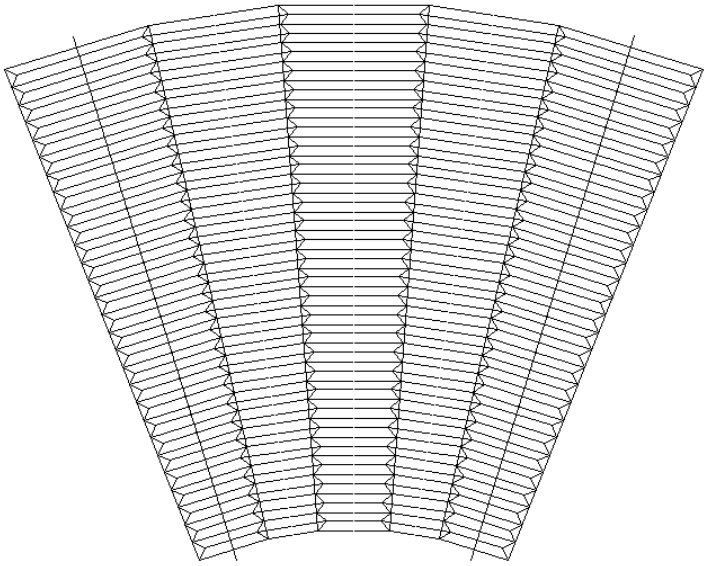
BELLOWS CONSTRUCTION



A BASIC TUTORIAL DETAILING THE DESIGN AND CONSTRUCTION OF YOUR OWN LARGE FORMAT CAMERA BELLOWS

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BELLOWS CONSTRUCTION

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BELLOWS CONSTRUCTION

By

JB Harlin

09/25/2008

I promised myself I would never do this. . . but never say never! What I mean is I promised myself I would never try to explain bellows building. But I have had so many inquiries and have answered so many e-mails, I have decided to go ahead and try to explain how we did it. First let me say, this is not the only method for bellows construction, this is my method. If you follow along step-by-step, you should be able to achieve similar results.

Keep in mind this is not an exact science, it is as much an art, or learned craft, as anything. There is a learning curve you have to go through. I will try and explain some of the pitfalls and mistakes we made and hopefully you will be able to avoid some of the frustration involved in learning this craft.

THINGS TO CONSIDER

Please remember, building your own bellows is not rocket science. It is science coupled with craft and experience. Though not a project for the faint of heart, the good news is you can eliminate most of the unknowns by drawing and building paper scale models. There are numerous variables that affect how the bellows folds and fits. My wife says these variables are very much like sewing. Anyone that has ever tired to sew a bag knows that cloth draws and puckers when you work with it and you don't always get the size you think you should. Since you are working with fabric to build a bellows, there are always things that just don't work the way you think they should, nor the way you calculate them.

A tapered bellows is the most difficult to construct. Since we have never built anything else, this discussion will only cover tapered bellows. If you are building a straight bellow, you may not be able to use this technique. I really don't know, never having tried.

THE DESIGN

If you are building a replacement bellows you should be able to use the original bellows as a guide to create your pattern. If you can unfold and open the seam of the old bellows you will have all of the dimensions necessary to build a replacement. But if you are

building from scratch, or you don't want to destroy the original bellows, then you will have to generate your own pattern.

The pattern is derived from the desired size and shape of the bellows. Once the total length and size of the openings at the two ends of the bellows are known, a scale pattern is created. This pattern describes the size and placement of the ribs. Card stock ribs are used as stiffeners and define the folds of the bellows. In a tapered bellows there are two widths of ribs. This is necessary to allow the bellows to taper. The bellows pattern defines the width of the ribs, their exact size and their placement. A correctly designed pattern is essential for the fabrication of the bellows.

BUILD A PAPER MODEL

I cannot stress how important the paper model can be. I have at least three complete bellows that are unusable for one reason or another. The one thing they all have in common is some error in design. We learned the hard way that a paper model can save you a world of frustration. Building a full-size model will not only confirm that your design will fold properly, it will also confirm that both ends fit properly. With every bellows we have built, and we have made to date eight of various sizes, small adjustments in the end dimensions were required for a proper fit to the bellows frames. If you skip this step, you just could end up starting over.

MATERIALS

Suitable light-tight material is always a problem for bellows construction. What is needed is a light, thin, strong material that is 100% light proof. This is a tough bill to fill. We were lucky to find a local fabric store that had in stock a black, 100 denier Nylon, that was vulcanized on one side. We attempted to order more, but they were unable to obtain more, so we bought their entire stock. There are other sources of similar material. An Internet search may turn up suitable materials.

We use a light weight, near flat black, cotton fabric for the inner lining which we purchase from a local fabric store. The brand on the bolt reads "Symphony Broad Cloth." This cloth is no where near light tight, we depend on the Nylon outer to be light proof. This liner is very strong and serves as an anti-reflective inner liner for the bellows as well as adding strength. The bellows has to be light and thin to fold properly.

The ribs of the bellows are made from black Railroad Board. Railroad Board is a smooth, thin, Bristol-type board, that is used for signs, posters, mailing cards and such. Thicknesses are 4 ply (about .017" or .43 mm) and 6 ply (about .022" or .56 mm) and is available in sheets up to 22" × 28" (56 cm × 71 cm). For small bellows up to 5x7 the 4 ply is adequate, but for larger bellows I would recommend the 6 ply.

The entire bellows is assembled using contact cement. Any high-quality commercial contact cement will work. I would not recommend any of the latex contact cements though. It is important to coat both bonding surfaces when using contact cement. A good bond is achieved by applying pressure. We use Weldwood Original Contact Cement for gluing the ribs and the bellows to its wooden frames. The cloth inner liner is attached using 3M Super 77 spray adhesive.

OUR TECHINIQUE

In the technique we employ, the bellows is constructed inside out. The pattern is drawn on the rubber lining of the outer material. This pattern is used as a guide to glue the ribs into place.

Once all four sides of the ribs are glued and the glue has had time to cure, the inner lining is added. The liner is glued in place with spray contact cement, which is applied to both surfaces.

It is important that all glued surfaces be firmly pressed into place to insure a good glue bond. The finished bellows should be allowed to dry for at least 24 hours. Once the glue has cured, the bellows is turned inside out, by passing the small end into the larger end. It is then folded and pressed flat for 24 hours under pressure to set the creases. The last step is to attach the bellows frames and the bellows are ready for use.

BEGINNING THE DESIGN

This design method assumes the bellows frames, both front and rear, are available. And, that the bellows will glue flush to the frames. Begin by measuring the frames. Both inside and outside dimensions are needed.

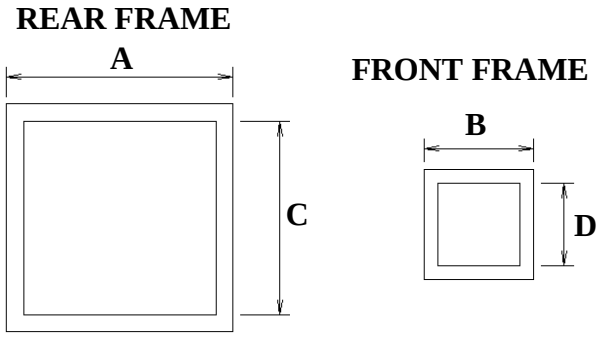


Figure 1

The front and rear bellows frames will determine the size of the finished bellows. Carefully measure the inner and outer dimensions.

With a tapered bellows, the corners of the top and bottom of the bellows have pointed ribs that form a 90 degree angle. The sides have ribs that are cut to the bellows side angle formed by the corner of the assembly.

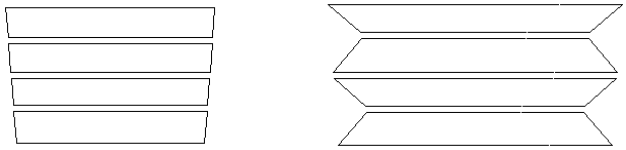


Figure 2

The ribs give the bellows its shape and are used to stiffen the bellows. In a tapered bellows the ribs have two widths.

The corners of the bellows must be defined and drawn. With this type of bellows, the top and bottom corners are measured as the widest portion of the front and rear frames to be covered by the bellows when glued. The side corner is measured from the inside of the frame opening in that plane.

As an example, using Figures 1 and 2, the top and bottom pattern dimensions would be A/B and the side pattern would be C/D as referenced to Figure 1. When combined with the length of the bellows and drawn to scale they form the corners of the bellows.

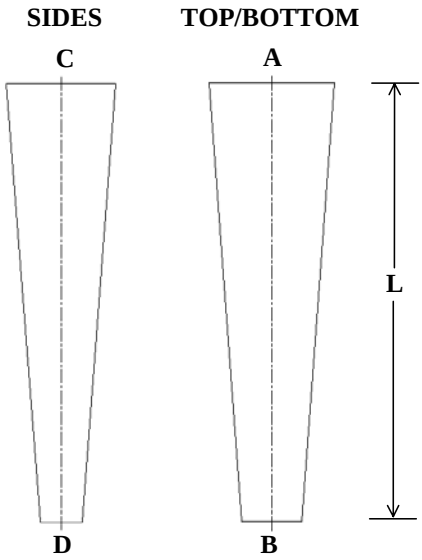


Figure 3

The beginning shape of the bellows pattern is determined by the size of the bellows frame opening at each end.

Next you need to know the fully extended length of the bellows. This is usually determined by the maximum extension of the camera, or the maximum focal length lens you plan to use. Keep in mind that once folded, the bellows will never fully extend to its

original pattern length. You should make the pattern length 10-15% longer than the longest extension needed with the finished bellows.

Having defined the basic dimensions of the bellows, the fold width must be determined along with the total number of folds. These numbers are calculated from the length of the bellows. Either an arbitrary fold width or the number of folds can be assigned. For a large bellows, you could use a fold width as wide as 1.50". A smaller bellows may require 0.50" to 1.00" wide folds. The fold width is also dictated by the width of the bellows frames. In order to glue flush, the ribs must be no wider than the frame face. Another determining factor in fold width is the amount of room required when the bellows is folded. There is really no hard and fast rule here.

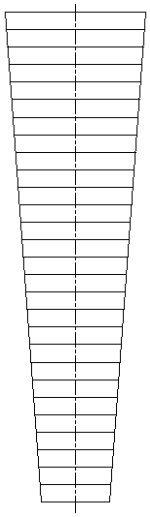
For an arbitrary bellows length, the Fold Width is determined by dividing the Length by the Number of folds, FW=L/N. Or, the Number of folds can be calculated by dividing the Length by the Fold Width, F=L/FW. Either way, the fold width must be determined in order to lay out the rib placement.

MAKING THE PATTERNS

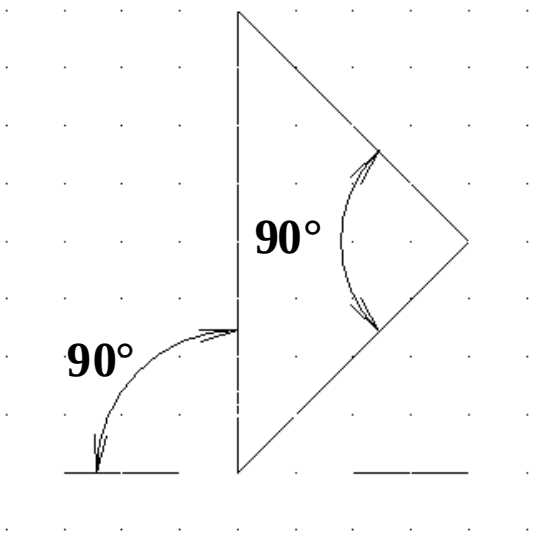
Once the basic dimensions of the bellows are known it is time to make a pattern. The pattern will define the exact shape of the ribs and their placement. Here is the procedure for making a pattern.

