Junk Rig Design.
Thoughts on Cambered Panels
and the Split Junk Rig.

Introduction.

The fully battened balanced lug rig which is generally referred to as the Chinese Junk Rig has been around for thousands of years, initially in the far east and more recently in the so called western world. The problem with these western versions of the rig has been that they have not necessarily retained all the useful features of the earlier rigs, but possibly more importantly, have been built at a time when the western Gaff Rig has developed into the Bermudan Rig. With the aid of serious financial backing the Bermudan rig has been developed as a competitive racing rig and become all popular, leaving just a few stalwarts to enjoy the advantages of the under-developed junk rig.

The book *Practical Junk Rig* (PJR) by 'Blondie' Hasler and Jock McLeod provided a lot of the information needed to build what many see as the typical Westernised Junk Rig, and it is of great value in that it has a lot of information on the detail required during construction.
PJR is considered by many to be the Bible of Junk Rig, though following the recent developments in design and performance it perhaps should be more accurately called 'The Old Testament' in Christian terms.

PJR points out that the bending of the battens will give camber to the sail and will improve the performance, but when wooden battens are made thin enough to bend they tend to break when put under compression. To prevent breakage the battens become stronger and therefore stiffer so the rig tended to end up flat and with the aerodynamic performance of a flat board. Although not critical when sailing well off the wind it does result in a very poor lift/ drag ratio and poor windward performance. In practice many users of the rig do not keep it well tensioned and do not get optimum performance out of the flat rig. Unfortunately the net result is that, quite reasonably, the average uninformed cruising sailor believes that the junk rig is slow and continuously reminds everyone of that fact.

In *The Chinese Sailing Rig* and the later edition *Design and build Your own Junk Rig* by Derek van Loan, the author describes the rig he developed which results in a lower yard angle and lower stresses on the rig. This rig has a lot to recommend it and many of the ideas have been incorporated in the split rig.

Both these books tend to lead the reader toward the style of rig used by the respective authors which is inevitable as anyone who builds a successful rig will find it useful to complete a write up on the process to answer the many questions that tend to follow. Such is the situation with the Split Junk Rig, which seems to show potential as a modern development of the fully battened lug rig. The following notes give information on building cambered panels on rigs with stiff battens which is the basis of the split rig, as well as information on the jib panels in front of the mast. Hopefully the reader will find something useful and of interest.

Various members of the Junk Rig Association have experimented with rigs in an effort to improve the performance, initially using modern materials to make synthetic bendy battens and later to fit hinges in the battens to introduce camber in the sail. Where there has been some gain in performance, both methods have their weaknesses. In particular, with both arrangements the front portion of the sail can curve the wrong way and thus are not able to provide the camber in the correct area to produce the best windward performance.

Over many years David Tyler has probably looked at a wider range of ideas that anyone else in the junk rig movement, and like all good experimenters, has been prepared to share his experience with us all. There are others who should be acknowledged for their work with full and half wishbone battens like Paul McKay and Nils Myklebust, and of course all those I will offend by not mentioning. My apologies to all of them, but it has all added to the useful pool of knowledge.

One JRA member, Arne Kverneland based in Stavanger, initially experimented with hinged battens but then moved on to stiff battens with the camber built into the material of the sail. Although not necessarily the first to experiment with the concept, by working alone Arne was able to experiment without being told that he was working outside the usual parameters with the result that he achieved what he wanted to do and has ended up with an excellent uncomplicated and easy to use junk rig based on the PJR shape with extremely good performance. More importantly, Arne has gone to a lot of trouble to publish what, why and how he did it so that all could benefit from his experience.

Despite have read all of Arne's information and even having enjoyed sailing his second cambered rigged boat *Johanna* I still felt that it was worth looking further. There seemed to be no reason why even better performance could not be obtained from a junk rig by presenting a clear cambered area in front of the turbulence caused by the mast and further improving the windward performance. With this reasoning there seemed to be no reason why a junk rigged boat could not consistently perform at least as well as a Bermudan rigged boat on all points of sail. Writing my thought on the subject into the word processor and knocking the words into some shape produced the article 'Some Thoughts' (Appendix 1). The idea of the split rig seemed to make sense, and possibly offering some advantages in mast position and sail balance, as well as having lower structural forces in the rig but the only way to be sure was to build it and try it. I'm pleased to report that the rig seems to surpass the original expectations.

If starting to write 'Some Thoughts' now with the information I have gained from building and sailing the rig there would only be a few minor changes made. None of them would contradict the basic idea that it is the camber over the first third of the rig that is so important and which produces the high lift/ drag ratio that is required for good windward performance

Chapter 1.

General description of the Split Junk Rig.

The Split Junk Rig was designed and built in an effort to improve the all round performance of the westernised junk rig and with particular focus on the poor windward performance.

It is a ‘Chinese style’ fully battened balanced lugsail set on an unstayed mast with sheeting to most of the battens. It differs from the usual western version of the rig in that a large portion of the sail is set in front of the mast. Using stiff battens and with camber built into each panel, there is a ‘split’ in the sail just in front of the mast to allow the portion of the sail ahead of the mast form its designed camber on both tacks without being distorted by the mast. Designed with a low yard angle which results in there being low stresses within the structure, it is a simple rig to sail with the minimum of standing and running rigging, and once hoisted only requires adjustment of the sheet when changing point of sail.

All tests to date show that the rig has fully achieved its aim. It quickly became clear that this rig had the potential to upset the cruising Bermudan world, IF some potential weaknesses could be eliminated. In early reports these weren’t mentioned because they didn’t really cause a problem, but even so it seemed wrong to write a ‘how to do it’ article until there were answers to these concerns.

In the autumn of 2010 a destruction test was made on the rig and succeeded in damaging the sail and it became clear that the rig was much stronger than originally thought. The same treatment to a jib or Genoa on a Bermudan rigged boat would most probably have been shredded the sail beyond repair, yet there was little difficulty making a reinforced repair to the split junk jib. With this reinforcement built in there are no longer concerned about that structural weakness. In practice the damage was so slight that I had even considered sailing without making the repair, as a friend wanted to see the rig in action.

