Graphical Layout of Double Taper and Variable Fold-Depth Bellows

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Foreword

The following slides show a simple graphical method for determining the location of folds for camera bellows. The method should be generic enough to allow almost any straight or tapered bellows configuration to be designed.

The bellows may taper from front to back on the top/bottom and left/right, requiring a stagger in the fold depth on all sides in order to allow the bellows to fold flat.

The method also allows for the fold depth itself to be variable along the length of the bellows in order to allow the bellows mounting frames on the front and rear camera standards to have a different frame size.

I hope these slides prove helpful for anyone attempting to design either replacement bellows for an old camera, or for designing new installations.

I have based the instructions around the design of an example set of bellows for a small view camera that takes 6cm x 9cm negatives.

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Laying Out Panels

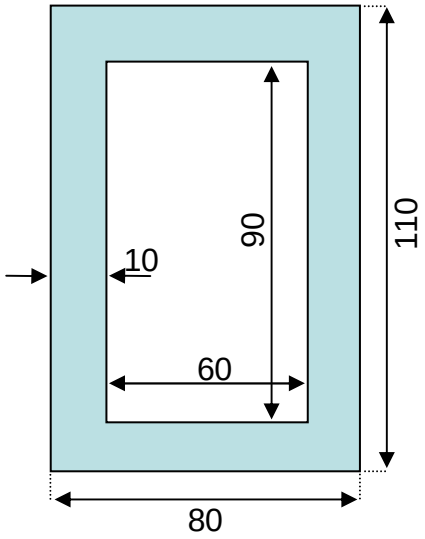
• Rear standard frame is 110mm x 80mm outer dimensions and 90mm x 60 mm inner dimensions

•Therefore use 10mm fold depth on bellows for mounting

• Top width of wide panel needs to be 110-10= 100mm

• Top width of narrow panel needs to be 80-10 = 70mm.

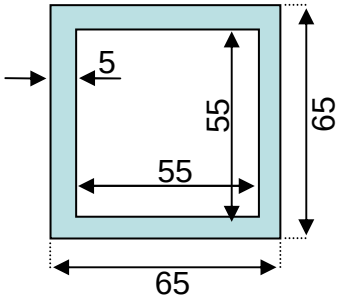
• When bellows folded, will have correct inner and outer dimensions.

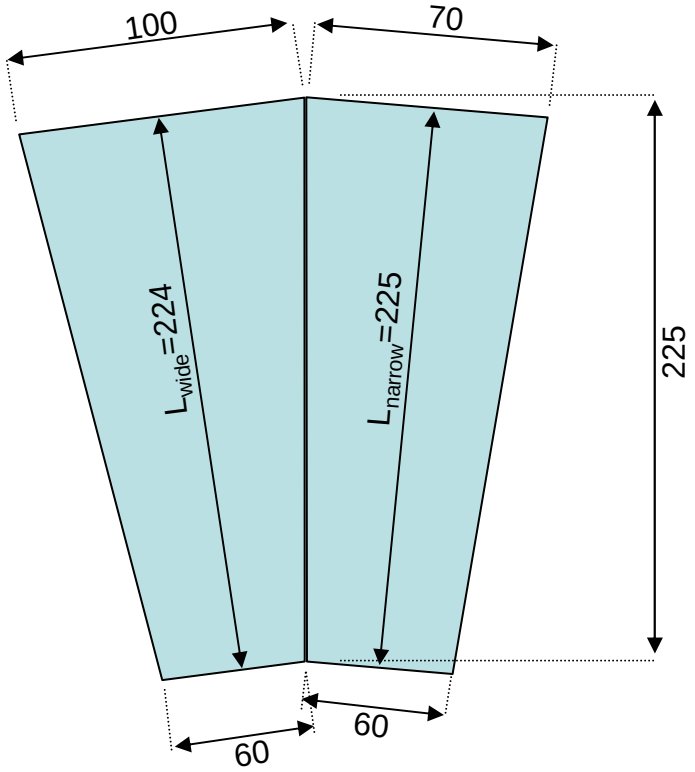


• Front standard frame is 65mm square on the outside and has a 55mm square aperture. The frame width is 5mm.

• Bellows folds need to taper down to 5mm deep.

• Panel base width needs to be 65-5=60mm for all panels.





• The maximum working bellows extension is to be 150mm.

• Make panel material longer to prevent overstretching

• Make ***joined side*** 150x3/2 = 225mm long

• Need to draw out panels carefully: paper template good solution. Top-to-Base length of each panel is:

$$L_{wide} = \sqrt{S^2 - \left(\frac{T_{wide} - B_{wide}}{2}\right)^2} = \sqrt{225^2 - \left(\frac{100-60}{2}\right)^2} = 224mm$$

$$L_{narrow} = \sqrt{S^2 - \left(\frac{T_{narrow} - B_{narrow}}{2}\right)^2} = \sqrt{225^2 - \left(\frac{70-60}{2}\right)^2} = 225mm$$

Adding Tramline Markings

• The width of the folds is determined by a set of ‘Tramlines’ that are drawn symmetrically about the joined side between two panels.

• **The panels have been laid out with the widest panel on the left, and the narrowest on the right (important for the subsequent steps)**

