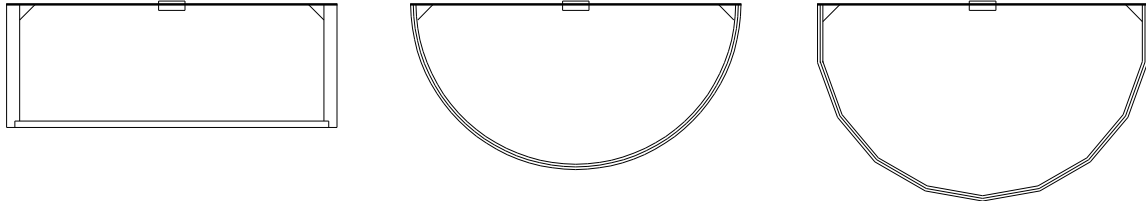


Chapter Three

Making the Sound Box Shell

Most harps use one of three types of sound boxes, or shells.

Cross Section of a square back, round back and stave back harp shell



In this chapter I will lay out the methods that I use to build each of these shell types.

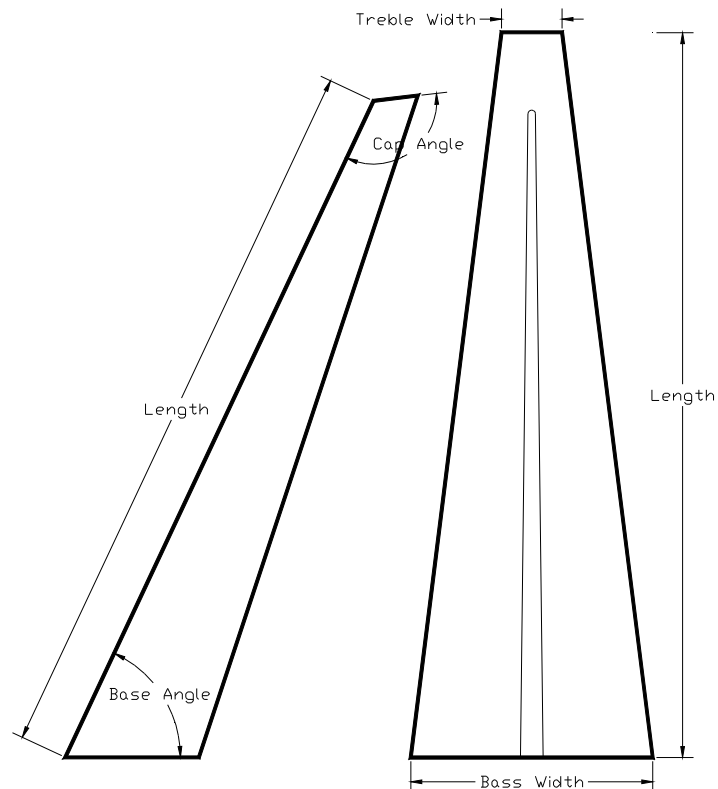
When I design a new harp, the size of the shell is dictated by the string band and string angle. Before I start to build, I will have decided on a few critical dimensions;

- length of Soundboard
- width of the Soundboard at the bass and treble ends
- angle of the cap (top) of the sound box relative to the soundboard
- angle the bottom of the sound box (the base) relative to the soundboard

Critical dimensions of the sound box- Length, Widths, and angles of the cap and base.

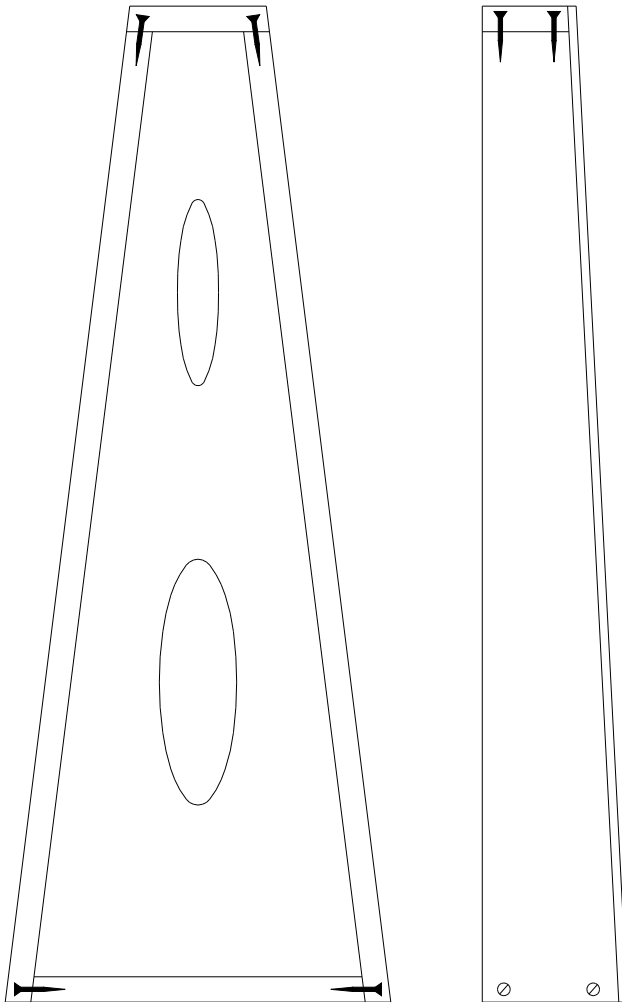
These dimensions are common to a round back, stave back or square back shell.

