sail backwinds another when it deflects the airflow on to the other's lee side.

Balance A boat's ability to stay on course with the helm left free.

Barber hauler A control line from the clew of a headsail, or from a block running on its sheet, used to adjust the fullness of the sail.

Batten A flexible strip, usually made of plastic, inserted in a pocket in the leech of a sail to support the roach. Some high performance boats use full-length battens running from leech to luff.

Beam reach The point of sailing where the wind is abeam.

Bear away To turn the bows away from the wind, to alter course to leeward.

Beat To sail to windward close-hauled, as close to the wind as is practicable.

Bias The diagonal direction, at 45° to the warp and fill of a woven cloth, at which a load will stretch it most.

Bight A loop in a rope, or a coastal bay.

Block A pulley for changing the direction of pull on a rope.One or more blocks can be used to form a tackle or purchase which reduces the effort by improving the mechanical advantage.

Boom A horizontal spar to extend the foot of a sail and help to control it.

Boltrope Rope sewn along one or more edges of a sail to strengthen it and take some of the stress of the cloth when it is stretched tightly.

Brail Ropes running either side of the leech of a sail to gather it into the mast.

Bowsprit A spar projecting from the bow and from which a jib may be set. It provides a means of increasing the available sail area ahead of the mast.

Broach To slew round and luff uncontrollably broadside to wind and sea, heeling dangerously.

Broad reach The point of sailing between a beam reach and a run.

Broadseam A seam in a sail, in which the edges of neighbouring panels are cut in a convex curve, so that when they are sewn together the resulting taper in the panels forces fullness into the sail.

Bumkin A spar protruding from the stern to carry the backstay and mizzen sheet blocks.

Bunt The middle of a sail.
By the lee Running with the wind on the same side as the boom and mainsail. Easily leads to an accidental gybe.
Calendering The process of passing sailcloth between heated rollers under heavy pressure to flatten it and to make it more stable and less porous.
Camber The fore-and-aft curvature of a sail in relation to its chord.
Centre of effort The geometric point at which the wind forces on a sail, or on a combination of sails, is concentrated.
Centre of lateral resistance The geometric centre of the lateral underwater area of a hull.
Centreboard A streamlined board or plate that is lowered through a slot in the keel to provide increased lateral resistance and reduce leeway, and which can be raised to reduce the draft when sailing in shallow water.
Chord A straight line between the luff and leech of a sail.
Claw off To beat with difficulty away from a dangerous lee shore.
Clew The lower, after corner of a fore-and-aft sail, where the leech meets the foot.
Close-hauled The point of sailing where a boat is lying as close to the wind as she can without 'pinching'.
Close reach Sailing with the wind forward of the beam but not so close as to be close-hauled.
Crimp The undulation of the yarns in a woven cloth as they go over and under the crossed yarns.
Cringle A rope eye worked into the boltrope of a sail and fitted with a metal or plastic thimble.
Cunningham hole A cringle fitted a short distance above the tack, through which a line or tackle is rove to tension the luff.
Decitex Dernier. A measure of the thickness of a yarn. The higher the number, the coarser the yarn.
Downhaul A rope with which a sail or spar can be hauled down.
Draft The camber or fullness of a sail. The depth of water that a boat needs to remain afloat.
Edge curve The curvature cut into a panel of sailcloth before it is sewn up.
Euphroe A wooden block, with two or three smoothed holes instead of pulley wheels, through which are run the multi-part sheets of a Chinese junk.
Eyelet A small hole formed in a sail with a metal grommet through which a line or lacing can be passed.
Eye splice An eye formed in the end of a rope so that it can be shackled to a fitting.
Fall The hauling part of a rope or tackle.
False seam A seam made to reduce the width of a cloth by doubling it in the form of a 'Z' and sewing it down.
Fetch To reach a mark to windward without having to tack.
Fid A tapered wooden spike for opening out splices and cringles, or the lay of a rope.
Fill The yarns that run across the cloth from edge to edge.
Flake To lay a sail in folds either side of the boom. To lay a rope or chain out on deck so that it will run out easily.