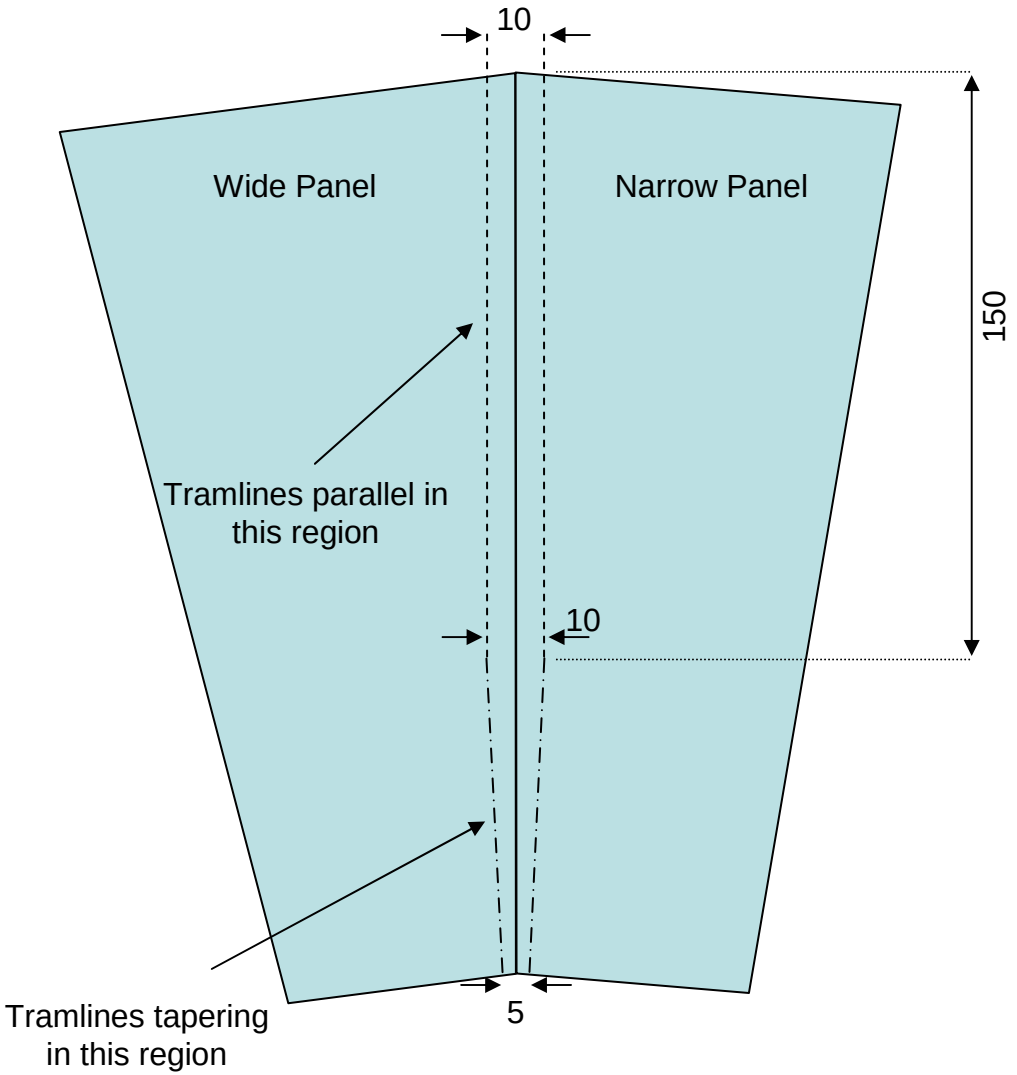
• At the top of the panels, the tramlines are 5mm each side of the join line, giving a total tramline and therefore fold depth of 10mm

• The tramlines have been drawn as parallel for 150mm down from the top to give a constant 10mm fold depth.

• Below 150mm from the top, the tramlines have been drawn tapering down to 2.5mm each side of the join line, giving a total tramline separation of 5mm at the bottom.

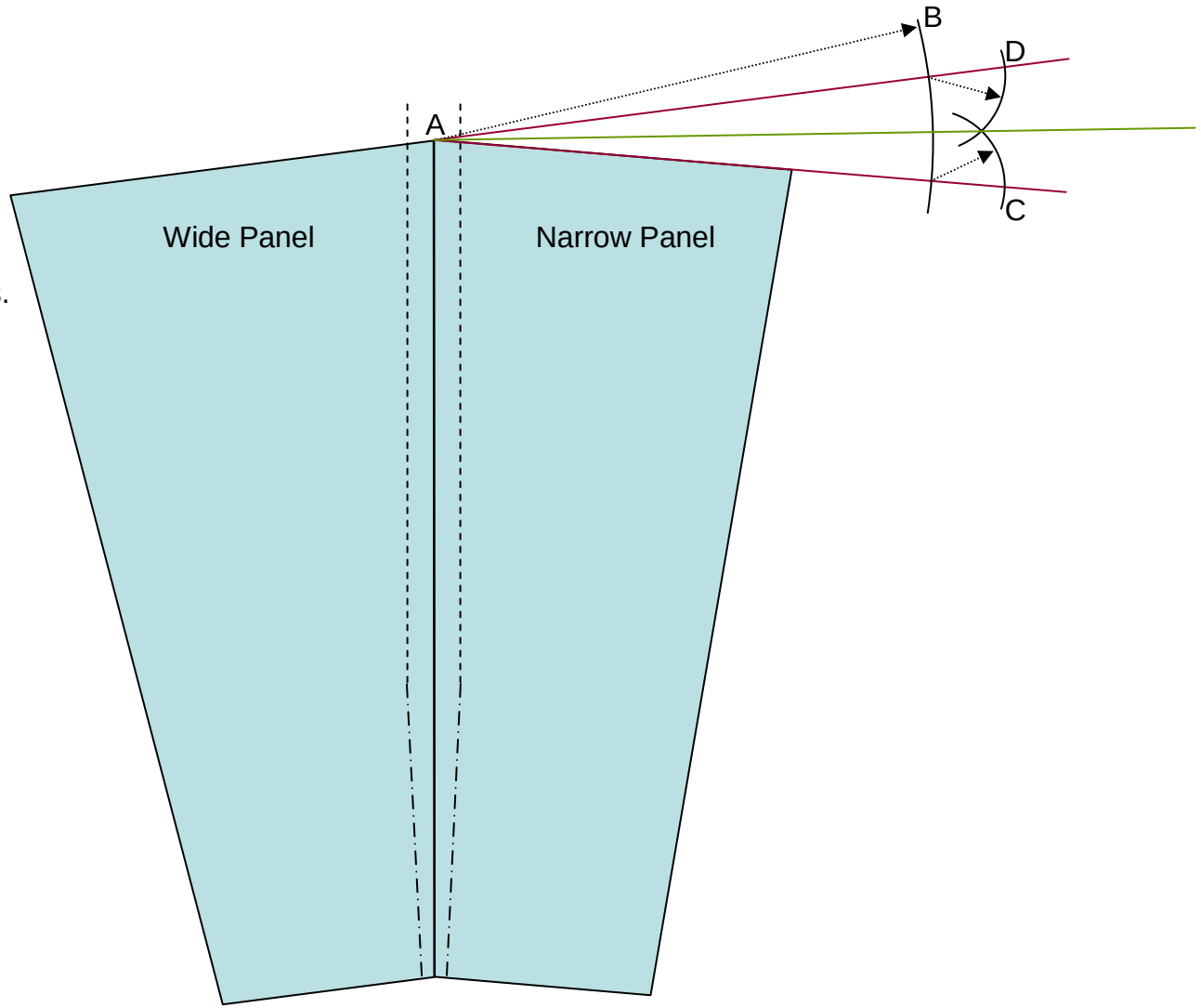
• The 5mm separation will result in a final fold depth of 5mm.

• As long as the tramlines are drawn symmetrically, they can expand out or taper in as required to control the fold depth along the length of the bellows.