When making the repair a modification to the ‘cut of my jibs’ was also made, literally, to correct the other main weakness which caused concerned. No doubt there are further improvements that will be made to the jib design, but for now it appears good enough to offer the information for general consumption.

Disclaimer.
Although I have followed activities which involve airflow most of my life I make no claim to be a professional in the field. I have read a lot and learnt a lot through practical experience, and have seen what does and does not work. I have always been amazed at the standards many sailors consider to be acceptable and where I am not looking to win the America’s Cup I am looking for

respectable performance from a basically simple to build and maintain cruising rig that is also simple to use.

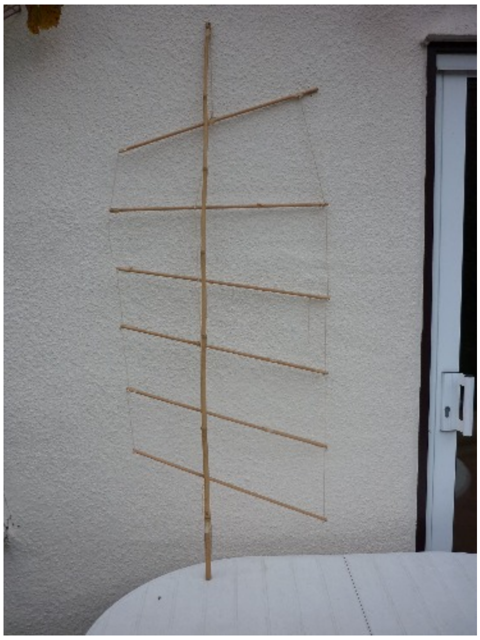
If anyone follows my example or uses information given by me they do so at their own risk. The information is given freely for personal use, and if you make use of it I would like to hear about your experiences as the information may help to improve the breed. On the other hand, if anyone wishes to use this information to make financial gain and reward then I feel it is reasonable to ask them to discuss the situation with me so that I may also make some small gain for my efforts.

Chapter 2.

Modelling and Designing the rig outline.

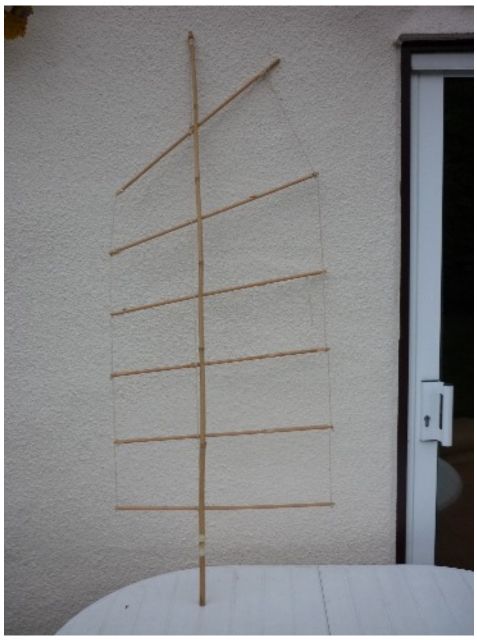
Looking for a boat to try the rig on I found a 31 foot Westerly Longbow with a damaged mast, time expired rigging and worn out sails; in other words a good hull in need of a new rig. The project was on, and the parameters started to fall into place. Aiming to compare the new rig with the typical cruising rig fixed the sail area at the area of the full mainsail plus the area of the typical roller Genoa at about 135%J (between a No.1 and No.2 genoa), and resulted in a total sail area of 515 sq.ft/ 47.5 sq.m. In practice the performance of the rig is so good that there has never been a desire to have more area than this, even down to 4 knots of wind which gives 2 knots boat speed in any direction. With less wind then it is just impossible and impractical to have enough sail area on any boat.

Some of the rigs produced in the '90's seemed to have a multiple of strings and apparently necessary adjustments to make them work. It seemed sensible to try to produce a rig that simply hung from the halyard in its own natural shape, and therefore have a minimum of stresses on the the various parts.



A model was built out of dowels about 600 mm long, string and a garden bamboo cane in an effort to devise a simple low stress set up. There was no need to add cloth to see how it works, as the sail material should not be required to add strength to the structure. The creases that can be seen in the photos of the finished rig are a result of the first sail not being quite right and a new rig with increased balance and the peaking halyard/ parrel fitted should not have the same problems.