Foot The lower edge of a sail.
Forestay A wire running from high on the mast to the bows or bowsprit in order to support the mast and carry a jib or genoa.
Free Not close-hauled. A boat is said to be sailing free when the wind comes from abaft the beam.
Furl To roll up or gather and lash a lowered sail.
Gaff The spar to which the head of a quadrilateral sail is attached.
Genoa A large triangular headsail extending abaft the mast.
Go about To change from one tack to another.
Gooseneck A fitting which attaches the boom to the mast, and allows it to articulate.
Gore The wedge-shaped panels of cloth in a spinnaker.
Greige Newly woven cloth before it is scoured to remove the size used to lubricate the yarns during weaving.
Grommet Originally a ring made from a single strand of rope, often worked into the boltrope. Nowadays a small grommet is referred to as an eyelet, a large one as a cringle.
Guy A rope or line used to restrain a spar such as a boom or spinnaker pole. A foreguy leads forward, an afterguy leads aft, a lazy guy is one on which there is no strain.
Gybe Jibe (US) When running, to turn the stern through the wind, bringing it across from one quarter to the other so that the boom swings across.
Halyard A line or rope used to hoist a spar, sail or flag.
Hand To lower, take in or furl a sail.
Hank A metal or nylon clip used to hold the luff of a headsail or staysail to a forestay.
Harden in To haul in a sheet so as to flatten a sail or bring it closer to the centreline of the boat.
Head The bow or stem of a boat. The top of the mast. The top edge of a four-sided sail or the top corner of a triangular one. The toilet.
Headboard A reinforcing plate sewn into the head of a triangular sail.
Headsail A general term describing any sail set forward of the mast (or foremast if there is more than one.)
Heave to A boat is hove-to by backing the headsail(s) and adjusting the mainsail and helm so that she is held quiet and steady, making almost no headway.
Hoist To haul aloft.
Horse A bar, rope or metal track on which the lower block of a mainsheet or jib boom tackle may travel athwartships.
Hounds The position where the lower shrouds and spreaders are attached. Traditionally, wooden chocks to locate the spliced eyes on the ends of the shrouds.
Jib The foremost headsail.
Kicking strap See Vang.
Lazyjacks Lines either side of a mainsail, led from the mast and under the boom, to gather in the sail as it is being lowered.
Leeboard A pivoting board, normally fitted in pairs, one on either side of a flat-bottomed boat, the leeward one being lowered to provide lateral resistance in place of a keel or centreboard.

Lee-bowing Sailing close-hauled with the tidal stream on the lee bow, so that the boat is pushed up to windward. This increases the apparent windspeed and enables the boat to point closer to the wind.
Leech The aftermost edge of a sail.
Leechline A very light line running through the tabling (hem) of the leech to prevent it from fluttering by adjusting its tension.
Lee helm The tendency of a boat to turn her bows away from the wind.
Leeward The direction in which the wind is blowing. Downwind. Opposite to windward.
Leeway The sideways drift to leeward caused by the wind.
Loose-footed A mainsail whose foot is not attached to the boom except at the clew.
Luff The forward edge of a sail.
Luff, to Sail closer to the wind. Luff up.
Mitre A central seam that roughly bisects the clew, so that the cloths run at right angles to both leech and foot.
Mizzen The after mast of a ketch or a yawl. The fore-and-aft sail set on the mizzen mast.
Offsets A table of measurements giving the co-ordinates of the various points along the edge of a sail panel to define its shape (or on the lines plan of a hull.)
Off the wind Not sailing close to the wind.
On the wind Sailing close-hauled.
Outhaul The line or tackle used to pull a sail out along a spar.
Palm A leather strap worn on the palm of the hand for thrusting a needle through sailcloth.
Parrel A strop or collar to hold the jaws of a gaff to the mast.
Peak The upper aft corner of a gaff sail where the head and leech meet. The aft end of the gaff itself.
Pinch to sail so close to the wind that the sails lose drive.
Pitch The rocking horse motion of a boat in a seaway. The distance that a propeller would advance in one revolution, assuming no slip.
Point The ability of a boat to sail close to the wind. To 'point' up is to sail closer.
Port tack Sailing with the wind blowing from the port side, mainsail across to starboard. A boat on port tack is required to keep clear of one on starboard tack.
Quarter The after side of a boat from amidships to astern.
Radial Cloth panels radiating from the clew and increasing in width towards the luff.
Rake The fore-and-aft angle of the mast or other part of a boat such as the stem, stern or rudder.
Reach A boat is reaching when she is neither close-hauled nor running. (See also close reach and broad reach.)
Reef, to To reduce the area of a sail by hauling a 'slab' down to the boom (slab, or jiffy reefing), or rolling up part of it.
Reef points A row of eyelets and ties to tie the loose folds (bunt) of a reefed sail down to its foot.
Rig The arrangement of sails and spars on a boat.
Rigging The ropes and lines that support the mast (known as the standing rigging) and those that hoist or control the spars and sails (the running rigging.)