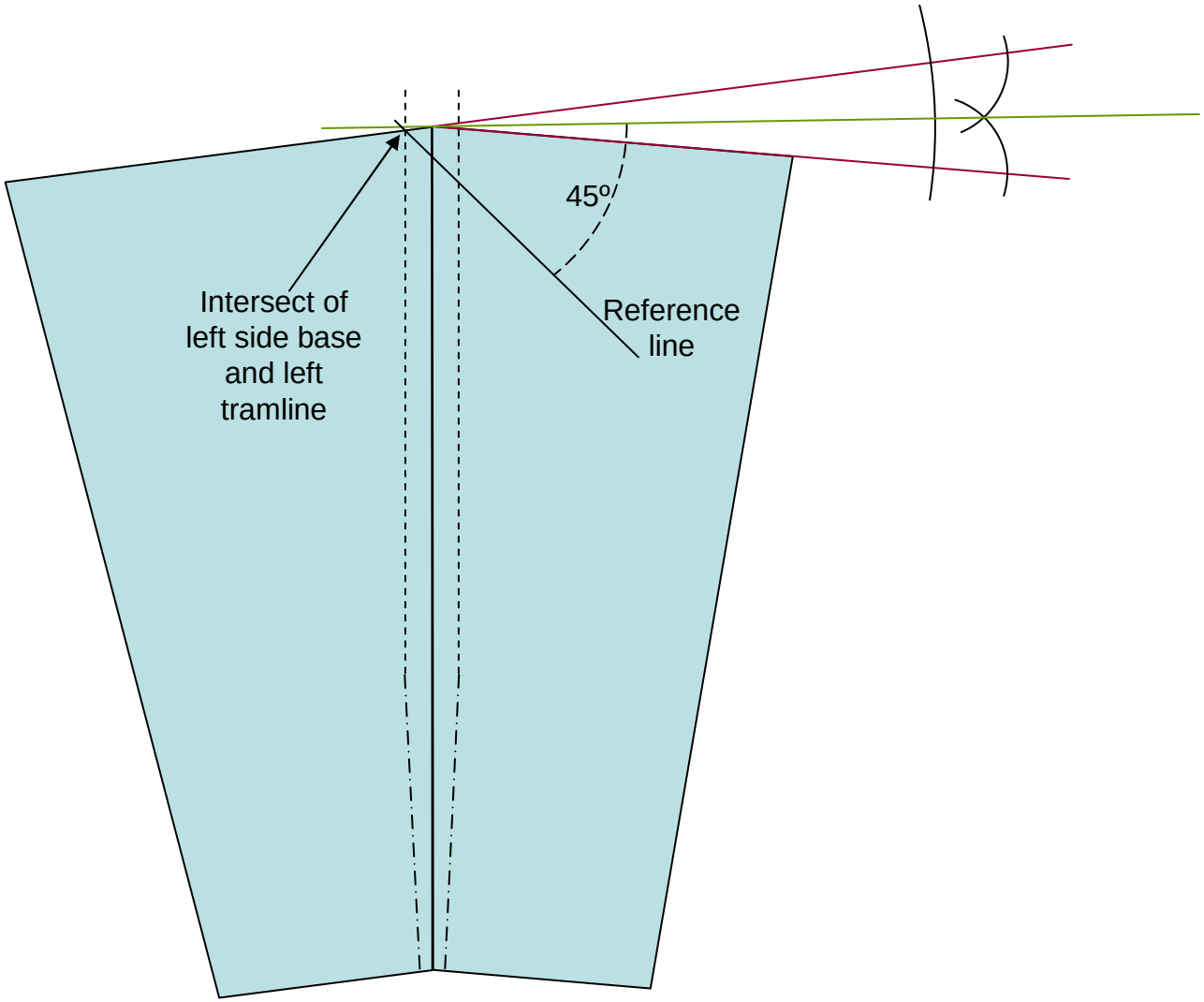


Calculating Angle Bisector Line

- The two top-side edges are extended out to the right as shown by the red lines.
- Point **A** marks where the joined edge meets the two panel top edges.
- A pair of compasses are stretched out to a long length, and with the spike placed at point **A**, draw an arc **B** that cuts the two red lines. The distance from point **A** to arc **B** is not critical, but the further it is, the more accurately the position of the bisector line can be drawn.
- With the compasses set to a much smaller distance, place the point in turn where arc **B** cuts each of the red lines and draw arcs **C** and **D**.
- Draw the angle bisector line (shown in green) between the intersection of arcs **C** & **D** and the point **A**.