1. Begin by marking off the top and bottom pattern with the fold width measurement determined.

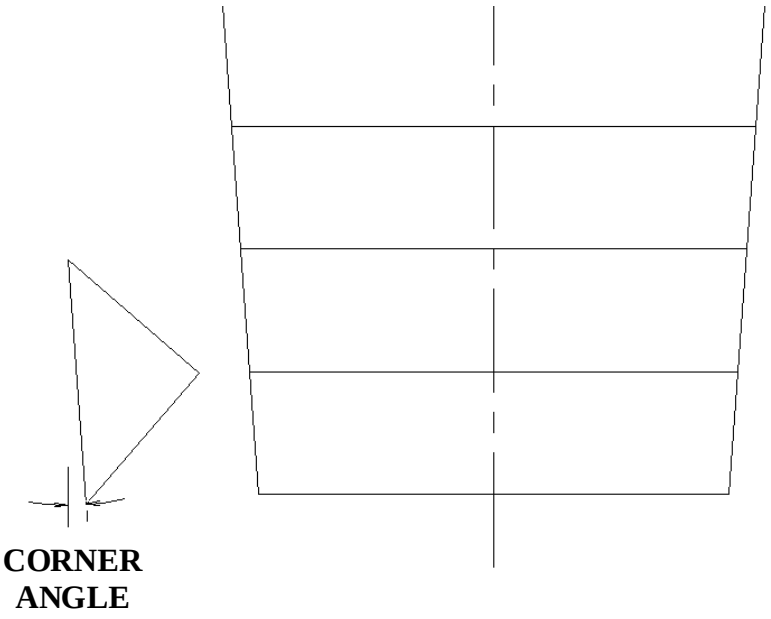
TOP/BOTTOM



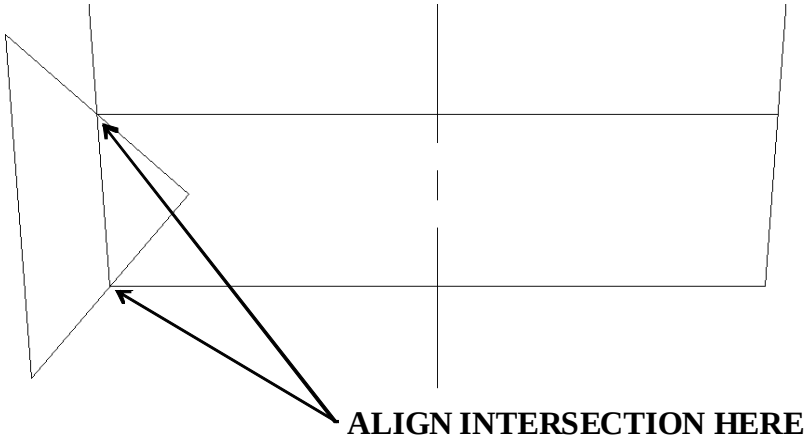
2. Create a triangle with a base of about 2 inches. This triangle may need to be 3 inches across its base for a large bellows. Lay out your triangle pattern on stiff card stock as shown and cut out. **Note:** Grid set to 0.250" in the example below.



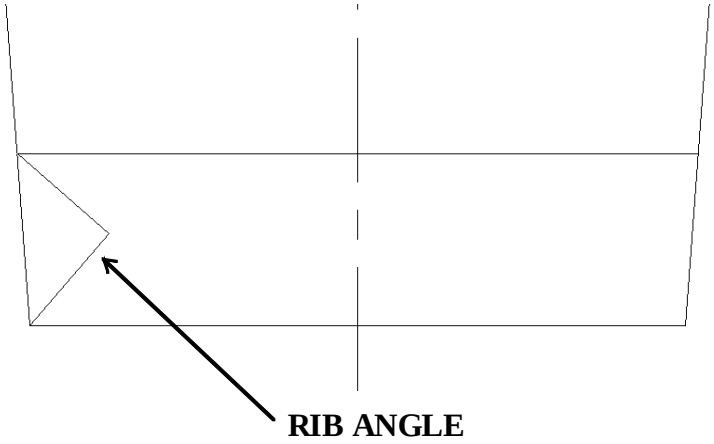
3. Rotate triangle to the same angle as the bellows corner angle.



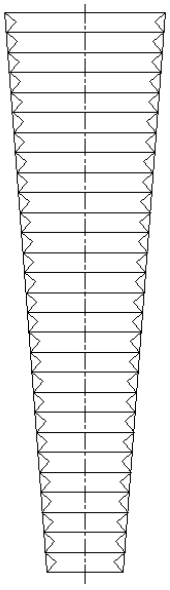
4. Move rotated triangle to intersect the fold width lines.



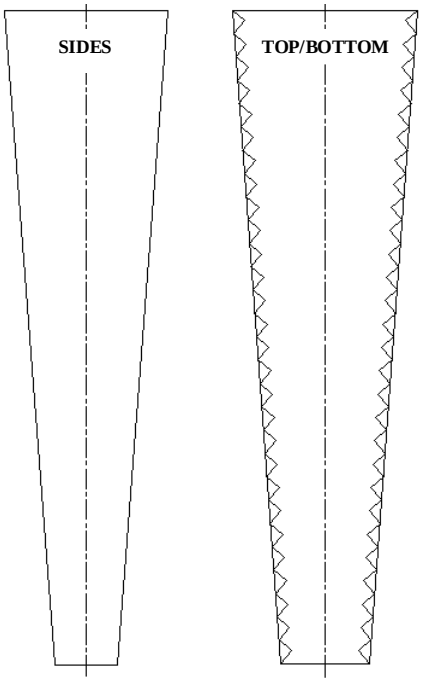
5. Trace around the triangle pattern connecting the fold lines at their ends along the pattern edge. This defines the rib angle.



6. Trace the rib angle using the triangle to each fold line on both side of the pattern for its full length. It is also a good idea to mark a center line through the full length of the pattern for alignment later.



7. The pattern for the sides of the bellows is much easier. All that is needed is the front and rear dimension and the length of the bellows. Below is the finished Top/Bottom along with the side pattern.



There are a couple of options for laying out your pattern. I prefer to use CAD software to draw my patterns. Using a computer drawing I can check my layout for size and fit onto the bellows fabric and easily make changes. Once I am satisfied with my pattern, I just print it out on a printer at 1:1. You can draw your pattern by hand also. Your pattern needs to be made from a fairly heavy paper stock, since you will need to trace around it. You can find rolls of medium weight brown wrapping paper at your craft store that should work well. Drawing the pattern by hand or with a computer works equally well.

Once you have your pattern laid out as shown in step #7 above, you need to cut it out. Use a sharp craft knife to cut around both patterns. These two patterns will be used to layout the guide lines on the bellows material and to determine the rib shapes.

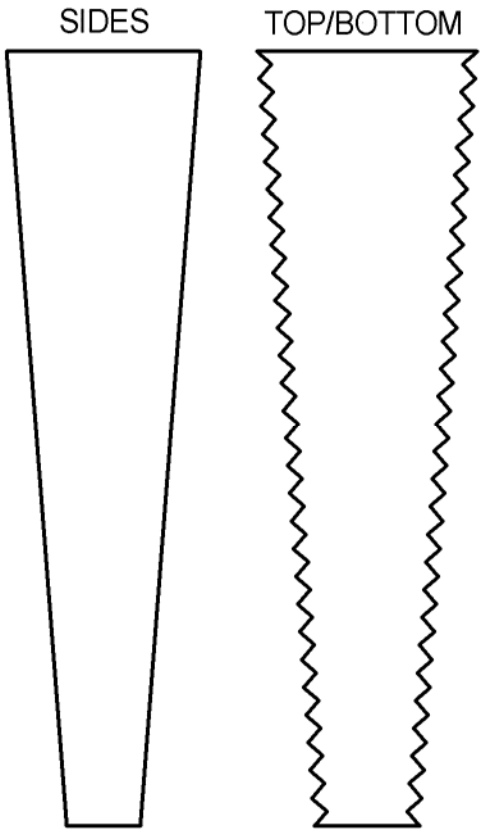


Figure 4

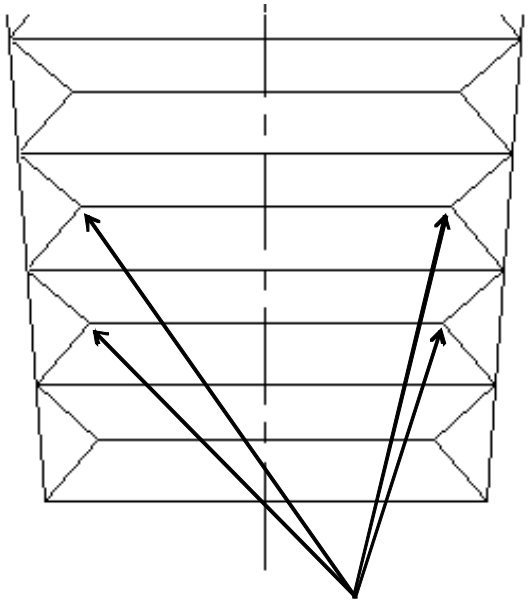
When complete, the Top/Bottom and Side templates are cut out and should look like this. The pattern should be made of heavy craft paper. You will need to trace around each pattern to lay out the bellows design.

DEFINING THE RIBS

Next the rib dimensions and angles must be ascertained. A tapered bellows uses alternating rib widths in order to allow the bellows to taper. The ribs alternate between a wide and a narrow rib. On a bellows that is symmetrical the Top/Bottom and side ribs use the same wide and narrow widths. On a very asymmetrical bellows, such as one designed for an 8x20 or 7x17, where the rear frame is much longer in one dimension than the other, the ribs for the Top/Bottom and side will be different widths. A symmetrical design uses one set of wide and narrow ribs, while the asymmetrical design uses two sets of wide and narrow ribs.

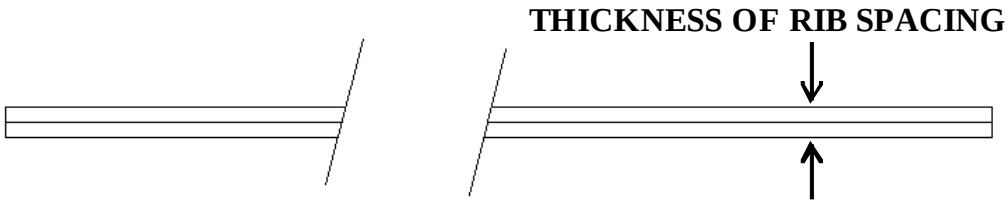
Here is the step-by-step procedure for determining how to cut the ribs.

1. Using the Top/Bottom with the fold lines drawn in, add the second fold line by connecting the peak of each rib angle for the first few ribs. You can either draw only the first few ribs, or you can trace around your Top/Bottom pattern.

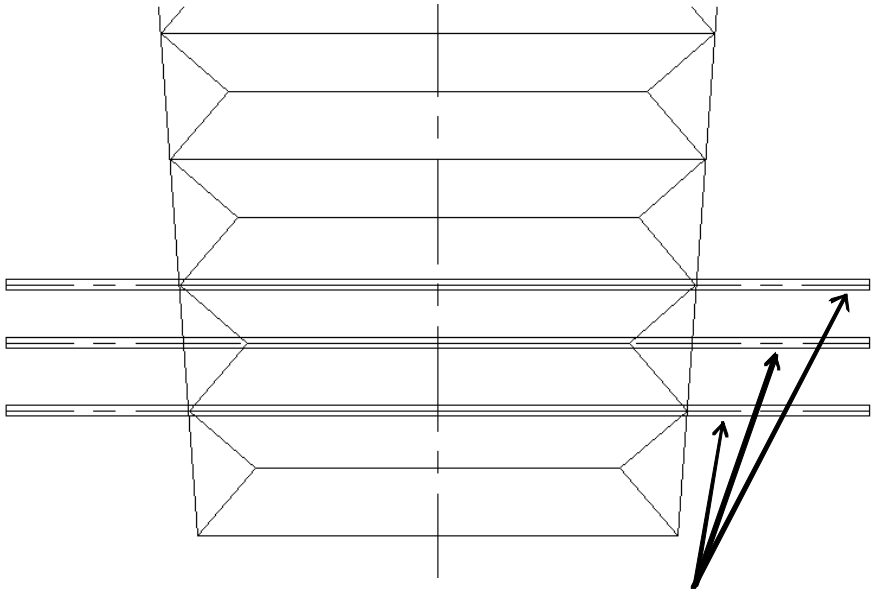


CONNECT POINTS

2. Determine a spacing width between the ribs that will allow the bellows to fold. This space must be at least the thickness of two layers of the bellows total thickness. In reality, a little more is necessary for the bellows to fold flat. Typically, for a large bellows, somewhere around 0.125" is about right.

