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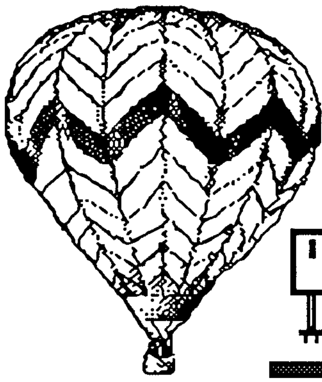
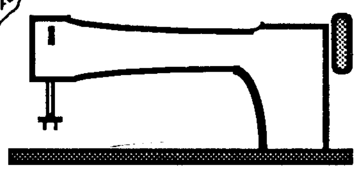


Dedicated to the Sport Balloon Home-Builder



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THE BALLOON BUILDERS' JOURNAL

July-August 1994

In This Issue

Up and Coming

In part 2 of his article, Adrian Brookes will follow up on the Tracy Barnes philosophy of envelope construction. Construction details will be presented for the builder. Look for more from the Vermont Experimental Balloon Meet.

Notices To Readers

Financial Summary for Year	
Ending June 1994	
	Dollars
Expenses/Obligations	
Printing Costs	($506.68)
Postage	($452.48)
Other Goods and Supplies	($263.31)
Telephone Charges	($6.66)
Subscribed-for Future Issues	($192.00)
Total Expenses	**($1,421.13)**
Revenues/Inventory	
Subscriptions	$1,400.00
Postage Inventory	$78.56
Total Revenues	**$1,478.56**
Outstanding Balance	**$57.43**

Building Balloons Using Barnes Construction Techniques

By Adrian Brookes,

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Editor's note: In addition to discussing this alternative envelope design, Adrian raises interesting questions about the concentration of load stress in a balloon envelope.

There are or have been some 20 manufacturers of hot air balloons world-wide over the last decade. With the exception of only a few of these companies, they all build their envelopes based on a similar construction method which can be generally described as:

"Multi-panel gores assembled together with felled seams and overlapping vertical and horizontal load tapes."

With this method, a strong flat or tubular load tape, or webbing, is sewn over the vertical seams, starting from the mouth opening and running up to the vent/deflation opening, and then continuing for some extra distance to the crown ring. Horizontal tapes are sewn at regular vertical spacings along horizontal seams, and also along the circumferential mouth and deflation openings. In some cases, especially when there are a large number of gores (usually 36 or more) the vertical load tapes might only be placed on every second vertical seam. In most cases the horizontal tapes are located vertically on every 3rd or 4th panel.

A few manufacturers build envelopes using a variation of this method: the entire gore may be either one continuous panel or comprised of a small number of panels, bounded by vertical load tape or mid-gore fabric seams and horizontal load tape or fabric seams. This method is generally described as the "Aerostar method", as Aerostar™ builds its models using this technique. The horizontal tapes are sewn onto the envelope at or near the equator and at other pre-determined stations, not at specific horizontal seam locations as with other brands. Where an Aerostar envelope has, what appears to be multiple vertical panels in a gore, the panel seams occur at the predefined horizontal tape locations. In other words, load tape placement is not determined by the panel seams but panel seams are determined by tape placement. This applies to non-artwork balloons only, artwork balloons may have seams at other than load tape locations.

Panel Shapes

An observation of low stress balloon envelopes shows that the surface of an envelope is smoother as the number of load carrying vertical gores increases because the load is more evenly distributed through the envelope. A larger gore area or fewer number of gores (a direct inverse relationship for an envelope of fixed size) results in the gores becoming more bulbous. As the bulbousness increases, the envelope's total gore length along the mid-gore point becomes longer than the gore length along the vertical load tape (see *figure 1* for clarification).

In a low stress, natural shape envelope, this can only be achieved by making the horizontal and vertical panel edges curved (convex). Panels near the equator must also have more curvature than panels near the mouth or deflation port. The panels of smooth shaped, high-gore count envelopes have much less curvature at the panel edges than bulbous (low gore count) envelopes. This is due to the panels being required to cover, what is effectively, a much smaller circumferential profile. Refer to *figure 2* for clarification. In the low gore count, bulbous shape envelope, the spherical shape generated within a single gore panel will have a relatively short radius. In an envelope with many gores, this gore panel radius is longer.

Previous issues of *The Balloon Builders Journal* have carried design and construction articles based on the Aerostar-type construction method, where entire gore halves are cut from fabric, and then the two long straight vertical edges of the gore halves are sewn together to make a complete gore as a two-piece panel. This construction is an easy task for the repairman or homebuilder. This method also eliminates the task of joining the horizontal curved edges of many panels of the multi-panel gore construction type balloon.