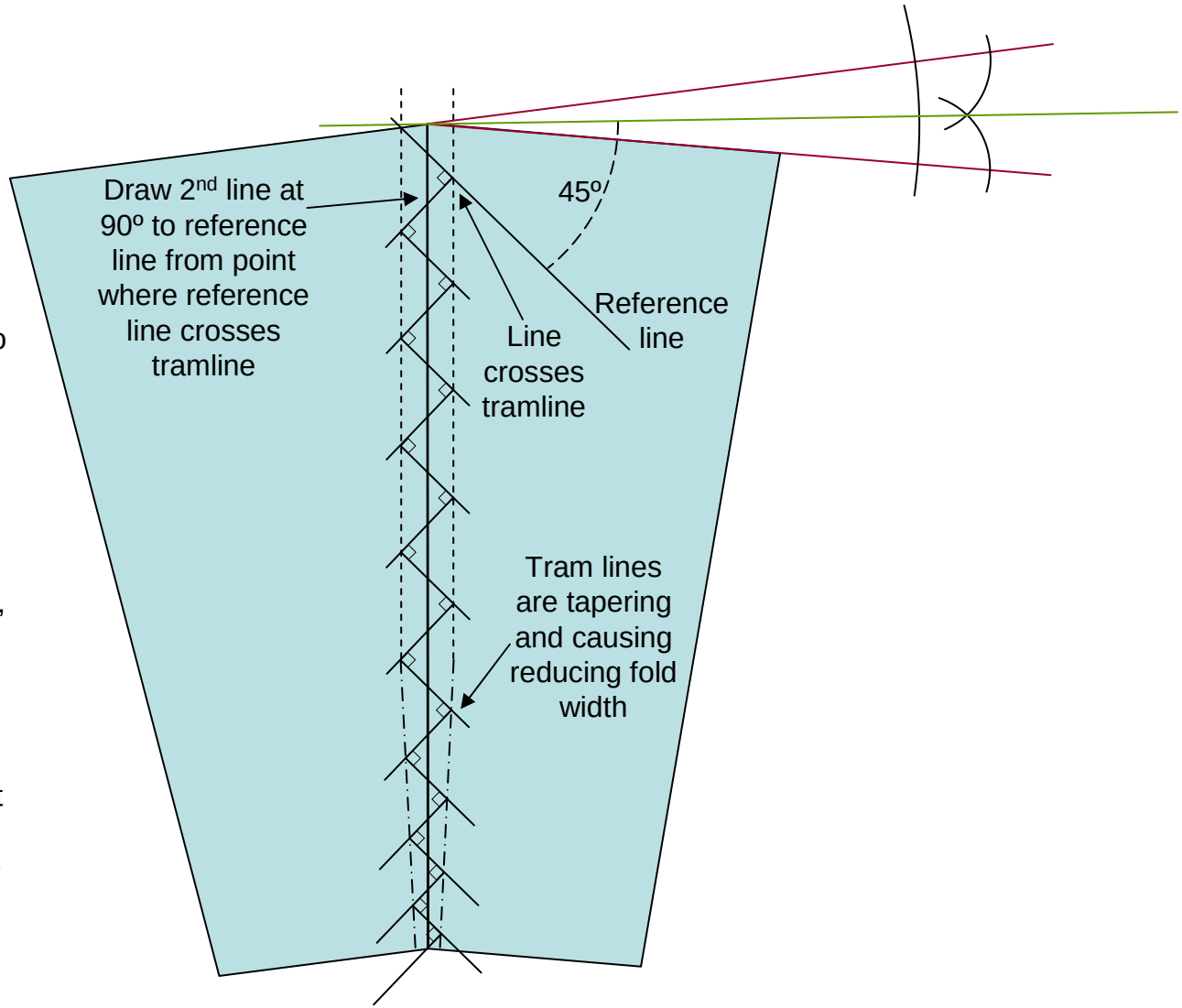
Calculating Zig-Zag Reference Line



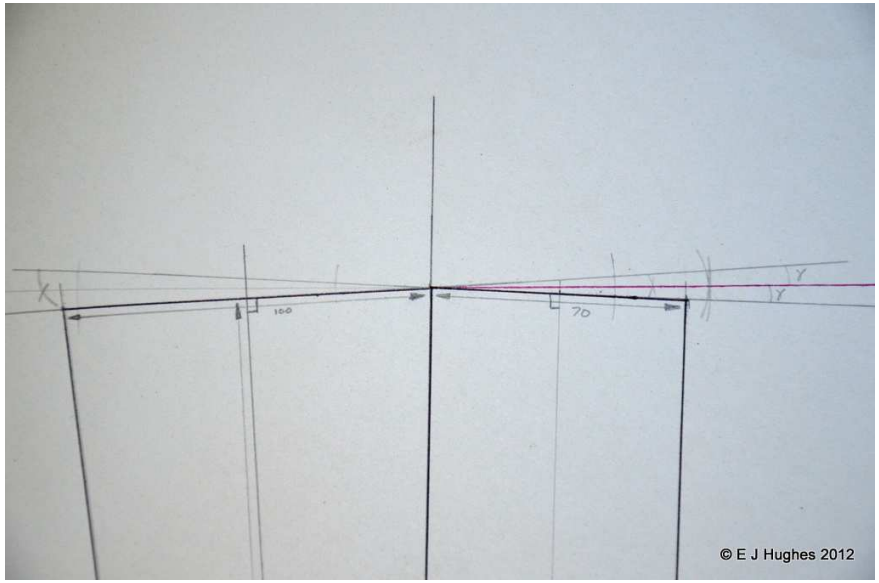
- The angle bisector line (in green) is extended to the left so that it passes beyond the left tramline. This extension helps with aligning a set square for drawing the zig-zag reference line.
- From the intersection of the left-hand side base and the left tramline, draw the Zig-Zag reference line at **an angle of 45 degrees to the green bisector line**.
- The reference line is critical in forming the fold positions and the more accurately it can be marked, the easier it will be to fold the bellows.

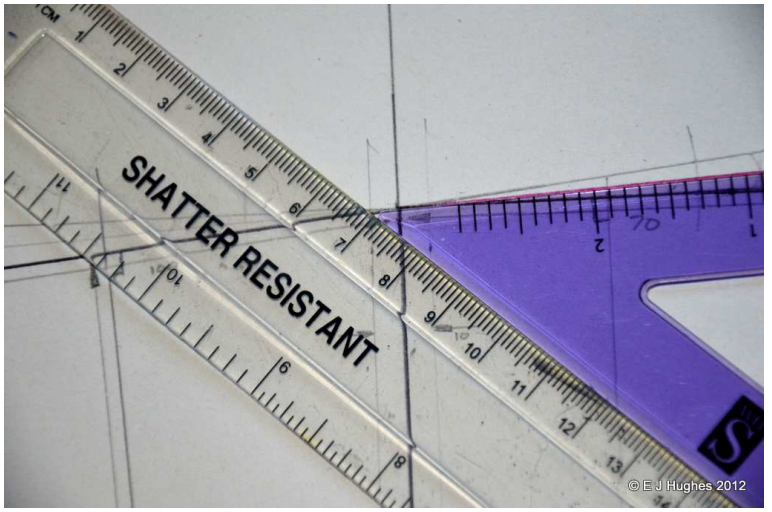
Drawing in the Zig-Zag

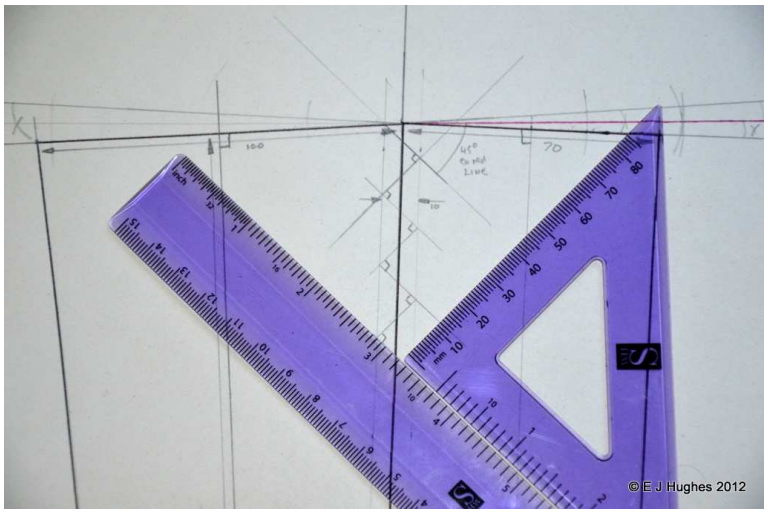
- The Zig-Zag is the critical element of the bellows design that allows all the fold positions to be marked.
- The reference line forms the first line of the zig-zag.
- The second line is drawn at 90 degrees to the reference line from the point where the reference line crosses the right-hand tramline.
- The third line is drawn at 90 degrees to the second line and starts where the second line crosses the left-hand tramline.
- The process continues along the joined edge, taking care to make sure that all the lines that should be parallel to the reference line, are indeed parallel, and all those that should be 90 degrees to the reference line, are truly at 90 degrees.
- The points where each zig-zag line cross the tramlines are used as the start of the next part of the zig-zag; the taper of the tramlines will cause the zig-zag to change its pitch as can be seen by the zig-zag getting more compact towards the bottom of the panels.