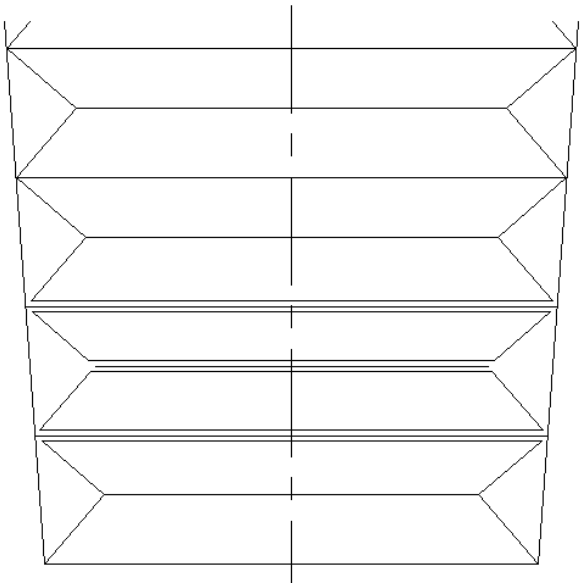


3. Next measure one half the distance of the determined fold spacing above and below the fold line on the pattern. Mark off this distance on two complete ribs.

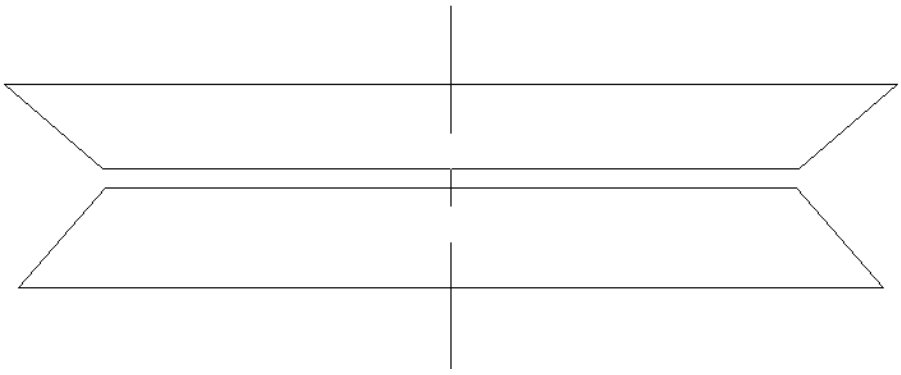


SPACING CENTERED ON FOLD LINES

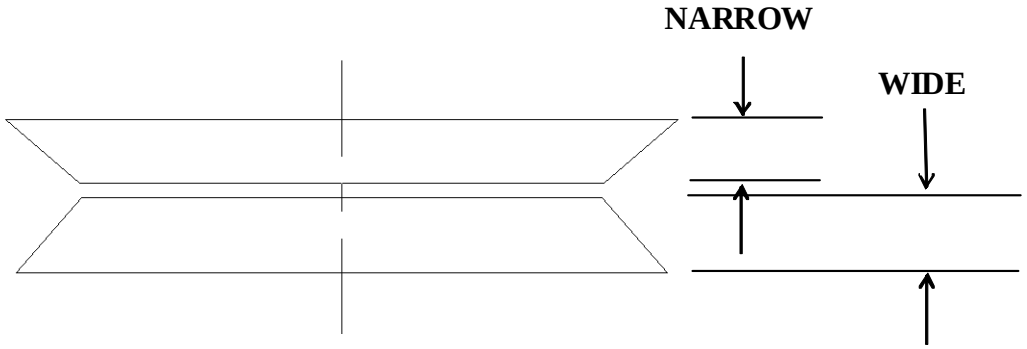
4. Erase the extra spacing lines and the spacing center lines and you will have full size dimension for the Top/Bottom ribs.



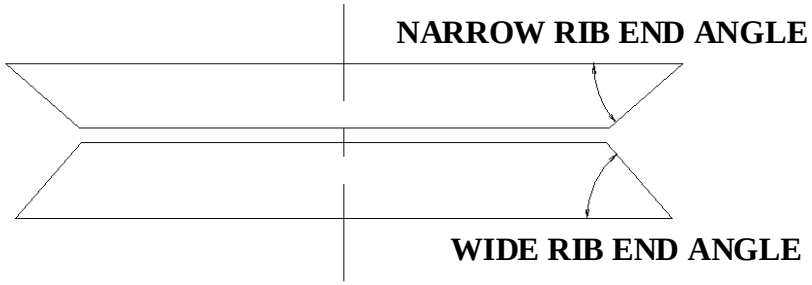
5. If you remove the rest of the lines your ribs should look like this. You will end up with two ribs with different widths and angles at their ends. The end angle will be 90 degrees.



6. Measure rib widths. This is the width for the Wide and Narrow ribs for the Top/Bottom of the bellows.

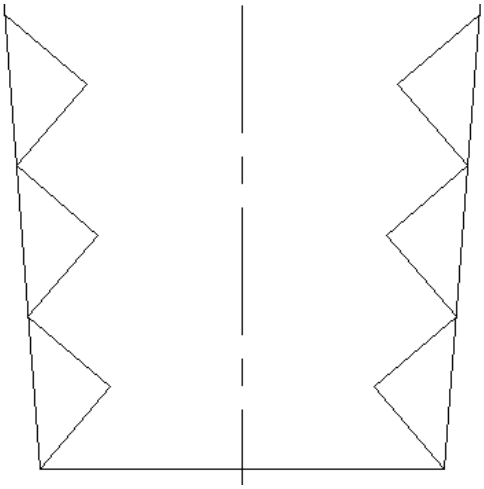


7. Measure the end angles. This is the angles that must be cut on the ends of the ribs on the Top/Bottom of the bellows. The sum of the Narrow Rib End Angle and the Wide Rib End Angle should equal 90°.

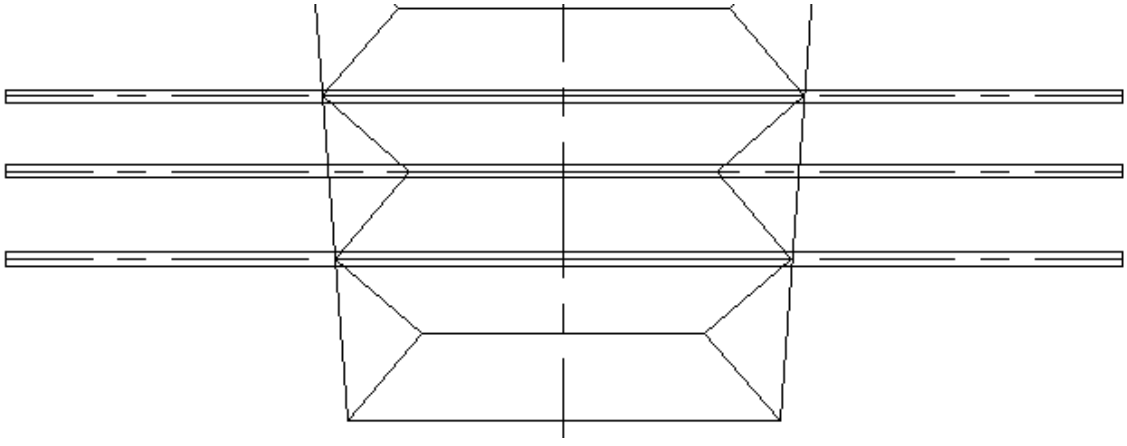


NOTE: With a symmetrical bellows, the Wide and Narrow ribs will be the same on the sides as on the Top/Bottom. With an asymmetrical design, the layout is done on the shortest side, which is usually the Sides, not the Top/Bottom of the bellows. The angled ribs are still on the Top/Bottom, but the layout is referenced to the Sides. Also the asymmetrical design uses different width rib sets for the Top/Bottom and Sides.

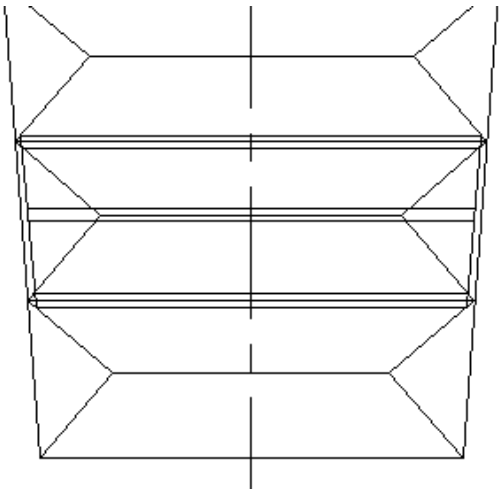
8. To create the side ribs, lay the Top/Bottom pattern on top of the side pattern. Align the edges and trace around the peaks and valleys for several folds. Then do the same for the opposite side of the Side pattern.



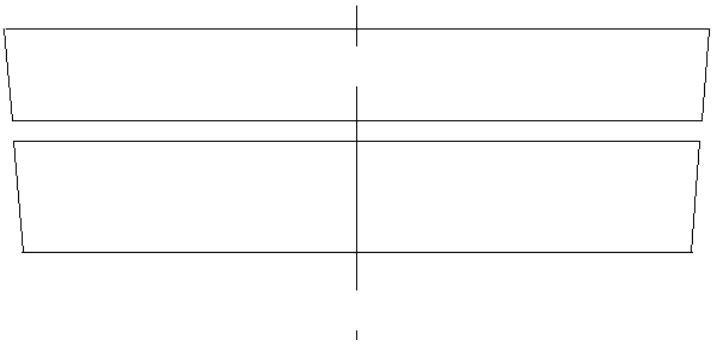
9. As before with the Top/Bottom pattern, connect the peaks and valleys and draw in the same fold spacing as before.



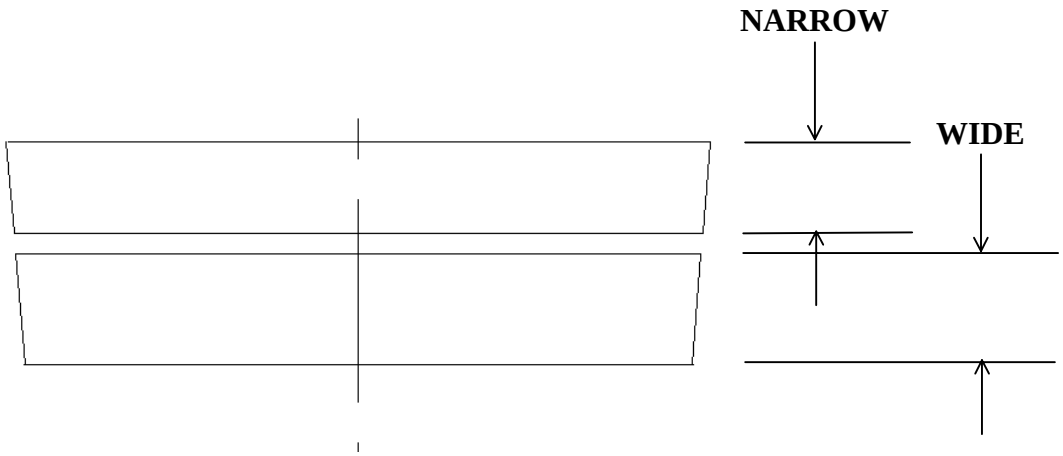
10. Erase the unused portions of the spacing and center lines. Draw a line from narrow rib point to wide rib point on each side next to the edge of the bellows.



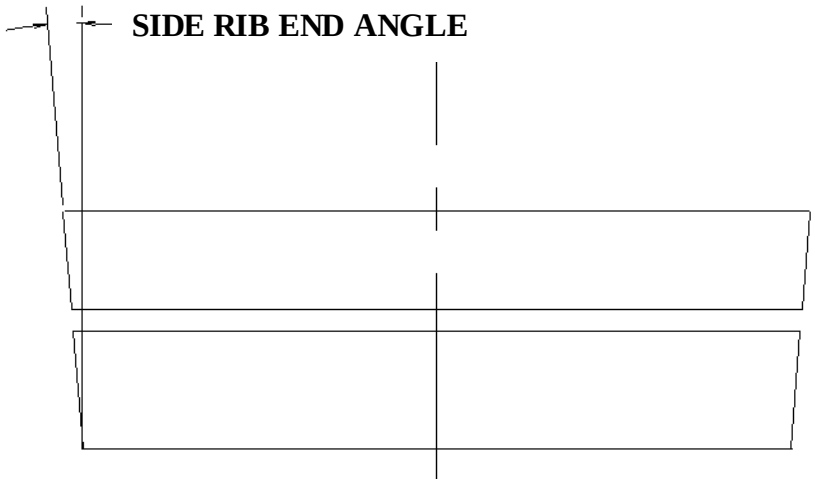
11. Remove all other unnecessary lines to leave side ribs. Again you will find there are two widths, a wide and a narrow.



