

The *Serpent Website's* Box-O-Cleide

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Disclaimer

Neither The Serpent Website or the author make any guarantees that the following instructions are free of errors, or that a resulting instrument (the "Box-O-Cleide", henceforth referred to in this document as BOC) will play at any anticipated level the builder might desire or expect. These instructions are intended to be used in conjunction with certain basic construction information as described in The Serpent Website's 'Squarpent' construction webpage and article, in order to duplicate the author's prototype. The resulting instrument is intended to be an educational device, and no promise is made regarding its suitability for performance situations.

The Serpent Website's 'Squarpent' article and photos may be used to better understand how the basic wooden pieces must be laid out, cut and trimmed for the 'rabbet' joints, as well as how to fabricate and use jigs that will be required to assemble the basic pieces into the square tube that is the basis of the BOC; however, this BOC article provides an overview of these steps. Refer to www.serpentwebsite.com



the author playing the Box-O-Cleide prototype

Some photos in this article are from an initial (and aborted) attempt to build the BOC prototype, and some others are from the Squarpent prototype's construction. For this reason, the alert reader may notice certain small discrepancies between the various views, as well as between the views and the text.

Materials

- 4' x 8' [122 x 244 cm] sheet of 1/4" plywood (actually 0.2" [0.5 cm]), with two finished/good sides, preferably exterior grade, preferably hardwood type (Oak, etc.)
- scrap of 1/2" [1.27 cm] dia. wooden dowel
- scrap of 3/4" [1.9 cm] dia. (approx.) wooden dowel
- wood glue, exterior (water resistant) type, preferably gel formulation to resist running, e.g. Elmer's "Pro Bond Weather Resistant Wood Glue for Exterior Use"
- 5/32" [0.4 cm] dia. brass rod (for levers)
- rubber or plastic tubing to fit over brass rod (for buttons)
- small hinges & associated wood screws
- small wood screws, for securing levers to keys & for anchoring rubber bands
- rubber contact cement
- thin leather with at least one fairly smooth surface (felt cloth might be a suitable substitute)
- 0.2" [0.5 cm] thick foam rubber (the prototype used weather stripping)
- felt pads, of the type intended for attaching to furniture legs to avoid damage to floors
- 5 minute epoxy (2-part)
- mouthpiece; most trombone/baritone/euphonium types will work
- steel wire, for twisting twight to hold objects together during gluing (approx. 19 gauge [0.7 mm])
- cotton swabs ("Q-Tips" or similar)
- polyurethane varnish
- rubber bands (1/8" x 3" [0.3 cm x 7.5 cm] were used on prototype)

Tools

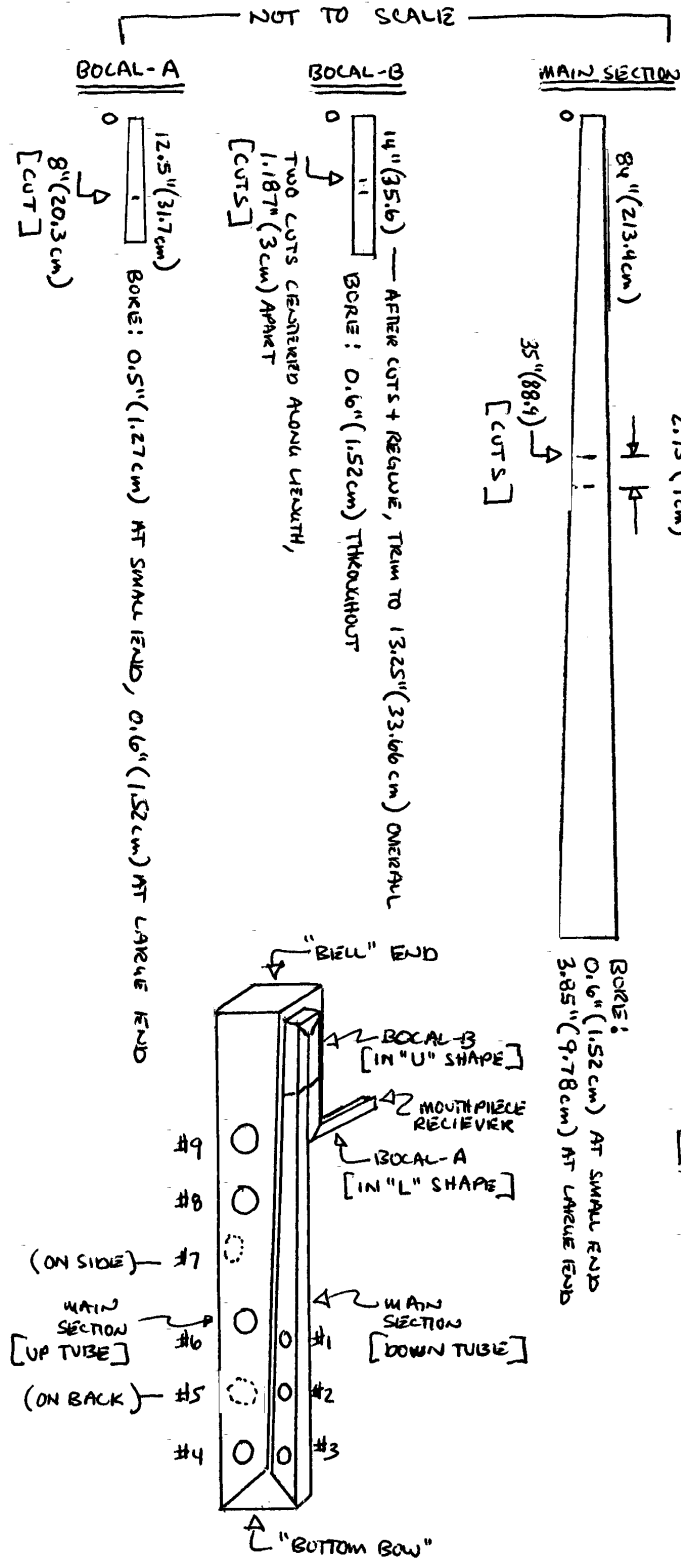
- hand drill, with assorted bits
- assorted wood boring bits (see text & diagram on page 2)
- assorted hole saws (see text & diagram on page 2)
- wood saw, circular or table type preferable, 'saber' or 'jig' saws or handsaws will also work
- saw or drill-operated rotary cutter for cutting brass rod
- file for finishing and notching brass rod
- X-Acto knife or similar razor edge modeling or woodworking blade
- pencil with suitable lead for marking wood