I think of the sound box as a foundation for the sound board. Like the foundation for a building, the part underneath has to be the right size, and it needs to be strong enough to take the load the strings impose on the neck, pillar and sound board.



Building a Square back

The Square back is probably easiest type for a beginner to build, and some argue that it makes for the best sounding harp. It can be as simple as four boards screwed together into a long trapezoidal frame and a plywood back tacked or glued into place. A square back is certainly easier to clamp when you want to cut sound holes, attach the sound board, or add an edge treatment for the soundboard.

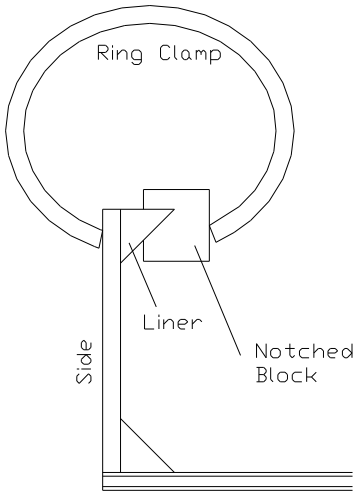


Really simple square back construction. The cap and base angle are 90°. Because the box is trapezoidal, the end of each board has to be cut cross cut at the appropriate bevel (about 7° in this case). The sides are cut from “one by” stock (3/4 thick) The sides are tapered from 4” wide at the base to 2.5 at the top. The boards are attached with a pair of counter sunk screws at each corner. The back is made from a piece of 1/4” plywood with two oval sound holes cut into it. This is actually easier than building a dog house.

I have tried book matching two planks of solid wood for the back (resawn to 1/4 thickness). They invariably crack near the center seam on the bass end. 12” seems too wide given the normal changes in humidity.

Planning for stresses

The string tension will make the neck push down on the top of the box with about 40% of the overall tension. The foot of the pillar will be pushing down with the other 60%. On all but the most lightly strung harps, I like to make a cap that bridges across the sides so the joint is in compression. If the design has a pillar that pushes down on the base of the box (instead of being bolted to the string band), you will need to ensure that the base is sturdily attached to the sides of the box, string ribs and bass end of the sound box.



A refinement for a square back

A sound box made with $\frac{3}{4}$ " sides is going to be fairly heavy. To lighten it, I will resaw the sides to $\frac{1}{4}$ " from solid wood. This saves lumber and allows me to book match the sides. Resawing the sides and adding the liners takes a significant amount of time, but the lighter box usually improves the instrument's volume and tone (to my ear). I worry about making sides too light though. They have to be able to take the load imposed by the soundboard

The joint between the sides, soundboard and back will need additional glue area, usually a full inch on the bass end. Pine liners are typically added. They can be made square, but some builders use triangular liners. I clamp triangular liners using small notched blocks and PVC ring clamps every 3-4" along the length of the liner. I usually taper the liner so it gets thinner at the treble end.

Building a Stave Back



My first two harps had been square back harps, and I had been mulling over different techniques to produce a stave back. With two simple jigs, I was able to turn a quarter sheet of $\frac{1}{4}$ " BC fir ply into a pleasing stave back shell. If you are nervous about the process, I suggest you do a trial run using plywood first.

The Ying and Yang of harp design

Some harp builders get really anal about planning every dimension and mitered angle very precisely. It works well for square backs but gets unmanageable on stave backs where $N_{\text{staves}} > 5$ or so. As I developed this process, I had to suppress the rigid Teutonic right brain engineer/builder that tries to dominate my mind while building. An appendix at the end of the book *Reference points, "Critical" dimensions, and Fudging* can help A-type control freaks to overcome the fixation on precision just long enough to try this approach. Freeing up the creative side has provided me with many of the best "leaps forward" on the harp building and design process.