12. Measure width of Wide and Narrow ribs. For a symmetrical bellows they should be within ± 0 .010 - 0.015 of the width for the Top/Bottom. This is close enough to call the same and you can use the same width for all ribs.



13. Measure the end angle of side ribs. This is the angle that must be cut in the side ribs to fit the pattern.



After all of this you are about ready to build a bellows. You can go directly to your bellows material and start if you like, but I strongly recommend you make a model from craft paper to be sure your design will fit properly.

MAKING MODELS

Before committing to making a finished bellows from the actual bellows materials, you may want to consider making a paper model to check the design. It is critical that the front and rear of the bellows properly fit the frames. It is also critical that the bellows fold correctly so the camera will close. It is easy to make a full size model of the bellows from craft paper and the frames from mat board.

Remember, you are working with cloth with many folds. What you measure and calculate may not be exactly what you get when assembled. A little time marking and folding paper can save you a lot of frustration. Believe me I know!

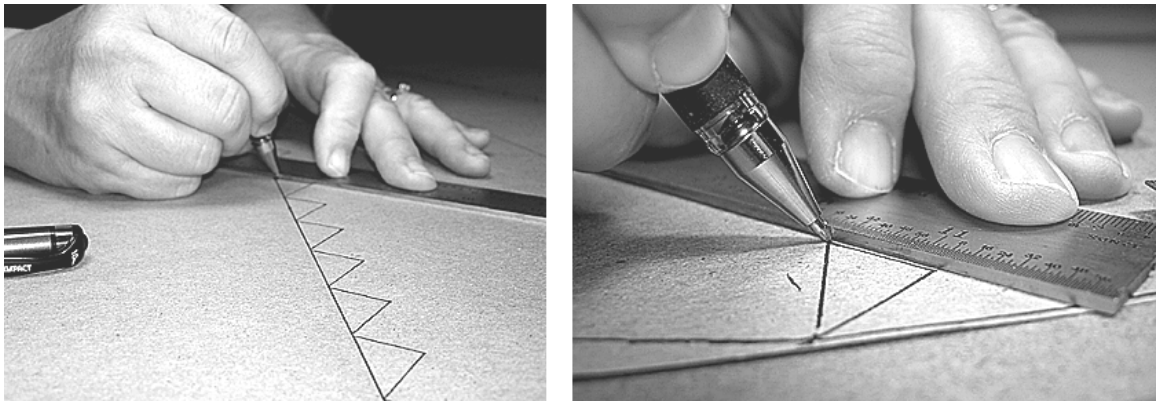


Figure 5

The bellows pattern is traced onto craft paper then scored using a ball point pen that has no ink.

We use brown craft paper that comes on a roll for bellows models. This paper is about the same weight as a paper grocery store bag. The bellows patterns are traced onto the paper then scored using a ball point pen that has run out of ink. The score lines define the necessary folding points and allow you to easily fold up the paper model.

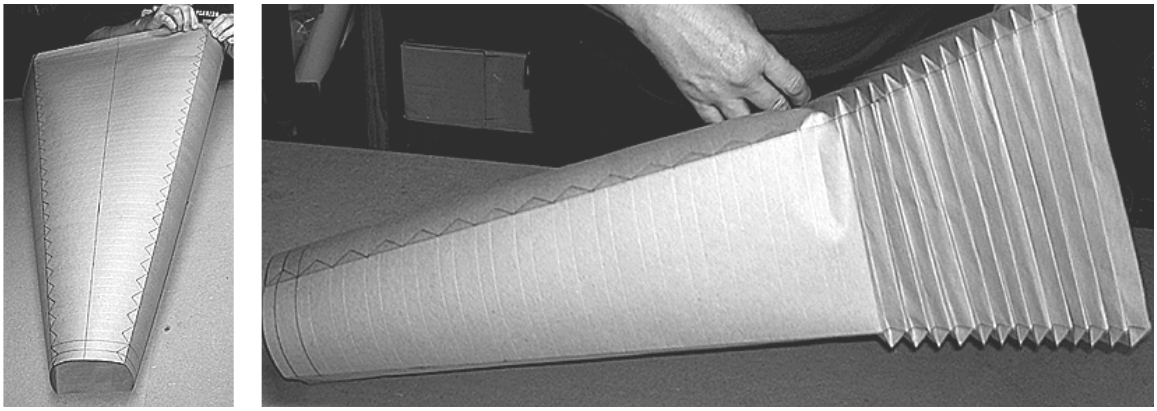


Figure 6

Once the bellows layout is scribed onto the craft paper, the corners are folded and the opposite sides are cut and joined using white glue. Then the bellows model is carefully folded.

If you feel there could be issues with the way the bellows folds, you can also make a scale model of the entire bellows from craft paper. Using the scale function of CAD software, it is easy to make a pattern set that is 50% of full size. Or, alternatively, you can hand draw a pattern at half scale. For a large bellows, scaling a pattern so that it will fit the size of the craft paper you have may work better. You can also glue sheets of craft paper together for a larger model. The paper model will reveal any potential problems.

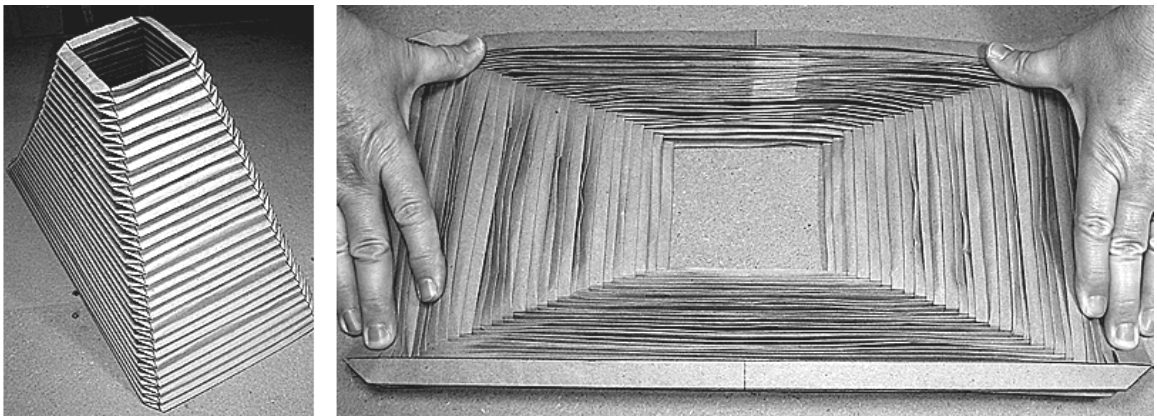


Figure 7

Once the paper model is folded, it will be apparent if the design is workable. It will be immediately known if the bellows will fold correctly. This is a model for a 4x10 camera. It is also a 50% model for an 8x20.

At the very least it is important to know if your design will fit your camera before you commit to actually building the finished bellows. If you are off on your design, the bellows will not fit the frames it mounts to at each end. The easiest way to prove the

ends will fit correctly is to build a partial 1:1 model. You only need a few folds of both ends of the bellows to check the fit.

Begin by tracing the first 6-8 folds of the complete 1:1 pattern onto a suitable piece of craft paper and score the fold lines. Make a seam on the fourth side and glue together with some white glue. Refer to the section titled *BELLOWS CONSTRUCTION* for details on how the bellows fits together. This scored paper model should easily fold. Make a 1:1 replica of the bellows frames out of mat board. Check the fit and glue the assembly together.

Make a model for both the front and rear of the bellows to check for proper fit. It may be necessary to adjust the size of the opening on the pattern. It is better to find this out now than after completing an entire bellows that will not properly fit.

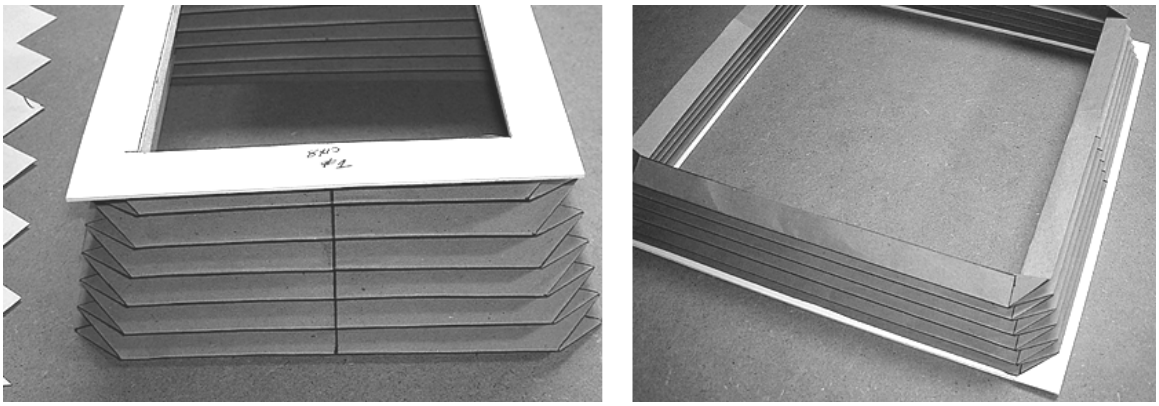


Figure 8

A 1:1 model of the front and rear sections of the bellows are made from craft paper to confirm the fit. This full scale model only uses a few folds of each end of the bellow which are glued to 1:1 models of the front and rear bellows frames.

It is a good idea to make a model to check the validity of the design. A little time spent here can save you a lot of frustration.

BELLOWS FORMS

In addition to the raw materials, patterns and tools, you will need a set of wooden forms to hold the bellows while gluing the fourth side and the liner. The forms are made from plywood, typically 0.50 inch thick and are cut from the patterns. Two forms are required, one cut to the taper of the Top/Bottom and one the taper of the Sides.

The forms need to be about 15-20% longer on each end than the total length of the finished bellows. This allows room to work and clamp the form to a table. You need to

be sure the form can be held securely while you glue the bellows fourth side and the liner material.

These forms look much like an ironing board. They need to be stiffened so they do not sag and flex while you are working on them. This can be accomplished by screwing the form to a 2x4 or a piece of sturdy steel or aluminum. My large forms are attached to two lengths of angle iron. Be sure to sand all of the edges of the forms so the bellows material will easily slide on and off the form without catching on splinters.

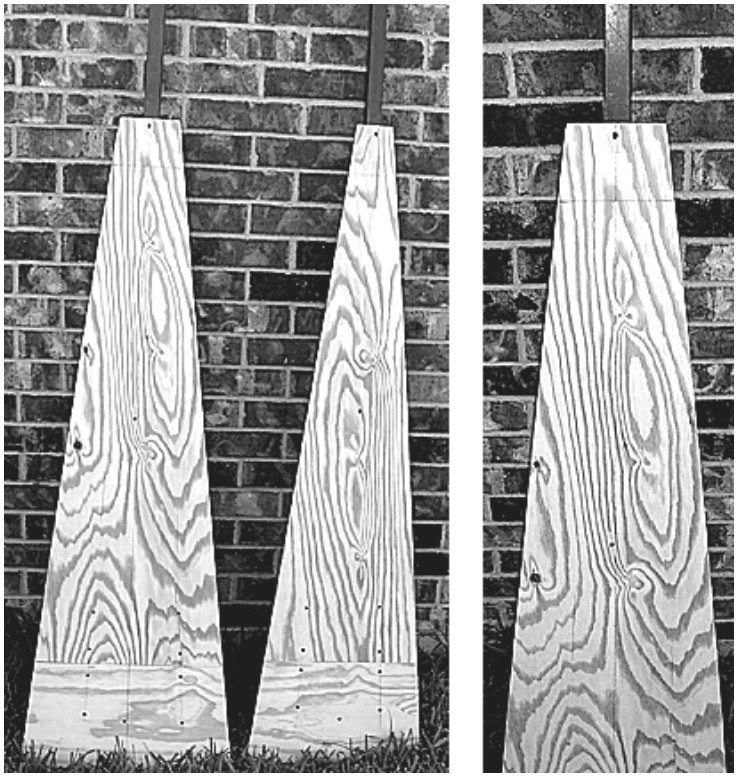


Figure 9

Bellows forms for a very large bellows. These forms are made of 0.50" plywood reinforced with angle iron and were used to construct bellows for an 8x20 camera with 45 inches of draw. Forms need to be rigid and longer than the actual bellows.