For a typical 8 to 24 gore AX-7 envelope, assembled from gores with multiple panels per gore, there will be many curved horizontal panel seams. For a homebuilder

Figure 1 - Gore Length vs. Gore Bulbuousness

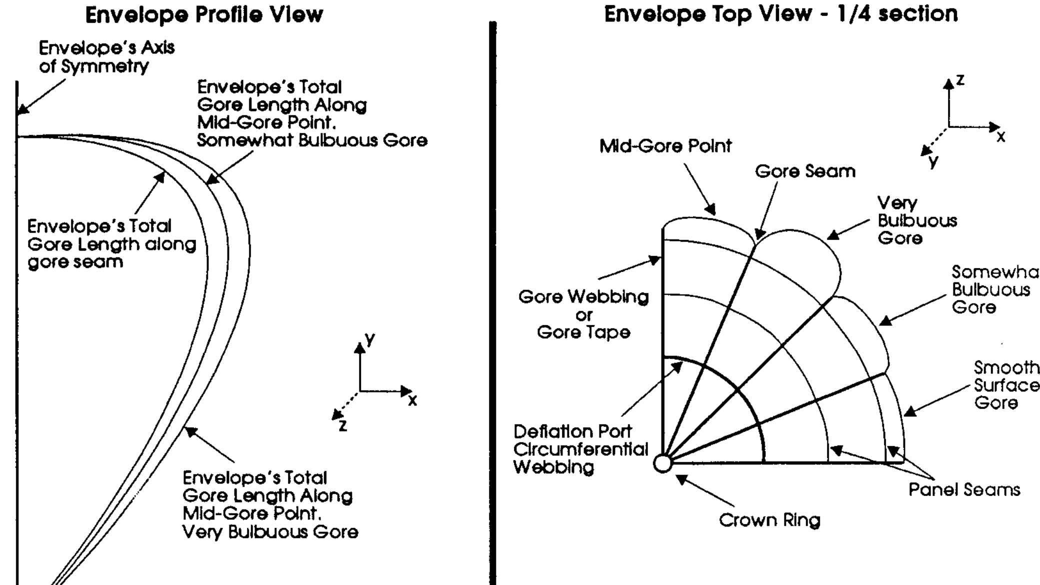


Figure 1 - Part A

Figure 1 - Part B

Figure 2 - Gore Bulbuousness vs. Effective Radius Center Point

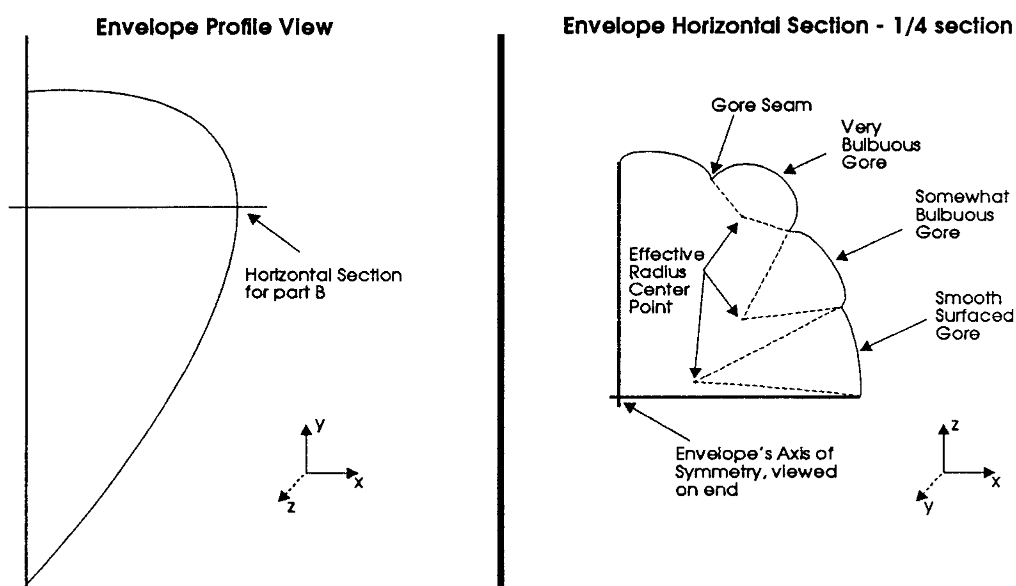


Figure 2 - Part A

Figure 2 - Part B

this means having to duplicate the panel curvatures at fabric cutting time, and then having to sew the many curved edges together. This is not an easy task, for a first time project, and is much more time consuming when compared to the single or two-piece gore construction method. As well, fabric wastage is high on a design which uses many curved edged panels.

The Exception

The exception to manufacturers who use the industry wide standard construction methods is The Balloon Works™ (TBW) and its sister company Galaxy Balloons ™ (both balloons are built in the same facilities).

Tracy Barnes, who founded "Barnes Balloons", now The Balloon Works, first started building experimental balloons when he was in Minnesota in the 1960's. One of his early homebuilt balloons used a number of surplus parachutes sewn together to form the envelope. These parachutes were built with a system of sliding cords in the radial seams, so that stress would be more evenly distributed and strain reduced during the sudden opening of the chute. Tracy later adopted this same construction technique into his production balloons, allowing the gore seams to "slide" freely, to a limited amount, around a load carrying vertical cord which carries the basket load over the envelope to the crown ring. Although this system allows small localized stresses to be dynamically equalized, this isn't as much of a concern in ballooning as it is in parachuting. The real benefit of this design becomes apparent when you analyze the manufacturing process.