Marking Out in Practice

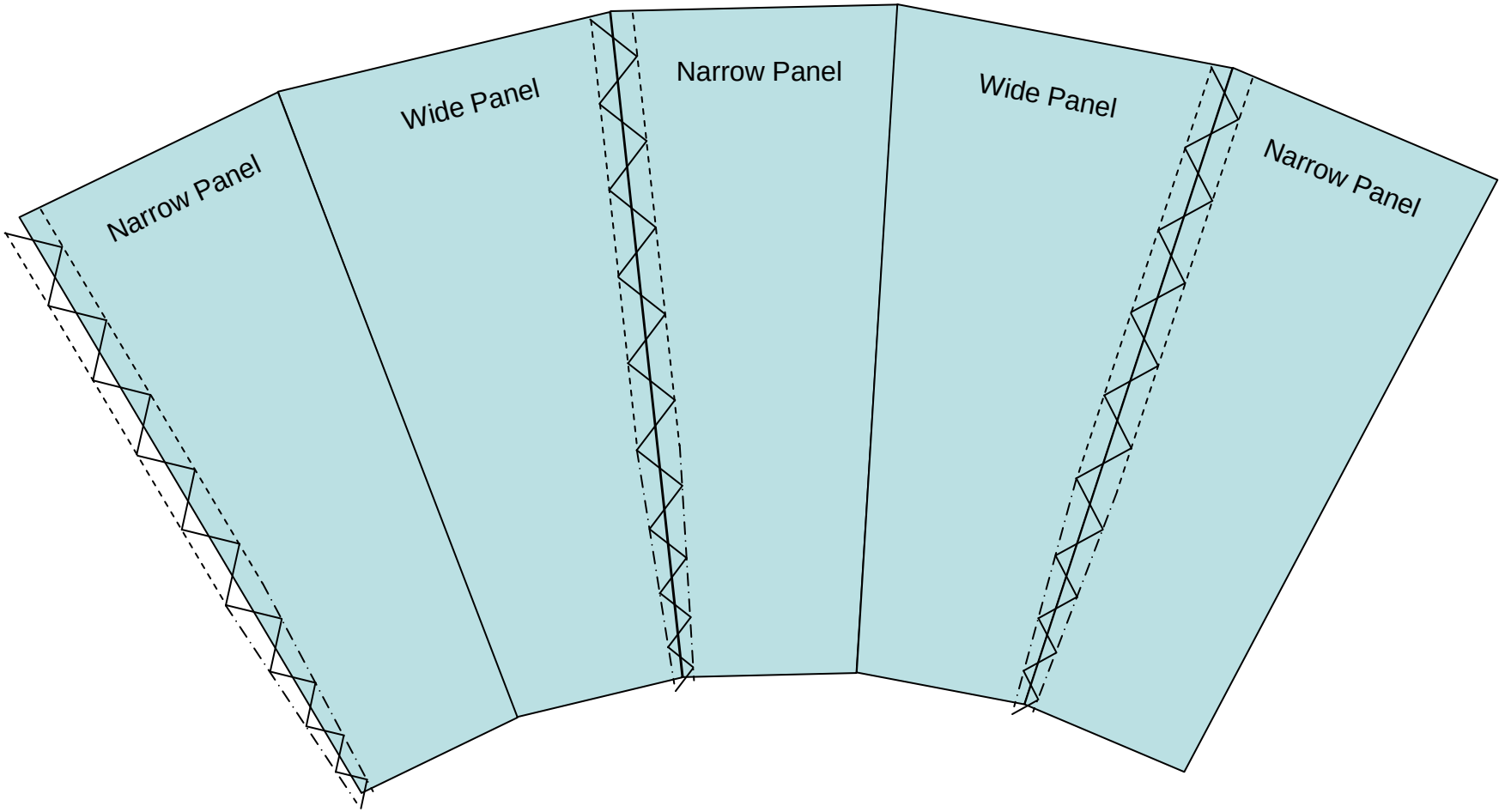






- A large sheet of paper has been used to make a prototype of the bellows
- The angles have been drawn out using ruler and compasses
- When marking the 45º and 90º angles, it is best to place the set square against a ruler so that the set square can be slid back-and-fore along the ruler.
- The set square can then be aligned to the reference line, and then slid along the ruler to the position where the next line of the zig-zag is to be drawn.
- Thus all the lines on the zig-zag can easily be made to be parallel to their corresponding reference lines.