BELLOWS CONSTRUCTION

LAYING OUT THE PATTERN

The patterns are now ready to be transferred to the bellows material. A tapered bellows is made inside out. The outer material is cut to size and the patterns are traced onto the inner, rubberized, side of the material. It took some experimenting to find a good way to

trace the pattern to the rubber inner. You can use a white china marker, but we have found that a silver Sharpie® is the best way to transfer the layout.

It is possible, using the computer, to layout the entire pattern to see exactly how much material is required. You can also trace the layout to a large piece of craft paper. Either way, it is a good idea to know how much bellows material will be required.

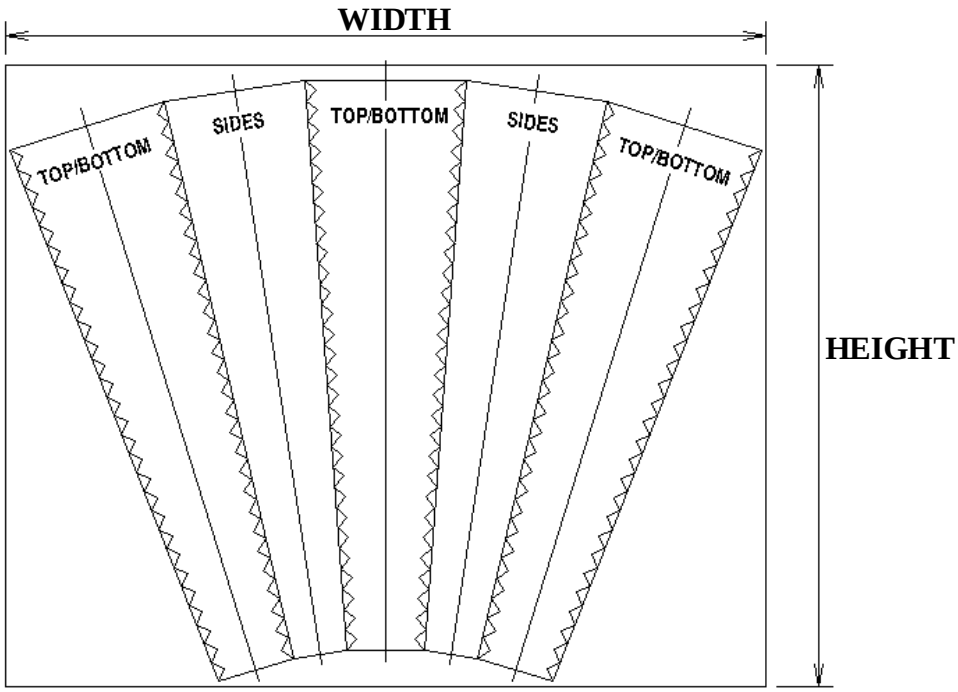
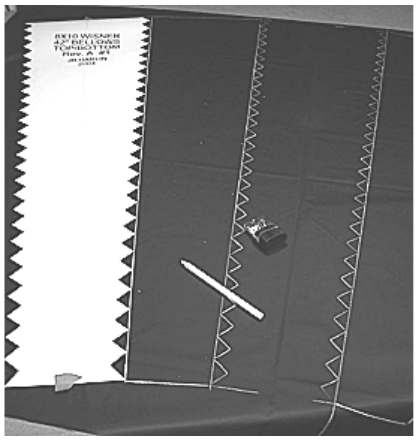


Figure 10

The two patterns are alternately traced side by side to form the four sides of the bellows. Alternating the two patterns side to side gives you the total amount of material required. This is what the entire pattern will looks like when drawn on the bellows material.

Cut a piece of outer material to the size determined for the bellows. It is a good idea to check the material for any defects. You don't want to find a hole after you have assembled the bellows.

For a large bellows you will need a large work table. It is hard to imagine just how large a piece of material it takes to form a big bellows. To build a bellows for an 8x20 camera with 45" of draw, requires a piece of material 48x80 inches.



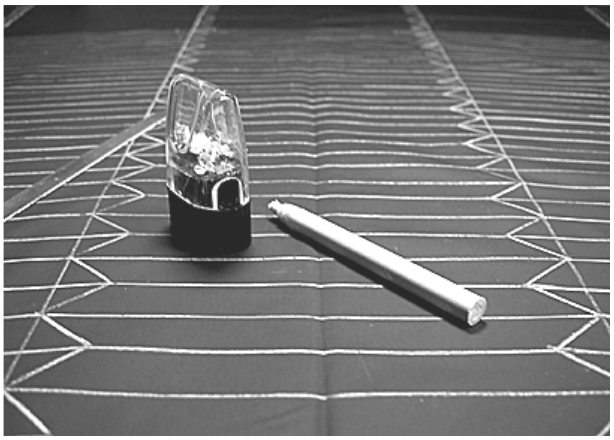


Figure 11

The patterns are taped to the rubber side of the bellows material and are alternately traced around forming the layout of the ribs.

Place the material, rubberized side facing up, on a large flat table. Measure the center of the material and center the Top/Bottom pattern on the center line. Tape in place. Using either a china marker or a silver Sharpie®, trace around the pattern. Be careful to define each intersecting point on the pattern. These intersecting points will define the folds of the bellows and are the alignment marks for gluing the ribs.

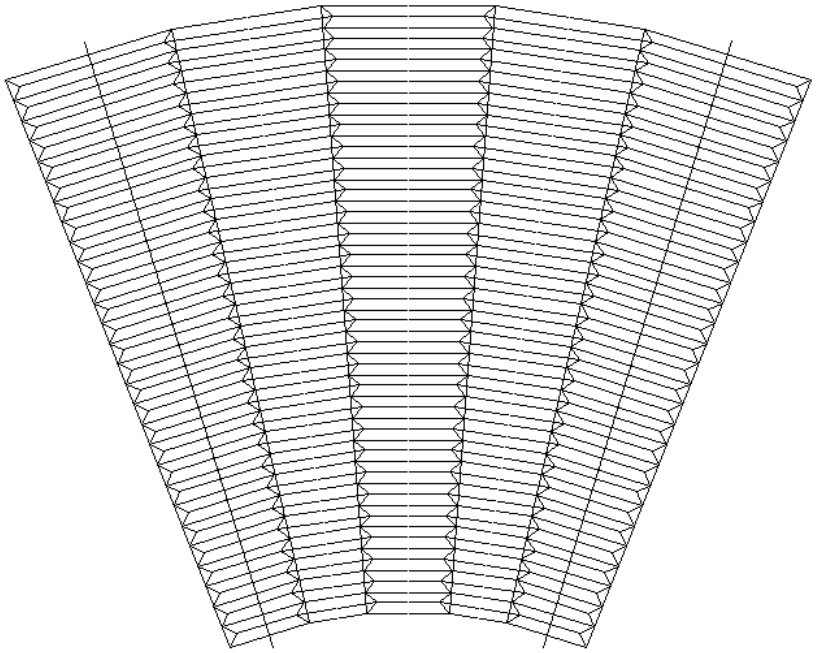


Figure 12

Once the patterns are transferred to the material, lines are drawn from the peak and valley of each side. These lines will be used to align the ribs.

With the Top/Bottom pattern traced onto the material, next draw a line that just touches the outer most points of the Top/Bottom pattern on the left and right sides. Then fit the Side pattern next to this line along each edge of the Top/Bottom pattern and carefully trace around the pattern. Once the Side pattern is traced on both sides of the Top/Bottom pattern, remove the tape and align the points of the Top/Bottom pattern again with the outer lines from the Side patterns. Do this again on both sides. This completes the transfer of the patterns.

Next connect all of the peaks and valleys traced onto the bellows material. The bellows material should look like the full pattern layout drawing in Figure 12.

MAKING RIBS

The railroad board ribs need to be cut cleanly and evenly to the correct width. On a large bellows there may be as many as 200 or more ribs required to finish the bellows. A rotary or guillotine type cutter can be modified with an adjustable stop for cutting the ribs accurately. A sliding stop can be fabricated from aluminum or brass and attached with threaded bushings to the bottom of the cutter. This way the stop can be adjusted for the required rib widths and removed so the cutter can be used for other purposes.

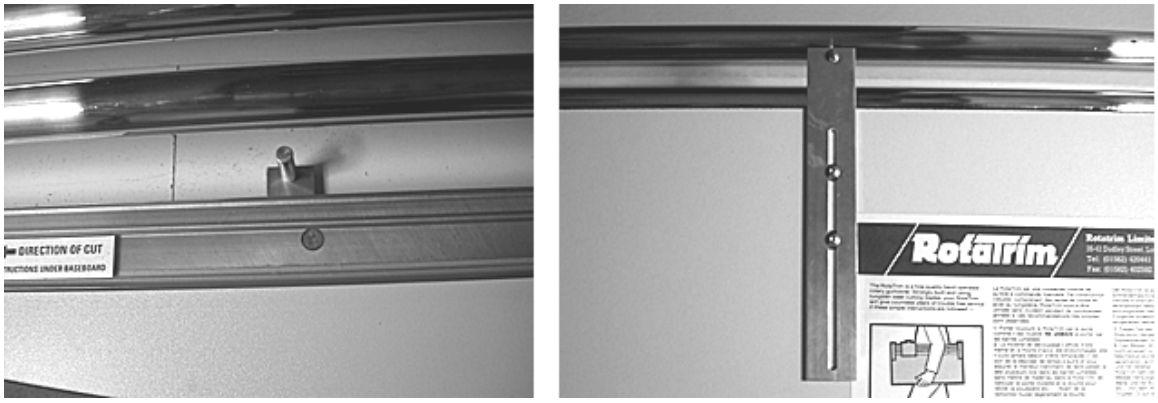


Figure 13

Here is my modified rotary trimmer that I use to cut the ribs to the correct width. I fabricated a sliding stop that attaches to the bottom of the trimmer.

Once the raw rib stock is cut to the widths needed, each rib must be hand fitted to the bellows material. A rotary or guillotine type cutter can be further modified to cut the angles required for the top, bottom and sides of the bellows.

The total angle of the Top/Bottom ribs is 90 degrees, so by attaching a square metal plate to the top of the cutter both angles can be cut with one set up of the cutter. A square piece of aluminum about 0.125 inch thick can be fabricated with a mounting hole in the exact center. This plate is attached via a threaded bushing to the top of the cutter with a single machine screw. The angles are set using a machinist's square equipped with an adjustable head.

With the rib material cut to the correct widths and the pattern laid out on the bellows outer material, it is time to start fitting and gluing. Working with contact cement is not difficult. Just keep in mind that for contact cement to work properly, it must be applied to both surfaces to properly bond. A solid bond is achieved once the glue has dried and sufficient pressure has been applied.

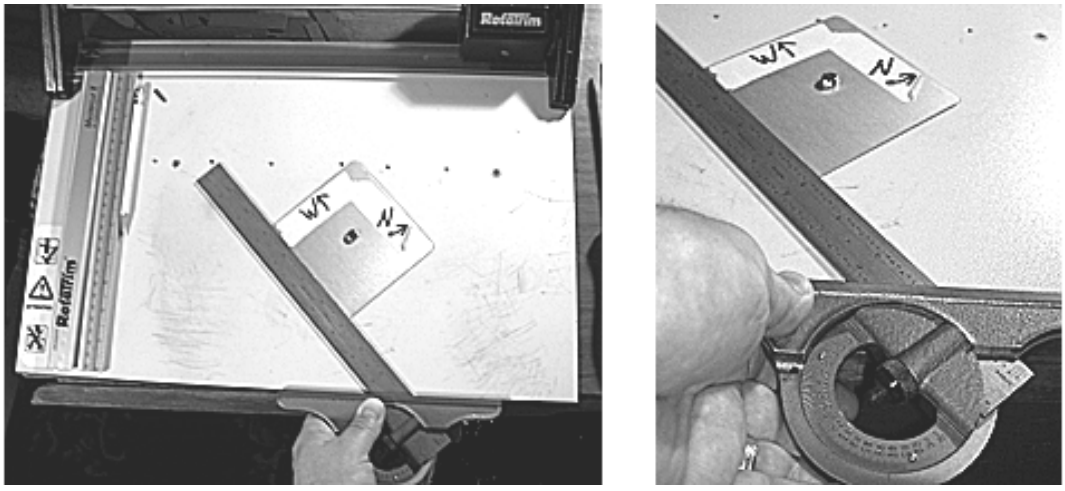


Figure 14

A square of aluminum it attached to the top of the rotary trimmer and adjusted to the angle required for the top and bottom ribs.