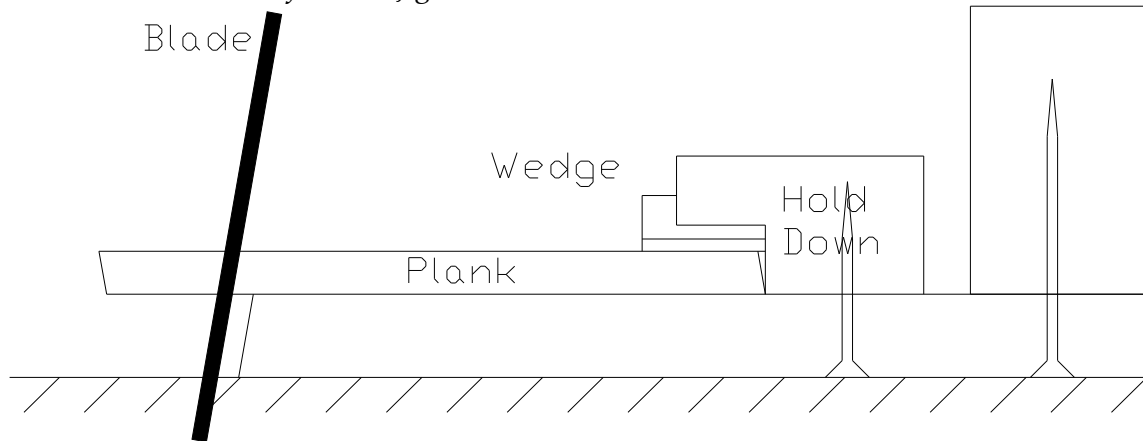
Making the Stave jig:

Start by building the table saw stave cutting jig. The cutting jig holds a rectangular plank while making a long, true bevel cut to make two staves.

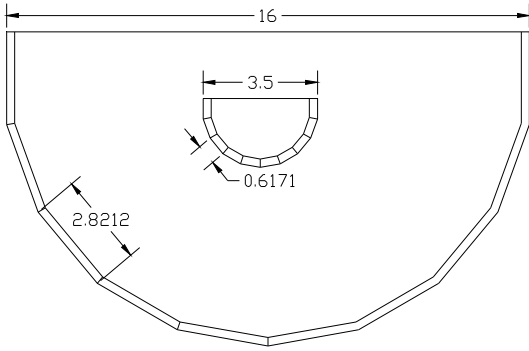


Jig cutting tapered Bubinga staves on the table saw with wedges in place
I make my stave cutting jigs from 1/2" scrap plywood or wafer board (construction site dumpsters are a cheap source). It should be at least 5" wide and 2-3" longer than the staves to be cut. I glue a 1x2 along the edge to stiffen it, and a block at the bottom to keep the plank from sliding back as it is pushed into the table saw blade. The hold down blocks secure the stave blank securely and control the taper of the stave. When I am ready to cut the staves, I use small thin wedges of wood to clamp the plank into place.

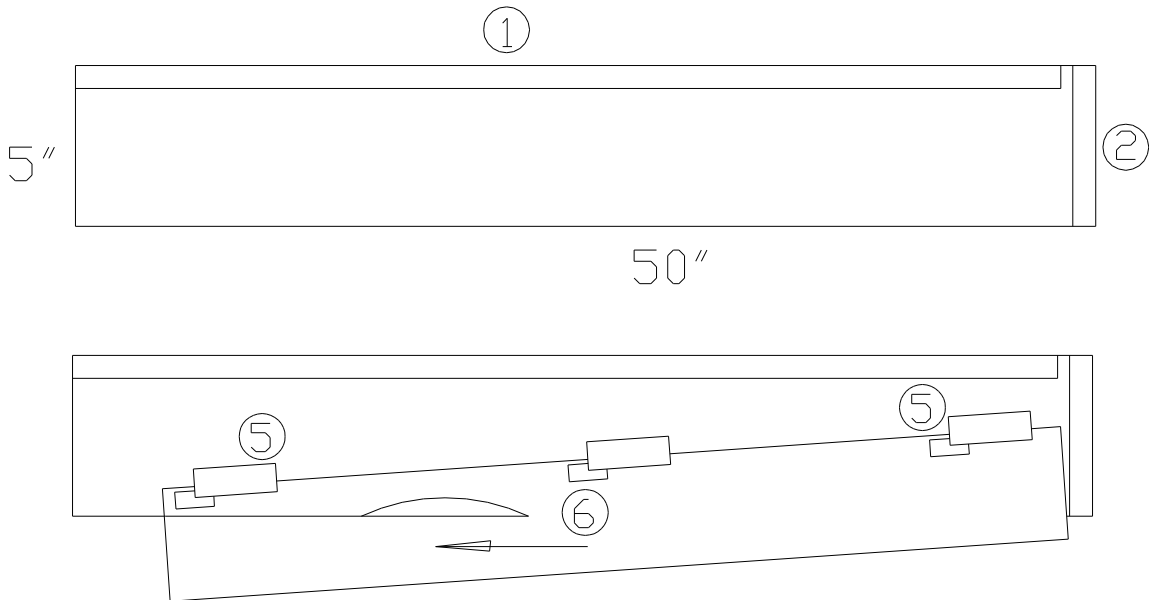
Cross Section Detail of loaded Jig on the table saw



1. Glue the 1x2 stiffener along the edge of a 5x50 board
2. Glue on the tail block
3. Rabbet a 1x2 for hold down blocks
4. Run the board through the table saw at a 10 degree bevel



5. Attach top and bottom hold down blocks at precise offsets from the edge. For a 10-stave shell that will be 3½" wide at the top end and 16" wide at the bass end, these offsets will be .62" at the narrow end of the stave and 2.83" at the wide end.
6. Use wedges to secure test piece.