Eliminating Curved Panel Edges

Go back for a moment and compare the envelope's total gore length at a gore seam versus the gore length at mid-gore location as shown in *figure 1.* It is obvious that a panel's horizontal edge curvature must take this difference in length into account. This is accomplished by changing the length of the panel edge as the curvature changes. More curvature of the panel's horizontal edges makes the vertical edge dimensions shorter. Otherwise you have extra fabric at the gore seam.

What would happen if we disregard this length difference and allow the panel height on its two outer edges to be the same height as at the center of the gore? In other words, suppose we create a square, rectangular or trapezoidal panel with no curved horizontal edges?

Let's assume we must fit this "extra" length of fabric at the panel edge onto a shorter length of load tape. Remember, the total load carrying gore length is shorter than the gore's mid-panel length, so the fabric must be puckered during sewing as it is attached to the vertical load tape. In theory this solution would work fine, but in practice this kind of evenly distributed puckering is difficult to accomplish by hand and requires a complex and expensive sewing machine to achieve automatically.

Furthermore, each load tape must be accurately marked with close spaced reference marks so that the panels of each gore fit exactly onto a specific vertical length of gore tape. If the puckering tension is off during sewing, then you must rip out the stitching and start over. As well, repairs to this kind of construction are more complex and time consuming than non-puckered assembly. A secondary effect of puckered sewing is that the panel seams at the vertical gores will be aesthetically poor, especially for artwork envelopes, with puckered sewing and bunched fabric running the entire length of the vertical gore and noticeable for several inches on each side of the gore seam. Although TBW and Galaxy envelopes suffer from fabric bunching along the gore seam, it only occurs after construction of the gores is complete, the actual construction does not require puckering.

The Tracy Barnes Solution

With the Barnes' construction method, each panel is cut as a trapezoid, as shown in *figure 3A.* This provides a panel edge's vertical pseudo-curve through 2 points of the gore's vertical arc, where the arc can be determined with one of the adjacent panel's corner points providing the 3rd point of the gore's arc. In other words, the gore's curve running through the top and bottom corner of the panel, are in fact, a purely linear measure. The edge is slightly longer than the length of the mid-panel dimension, as shown in *figure 3C.* The edge is longer for panels near the bottom and top of the envelope and less 'longer' for panels near the equator due to the angled cut of the fabric edge. The length is also longer in balloons having fewer gores for a similar size envelope.

You may be wondering about the slight gap between the fabric edge and the pseudo-curve