Box-O-Cleide Construction

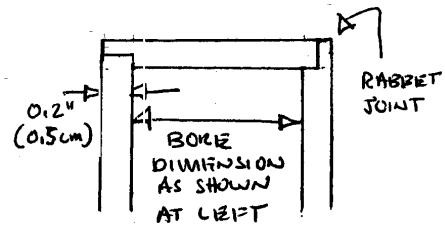
- sand paper
- metal straight edge to guide knife
- carpenter's 'square' or drafting triangle, to assist in marking accurate 45 and 90 degree angles
- ruler or drafting scale
- tape measure

- router with straight bit, for making rabbet cuts (optional; other methods may also be used to make these cuts)
- wide pliers (for twisting wire tightly)
- wire cutters
- heavy twine or nylon cord (clothes line, etc.), about 10' [305 cm] required

BOX-O-CLEIDE SECTION DETAILS



TYPICAL BORE DETAIL



HOLE DIMENSIONS

HOLE #	DISTANCE	DIAMETER
1	49.25" (125.1 cm)	0.75 (1.90)
2	53" (134.6 cm)	0.875 (2.22)
3	60.875" (154.6 cm)	0.875 (2.22)
4	68.375" (173.7 cm)	1.125 (2.86)
5	72.25" (183.5 cm)	1.5 (3.81)
6	79.625" (202.2 cm)	1.5 (3.81)
7	84.875" (215.6 cm)	1.75 (4.44)
8	90" (228.6 cm)	1.5 (3.81)
9	96.25" (224.5 cm)	2 (5.1)

ONLY NORMALLY OPEN HOLE

* DISTANCES MEASURED FROM MOUTHPIECE RECEIVER END OF BORE, ALONG CENTERLINE, AFTER ALL BORE SECTIONS HAVE BEEN ASSEMBLED AND GLUED INTO FINAL SHAPE.

Box-O-Cleide Construction

Initial Cuts

The bore of the BOC is made from three main sections, each with a different bore profile, or taper. Refer to the *Section Details diagram*. The first section is 'Bocal-A', and has a very slight taper, i.e. it gets wider along its length. The next section is 'Bocal-B', and it has a uniform cross section with no taper. The third section is 'Main', and it has the most significant taper.

Each of the sections are made from four identical pieces of plywood, cut in either a tapered (Bocal-A and Main) or rectangular (Bocal-B) shape and called *trapezoids*. After cutting the trapezoids from the plywood sheet, they need to be cut for making 'rabbet' type joints where they come together.

- Determine the actual thickness of the plywood; this will be dimension 'A'. Dimension 'B' will be half of 'A'.

- Decide which surface of the plywood has the better finish, and place it facing up on the floor. Mark lines on the better side of the plywood; there will be four lines per each of the three sections, and their lengths will be the dimensions shown on the Section Details diagram, e.g. the lines for the Main section will be 84" [213.4 cm] long. The lines will be the *centerlines* of the bore, and will be used for several critical measurements and cuts during construction. Make sure that the lines are far enough apart to allow for the tapering width of the sections. Make sure that the centerlines are accurate, straight and clearly visible.

- At one end of the lines, make small marks to either side of the centerline, e.g. 0.25" [0.635 cm] for Bocal-A. At the other end of the lines, make similar marks to either side of the centerline, e.g. 0.3" [0.762 cm] for Bocal-A. Cut a strip about 3" [or about 4 cm] from the long side of the plywood sheet opposite the part of the sheet that is being marked; the factory cut edge of this strip will be used as a straight edge for marking the trapezoids (a carpenter's long straight edge may also be used if available). Using the straight edge, draw lines between the small marks to define the trapezoid shapes for all four sides of all three sections. These marks define the edges of the inside of the bore.