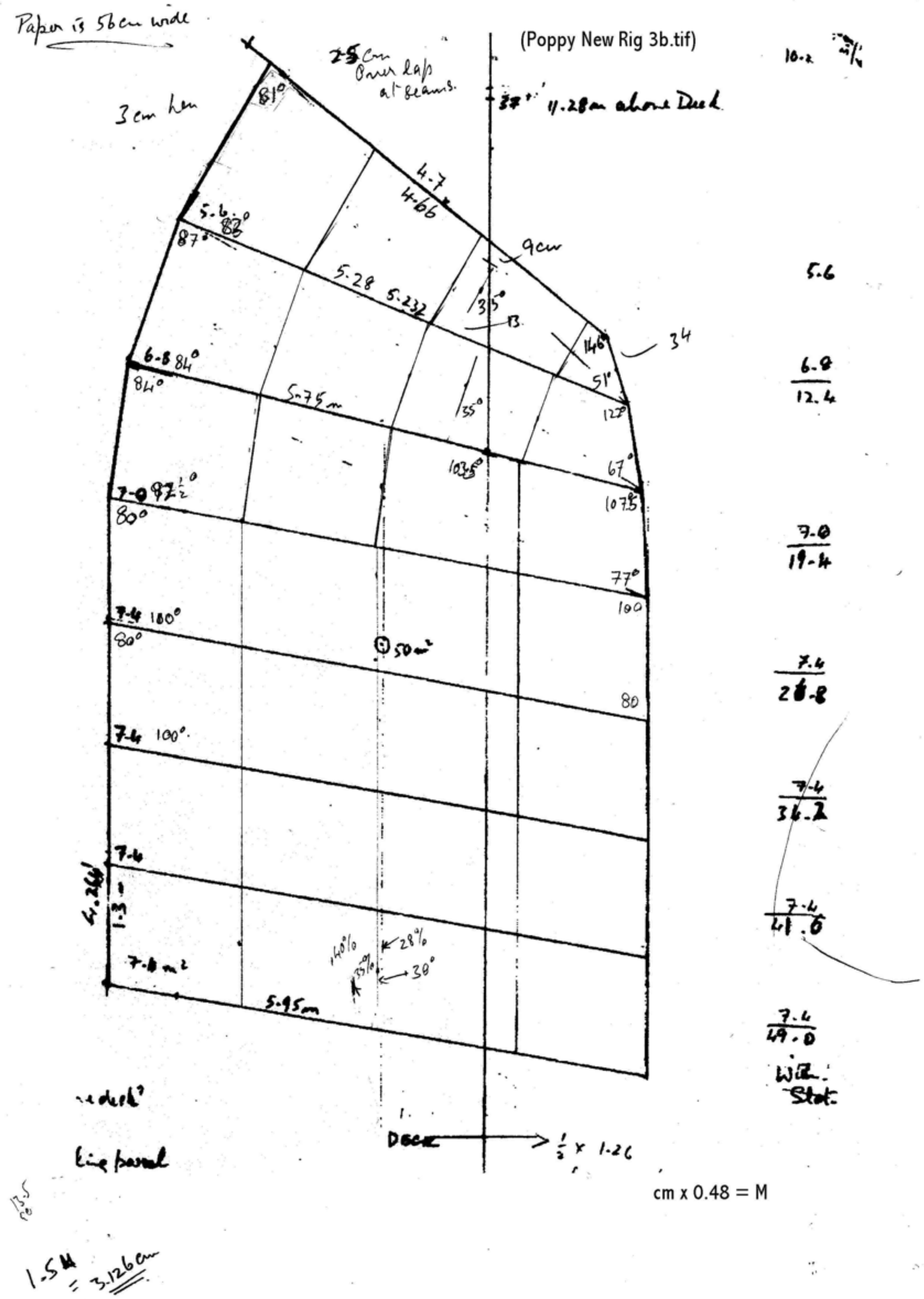
The photos are for illustration purposes only as they show the model after having been hung neglected on the garage wall for a couple of years, so is not properly set up. The first photo shows the rig simply hanging limply from the halyard, but the second shows how the rig peaks up simply by pulling down on a downhaul tied to the lowest batten. Using models it was easy to see how the rig would behave in practice, what lines were necessary and which were not, and to see how it would reef and sheet. It was easy to adjust the sail balance and try a number of ideas. The main aim was to arrange the rig and its controlling lines to produce a rig with the minimum of stresses on any one part. One clear observation was that when the yard was correctly set up the sail and battens simply hung down like a curtain with no significant forces to worry about. This modelling was a useful tool which saved a lot of time and expense.



One clear feature was that the pressures on the battens were lower with the low angled yard and high sail balance rig compared with a high peaked Hasler-McLeod rig.

When considering the general shape of the sail a few sketches of a full sail, a half reefed sail and a reefed to storm canvas sail quickly indicated a 'comfortable' shape with a height at mid boom/ chord ratio of about 1.6 to 1.65 and this would seem to be a sensible ratio to use, and when checked seem to tie in well with *PJR*.

From the models it was simple to make a scale drawing of the rig with the convex luff and leech in balance. It is essential to build this into the rig, and not just draw the straight line luff that has been used on most western junk rigs. This initial drawing was the basis of the final drawing on an A4 page that the Poppy rig was built from. (See below). Note that the layout of the seams between each individual cloth has been drawn in the diagram to help plan the broadseaming.



Note that the original split rig has less than 30% balance, which would be increased to 35% in future rigs.
If starting from scratch I would now probably plan on a **mast position** at 35% chord and fit a downhaul at 35% of the bottom batten (boom), and build a model to these proportions. I would aim for the bottom 4 or preferably 5 bottom panels to be parallel, and identical, and set the yard angle as on Poppy at 40° to the horizontal, or possibly down to 35° with the greater balance. With such a rig simply hanging from near the middle of the yard there should not be need for luff hauling parrels and Hong Kong parrels if combined downhaul/ batten parrels are used. The main problem has been to set and peak up the yard against the downward pull of the sheet. The present yard controls consist of halyard, yard hauling parrel and the current experiments are with a yard peaking parrel or peak halyard. The sheet loads on Poppy are heavier than wanted as the balance is less, but increasing to 35% they should be much lighter. There will be no need to stress the rig with kicking straps and other gimmicks as the sail is already balanced across the boat when off the wind. How simple can it get?

The batten angle was set at 10° to the horizontal simply for appearance sake as there is no problem with the battens moving forward as the relatively square sail is lowered, and the battens are restrained by the downhaul/ batten parrels. The use of the spanned downhauls requires the height of the lowest batten (boom) to be as least half the panel width above the turning block arrangement at the foot of the mast.

The **width of the split** was set on Poppy at about 333 mm with the 150 mm mast, and it would appear that this could be reduced to about 200 mm. Note that this is the width along the batten and that with the hollow that is formed in the jib leech by the construction method, then the actual width of the split about the centre of the panel will be greater.

In planning the sail for Poppy it was decided to build the top two panels without a split as these panels were considered to be the ‘storm canvas’ and therefore had to be robust. Not knowing how well the split panels would stand up to extreme weather this was felt to be the safer option. Now with past experience and realising that the jibs can stand up to remarkably harsh treatment I would still build the storm canvas without the split for long coastal cruising and offshore sailing, but would consider fitting the split to all the panels for estuary and local sailing.

The top 3 panels were tapered for aesthetic reasons, but again there is no reason why this should not be limited to the top 2 battens to make the lofting easier. The profile of the sail with its gentle rising yard and quite broad top is not accidental. The object of drawing this shape was to try to encourage the vortex which forms at the head of the sail to move upward as it developed and leave the sail as high as possible and with as small a diameter as possible in an effort to reduce induced drag. Just as modern commercial aeroplanes are being designed with fancy wingtips and yacht keels are sprouting fins, the quest for low drag can be critical in achieving the high lift/ drag ratio required for good windward performance.