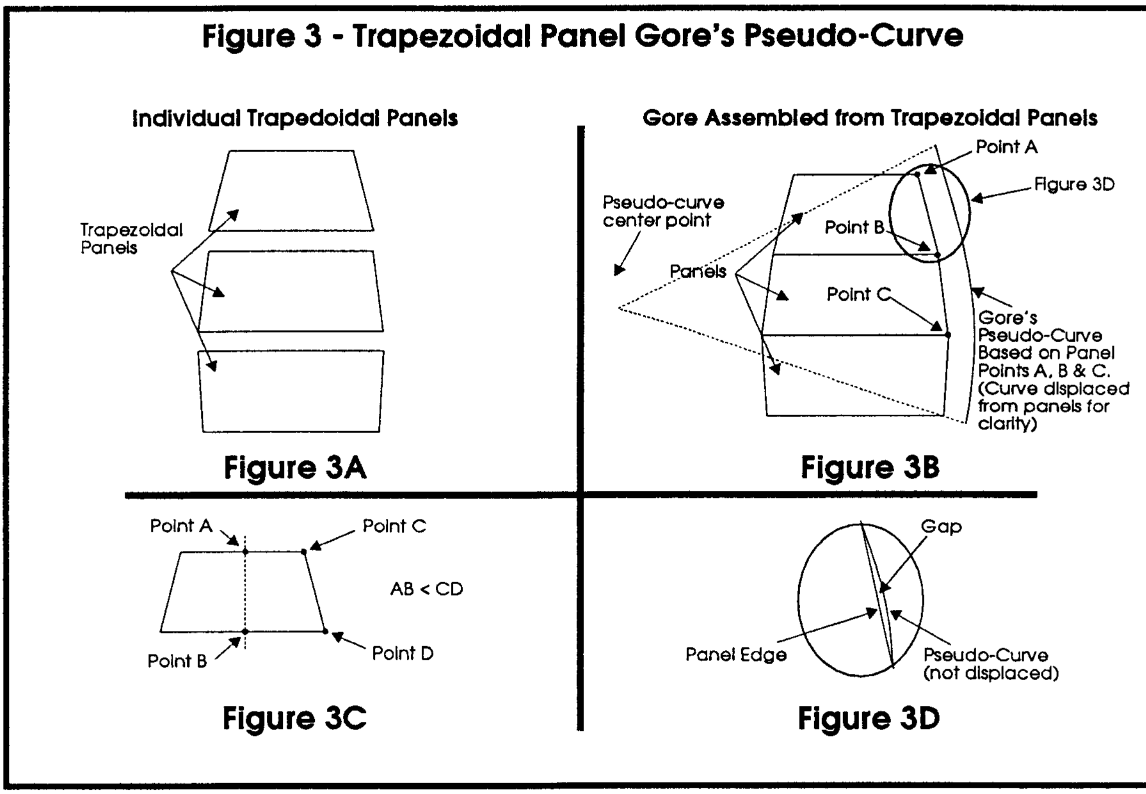


Figure 3 - Trapezoidal Panel Gore's Pseudo-Curve
Individual Trapedoidal Panels
Trapezoidal Panels
Figure 3A
Gore Assembled from Trapezoidal Panels
Point A
Figure 3D
Pseudo-curve center point
Point B
Panels
Point C
Gore's Pseudo-Curve Based on Panel Points A, B & C. (Curve displaced from panels for clarity)
Figure 3B
Point A
Point C
AB < CD
Point B
Point D
Figure 3C
Gap
Panel Edge
Pseudo-Curve (not displaced)
Figure 3D

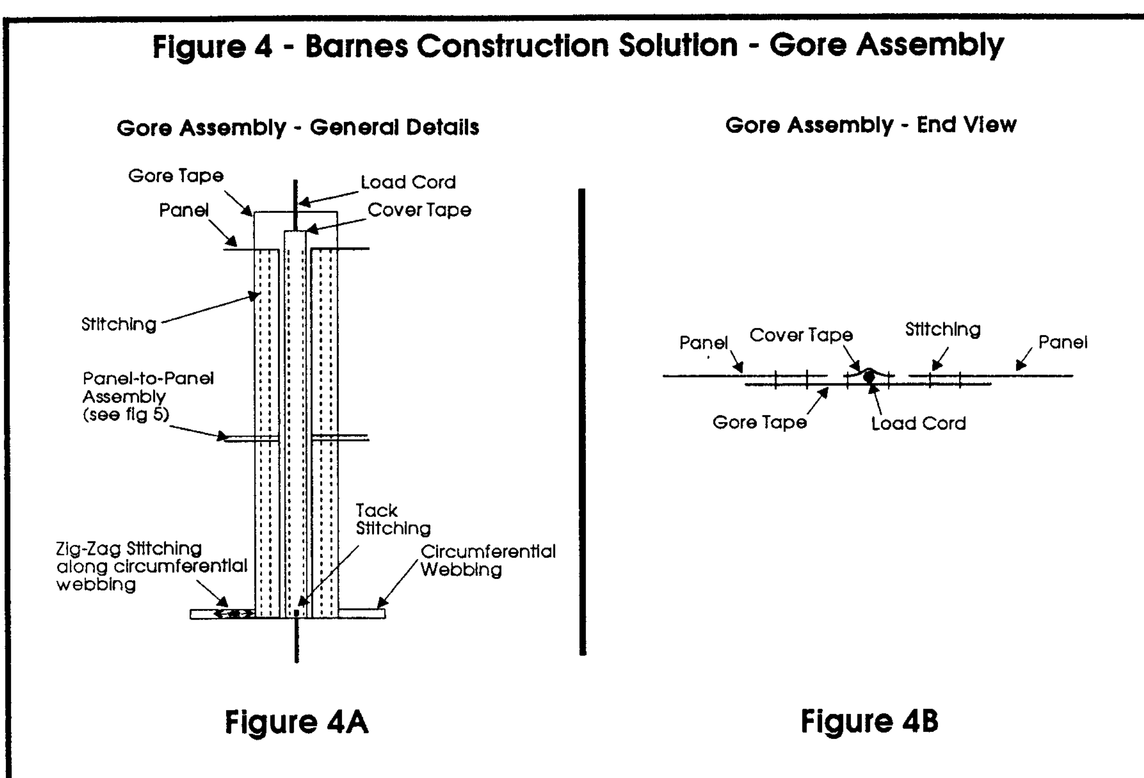


Figure 4 - Barnes Construction Solution - Gore Assembly
Gore Assembly - General Details
Gore Tape
Load Cord
Panel
Cover Tape
Stitching
Panel-to-Panel Assembly (see fig 5)
Tack Stitching
Zig-Zag Stitching along circumferential webbing
Circumferential Webbing
Figure 4A
Gore Assembly - End View
Panel
Cover Tape
Stitching
Panel
Gore Tape
Load Cord
Figure 4B

in *figure 3D*, and how it is filled. After all, if it is not filled then the fabric must stretch to fill it, right? Consider that this gap exists for a pseudo-curve which has a specific 2-dimensional radius center point as illustrated in *figure 3B*. This curve would become flatter (and thereby shorter) if the radius center point were moved further away, lessening the size of the gap. If the point is moved towards infinity, the curve becomes almost a straight line and matches the straight edge of the panel. When transferring this 2-dimensional illustration into the 3-dimensional real world, we can't just move the radius center point further away, but the length of the curve between points A and B can be made shorter in another way; by moving the curve, which is the gore seam, closer to the axis of symmetry (*see figure 1*). When this happens the length of the points between A and B on the panel itself remain the same, as they are a fixed length for a certain panel size and cannot change. In practice, when the load cord is snugged up in the load tape channel of a Barnes type envelope, this effectively brings the load cord closer to the axis of symmetry in the inflated balloon (see *figure 1,* again), with the result of the gap being filled without stretching the fabric to do so.