Roach The part of the sail that extends beyond the straight line between the head and the clew. Roach is sometimes also applied to the foot.
Roband A rope band or loose-fitting loop of rope round a mast, as an alternative to lacings or hoops, to hold the luff of a mainsail to the mast.
Roping See boltrope.
Run To sail before the wind.
Runner Short for running backstay, one that can be slackened off, only the weather one being set up to support the mast from aft.
Sailmaker's yard. A unit of measurement used only in the US, where most sailcloth originates, and amounting to 28½ in. The reason is that cotton cloth used to be woven 28½ in for sailing ships, although weight was, and still is, measured per running yard.
Scandalise To reduce the area of a mainsail by topping up the boom, or on a gaff sail by lowering the peak and tricing up the tack.
Scrim A very loose, open weave cloth sandwiched between Mylar laminates to strengthen high stress areas of a sail.
Self-tacking A headsail that automatically shifts from one side to the other when the boat is tacked, as does a mainsail.
Serve To bind the end of a rope tightly with small thread to prevent fraying. The result is known as a whipping.
Set flying A sail attached only at its head, tack and clew, the luff not secured to a stay or mast.
Sheet A rope atached to the boom or to the clew of a sail in order to harden it in or ease it out.
Shroud Those parts of the standing rigging that support the mast laterally, the cap shrouds running to the masthead and the lowers to an intermediate point where the spreaders are fitted.
Snotter A strop, usually of rope, to support the heel of a sprit or to take the thrust of a sprit boom and hold it close to the mast.
Spreaders Struts that spread the shrouds out sideways away from the mast, reducing the angle they make with the mast and hence the load on them.
Sprit A spar set diagonally across a spritsail to hold out its peak, or horizontally as a spirit boom to extend its clew.
Square rig One that carries rectangular sails suspended from yards which lie across the mast.
Standing part That part of a rope or tackle that is made fast and not hauled upon.
Starboard tack Sailing with the wind blowing from the starboard side, mainsail across to port. When two boats meet on crossing courses, the starboard tack boat has right of way.
Stay Part of the standing rigging giving fore-and-aft support to the mast.
Staysail A sail set on a stay or set flying, as distinct from those with their luffs attached to the mast. A sloop's staysail is known as a jib. Where more than one headsail is set, as on a cutter, the foremost is termed the jib. Boats with more than one mast may carry a number of staysails between the masts.
Stem The forward edge of the bow.
Strain The linear deformation of material subjected to load.

Stress The load applied to a material, divided by its cross-sectional area.
Strike-up marks Short pencil lines at intervals across the join of sail cloths laid out on the loft floor, to ensure that they match up when they are sewn together.
Tabernacle A housing on deck which carries the heel and pivot of a lowering mast.
Tabling The folded hem, or additional pieces of cloth, sewn to the edges of a sail to reinforce them.
Tack The lower forward corner of a sail.
Tack, to To go about when close-hauled, to change from one downwind tack to the other by gybing.
Tackle A purchase, with rope rove through one or more blocks to increase the mechanical advantage and hence the pulling power.
Telltales Short lengths of light material or tufts of wool fastened either side of a sail, or to the leech, to show the direction and behaviour of the airflow at that point.
Throat The upper forward corner of a gaff sail.
Topping lift An adjustable line from the mast to support the after end of the boom and to support it when the mainsail is lowered or being reefed.
Topsail A triangular sail set above the mainsail of a gaff or sprit rigged boat.
Traveller A roller- or ball-bearing car running on a track. A ring sliding on a horse or along a spar such as a bowsprit.
Vang A tackle or adjustable strut, usually running from the foot of the mast to a short distance along the boom, to pull it downwards and prevent it from lifting, and to control leech tension. A line or lines from the deck to the peak of a gaff or sprit to control its movement.
Vmg Velocity made good, being the best combination of direction and speed through the water to windward (or downwind), or actual speed over the ground towards a waypoint, using GPS.
Warp The yarns that run lengthways in a woven cloth across the fill yarns. A line used for mooring, anchoring or towing.
Wear To change tacks by turning away from the wind and gybing round.
Weather, to To be able to pass something without having to tack.
Weather helm The tendency of a boat to turn her bows to windward.
Windage Those parts of a boat exposed to the wind that contribute to the total air drag, eg superstructure, spars and rigging.
Wind-rode A boat is said to be wind-rode when lying at anchor or moored head to wind, and tide-rode when she lies to the tidal stream. It depends on which has the stronger influence.
Windward The weather side. The direction from which the wind is blowing. Towards the wind. Opposite leeward.
Wishbone A boom in two halves, outwardly curved in the shape of an airfoil, between which the sail is set.
Yard The spar carrying the head of a lateen, lug or gunter sail, or on which a squaresail is set.

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