For convenience the sail was built in 3 separate sections, the top 2 panels or storm sail, the five mains panels and the five jibs, which allows for modifications of one section at a time. It would make sense to build a conventional junk sail for long distance sailing in, say, 3 separate sections, so that one could be taken out of service for repair and the trip could continue under the other two. It is much easier to manhandle the smaller sail sections when building it. It is possible to build the sail of fully separate panels, ‘Thai’ style, but that can become fiddly and possibly less reliable with more bits of string to go wrong, but building is in 2 or 3 sections could be a practical compromise.

Apart from the top two panels which are full length all the lower panels are split and are therefore shorter and easier to work with. As the main panels are set behind a jib they do not need to have as much camber as for a standard junk sail and by being only 2/3 of the batten length there is a lot less round and broadseam to work with. They are therefore really easy to build.

Note that so far we have only discussed **sloop or single sailed rigs**. I have no experience of using a split rig on a **multi masted boat**, but feel that it could be an advantage to use it on the fore mast where among other advantages, with its greater balance it would permit placing the mast further back from the bows. One possible problem is that as it is so much more powerful it must bend the wind more than a flatter less powerful sail and therefore it would probably be necessary to sheet the rear sail in further than normal as it would be headed with the bent relative wind.

Mast placement on the hull.

When it came time to decide where to position the mast everything fell into position automatically with Poppy. Not everyone will be so lucky.

In *Practical Junk Rig*, Hasler and Mcleod advise on how to find the Centre of Lateral Resistance of the hull and the Centre of Effort (or more accurately Centre of Area) of the rig and then discuss the amount of ‘lead’ to allow. They gave information for a typical flat junk rig, but it was felt that this would not apply to the cambered split rig.

As the forces with the cambered split junk rig are developed in a similar way to a standard Bermudan rig, it was a simple case of positioning the centre of area of the split junk rig in the same fore and aft position as used for the Bermudan rig. This has the interesting effect that on some fractional rigged boats with quite small jibs the mast may end up being placed in the same position as on the Bermudan rigged boat, or maybe even further back! The drawings for the FolkBoat are particularly interesting in this respect.

When it came to deciding about sloping the mast fore or aft the answer was simple - upright. There are some advantages in raking a mast forward, but possibly also some additional stresses on the mast and rig, so rather than try to compromise the answer was simply to KISS.

Chapter 3.
Designing Cambered Panels.

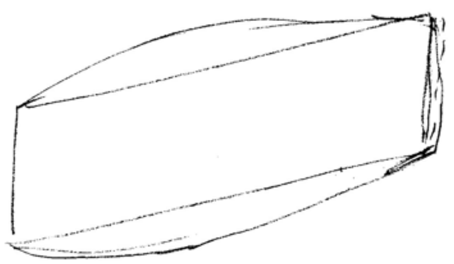
There are a number of ways of introducing camber into a junk rigged sail such as bendy battens, hinged battens, fanned battens, wishbone battens as well as stiff battens with the camber built into the sail material. Each method has its followers and rather than discuss the strengths and weaknesses of the various methods, the following notes concentrate on the construction of rigs with stiff battens and camber built into the material of each panel. The fact that I am writing this will show that with the present state of knowledge I believe the stiff batten and cambered panel to be the best way to build a simple efficient junk rig.

There are currently five different methods being used to build cambered panels for standard junk sails, though the 'jibs' of the split rig need separate attention. Each method has their strong and weak points but the following notes may help to explain their various merits.

To the average person in the street a sail is a flat piece of cloth stretched between spars, but to the informed sailor it is a three dimensional shape that has been carefully tailored to accurately hold the designed shape. Modern racing Bermudan sails are now being moulded in expensive synthetic film material over three dimensioned patterns. So far it has not been found necessary to go to such trouble for a cambered junk sail, but who knows what the future may bring. (Since writing this I have received mail from an experimenter who has actually used moulds to help him build both the main and jib panels for a Split Junk Rig, so things are moving on.)

The standard sail making techniques to provide the three dimensional shape involve using 'round' and 'broadseam'.

From our earliest day in school we are all taught that a straight line is the shortest distance between two points. This means that for a curve between the same two points then the line must be longer. So it is with the cambered sail panel. This means that the length of the material in a cambered panel is slightly longer than the designed length. This is more noticeable across the panel, from top to bottom. Because of the greater curvature across the shorter distance the difference in length of the curve compared to the straight line is proportionally bigger, so more material has to be added at the top and the bottom of the panel shape. The basic shape is drawn in the sketch, showing the parallelogram of the required panel shape and the actual curved shape of the material needed to make the cambered panel. In sailmaking terminology this extra material is referred to as 'Round'. All cambered panels require round, but by cutting and joining the individual pieces of cloth in different ways the result may be made to produce either prettier or more efficient shapes. This is the reason different techniques have developed to produce these sails.



Throughout these notes there are many simple references to making the camber shape, as if it was a standard 'off the shelf' item, or something to be drawn on the back of an envelope. Experience has shown that it is far from being that simple so information on the subject has been combined and all placed in chapter 4 and appendix 5, for easy reference.

3.1 The Barrel Cut, or more correctly, the Round Only Cut.
This is the simplest way to produce a cambered panel, and has been used by Arne for all the rigs based on his drawings. It has been mentioned above that the length along the batten is less than the length around the edge of the material, therefore when the material is forced into the correct length along the battens the extra material forms little wrinkles along the battens. In practice, the difference in length is about 100 mm on a 5000 mm batten, which is only about 2%.

As the loads on the material are very light in a cambered panel sail it is possible to use a wide variety of material types to make the sail. If you use a soft flexible cloth, as Arne does, then the little wrinkles along the batten are small and are not really noticeable, and can have little effect on the performance. On the other hand, if you choose to use polyester sail cloth such as Terylene or Dacron which can be like thin plywood when new then the little wrinkles appear more significant and encourage a more sophisticated building method to be used.

A major advantage of the Barrel/ Round Only cut is that for smaller sails is may be possible to cut the whole panel out of one piece of cloth and require no seams to be sewn other that at the edges. This makes for very easy sail making, though there can often be high wastage of material.