Now, getting back to actual construction details. Fitting of the "extra" fabric onto a correspondingly shorter gore cord dimension allowance is accomplished, without fabric puckering during construction, by using the sliding channel construction of the vertical gore tape around the load cord. When first assembled, the length of the gore tape, from deflation port to mouth, will be shorter than the load cord that it surrounds. Extra cord is needed for the basket attachment end, below the mouth, and the load cord must exit the deflation opening at the top and continue on to the top crown ring. Since the load tape is not attached to the load cord yet, no fabric bunching occurs and the gore assembly is free to slide over the entire length of the load cord.

The vertical edges of entire fabric gore sections are sewn to a narrow (3" wide) fabric tape which runs the length of the gore (the "gore tape"). At final assembly, the gore tape and the load cord at the deflation port opening is tacked together to the circumferential webbing at a predetermined distance from the crown ring. This makes a fixed deflation port opening which is slightly smaller then the parachute valve which will fill the space. Then, at the other end of the gore, the gore tape is pulled back along the load cord (much like the drawstring in a pair of athletic track pants or a winter coat's hood) to reveal more load cord, and at a predetermined location, the free end of the gore tape is tacked along with the load cord to the mouth opening's circumferential webbing (see *figure 4* for clarification of the gore construction).

This 'pulling back of the gore tape so it covers a shorter cord length' actually accomplishes two tasks. First, it shortens the load cord's distance (relative to the load tape's distance without it being shortened) to the axis of symmetry and takes up the "gap" between the panel and its two dimensional pseudo-curve as discussed earlier. Next, pulling back the gore tape, even further, results in taking up the extra panel edge lengths. Remember, the Barnes panel edges are as long or longer than the mid-panel height. The first task is accomplished when just a few inches of cord is pulled out of the gore tape channel, while the second task is accomplished when several times the first distance is pulled out. The exact amount of gore tape pull back along the load cord is not critical, and can be adjusted after a trial inflation.

After both the top and bottom circumferential webbings have been tack stitched to the load cord, the length of the fabric gore is actually longer than the load cord running through it. There is no need to pucker anything during gore construction. The balloon automatically adjusts this puckering at this final assembly point when the entire gore seam is bunched a little over the entire length of the load cord which is inside the channel.

Gore Assembly

The number of components used in forming the load carrying gore is higher than in standard construction methods, but the items are light in weight and easily sewn. At TBW, a single sewing machine assembles two complete fabric gores onto a gore tape, overlays the load cord, and covers the load cord with a cover tape all in one pass. There are six straight sewing lines running the length of the gore tape; 2 on each panel edge and one on each side of the cover tape to keep the load cord in position (see *figure 4*). Although the stitching used is chain stitch and can more easily unravel, the two lines of stitching provide some backup. Chain stitch in a production environment means the sewing machine operator can sew an entire gore from mouth to deflation port without stopping to refill empty bobbins. This means time saved = cheaper to build.

In the early 1980's, The Balloon Works assembled gores and panels using a zigzag lock stitch instead of straight chainstitch. At one point the load cord channel was assembled from two separate gore tapes (one from each gore being assembled) overlapping to provide a channel for the load cord to run through. The cover tape was not needed. With this method, however, the load cord had to be manually passed through the channel with a fid and that is a tedious job and costly in terms of labor.