Start gluing with the center section of the pattern. This will be the Top of the finished bellows. Be sure to mark your cutter as to which guide is for the wide and narrow ribs. They will only fit the pattern one way, so as long as you cut the correct angle on the wide and narrow ribs you can't make a mistake.

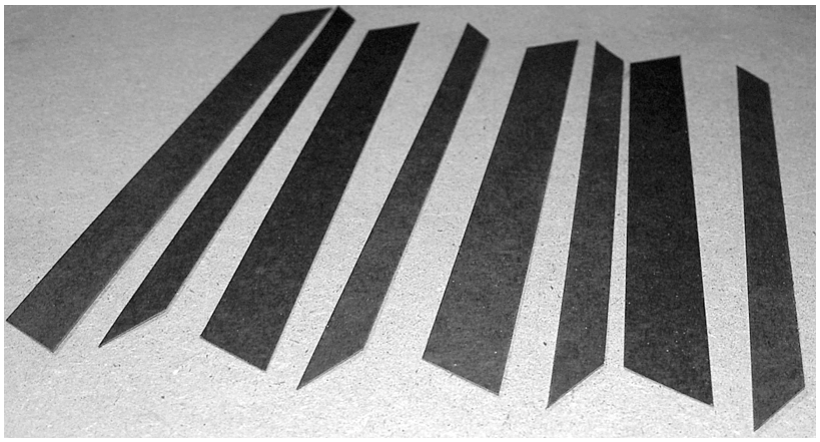


Figure 15

Here is a set of ribs cut to fit the bellows layout and ready to be glued in place. Note the different width of the ribs. This is an extremely sharp taper of a very asymmetrical design used on an 8x20 camera.

Begin with the longest ribs first. Cut several ribs to fit the pattern. Each rib is hand fitted to the correct pattern location. I normally cut 8-10 ribs at a time and lay them out in the correct order of assembly.

Apply glue to the bellows material first. Coat the area for two ribs at a time. Once the glue is applied to the material, brush one side of the first rib. Be sure to completely cover and work the glue into the rubberized fabric and the rib.

Position the first rib between the fold lines drawn on the material and press into place. You will have a few seconds to slide the piece around before it bonds. Once you are satisfied with the position, press the rib firmly down and then coat the next rib and position in place. Next coat two more marked ribs on the material and repeat. Work your way all the way to the shortest rib. Let the assembly dry for at least thirty minutes to an hour.

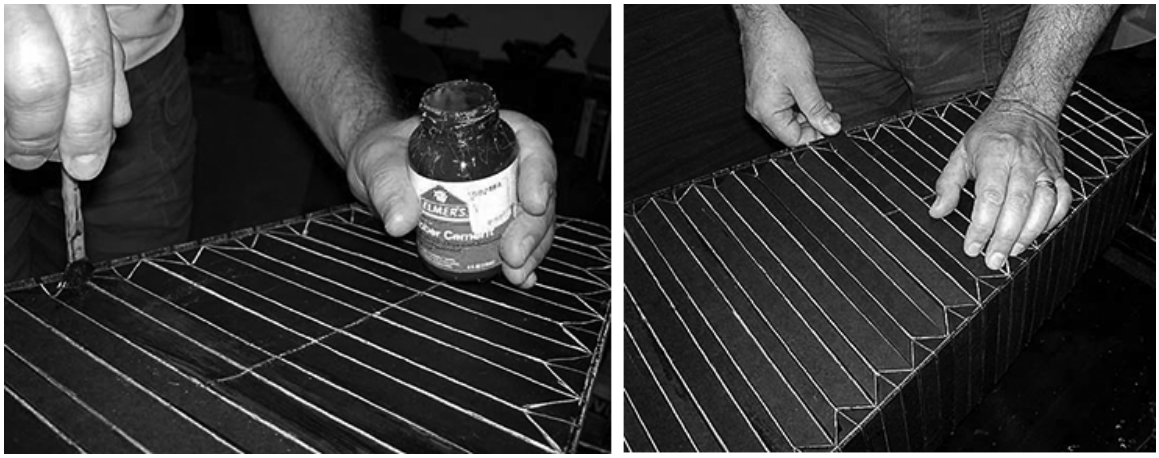


Figure 16

I like to apply glue to the material two ribs at a time. Then paint one side of the rib material and place and align on the layout. Once you are satisfied with the alignment, press the rib firmly into place.

It is important that the contact cement fully coat both surfaces to be bonded. I coat the ribs on a sheet of craft paper taped to the table top. Each rib is thoroughly coated as well as the rubber inner of the bellows. Remember to press the rib firmly into place, contact cement requires pressure to form a strong bond.

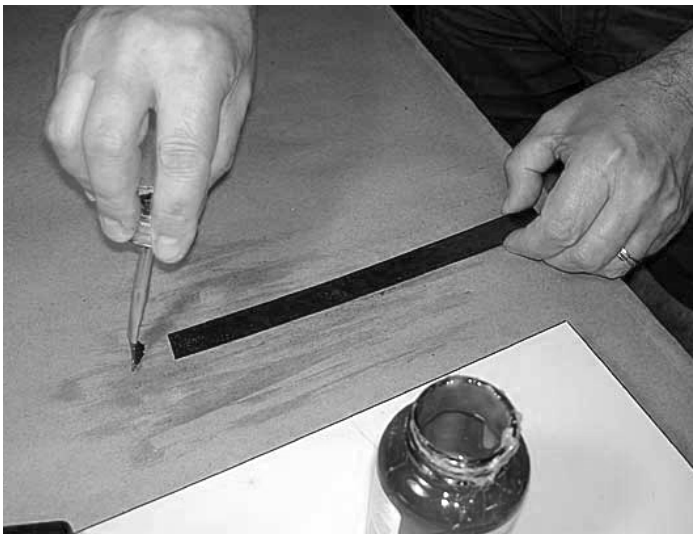


Figure 17

Coat the bonding side of each rib completely with contact cement. A good bond is dependent on a thorough coating.

Next, reset the cutter for the angle of the side ribs. All of the side ribs are cut to the same angle. They usually go faster since the fit is much easier. Again start with the longest and work toward the shortest rib. Once one side is finished, let it dry and start on the other side. The first three sides are done with the bellows flat on the work surface.

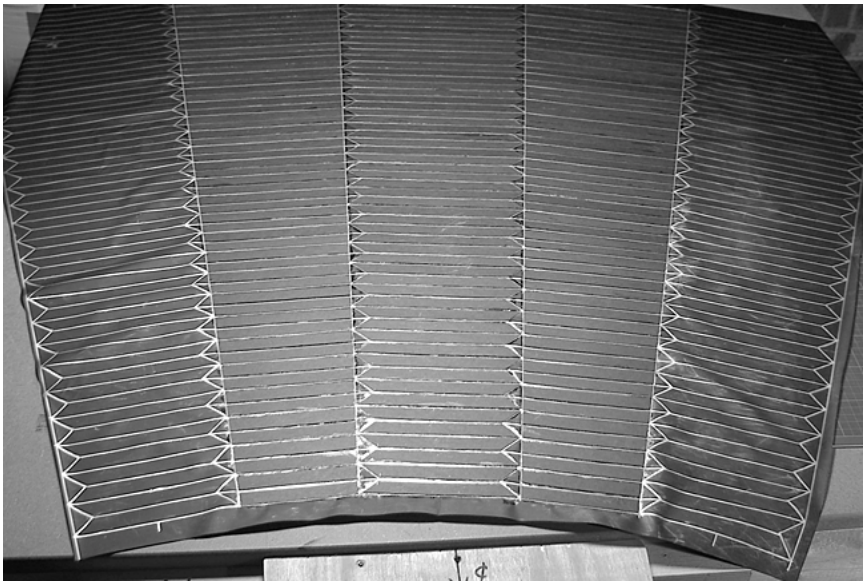


Figure 18

Three sides of the bellows are glued while the bellows is flat on the work table. Next the remaining two Top/Bottom patterns are joined to form the fourth side of the bellows.

Once the three sides of the bellows have the ribs glued, (the top and two sides) then the fourth side is made of the two remaining parts of the Top/Bottom pattern. The two sides are cut to form the two halves of the fourth side. This fourth side has the seam and is the bottom of the bellows. This seam should be cut at an angle to the center line of the side. This allows the bellows to fold more evenly by distributing the extra thickness of the seam across the length of the bellows.

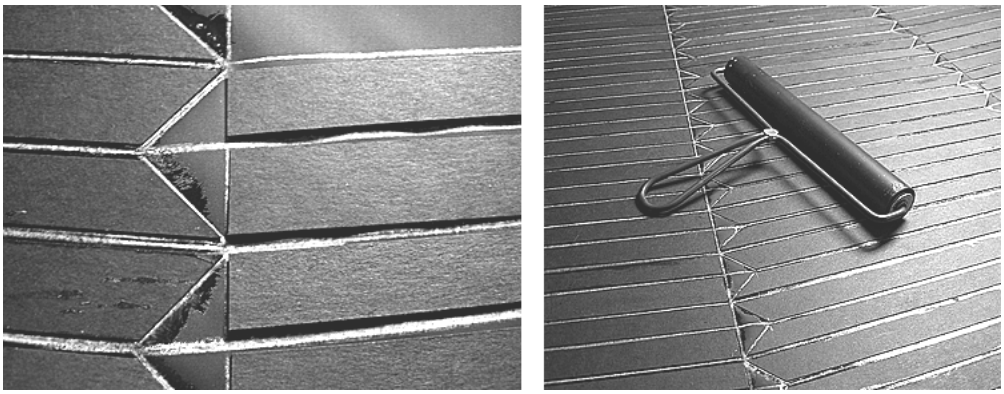


Figure 19

The ribs are glued onto the bellows rubberized side using contact cement. Contact cement forms its bond under pressure. You can use a hard rubber roller to apply pressure once the ribs are glued. Allow the glue to cure for several hours before handling.

To glue the fourth side will require the wooden form to hold the two halves in perfect alignment. The form must not sag during gluing or the bellows fourth side will not line up correctly. It is a good idea to attach the form to a sturdy table using a clamp.

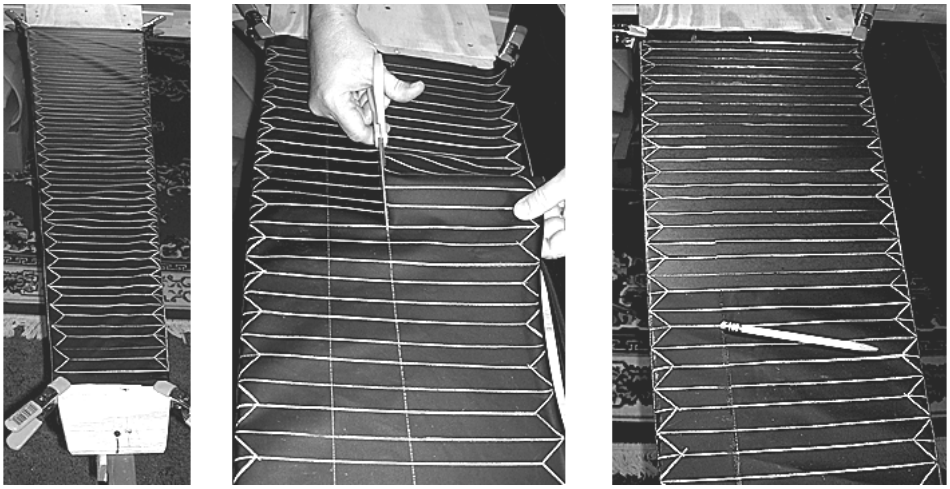


Figure 20

The fourth side of the bellow is comprised of the two halves of the remaining Top/Bottom pattern layout. Each end of the pattern is carefully aligned using the wooden form as a guide.

One side of bellows material is wrapped around the form, rubber side up, and the marked corner line is carefully aligned with the form edge and taped in place. Then the second side is wrapped over the opposite side and the opposite corner is aligned. The marked fold lines are carefully aligned and the fit is checked for accurate mating of the two sides.