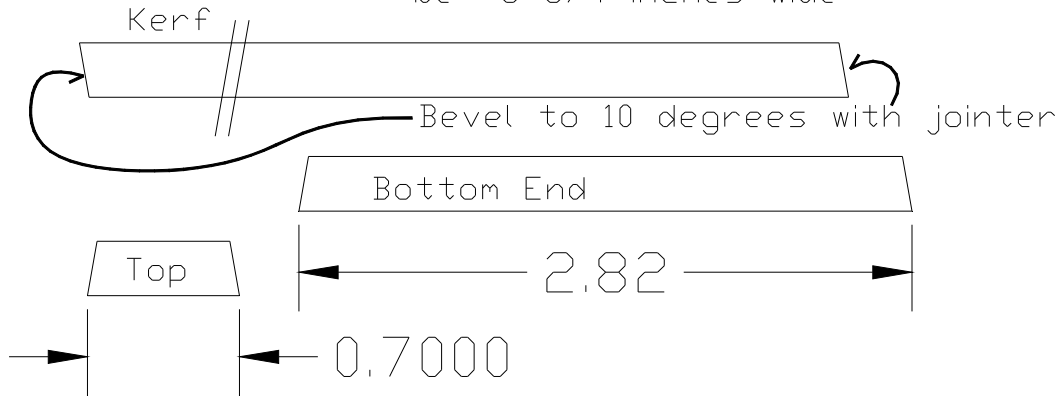


Preparing the staves:

The staves are ripped from a plank that is ¼" thick, 2-3" longer than the sound box and 3-3/4 wide. On a 10 stave harp, each stave needs to be beveled 10° on each edge. I use a joiner to bevel each side of the plank before cutting it into a stave. It is important that the jig hold the blank firmly, and that the top (narrow end) of the resulting stave be $.70 \pm .03$ " Wide. If the stave is 1/8" too wide, the sound box ends up being ½" wider at the top. The width of the stave at the bottom end is not as critical, but it should be about 2.8" wide. Set the table saw to cut a 10° bevel, and adjust the rip fence, jig and hold down blocks till you get a smooth cut and the correct dimensions. It pays to be fussy here.

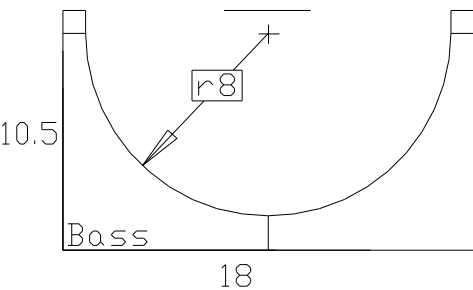
Dimensioned cross sections of the stave blanks:

The stave blank should cut with these bevels and be ~3-3/4 inches wide



Making the Cradle for the Shell

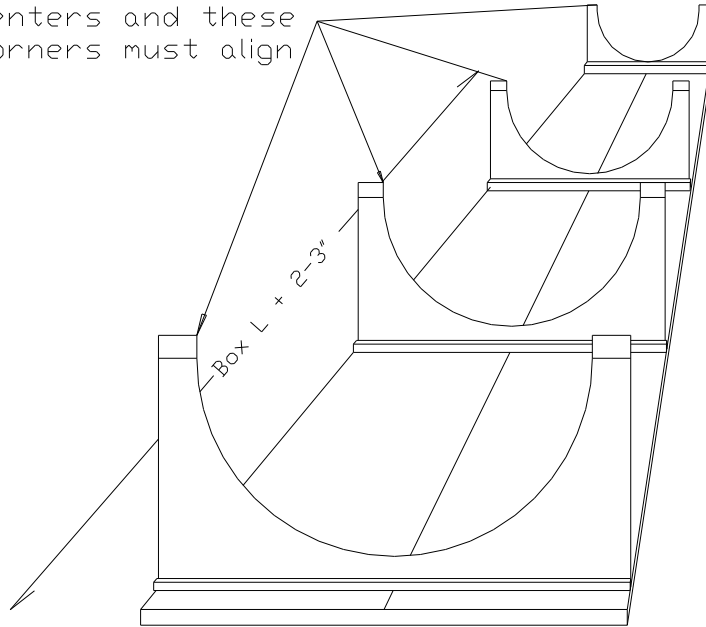
The next step is to make the cradle for holding the staves. It can be made from cheap scrap plywood or wafer board. It basically consists of four rectangular forms with a semicircle cut out of the top end, screwed down to long trapezoidal base.