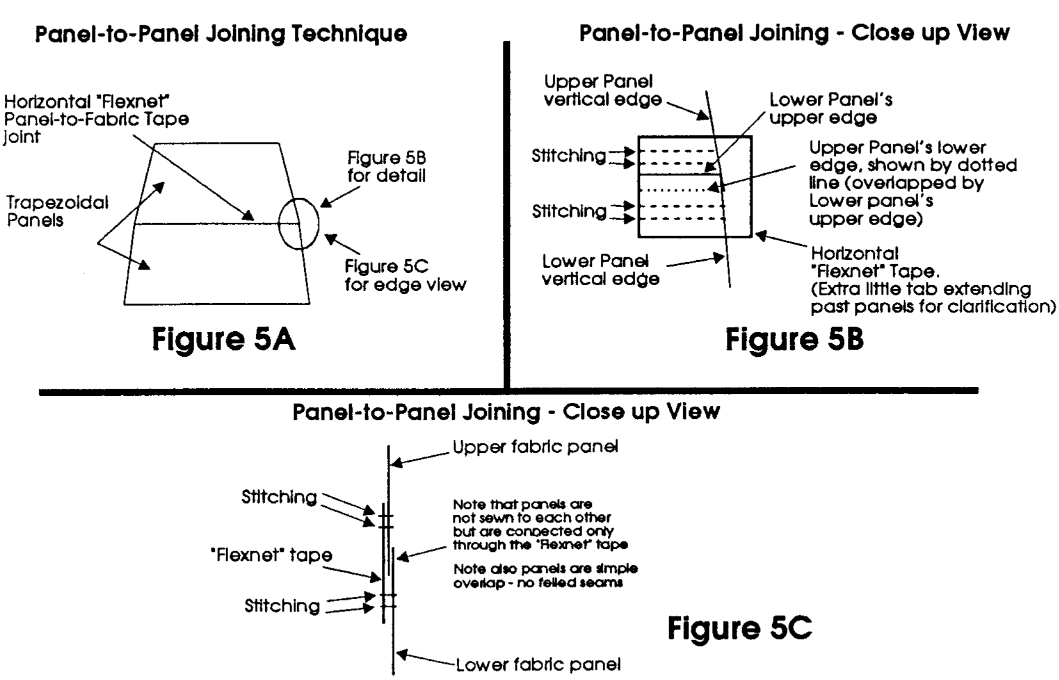
Let's comment on the Flexnet™ style of construction used by The Balloon Works. "Flexnet" refers to how the panels are joined to each other, not the sliding gore channel that Tracy Barnes designed after seeing it used in parachutes. Panels in the gore are connected to each other via a narrow fabric tape. The panels are sewn to the tape, and not to each other (see *Figure 5* for clarification). It matters not if the "Flexnet" is inside or outside of the envelope, or if the upper panel overlaps the lower or vice versa.

Barnes Construction Method Benefits

The major benefit of the Barnes construction method, with the panels being assembled into a gore through the horizontal tape interface, and the gores being assembled together through the vertical gore tape, is that there is no need for any felled seams. Everything is simple overlap construction and all the fabric edges are straight. With the trapezoidal panel shape, a minimum of fabric wastage also occurs. It requires a minimum amount of labor and sewing ability and achieves maximum usage from a roll of fabric. This combination is both cheap and easy!

The only complex part for the homebuilder to duplicate comes from understanding the sliding cord feature and how to adjust the length of the cord inside the fixed length channel. Part 2 of this article will detail panel dimension calculations and homebuilder assembly techniques for Barnes type envelope construction.

Figure 5 - Barnes Construction Solution - Panel-to-Panel Assembly



Looking Back at Vermont: The Boland Basket

By Bob LeDoux,

2895 Brandi Lane, Jefferson, OR 97352 CompuServe: 73474,76

This is the first in a series of articles discussing the balloons at the May Experimental Balloon Meet in Vermont. We begin our discussion of baskets with the Boland ligthweight basket.

While at the Experimental Meet in Vermont, Mari and I had the opportunity to examine a number of the Brian Boland baskets. Mike Emich allowed us to take detail pictures of his single place system. As the pictures show, this is a very light AX-5 balloon with an envelope weight of about 50 pounds and a basket weight of 27 pounds, not including tanks. This size system can be flown without a license, under FAR Part 103, if the pilot is willing to accept the fuel quantity limits under the ultralight rules.

Construction Details

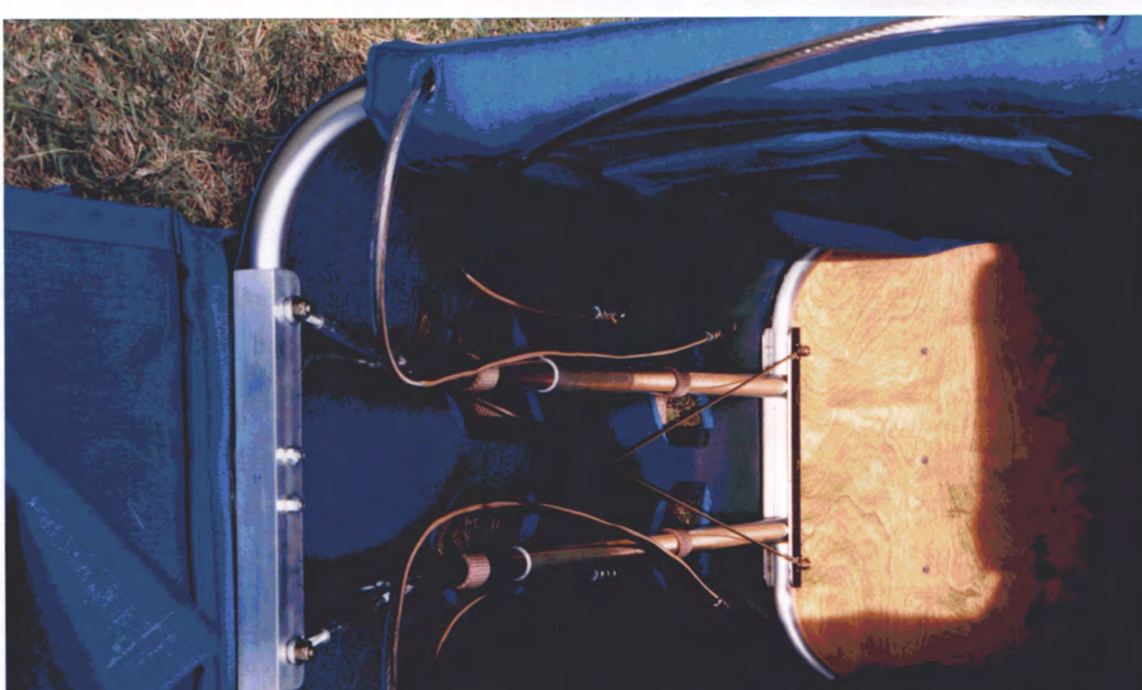
Mike used oak for his basket skids, which provide more abrasion resistance, at greater weight, than the pine called out in the Boland plans. The basket floor is made from an imported cabinet plywood commonly called 'Baltic birch,' This plywood has thin plys and no voids, it's a quality product. If you purchase your own Baltic birch remember its often glued up with water soluble glue, so a good varnish coat is important for weather protection. Mike used bolts to assemble his basket floor, while the Boland plans call for screws. In keeping with traditional aircraft construction standards, I prefer bolts in load bearing structures.