Marking Zig-Zag on Panels

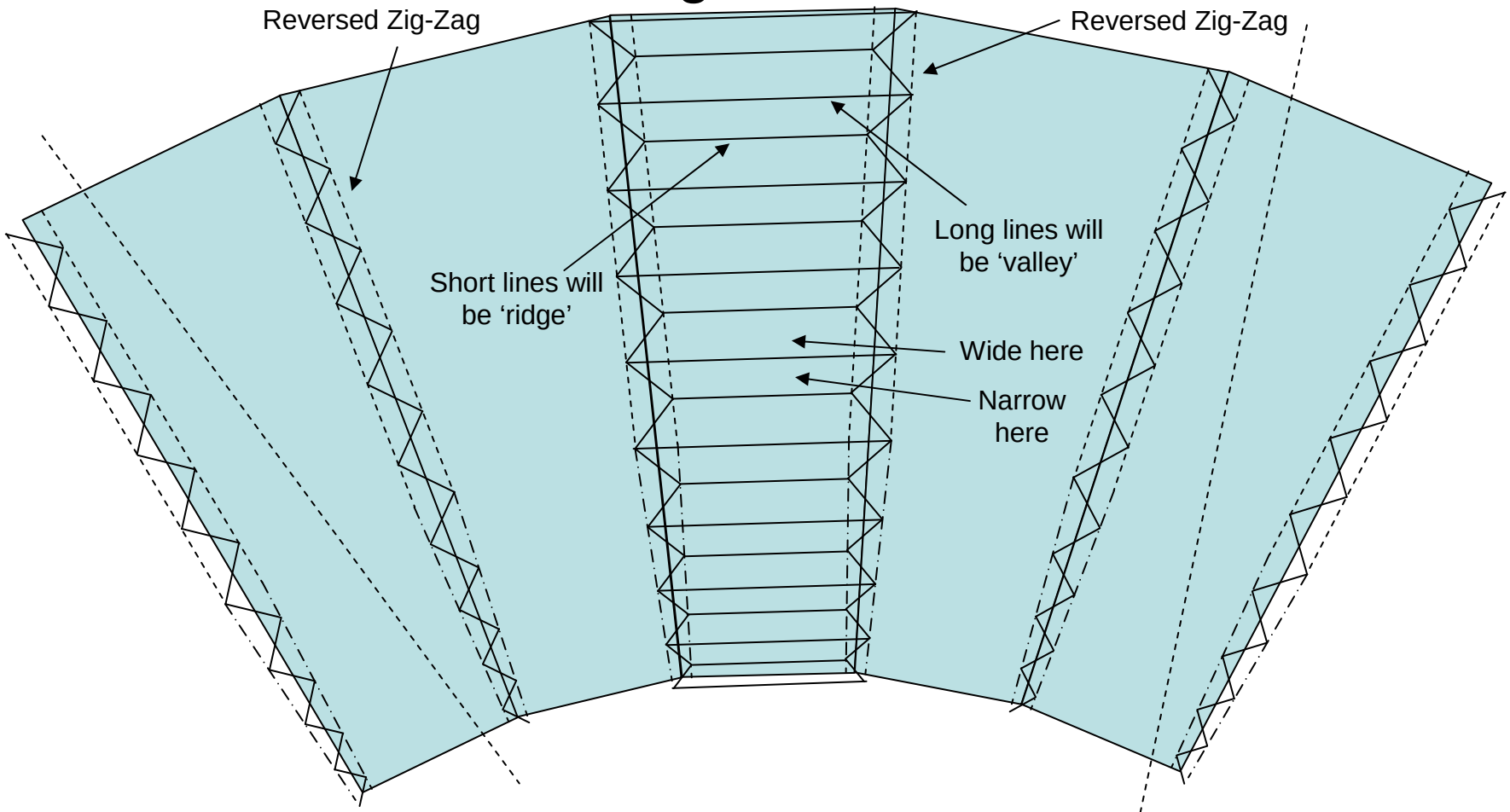


• The paper templates that were made for the two panel sizes are now used to mark out the full unfolded shape of the bellows. An extra panel is drawn on one side to allow the bellows sides to be joined. Pick a panel that will be on the underside of the installed bellows so that the join cannot be seen easily.

• The zig-zag line is copied to each panel joint which has a wide panel on the left and narrow on the right.

• **NOTE**: the zig-zag was drawn with the wider panel on the left and the narrower on the right; make sure the zig-zag pattern is copied over in the same orientation and not reversed! If the zig-zag is reversed, the bellows will not fold properly.

Drawing Fold Lines



• The zig-zag is now **reversed horizontally** and copied to the remaining joined edges (narrow left, wide right)

• The points of the zig-zags on opposite sizes of each panel may now be joined by parallel lines. The last fold at the bottom may not have been marked as a full fold as the length of the panel was only approximate. Extend the lines past the bottom of the panels and draw in this final fold.

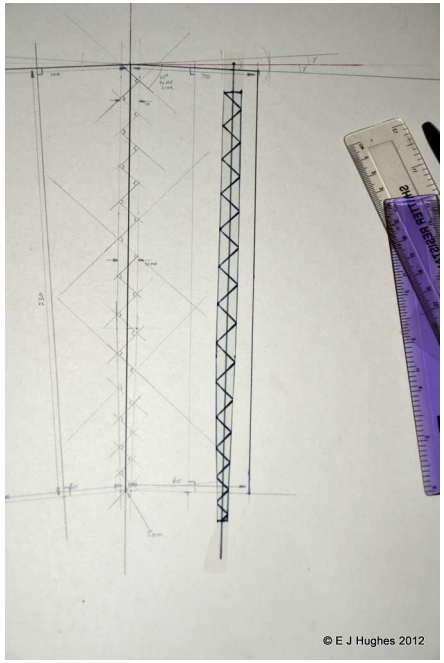
• When folding, the long lines will form the valleys in the bellows, while the short lines will form the ridges.

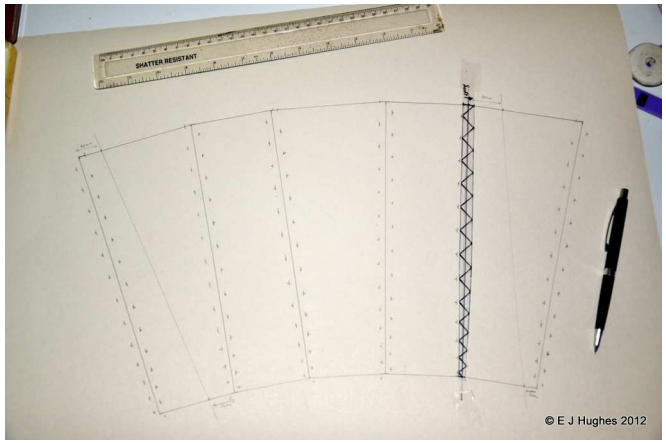
• When tapered bellows are being made, the material width on each side of the fold will be different. If the tramlines are made to taper, even on straight bellows, there may be folds where the material width is different on each side of the fold.

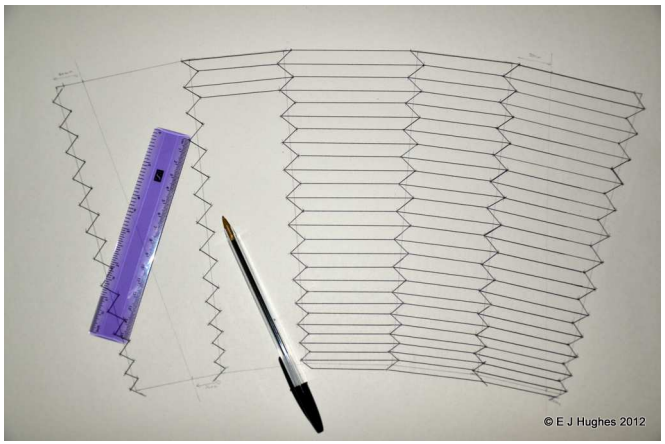
• The dashed diagonal lines on the two end panels are used to mark where the bellows will be joined (see later)