1. Cut the sheet stock into four rectangles specified on the table below. The bass (largest) form will be 18" wide and 10.5" tall
2. On each form strike a centerline then draw a semicircle of the diameter specified *one inch down from the top*. For the bass form, this would be an 8" radius.
3. Attach the forms to a base board with 1x2 cleats and sheetrock screws

Form	Width	Height	Radius
Soprano	6	4.5	2
Alto	10	6.5	4
Tenor	14	8.5	6
Bass	18	10.5	8

Centers and these corners must align

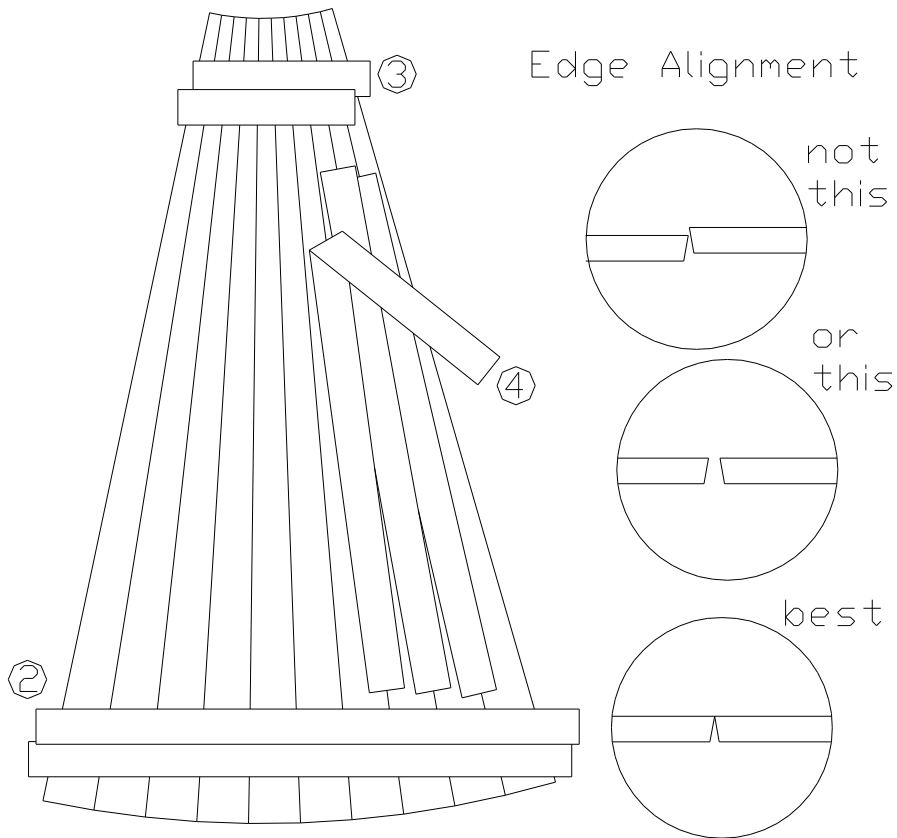


It may be necessary to adjust the four forms up or down along the base once you have your staves cut and have placed them in the form for a trial fit.

Gluing the staves:

Arrange the 10 best looking staves side by side into a fan pattern. Each staff has two sides and the staff sides that are slightly wider should be facing UP. I take some time match the grain and to place any blemishes where the sound holes will be cut or on in the middle bottom (which will be cut away). Tape each seam with 2" wide packing tape (the cheap 3M stuff is fine). It is important to keep pointed edges of the staves together and the gap between the staves as small as possible.

1. Arrange Staves
2. Hold staves together and tape across bass end
3. Hold staves together tape across treble end
4. Tape each seam inbetween



Taping the Staves-An extra pair of hands to hold the edges aligned is a big help.



These Bubinga staves have been taped and flipped over. They are now ready for glue.

Straight, smooth edges on the staves make this a lot easier. Once the back of the staves are taped, flip the assembly over (it will be like the handling the tambour for a roll top desk). If this is your first time trying it, you should probably check to make sure the taped staves fit; they should slide into the jig with a little gentle pressure.

The staves will fit “looser” into the jig if you place them towards the bass end, tighter if you slide them in higher. Inspect the joints between the staves and check to see if they are tight. If the joints open up at one end of the cradle, you may need to adjust the location of the forms. Once you are satisfied that the cradle fits the staves you have cut, it is time to glue them together.

With the tape side down, and the staves spread out flat on a work bench, there will be a narrow V shaped seam between each stave. Run a bead of yellow glue down each of the V shaped seams. I chase the glue with a tooth pick to ensure the glue is worked down into the bottom of the seam. Lift the assembly up by the edges so the middle droops, and place it into the cradle. Use a wet rag to clean out the excess glue that squeezes out of the sound box. Check to make sure each side of the shell is about the same height in the cradle.