Mike Emich holds his single place basket while Marianne LeDoux carries an AX-5 envelope.

Two 3/16 inch cables carry the basket loads to the burner frame. Each of these cables begins at the burner frame, runs around the basket bottom and ends back up at the burner frame. Each cable runs under the basket floor through a groove cut lengthwise in one of the basket skid cross members. Nicopress stops are squeezed on the cable to keep it from sliding and to act as a 'butt saver,' keeping the cable suspension intact in the unlikely event that one end comes loose at the burner ring. If you build your own basket remember it is important to build in a radius where the cable makes the corner in the basket bottom. Sharp corners in cables lead to early cable breaks. Also make certain there are no sharp bends where a cable comes out of a nicopress sleeve or stop.

Looking at the basket interior we see two horizontal rectangular rings, constructed of aluminum 'U' channel and round tube. One of these rings is mounted on the basket floor and the second ring is the basket top. The upper ring is supported, in space, with vertical, 1 inch diameter aluminum tubes. The Boland plans call for 2 tubes in each long side, and 1 tube in each end. Mike modified his basket by putting 2 tubes in each end. The basket is made rigid through the use of crossed 3/32 inch cables on all 4 sides. Mike added turnbuckles in his cables to take all 'play' out of his system. We talked to a number of builders who did not use turnbuckles. They had not complaints about basket rigidity. To ease assembly, the vertical end tubes are cut in two pieces, creating a 'knee' joint in the middle. A short length of larger diameter tube slides over the joint to lock the joint in place.

Fuel tanks hang from parachute grade "V" rings bolted to the basket sides. These engage a snap fitting attached with heavy webbing to each fuel tank. These fittings are rated for a 2,500 pound breaking strength. The tank is also lightly strapped around its



middle to keep it from swinging. The extra vertical tube in the end of Mike's basket creates a "saddle" into which the single tank can fit on each end.

The basket exterior is a heavy Cordura fabric cover. This is attached to the basket structure with Velcro™ fastener around the base and top ring. The cover wraps around the basket and closes with a vertical seam. This should give fairly secure assembly. Velcro has poor peel strength but good shear strength. The basket corners, made from bent round tube, provide limited surface area for the Velcro. Brian is experimenting with square cross section corners laminated from wood. These corners fit tightly into the channel and give more attachment area.

The burner of choice in Vermont was the Balloon Works T3-017, chosen in part for its low weight. The burner clips to attach points inside a load ring constructed from a bicycle tire rim. Mike's rim uses eye bolts for the burner attachment, while Brian uses a short length of cable nicopressed to form an eye with a stop fitting though the rim. Eyebolts in the rim are used to attach the basket support cables to the envelope with caribiners. Most builders were using Aeroquip fuel hoses.

Some Personal Comments

The Boland basket shows considerable thought and development. Its light construction, may require more maintenance than on a traditional rattan carriage. But all the basket parts are of standard, generally aircraft grade materials, simply constructed, and readily repaired or replaced. Here is a clear example where the homebuilt system can be designed to performance and maintenance standards which would not be acceptable in factory built balloons. Factories are limited by product liability, and type certification standards. The FAA rules limiting owner maintenance also encourage overweight, over strength systems.

Mari and I had the opportunity to fly one of Brian's 48,000 cubic foot systems. The basket had flown over 600 hours. We represented a 400 pound payload so I was curious about the integrity of a basket designed by Brian who is reported to, 'perpetually weigh 167 pounds.' We found the basket solid and comfortable. This was our first experience with a flexible cable suspension. I never realized how much I like to steady myself against an upright. Pilots of old traditional flexible systems like the Piccard and Camerons generally wore helmets while flying. I don't recall seeing any pilots wearing helmets at Post Mills.