Sail makers normally cut sails with the thread lines of the material laid parallel to the highest stresses along the leeches of the sail. Although this is not considered to be so important with the lower stressed junk rigs, it is still desirable to run the threads parallel to discourage stretching of the sail just forward of the tight load supporting leech and forming a cupped leech which will be detrimental to the performance. It is usually not possible to run the threads parallel to the leech when cutting the whole panel from one piece of cloth if there is any rise to the battens.

In his pages on the JRA website and on the Yahoo Junk Rig Group, Arne has written excellent notes on how to build his rig, including his clever chain calculator, so there there should be no problem in building a sail using this technique.

The Barrel/ Round Only cut is the easiest to understand and build with a soft and flexible cloth.

3.2 Round and Broadseam, using standard sail making techniques.

The obvious way to remove the extra length round the curved edge of the cambered junk panel that cause the little wrinkles in Arne's 'Round Only' method is to make little darts along the edge of the barrel shape.

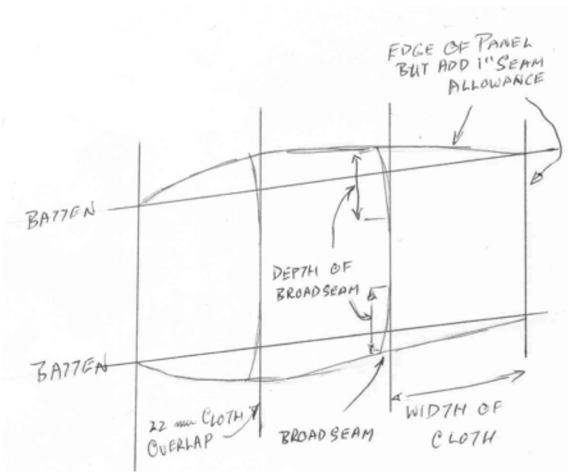
Unfortunately normal sail material will not fold easily to make a smooth shape if folded darts are used, so sail makers remove the extra cloth by increasing the width of the overlap towards the end of a seam where 2 pieces of material meet. This is referred to as 'Broadseam', as the seam gets broader towards its end, and is the standard technique used to build shape into virtually every sail built. The reason the increased seam width is not noticeable in commercially made sails is that the sail makers use their laser cutters to trim the the edge of the 'broadseam' so that their competitors cannot see how much shaping they are putting into a sail. This means that the machinist only has to sew the tapered cloths with a parallel seam to make a tidy sail. Unless we are being very secretive there is no need for the amateur to hide his parameters. In the photograph on the next page it is possible to see how the vertical seam is parallel in the middle of the panel in the main panels, but also how the seam overlap widens as it approaches the upper batten. The broadseam towards the lower batten is the same as towards the upper batten, but because of the curvature of the panel it does not show up in the photograph.

The 'Broadening' of the seams in the main panels can be seen as they approach the batten at the top of each panel. Note the lack of rope work compared to many other junk rigs, with only the spare halyard and the slack yard hauling parrel adding to the halyard and lazyjacks.

The shape of a broadseam is defined by three considerations, width, depth and shaping. Initially this seems rather daunting, but in practice it is very simple.

Rather than try to work it out with pieces of material when building the sail for Poppy, I made a spreadsheet to do the calculations for one panel and obtained the answers for all the panels by simply plugging in the relevant information. Talk of spreadsheets may seem scary, but to have a simple table of numbers available as the pieces of cloth are stuck together with two sided sticky tape makes it very easy to produce the panel. See Appendix 2, Tip 4 for more detail on making broadseams.

Each of the 'main sail' panels in the photo were made of three pieces of cloth laid parallel to the leech and with their top and bottom cut with a similar 'barrel' shape or 'round' as required in Arne's barrel cut method. With a couple of pencil marks on the material showing the width of the broadseam required and the depth of the broadseam then the two sided basting tape is stuck to one cloth with the backing paper still in place in the shape required for the seam with the slight curve towards the top and the bottom. After the first couple of seams have been done this becomes a very quick



and easy exercise. The next cloth is laid in place on top and as the backing paper is removed from the tape the cloths are pressed together with the edge of the cloth aligned to the inner edge of the tape and the panel is ready for sewing with the cambered shape built in. Two rows of stitching are then run across the panel and the job's done.

This probably is the easiest and quickest way to build a cambered panel out of stiff and unwieldy material that will not accept tiny wrinkles. There is no restriction on the amount of camber used with this method. The end result has an advantage over the simple 'barrel' cut in that the seam between panels can be stretched along the batten without having to judge how much slack to allow for the camber to form.

No doubt the calculations performed by the spread sheet may seem to be a problem, but this will be illustrated in Appendix 3 Hopefully I will produce an easy reference table to give the required parameters.

The 'Chain Calculator' used by Arne and my spreadsheet/ table both end up with the same height of material in the panel from batten to batten, and at the point of maximum camber the finished height of the material in the panel from batten to batten is very close to Ht + Ca, where Ht is the distance between the battens and Ca is the depth of camber.

In both of the methods discussed so far there has been no mention about joining the panels together and this is a separate issue which will be discussed in a later chapter.

There is another way to build a cambered sail using broadseam as devised by David Tyler, but this will be discussed later in this chapter (Section 3.5) after discussing the shelf foot techniques.

Note - Since writing this section I have had what could be a 'Eureka' moment. As mentioned it is difficult to fold sail material to put a dart in a panel where there isn't a seam without making a 'hard spot' at the end of the dart. However there possibly is a way where a dart could be cut rather than folded and re-joined to form a smooth broadseam effect at any point at the edge of a panel. The details of the idea have been written up in Tip 5 at the end of Appendix 2 on sail making on page 45??, under the title 'The Seamless Broadseam'. At the time of writing it has not been tried, but there is no reason why it should not give a good, smooth and structurally strong result. This could encourage anyone who is worried about the little wrinkles in Arne's Round only method to convert it to a simple Round and Broadseam, even in small sails which may not have enough seams to give a smooth result.