Marking Out in Practice

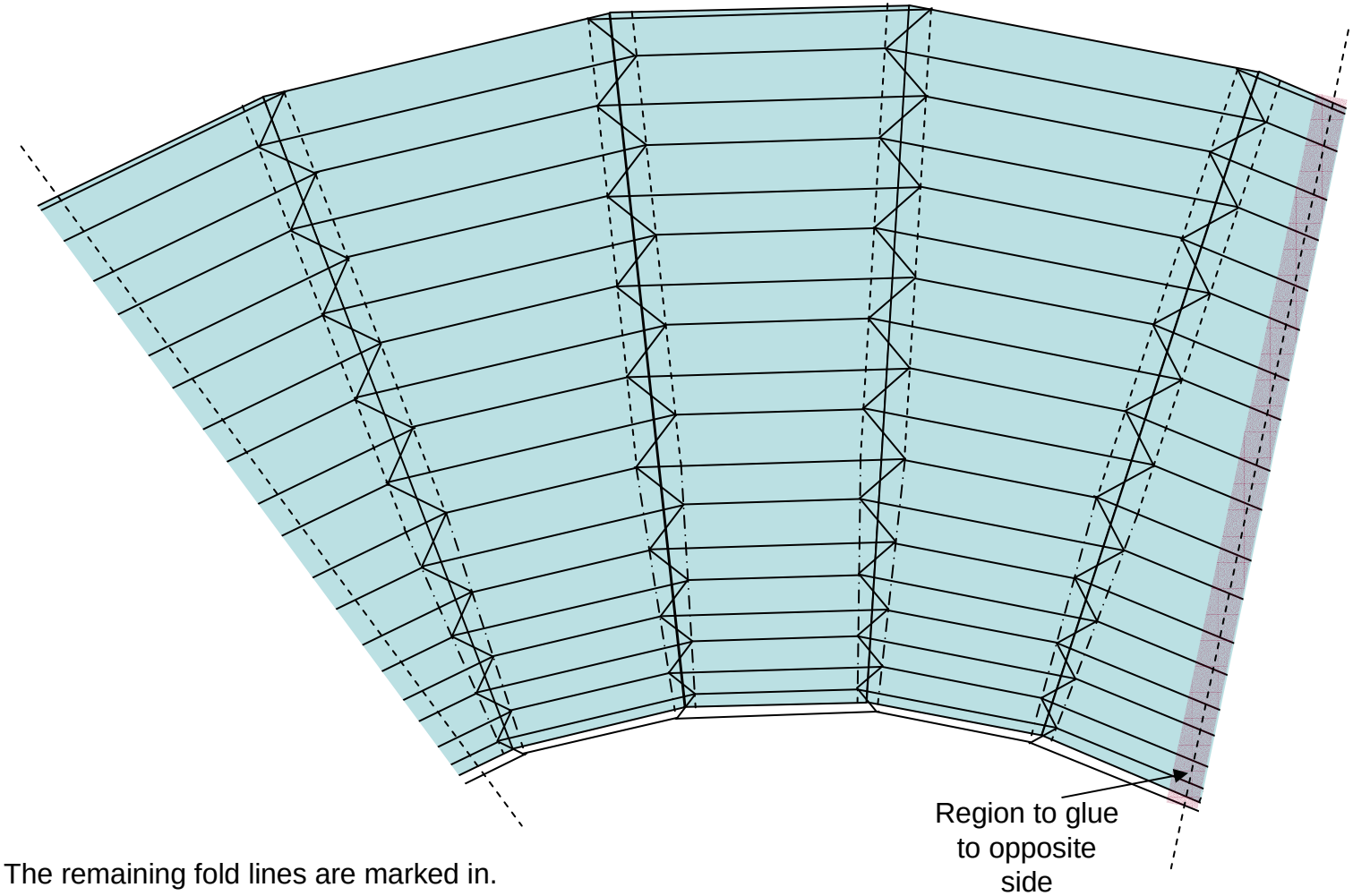
- To allow the zig-zag to be transferred to the full set of panels, it is traced onto a sheet of acetate or tracing paper.
- The acetate is cut carefully along the tramlines so that marks can be made easily corresponding to the points on the zig-zag when transferring the shape.
- The acetate means that it can be flipped over for marking both sides of each panel.
- The paper templates for each of the panels are taped together and then used to mark out the full sequence of panels on a large sheet of paper
- The zig-zags can then be transcribed onto the panels.
- The points of the zig-zags are then joined to form the fold lines
- For a paper prototype, a ball-point pen is used to draw the lines as it helps to score the fold lines, making folding easier.