This is a nice point to pause and admire the shell. If the work has been done carefully, there will be about 36 linear feet of a nice, tight 1/4” glue seam between the staves. The tape acts as a hinge, and as the shell is curled into its final form, it generates sufficient pinching pressure to “clamp” the joint while the glue cures. I use spring clamps to hold the top edges of the shell to the cradle as the shell will try to curl inward as the wood dries and the glue cures.

Building a Round Back

Using a foam Mold and vacuum bag

The traditional approach for building round back harps starts with a wood mold and 7-12 layers of veneer that are glued successively to each other using long strips of rubber to generate pressure. A good shell can be made with this

technique, but it takes a significant amount of time and skill to produce a smooth, void free shell.

One of my harp building mentors, Lee Gayman, developed a method using two layers of 1/8" bending ply and a vacuum press. It is much faster than the traditional method and allows me to make a much smoother, stronger shell than I could with the traditional method.



A round back shell over a foam mold, curing in a vacuum press bag

To build shells this way, you will need a reliable vacuum bag system. Most harp builders start by vacuum veneering flat panels - soundboards or backs. I really suggest that you start on flat panels before attempting a round back (See the chapter on Soundboards)

You will also need a mold for the vacuum press

You can try to build a hollow wood mold, but realize a vacuum press will be generating about four tons of pressure on a mold big enough for a 36 string harp. A solid wooden mold is a possibility, but is obnoxiously heavy. Lee found that airplane builders made large wing coamings using structural foam and we made several molds using the same technique the airplane builders do (see appendix D)

Once you have a working press and mold, you will need to

1. Gather the materials
2. Make a veneer "Sandwich"
3. Put the sandwich in the press to cure

Gathering Materials

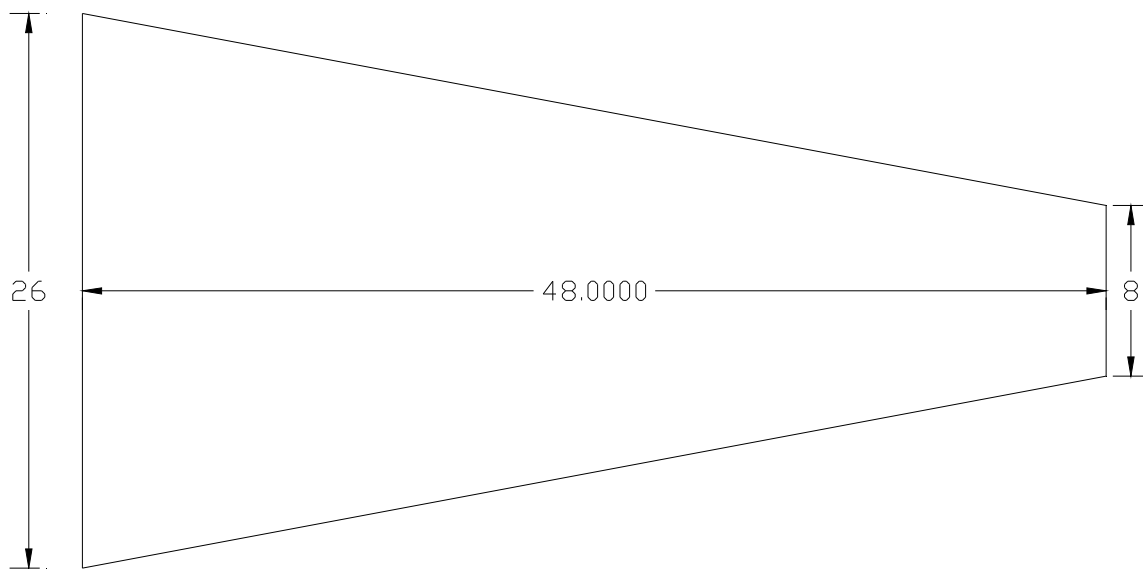
The shell is made from two layers 1/8" birch bending ply and an outer layer of veneer.

I have also used 1.5 mm aircraft birch bending ply, but it is more expensive. There are a couple of different kinds of 1/8" bending ply. The cheapest bending ply is made from three equal plies of a very blond, light wood. It looks like aspen, and will bend down to a diameter of about 6". The Birch bending ply (made in Italy) is made of two plies. The thicker layer looks like Luan and is

covered by a thinner veneer of birch. With a little coaxing, this will bend down to a 1.5" radius.

You may be able to find a local wood workers emporium that will special order the bending ply. If that fails, then you will have to mail order it from Boulter (www.boulterplywood.com) or L.L. Johnson (www.theworkbench.com). 1.5 mm Aircraft birch can be bought through Wickes (www.wicksaircraft.com).