3.3 Shelf foot construction.

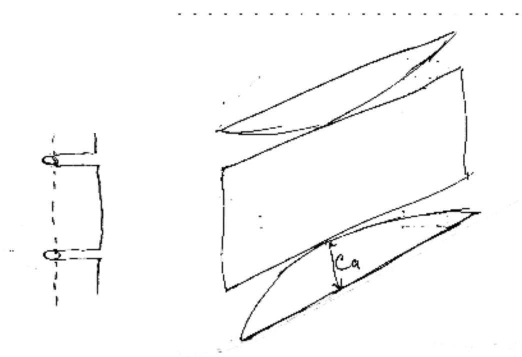
15 years after Arne first wrote about the success of his cambered panel sail there was still no evidence of anyone in the UK using such a cambered panel rig apart for the split rig on Poppy. I was approached by a commercial sailmaker who had a commission to build a cambered sail and despite having Arne's notes was having trouble. I was able to provide a design based on Arne's *Johanna* and with the aid of e-mailed photos and the telephone the sail was completed in about a week. At that point I made it clear that having helped with one sail I was not prepared to continue as an unpaid consultant for others to make financial gain for themselves.

Despite the experience of building the sail and having a copy of the spreadsheet I had developed, the sailmaker apparently was still not able to build another without help. However he had latched onto the idea of the shelf foot construction that I told him I had used when making the jib panels for Poppy, probably because shelf foot is a standard sail making technique sometimes used at the foot of a racing mainsail. Unfortunately he had not listened to the details of the method I used and started to build sails using the flat shelf foot method with the problems mentioned below. In addition the camber shape he built into these sails appears to carry the camber rather far aft in the sail with the resultant increase in weather helm and drag. The shaping of the camber is quite important and will be discussed in a late chapter.

As the name implies, the standard shelf foot is placed as a shelf at the foot of a conventional Bermudan or gaff sail where the material is supported from the head or gaff. It was traditionally made of a softer, lighter material and can be thought of as material simply closing the gap between the foot of a loose footed mainsail and the boom, and not providing the shaping the to the panel. A shelf is not designed to work at the top of a panel, a shelf head, so it's not surprising that it does not look good in light conditions when the material hangs down unsupported. To make an income a commercial sailmaker has to produce sails that sell well, so have to be pretty regardless of their performance or practicality. To achieve this the flat shelf foot panels cannot be built with more than a few percent camber as it will not set well.

3.3a. The flat shelf foot method.

To build a flat shelf foot cambered panel is simply a case of cutting out the parallelogram shape of the panel and sewing cambered pieces of material to the top and bottom of the panel with the curved edges inward as in the diagram. In theory the depth and shape of the cambered pieces dictates the depth and shape of the finished sail though it does not necessarily work out like this in practice as even stiff sail cloth is somewhat flexible.



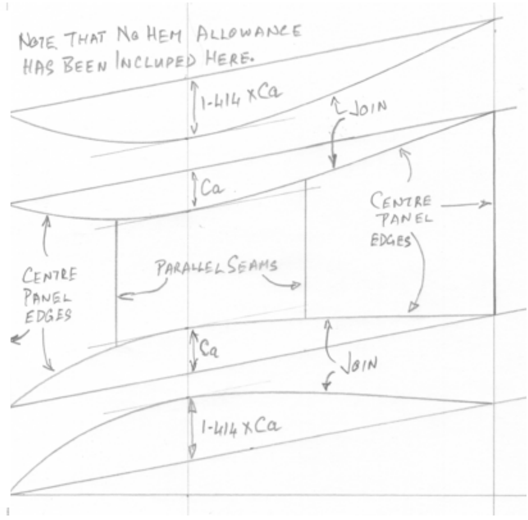
At the point of maximum camber the finished height of the material in the panel from batten to batten is Ht + 2Ca, where Ht is the distance between the battens and Ca is the depth of camber. In calm or light winds this excess material hangs down like the curtains in a classical West End theatre, and produces no significant drive until the wind is strong enough to fully lift and inflate the panel. This discourages the use of a useful amount of camber in the panels so the sails using this method tend to be rather flat with no more than 6% camber. When we consider that a typical Bermudan mainsail with a jib in front will have a camber in the range of 8 to 15% then fitting only 6% on a sloop with a single sail is not exactly adventurous, nor likely to realise the full potential of the rig.

Not having used this method I initially thought that it had great potential, but having see more photos of these rigs I now feel that the Round Only or Round and Broadseam panels are easier to build and can provide better performance.

The parallelogram panel is built of vertical cloths before the separately cut cambered panels are sewn to it, which is actually more work and expense than sewing the broadseam into the round and broadseam panels which are not restricted in the amount of camber used.

3.3b The Angled Shelf Foot method.

In practice, the jibs of Poppy were designed with the shelf foot panels to slope at 45° to the horizontal as shown in the diagram, and which could also be used on the mainsail panels. To set the shelf at 45° requires the parallelogram panel to have the cambered shape to be cut out of the top and bottom edges of the panel and for cambered shaped pieces to be sewn to the top and bottom which are 1.414 times the depth of the camber. The result is that the finished height of the material in the panel is reduced to Ht + 0.828Ca. This significantly lesser amount of material does not hang down so badly and requires much less wind to start producing drive. With this technique it is practical to use increasing amounts of camber. Even with this shape it is still important to tailor the shape of the camber to produce the final aerodynamic panel shape required, and which will be discussed in detail in chapter 5?.



From a sail building point of view this method is not easier to produce for a reasonable sized sail than the Round and Broadseam method discussed in the previous section, and is probably even slower and more expensive for the commercial sail maker to use. The reason the method was developed was to control the camber shape right at the luff of the panel which is important for a headsail.

Again please note that in all these discussions there has been no mention of batten pockets and connection the panels together which will be discussed later, and that seam allowances will also have to be made when drawing up the panel shapes.

3.3c The David Tyler Broadseam method.
In the JRA Newsletter 50 David described the method of round and broadseam he had used when building the sails for Badger. Basically it involved sewing up the parallelogram shape of vertical cloths and extending them up and down to include the camber shape and depth. The end of each cloth was cut in a straight line, and to make the broadseams the straight line edges of adjacent cloths were aligned by overlapping the seam and sewn together.