Outside tanks permit the basket interior to be smaller for the same passenger payload. But it takes a certain minimum space in which to raise a leg to climb in or out over the side. Mari, who is 62 inches tall found it very difficult to climb in and out of our 24 by 36 inch basket. She needed a step in the basket side. I wondered about our ability to squeeze two bodies into the bottom of the carriage in the event of a rip out landing. The lack of interior tanks eliminates many hard points on which to bump human body parts. It also eliminates spaces between tanks, in which a foot can become lodged resulting in possible ankle injuries.

We think the padded basket sides would actually be superior to a rattan basket for most high wind landings. The padded sides should eliminate rash and bruises often suffered in standard baskets during ripout landings in marginal conditions. Under *very* windy conditions, I'd prefer to be in rattan.

For readers uncertain about exterior tanks or flexible suspension systems, read Bruce Comstock's comments in the Letter's section of this issue.

Due to the exposed tanks and flexible suspension, Brian recommends that pilot lights be extinguished on high wind landings. I discussed this with Bill Arras. Bill's position is that the liquid fuel lines should also be empty. (Bill flies over a historic volcanic area with abrasive rock capable of cutting fuel hoses.) There is a downside to his position. It takes so long to turn off a standard tank valve, that its often not possible to stop a descent to landing and then shut off the valve. The valve has to be shut off early which can make for a hard landing, as He can attest. Bill is looking at possibly putting a Thunder-Colt type quarter-turn tank valve on one of his Worthington tanks.

In closing, we are impressed with the Boland basket system. Brian has given considerable thought and development to his basket. While there is still room for improvement, it appears a safe and dependable basket for most flight operations. The sport pilot, with some flying experience, looking for a lightweight balloon system, should give the Boland basket a good look.

Letters to the Editor

External Tanks and Flexible Uprights

Bob,

"...Last year I become interested in a very easy-to-use hot air balloon and started developing such a balloon for myself....

The ideal manifestation of this balloon includes fuel tanks which snap and strap onto the outside of the basket, allowing its two-person basket to be incredibly compact. Although the fuel tanks are the strongest part of a hot air balloon system, and a basket provides little additional protection for them, there is strong resistance to this design from many balloonists. While I understand that those who recoil from this design concept have never dropped fuel tanks from 20 feet height onto concrete, it still got frustrating to deal with the many closed minds on this.

Another example of this kind of intolerance relates to baskets without burner supports. I don't mind the ignorance–that only requires open-mindedness and education to resolve, but I have a hard time with close-minded intolerance.

So one reason that homebuilders can lead the way is that they (we) are not beholden to the marketplace. Also, of course, airworthiness certification is much easier. I also think that homebuilding allows greater design latitude that can NEVER be found in, incorporated into, type certified design offerings due to the multitude of people always looking over the shoulders of balloon manufacturers. For example, homebuilding allows design and construction of a balloon with features suitable only for an experienced pilot, or only for calm conditions, or only for some other kind of limiting conditions. Balloon manufacturers are forced by the legal climate to design every balloon for the least competent pilot flying in the worst conditions that could exist or occur."

Bruce Comstock
P.O. Box 2863
Ann Arbor, MI 48106

Alternative Envelope Design Style

Dear Bob

Ron Cassidy forwarded a copy of your newsletter to me. I met you at Brian Boland's experimental rally in early May. The AX-10 we were flying was built on the old Ice Cream Cone formula developed and used in this part of the country extensively by Dennis Kamin, Brian, and others.

Kamin's computer model allows 5 inputs including radius at mouth, over all height, radius at the equator, panel height and gore width. If you want a working copy, on disc, let me know.

I entered your 'natural shape' model into my Mac and made one modification. I added a column that computes and totals the square yardage and running yardage (based on 60" goods). Of course this figure assumes zero waste and zero mistakes. If you think your readers would be interested in this change, let me know and I will send you a disk....

Tom Handcock
17 Freeman St.
Portland, ME 04013

Source of Fabric

Bob,

Just completed experimental 75% rebuild of Cameron Viva-77 (horrid fabric waste!) using 30% Soarcoat and the rest 1.1 ounce nylon from Don Piccard. This was his Kenyon Mills cloth used on the "Solo-System.' It is easy to sew and feels good. I am looking forward to seeing how it will hold up. Don still has the following [rolls] available: Red: 190, 400, 100, 60, 400, 200 yards; White: 248, 115 yards; Green: 445, 214, 117 yards. Don can be reached at (612) 333-6912.

Now that I'm back in an envelope, I can finish the Ed Yost baskets I've been putting off completing.

Craig Kennedy
7315 Mesquite Wood NW
Albuquerque, NM 87120

Internet Balloon Information Group

Richard Regenburgh reports there is an Internet balloon interest group. To receive information send a message to > internet: balloon-request@lut.ac.uk. In your message state: subscribe: your name and your internet address. He says to expect 5 or 6 messages a week.