The size and shape of your plywood blanks will vary with the mold - I took my measurements directly from the foam mold. The plywood blanks for my shells are 48" long, 8" wide at the treble end and 26" wide at the bass end.



Dimensions for bending ply blank

You will also need adhesive and a layer of the veneer that you use to cover the outside of the shell. I used epoxy for my first dozen shells, but found it bled through the veneer. I now use DAP Weldwood Powdered Resin exclusively. I mix it with water at a 10:4 ratio (by volume). This glue cures faster than epoxy, cleans up with water, has good creep resistance and has minimal bleed through.

Making a Veneer "Sandwich"

There are a few challenges that you will face:

- Developing and maintaining even vacuum pressure over the entire surface of the shell
- Keeping the veneer from getting wavy or the adhesive from "pooling" under the veneer.
- Keeping the excess glue that will be mooshed from between the layers from gluing the shell to the mold or bag.

- Keeping the two layers of plywood and veneer aligned with each other in the press. Most adhesives make the layers slick, so they tend to slide around.

To address each of these, I do the following:

I distribute the pressure using a “breather layer” to channel air from the shell to your vacuum connection. Some use bubble wrap as a breather layer. I use nylon window screen. This is the very top layer of the sandwich.

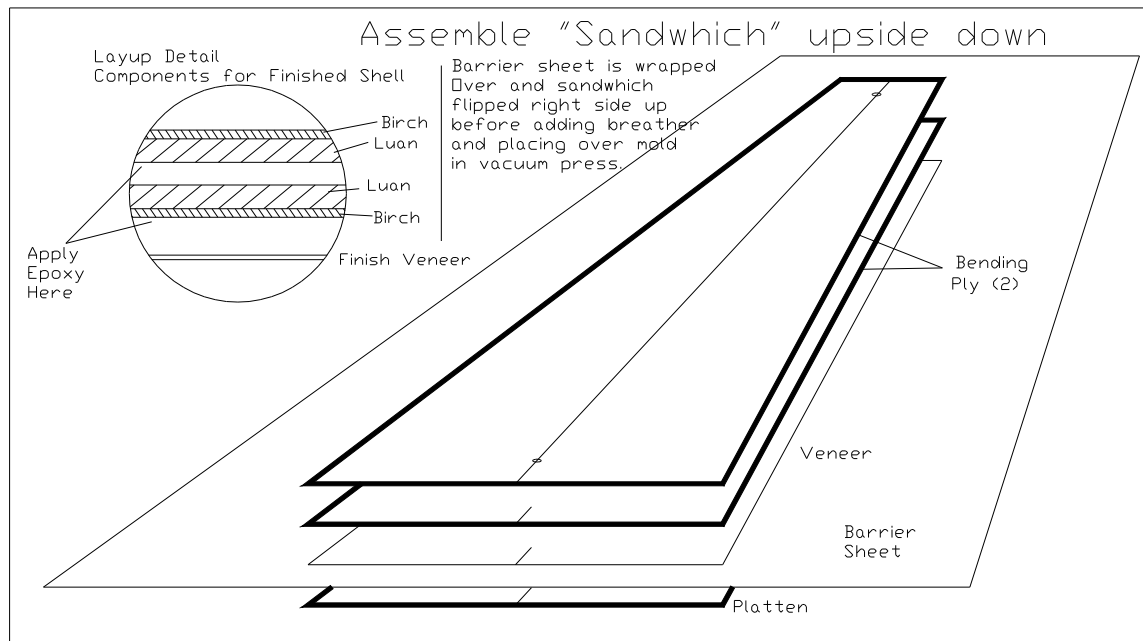
“Pooling” is less likely if I spread a thin, even coat of adhesive. Even then, I can get wrinkles, seam puckers or waviness. In flat veneering, the builder can use a stiff platen (usually a ½” MDF or ply) to ensure that the veneer is pressed flat to the substrate or core. For round back shells, I use a third sheet of bending ply as that platen. The platen should be placed right under the breather. You can use your platen as a pattern for cutting the veneer and bending ply to size. The surface of the finished panel will not be any flatter or smoother than the platen, so I pick the nicest piece for the platen, turning the A side (smoothest) towards the veneer.

Excess glue can bleed through pinholes in the top layer of veneer, along the seam and at the edges of the shell. To keep from gluing the shell to the platen, mold, vacuum bag or breather, I contain the excess glue by wrapping the outside of the veneer in an oversized sheet of freezer paper (this is like butchers paper, but it has a plastic coating on one side). I call this a barrier layer, and the edges of the barrier sheet are folded over onto the innermost layer of ply and taped into place.



Here is a “sandwich” ready to go showing alignment screws, barrier layer (wax paper) and the platen. Note the tape, and breather (window screen) at the ready in the background. The barrier still needs to be taped to the bottom of the stack before it goes into the vacuum bag.