This construction results in a form of flat shelf foot as described in 4.3a with the similar Ht + 2Ca material height. Unfortunately the straight edges of each cloth results in a camber shape which does not encourage a smooth curved camber running right to luff of the panel. The method does produce a simple to build cambered panel, but other methods will produce camber right up to the leading edge of the sail and therefore will produce better windward performance.

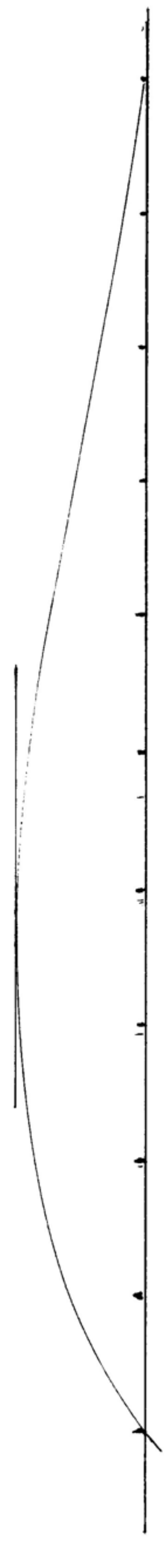
Which method of construction is the best?
This, of course, is the thousand dollar question. Having developed and used both the Round and Broadseam on Poppy's top and main panels and the 45° Shelf Foot on the Jibs then it is not surprising that I favour these methods. Neither are necessarily the simplest to use initially, but in practice both are easy to build once understood and under way. For a simple cambered panel the Round and Broadseam method is very quick to form once the calculations are completed, and hopefully a set of tables to provide the numbers conveniently for the home builder will be placed in Appendix 3. The Angled Shelf Foot requires more curves to be drawn, though may have advantages when it comes to including the batten pockets.

As suggested above, I now feel the Flat Shelf Foot is a rather crude method, though it is not so long ago that I was recommending it as it is so easy to understand. I think David Tyler's method is quite ingenious, but feel it suffers from the flat shelf excess material problem and will not produce an efficient camber shape right from the luff of the sail, which I believe to be important.

Perhaps the expression 'Horses for courses' applies here, or 'You pays your money, you makes your choice.'

Chapter 4.

The Camber shape.



This is a very controversial subject which may not be of interest to everyone, so it has been has been moved to Appendix 5, with only an introduction printed here.

The shape of the curve is one situation where WYSIWYG does not apply. Regardless of how much care you take in deciding on the camber you want, and how carefully you cut it into the material of the panels you will still end up with something with a different shape. The trick is to modify the curve used for cutting the material to achieve the shape you want the finished panel to have. Unfortunately too many of the existing cambered sails have ignored this situation and the sail makers are not looking critically at the achieved camber when checking their products.

The diagram shows a curve with about 10% camber placed about 37% chord and with a large entry angle to help produce high lift and a low exit angle to produce low drag. The shape is substantially flat over the last 40% though has a very slight reflex in the after section in an effort to flatten the camber just in front of the leech.

This curve may not be everyone's ideal, but it is offered as a well considered starting point.

Chapter 5.

Building a Round and Broadseam panel. (R&B for short)

This is a case of planning the exercise before you start, and then it will run smoothly and be very quick.

Assuming you have modelled your rig and made an A4 page scale drawing complete with the dimensions then you are ready to go. If you can borrow a sail loft with the nice clean floor, great, but if you 'borrow' the Boy Scout hut then remember that the floor will be extremely dusty and will make the material very dirty very quickly. In this case, and the case where, like me, you only have the family room floor with the carpet then you are advised to make a paper pattern of each panel, but if you have 5 identical panels then one will do for all 5. If you have 5 similar, but with lesser camber in the higher ones then make a pattern for the lowest (deepest camber) one and simply draw the lesser outlines on it as well. I used wall lining paper with the lengths glued together (with PVA, I think), and only made a pattern of the round, but it would be easier to make a full panel pattern. With the R&B method you simply build one panel at a time and when all completed you join them together, so you don't need a room the full size of the completed sail. When built I laid the completed sail sections out on the grass of the back garden (Yard in American English) to have a look see.

Assuming you are making a lower parallelogram panel, draw the parallelogram full size on the pattern. Extract the amount of round from the table/ spreadsheet and mark it in at the correct point of maximum camber. Now draw the camber shape along the battens to give you the outline of the cloth. When complete, draw in another outline outside the outline to show the waste material/ hem allowance. This should be (say)30 mm outside the top and bottom curve and 40 mm outside the luff and the leech straight lines. This is your cutting line. **Diagram here.**

Now you have to plan your seam placement to accommodate the total broadseam from the table. In an ideal world you will want 2 seams minimum with low camber and probably 3 seams with large camber to take out the required broadseam, and these seams should be positioned in the 15 to 50% chord area. **Draw a diagram here to show this.** The required broadseam should be divided over the seams, taking the most out where the panel is widest and curved the most. Work out how many seams there will be by dividing the length of the panel by the width of the cloth, allowing for for your standard seam allowance. I use 19 mm basting tape so used a 21 mm seam overlap. **Or Here.**

If you draw a sketch roughly to scale and using the material width with vertical cloths you can work out where the seams would fall. Then adjust the layout, for example if you have a half width you could move it to the 30% chord position you would have an extra seam to use for broadseam. Alternatively put in a narrower than full width panel to get the seams in convenient places to spread the broadseam as you desire. There should be no wastage of material with putting in half width cloths as the spare material can be used for leech patches or for batten pockets.

Think of the trouble a sailmaker goes to to make a radial sail, or a tri-radial sail just to control the shape, and then think just how simple the R&B system is and it starts to make sense.