Next a diagonal line is drawn along one side and that part of the outer material is trimmed away. This seam is taped to the form with masking tape to hold it in place. This is the seam that will join the two halves of the fourth side of the bellows. This seam needs to run diagonally along the length of the bellows. This allows the bellows to fold more evenly by distributing the extra thickness along its length.

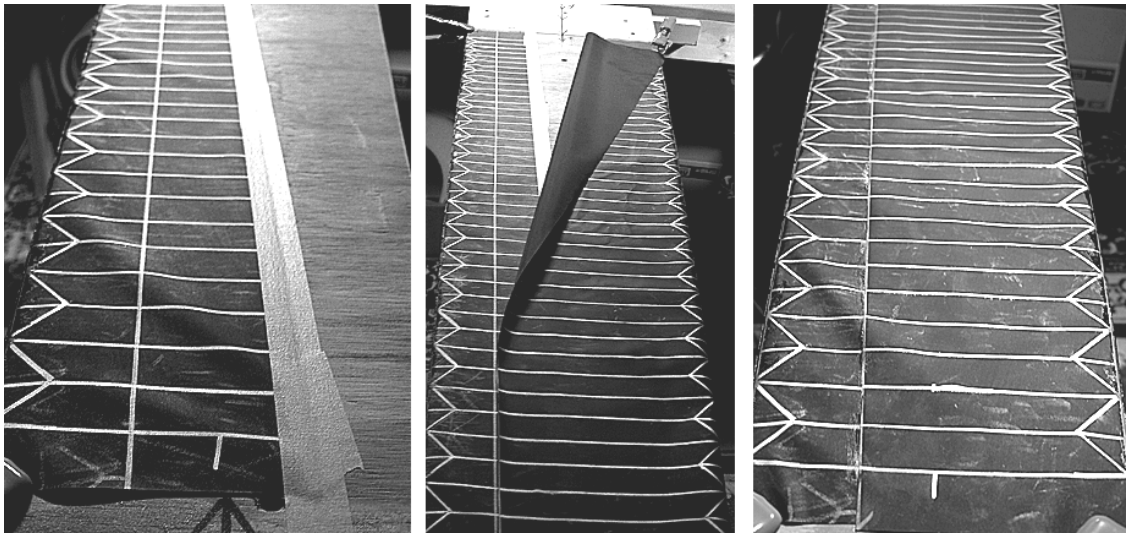


Figure 21

A seam line is marked at an angle along the length of the bellows and an overlapping seam is glued together. This forms the fourth side of the bellows. The seam side will be the bottom of the finished assembly.

Then the second half of the fourth side is carefully marked to allow for a 1.50 inch overlap of the joining seam. On a smaller bellows the overlap may be smaller. Next the second half of the fourth side is carefully cut away.

The seam is glued using the same contact cement used for the ribs. Coat the mating sides of the material and glue a small section of the seam at a time, making sure to carefully align the fold marks one to the other and keeping the corner lines true to the form. This seam is then allowed to dry.

Reset the cutter to the same angle used to cut the ribs for the top. Now glue the bottom ribs just like the top. The bellows now looks like a square megaphone. Leave the finished assembly on the form overnight to dry.

GLUING THE LINER

Next the inner liner is glued over the ribs. The liner cloth is cut to the proper size to cover the entire bellows inner area. The seam should also be angled and opposite the outer seam. Make the seam overlap about 1 inch. Again, this helps the bellows to fold smoothly by keeping the thickness as uniform as possible. The liner is glued using spray contact adhesive.

The bellows surface with the ribs exposed are sprayed with an even coating of glue. The liner material is best taped flat to a suitable piece of 0.250 inch plywood using masking tape. Once the liner is sprayed, it is lowered into place on the coated side of the bellows and the tape and board are removed. Smooth the liner onto the outer and ribs. Then using your fingernail or a suitable smooth object, form the inner lining around each rib. Be sure to form each fold area between each rib. These are the hinges of the bellows and what allows it to fold. Glue each side of the bellows inner liner one at a time.

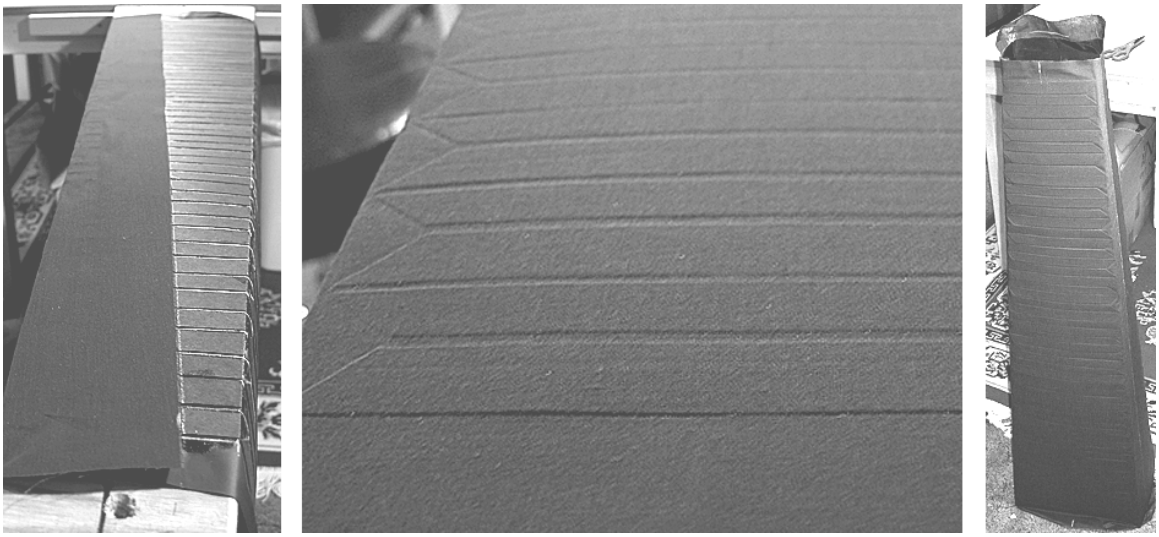


Figure 22

The fabric liner is glued to the ribs and the outer material using spray contact cement. Once the liner is positioned, it is carefully pressed into complete contact with the ribs and worked down into contact with the rubber side of the outer material.

Work around all four sides of the bellows, making an angled seam on the fourth side. On larger bellows, the liner may have to be made from two pieces of cloth, since the recommended broad cloth only comes 36 inches wide. This requires two inner seams. Glue one piece of inner cloth to the bottom section of the bellows and wrap the cloth around the sides. Create an angled seam on both sides. Then glue another piece of cloth to the top and overlap the seams on the sides.

We have found it to be a good idea to iron the inner liner before assembly to remove any wrinkles. Once all of the inner liner is glued onto the outer and the ribs have been worked down well to form the hinges, let the finished assembly dry overnight. Leaving the bellows on the form is a good idea.

TURNING AND FOLDING

Now the entire bellows assembly must be turned inside out. Begin by feeding the narrow end into itself. Work each rib set around the bellows until an entire fold is turned inside. Then move to the next set. Work around the bellows turning it slowly inside out. When completed the bellows will again look like a large square megaphone, except this time the outer will be on the outside.

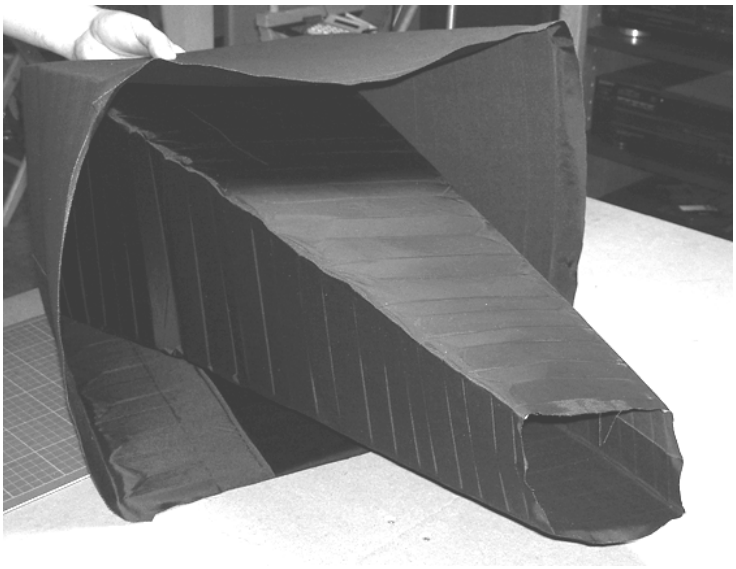


Figure 23

The bellows has been constructed inside out. After the lining has completely dried, it is time to turn the bellows. In this figure the bellows is about three fourths turned.

Next the bellows is folded. Begin with the large end. It should be apparent how the bellows folds. The longer ribs will fold outward making the bellows naturally follow its shape toward the small end. If you fold it in the wrong order it will not work. Take your time and crease each hinge all the way around the bellows. With a large bellows it is good to have a helper to hold while you fold. The assembly should easily fold and want to collapse.

Once the bellows is folded it needs to be trained to stay flat. Either stack books on the flattened bellows or clamp between two pieces of wood. The bellows should be clamped this way for at least 24 hours. This sets the creases so the bellows will fold easily.

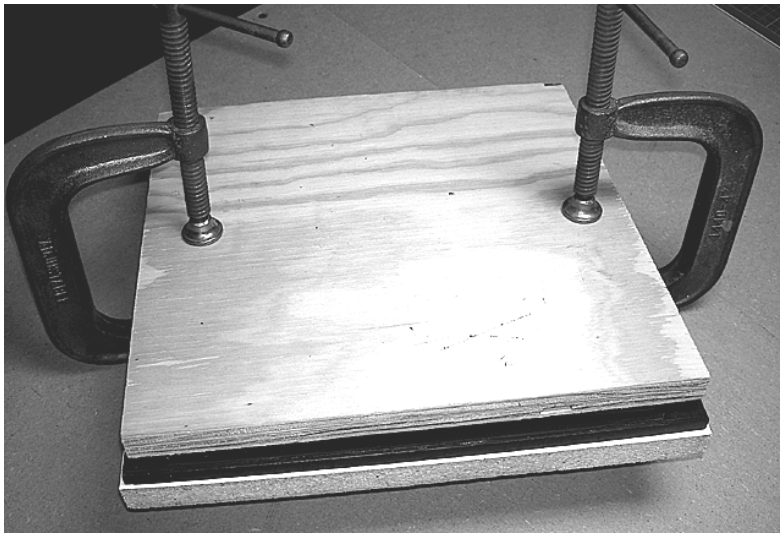


Figure 24

Once the bellows is folded it should be gently clamped to crease the folds. You can also weight the folded bellows down with a stack books.

GLUING THE FRAMES

All that is left to do now is to attach the bellows to their frames and install them on the camera. In this design the bellows glues to the face of the wooden frames. Begin by trimming away any excess material and test fit to be sure the end of the bellows fits properly to the frame.

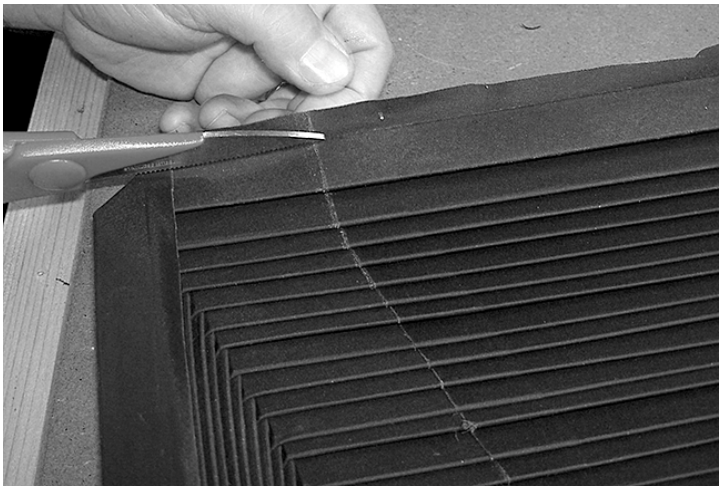


Figure 25

Trim away any extra material along the last rib of the bellows and test fit to the bellows frame.