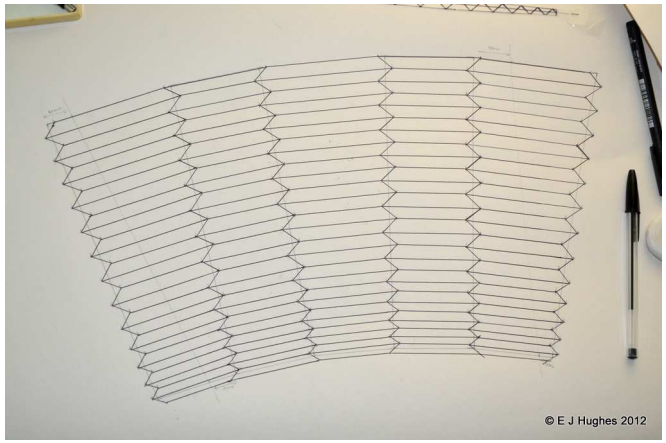


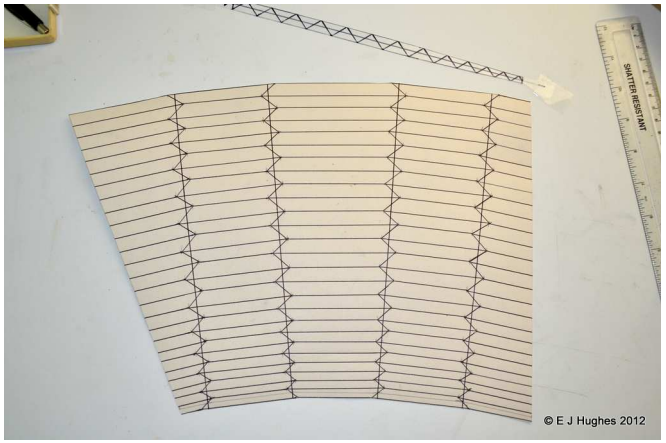
Drawing Fold and Glue Lines

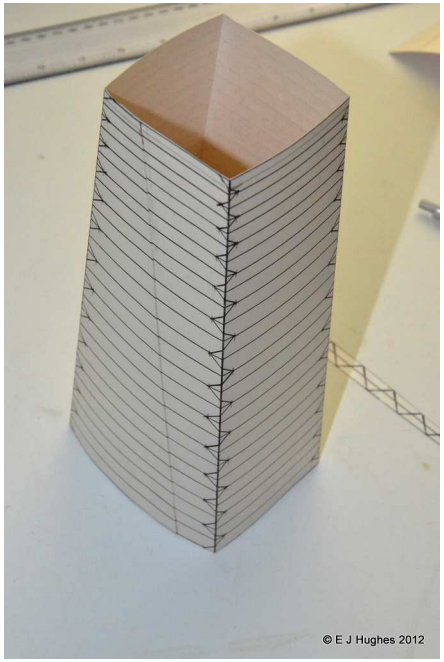


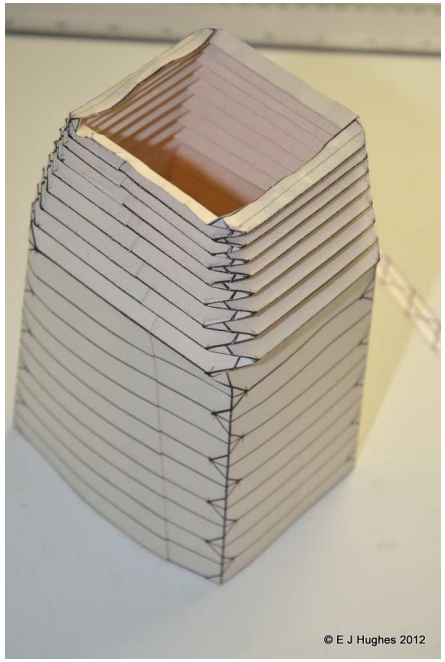
- The remaining fold lines are marked in.
- On the two outer marked panels, a diagonal line is drawn in an equivalent position in each panel (dashed lines)
- The diagonal line is extended either side to form a diagonal strip. This strip will be the glue line.
- The bellows material and stiffener patterns are then cut to allow for a glue overlap.
- The diagonal cut helps prevent the build-up of material layers when the bellows fold.

Joining and Folding Bellows



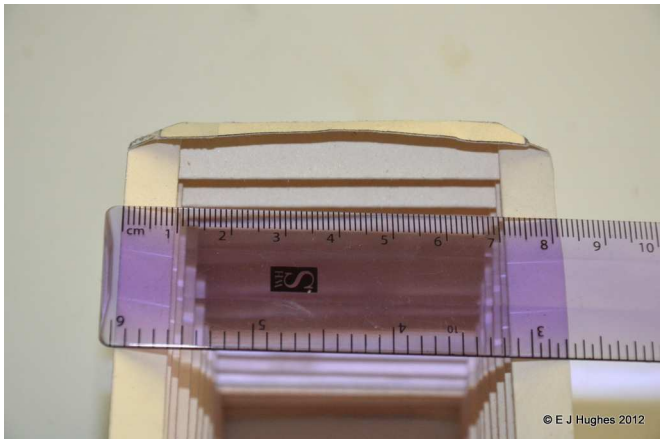


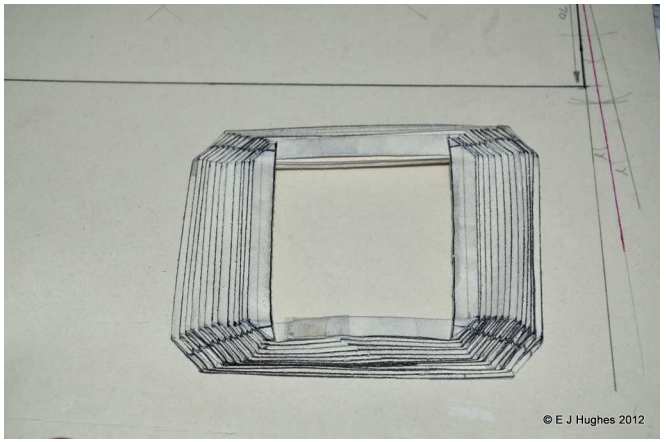


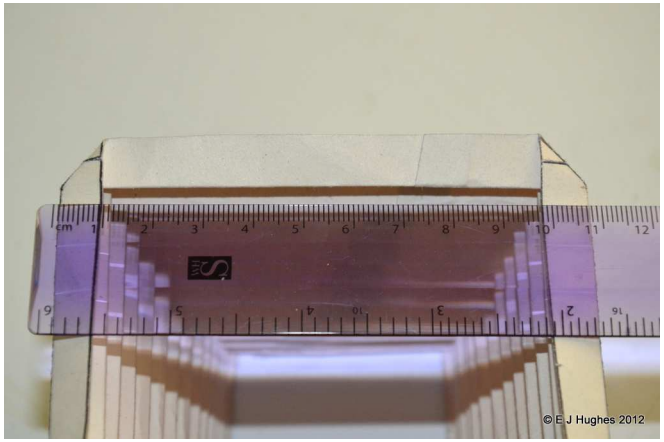


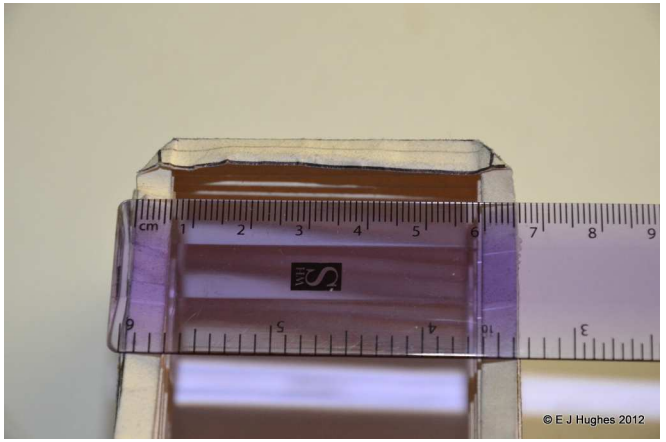
Checking Final Bellows Size

- The paper prototype is then squashed under books for a while in order to help the bellows flatten.
- The width of the folds can then be checked and also the apertures in the bellows at either ends and also the outer width.
- The pictures show that the fold depth is indeed the designed 10mm at the wide end of the bellows and 5mm at the narrower end.
- The upper right picture shows the bellows held flat under a sheet of glass to demonstrate that they do fold up properly.
- Once you are happy with the structure, the zig-zag on acetate and paper panel templates can be re-used for marking out the shapes of the bellows stiffeners.









Good Luck!

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