Once the seams are planned then it is a case of deciding how to split the total broadseam over the seams. Think of how the wrinkles would form if the outside edges were pushed into the straight line of the batten and you will find that there is more need for broadseam where the cloth is widest and in particular where the edge most curved. Then note down your broadseam width for each seam, possibly a zero allowance for a seam to the rear where the curve is a straight line and maybe a one third on the next one and two thirds on the next, or half and half. Common sense will spread it smoothly. **(This had to be re-written)**

Now that you have your plan the fun begins. Starting at the leech, place the roll of material with the edge just above the top edge and unroll it down across the panel pattern but keeping it exactly parallel to the leech. Mark the cloth and cut it (use portable cutting board and hot knife) along the bottom cutting line. Rotate the roll of material without lifting it so that what was the forward edge of the roll is now the back edge of the roll, and unroll the cloth upwards, with the 21mm seam overlap (in my case), and cut it off along the cutting line top and bottom. Rotate again and unroll downwards and so on until the panel is covered and you have the pattern covered and cut to the shape of the outer line.

As I actually drew my pattern on the sail cloth I had the final sewing line in place, but if you have worked with a pattern then it would be useful to draw the sewing line and the luff and leech on the material at this point.

The next job is to stick it together. The first couple of seams will be very slow but suddenly you will find that you run each seam off in seconds and with very little measuring and marking. Start with the leech cloth seam and with luck it may not have any broadseam. If not, as you unroll it, stick a line of basting tape along the seam edge and parallel to the edge. In my case with 19 mm tape and a 21 mm seam I placed the tape 2 mm from the edge. At first I marked the 2 mm with pencil ticks, but that didn't last long and it became an eyeball job. A sail maker would tear off the tape at the end but I preferred to cut with a small pair of scissors. Now line up the next cloth to the edge of the tape and with the panel edge lines aligned. Without disturbing anything, lift one end a little, and start to peel off the backing tape from the basting tape, but as you pull it out horizontally press the top cloth down on the bottom one. When you've got to the end you will have two panels joined. Easy!

You now have the choice of continuing to stick the next seam or to sew up the first one. If you decide to sew it simply run a line of wide zigzag, or long stitch straight if no zigzag, along close to the edge of the top cloth. Then turn it over and sew back close to the new exposed edge, and the jobs done. Some of my early seams were a bit wobbly, but they soon ran straight.

Take the joined panels back to the pattern and prepare to stick the tape on again for the next cloth, but this time there will probably be some broad seam to accommodate. Again, the first time will seem difficult, but after a couple you'll find it easy. Put a (pencil) mark at the depth of the broadseam in from the panel edge line. I recommend that you make that three times the distance from the panel edge line to the straight parallelogram line. In other words the depth of the broadseam is three times the height of the round at that seam. On the panel edge line mark the width you want that broadseam to be. Then it is a case of placing a mark at half the broadseam depth and one quarter of the broadseam width in from the seam edge, and then another at one quarter depth in from the edge line and half broadseam width in from the seam edge.

The first couple of broadseams you do I recommend that you do not use a single length of basting tape, but that you place one length along where there will be a parallel seam and two little 3 cm length tabs right at the end of the seam. Then separately stick down the basting tape for the broadseams, but make sure that all the centre and broadseam tapes are aligned in a very smooth curve, but ignoring the 3 cm tabs. (Use tip 6 when doing this) Then align the top cloth with the centre tape and the two short tabs to make sure the basic seam is parallel with the edge, and pull out the backing tape and stick the centre area before sticking the gentle curve of the broad seams to the edge of the slightly curved tapes. Even with only a couple of centimetres of broadseam it will be surprising how the finished seam will not want to lie flat any more.

The next task is to re-draw the panel edge line with a fair curve at the end of the seams where the broadseam will have dipped it in a little. (See the reference in Tip 4 in Appendix 2).

After a couple of seams practice you will quickly stick the seam but probably start from the centre area to make sure the centre is parallel. Once stuck then it is just a case of two rows of sewing and in no time the basic cambered panel is built.

Xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx

To be continued.

Join the panels together/ fit section heads or foots.

Add the batten pockets or lacing tapes.

Complete leeches.

Complete Luffs.

Chapter 7.

Designing the Jibs of the Split Rig.

Aiming to produce Bermudan performance it seemed reasonable to use Bermudan rig parameters to help shape the jibs. The Aero Rig provided a good starting inspiration. (The Aero Rig was copied from the balanced rig used on model yachts, and developed by Roger Stollery, so now I am am using model yachts to try and learn more about these balanced rigs). The Aero Rig used a small track to let the self-tacking jib sheet at 8 or 9° to the centre line, so this was taken as a starting point, and the cambered shape built on top of this.

It was obvious that the sail would not take the shape set by simple flat patterns, but it was felt better to build it with too much material in the panels and re-cut it to get the desired effect as experience was gained. Now, following a number of experiments the mark 2 version is proving to be a practical design. No double the shape will be improved in the future, but for the moment the following information from Poppy's current setup seems to produce an efficient rig.

The round and broadseam method of construction would not give control of the camber right at and immediately after the luff and as this is the most critical area for windward performance so another method with adjustable seams near the luff had to be used. The sloping shelf foot was developed and with the seams running to the top and bottom corners of the luff appeared to be the most effective construction method for this particular problem. In practice, when building a Bermudan mainsail, the sail maker will use significant broadseam in the seam running down to the tack as the major shaping tool, so this seemed to support the method.

As mentioned earlier, the slope chosen for the shelf in the jibs was set at 45°. The instructions for making the patterns will seem ridiculously complicated when first read, but after a couple of readings and drawing a few sketches, or cutting a paper model and sticking with tape it should all fall into place. On Poppy all 4 of the lower panels were identical so only one set of patterns was used for all of them, and the top split panel was only slightly fanned so the same pattern was used, off-set at a slight angle. In a more recent rig all 5 split panels were drawn to the same parallelogram shape for easy construction for the builder who only had the information in Appendix 4 to work from.

Note also that in an effort to allow the air flow through the slot as freely as possible on both tacks **the jib panels are placed on the mast side of the battens** as opposed to the main panels which are placed on the side away from the mast.

Note that no allowance has been made for the batten pockets in the information below, and that the length of the luff of the Jib, the luff and leeches mainsail panels must all align along the straight battens at the top and bottom of each panel so that the panels are equally tensioned by the downhauls.

For convenience I have placed the instructions on how to draw the patterns and the accompanying diagram in Appendix 4 for ease of printing off and use, rather than embed them in the chapter text.

The details of how to reinforce the leeches of the jibs has been included in chapter 8?.