Carefully test fit the bellows to the frame. When you are satisfied everything is correct, coat the mating surface of the bellows and the frame and glue the front and rear frames in place. You will have to be precise in your placement, once the glue grabs you will probably not be able to remove it, so work slowly and deliberately.

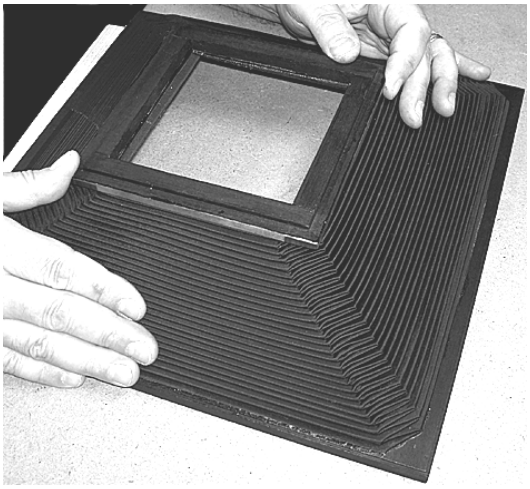


Figure 26

The bellows is complete once the frames are glued. It is a good idea to weight the assembled bellows overnight to allow the glue to cure.

Press the mating surfaces between the bellows and frames firmly together. Remember that contact cement requires pressure to achieve a complete bond. It is a good idea to again weight down the finished assembly with books overnight to be certain the glue has time to completely cure.

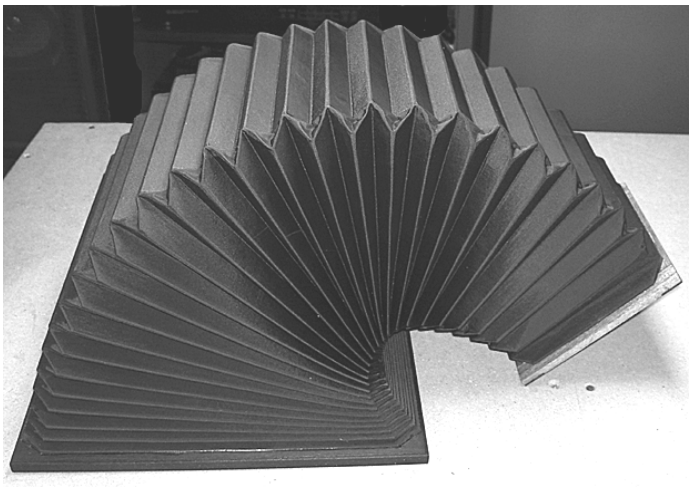


Figure 27

A fully assembled bellows ready to be installed on the camera.

Once the glue has had a chance to completely cure check to be sure the front and rear frames are securely glued into place. Go around the entire edge where the bellows joins the frame and check for any gaps that could leak light. If all looks good, then the bellows is ready to be installed on the camera.

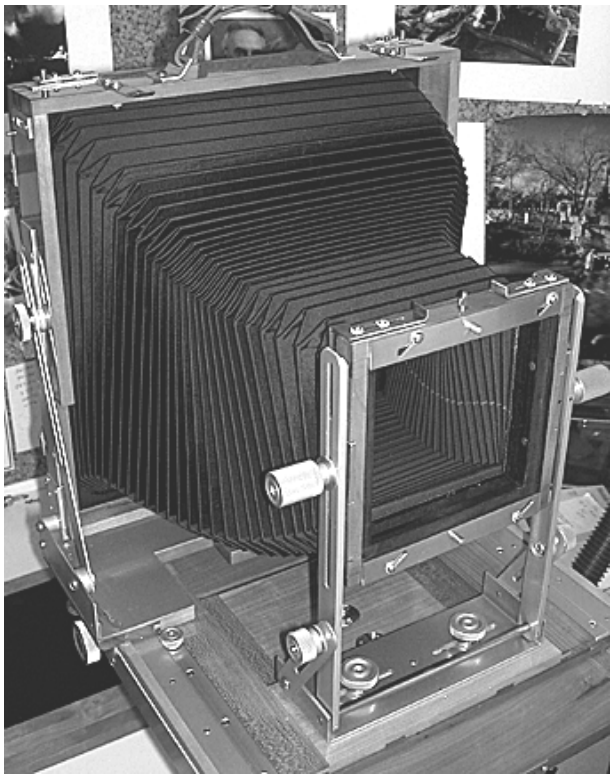


Figure 28

Complete custom bellows installed on my Wisner 8x10. I hated that red and the factory bellows was not long enough to focus my 30" lens.

RING TABS

Ring tabs are glued along the upper side of the bellows and are used to keep the bellows from sagging into the image path. The tabs are made from scraps of bellows material. Glue two piece of material together back to back (rubber facing rubber) to make the raw stock material for the tabs.

The rings are made from either 0.0625 or 0.1250 inch brass rod. Wind the rod around a suitable round form, such as a Phillips screwdriver. Then cut each turn apart and form into a small brass ring. The ID of the ring should be about 0.250 to 0.375 inch.

Patterns can be drawn for different lengths and sizes of ring tabs. The material is cut out, and slid through the brass ring and glued together. Be sure not to glue the entire tab since it will be glued to two sides of an upper fold on the outside of the bellows top.

RING TAB PATTERN

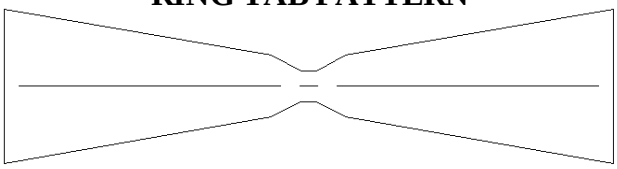


Figure 29

This is the basic shape of a ring tab. Looks like a bowtie. You may need to experiment with the size. Again, make a few from craft paper till you get what you need.

You will have to experiment with the size of the ring tab required for your bellows and camera. As always, make a few craft paper models and experiment before you cut up the real material.

Figure 30

Ring tabs are made from scrap bellows material glued together. Brass rings are made from brass rod.

You will need to determine suitable locations for the ring tabs and attach using contact cement. As always, apply the cement to both surfaces and clamp for at least 12 hours. Depending on the lenses you normally use, the placement of bellows tabs is really a personal choice. Use as many or as few as you require.

Figure 31

Install bellows tabs wherever you feel you need them. Glue to the outer of the bellows using contact cement. Clamp for at least 12 hours.

At this point your bellows project is pretty much finished. All that is left to do is test for function and light leaks and you are ready to go.

LIGHT LEAK TESTER

A handy item to have is a bellows/camera light leak detector. The easiest way to check a bellows, and your camera, for leaks is to put a light inside the camera, darken the room and look. The problem is getting a suitable light source inside the camera. For a view camera a flashlight can be used. What is really needed is a bright light that emits the minimum amount of heat.

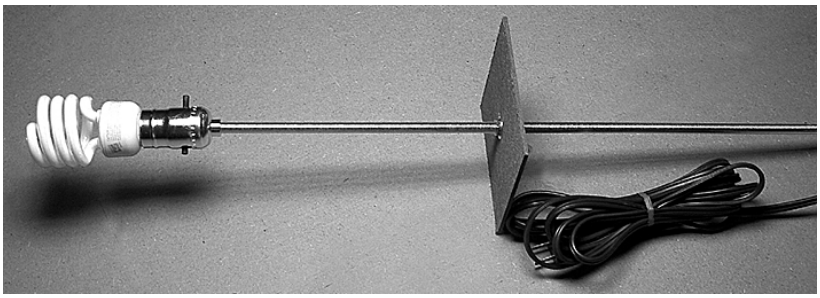


Figure 32

This is my light leak detector. A compact florescent lamp and some lamp hardware and socket are rigged to a lens board.

A compact florescent lamp (CFL) in a lamp socket is a great way to illuminate the inside of the camera. Standard lamp hardware can be used to fabricate a test fixture. Attach a standard lamp socket to a long threaded lamp rod. Run a power cord through the

threaded rod and attach it to the lamp socket. Either use an existing undrilled lens board, or fabricate a suitable lens board from aluminum or Masonite. Drill a hole for the threaded rod in the exact center of the lens board, then mount the rod and socket assembly using standard lamp hardware.

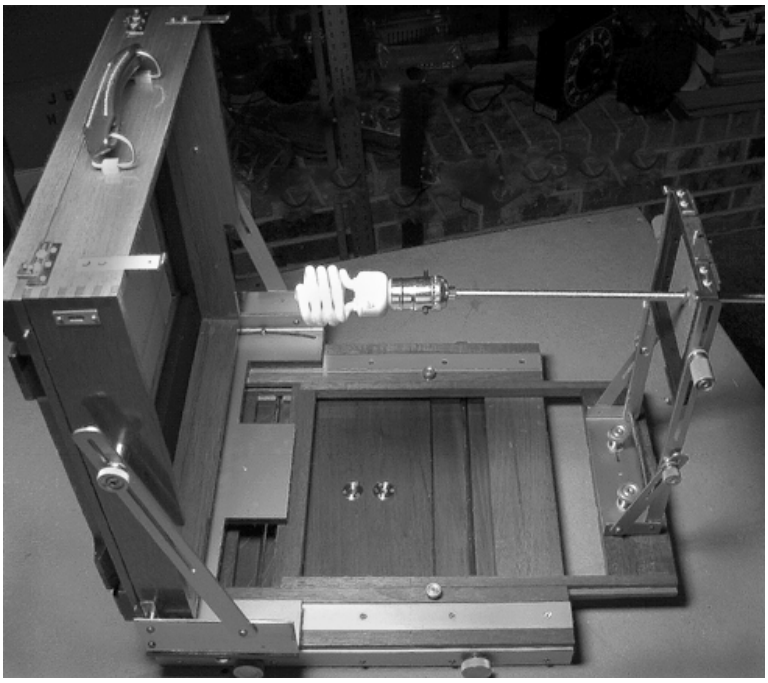


Figure 33

Here is the light leak tester mounted in position to test an 11x14 camera. The bellows has been removed to show how the lamp is adjusted for testing for light leaks.

Adjust the threaded rod so the lamp is in the middle of the camera with the bellows racked near maximum. Place a film holder in the back of the camera, turn out the lights and plug in the lamp. You can check for leaks all around the bellows frames, the folds and even the film holder.

Note that even a CFL generates some amount of heat, but not near what an incandescent lamp of similar wattage would. I would not recommend that you leave the CFL on inside your camera for an extended amount of time. I would say 10-15 minutes maximum. That should be more than enough time to check for any light leaks.

A FEW THOUGHTS

Acetone can be used to clean up excess contact cement on the bellows. This works well on the nylon outer. Be sure to test on a scrap piece of material to be sure the fabric will not be damaged by the acetone. Do not use acetone on the rubberized side of the

material. To clean up excess glue on the bellows outer material, dampen a cloth with a little acetone and rub gently.

Contact cement achieves its bond from coating both mating surfaces. Be sure to work the cement into the surface of the material with a brush. It also requires the bonding surfaces be joined by force. Pressure is used to achieve a good bond. This bond strengthens with time as the glue cures. It is a good idea to let contact cement cure for at least 24 hours for a good solid bond.

Contact cement thickens in the open container due to the evaporation of the carrier chemicals. This is the smell. If the cement begins to string excessively as the brush is loaded, the cement needs to be thinned. Use the manufacturer's recommended thinner and keep the consistency of the glue fairly thin for good penetration and bond. Consult the directions on the glue can or the manufacturer's web site for more detailed information on the use of contact cement.

It is important you have a clean flat work surface to build a bellows upon. We constructed a four foot square table just for this project. With some of the larger bellows we built, we could have used a larger table.

Suitable bellows material is hard to find. What you want is a dimensionally stable, light-tight material that is coated on one side with rubber. I have been told that Porter's Camera Store carries a blackout material that is suitable. We have not seen nor used this material. You can check them on the web at *porters.com*.

To see more about our camera building projects and other items of interest. . . remember both myself and my wife are ULF photographers. . . camera building is not our prime interest. . . please visit our web site. These building projects are more of necessity than a need to spend time building. There are just some things that you have to do yourself to get the results you expect.

MY DISCLAIMER

This little tutorial by no means represents the only way to build a bellows. This is just my method. I have presented this to you FREE of charge and as an older gentleman I use to work with would say, "Free advice is worth every penny you pay for it." I hope you find this helpful, somewhat accurate and worth more than nothing.

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