Some sandwich shops hold tall sandwiches together using oversized toothpicks piercing the center. I use two #6x 1¼ inch screws at opposite sides of the center seam to hold the ply, veneer and platen into alignment during assembly and in the press. Wood blocks are epoxied into the mold (and reinforced with fiberglass) where the screws hold the plywood and veneer into alignment.



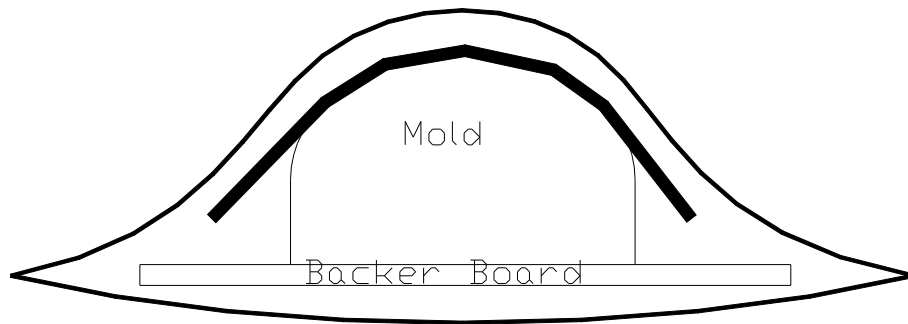
Here is the procedure I use to put this sandwich together -

1. I lay down two sheets of ply with the veneer on top. Each is marked with a centerline so I can line them up precisely.
2. I lay the barrier layer on top of the pile. The edges of the barrier layer should extend 4" or so beyond the edges of the bending ply.
3. I put the platen on top of the barrier layer.
4. I drill two small eighth inch holes though all four layers of the sandwich.
5. I place the 8d nails through the holes and I flip the entire assembly over. This will leave the tips of the nails pointing up.
6. I remove the two layers of ply and apply adhesive to the bending ply.
7. I stack the two layers of bending ply back onto the sandwich (Glue side down) using the nails as locator pins.
8. I tape the edges of the barrier layer onto the inner layer of bending ply.
9. Now I have a neatly wrapped sandwich pinned together with two nails. I flip the assembly back over and place it on the foam mold.
10. While I hold the layers together I remove the nail and drive a #6 x 1¼ screw through the sandwich and into the wood block embedded in the mold. I repeat this for the other end of the stack.
11. I tape the leading edge of my breather on top of the sandwich/mold and slide it into the vacuum bag.
12. Seal the closure, apply the vacuum. As the vacuum is applied, you may need to hold the sides of the bag out to the side to prevent the bag from sucking back between the mold and underside of the sandwich.
13. Leave mold and shell in the press until it is fully cured (6-8 hours)

Some Tips

Even Adhesive Coverage - I use a thin nap 4" foam roller to spread the DAP Resin. I use about 11 oz of glue for a shell. The glue is not absorbed evenly into the wood, so three or four minutes after the initial application, I go back to the sheet and play Robin Hood, redistributing the adhesive from the rich areas to the starving patches. I let the mixed resin sit open for about 5 minutes. A good part of the water evaporates off, eliminating bleed through.

Bag Suck - As the vacuum is applied, an oversized bag will have the tendency to be sucked up between the mold and sandwich. This prevents the sandwich from being pressed firmly to the sides of the mold. It can be mitigated by using a bottom plate.



Eliminating "Bag Suck" - the bottom plate

The bottom plate is used in a conventional bag. It is made from 3/4" MDF and extend 6-8" beyond the footprint of the mold. The bag needs to be large enough extend another 4-6" beyond the bottom plate.

Removing the Screws - If you wax the screws before driving them into place they are less likely to stick. If you have trouble removing them, heat them with a soldering iron till the adhesive softens and pull them out.

Cracked Shells - I can usually torture the birch bending plywood down to a 1.5" radius, but that is the limit. I have used other plywoods and could achieve the following radii in the vacuum press:

Substrate	Cost	Supplier	Minimum "in bag" bending radius
5.2mm Luan plywood with one face sanded off	\$12	Most large hardware stores	4.5 inches
1/8" Whacky Wood Three ply Luan/aspen	\$35	www.boulterplywood.com	3 inches
1/8" Birch Bending plywood (two ply)	\$35	www.theworkbench.com www.boulterplywood.com	1.5 inches
Birch Aircraft Plywood 1.5mm (1/16")	\$90	www.wicksaircraft.com	3/4" inch

I found you can get slightly tighter radii if you thin the plywood (on the luan side) by 1/3 or so to make the plywood more flexible.

Sharp Edges - To prevent sharp corners from puncturing your vacuum bag, Round the corners of the backing plate, plywood and platen to a 1/4" or greater radius.

With a completed shell, you are now ready to add the cap, bass and a few internal parts.