- To define the actual cut lines for the trapezoids, draw additional lines parallel to the first lines. On one side of each trapezoid, draw the line 'A' (remember dimension 'A' from above?) distance outside the bore line; this will be for the rabbet cut. On the other side of each trapezoid, draw the line 'B' distance outside the bore line; this will be the 'no varnish' zone that will be glued into the adjacent trapezoid's rabbet cut. Refer to the Section Details:Typical Bore Detail diagram to see how the rabbet joints and cuts work out.

- Cut the 12 trapezoids from the plywood sheet, being careful to make the cuts clean and accurate. Do not allow the saw to wander; the cuts must be straight.



12 trapezoids after cutting from plywood sheet

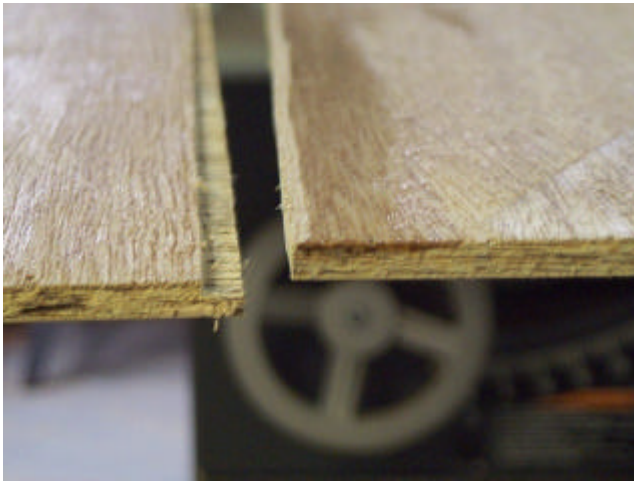


four trapezoids for Main section after varnishing

Box-O-Cleide Construction

- Varnish the unmarked (poorer) side of the trapezoids. For Bocal-A trapezoids, use two coats of varnish. Be careful to avoid varnishing the 'no varnish' zones; you will be varnishing the unmarked side, so the work does not need to be precise; it is better to get some varnish in the 'no varnish' zone than to leave others parts of the wood unprotected.

- Cut the rabbets along the 'A' edge of the trapezoids, making sure to cut on the varnished side of the wood. The cuts will be 'A' wide and 'B' deep. A router works best for this process, but successive adjacent shallow cuts with a table or circular saw work well, and other methods (including razor knife cuts) may also be used.



example of rabbet cut (left) and unvarnished area at left edge of trapezoid (right)

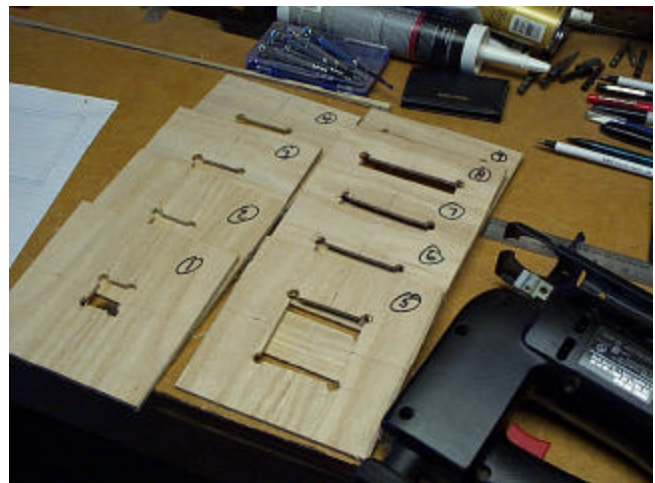
Jigs

The four trapezoids making up each section will be glued together into 'boxes', or tubes with a square cross section. The rabbet joints will help by keeping the edges locked together, and will help keep the glue in place for the best quality joint. However, it will still be difficult to align the eight edges of the four trapezoids in each section before the glue runs or begins to set. Making a set of jigs is the solution to this problem.

- From the remaining plywood, cut 10 squares, each 6" x 6" [15.24 sq cm]; these will be for the outer jigs of the Main section. Mark a square centered on each wooden piece, with progressively larger sizes (*see photo*). The marked squares should be sized so that the jigs will fit at even increments along the trapezoids, but with the smallest and largest sized to fit slightly inside the overall length (i.e. not right at the ends). Drill a 3/8" [1 cm] dia. Hole at each corner of the marked squares; this will help prevent excess glue at the rabbet joints from touching the jigs. Saw between the holes, being careful to cut straight along the marked lines.



incomplete outer jigs



completed outer jigs

- In the same manner, make about three jigs to fit the smaller sections Bocal-A and Bocal-B, but make the wooden pieces a more suitable size. In the case of Bocal-B, make the marked squares all the same size, and they should be very slightly larger than the width of the cut trapezoids for this section (yes, the author knows that these particular four parts are not actually trapezoids).

- For the Main section, make a set of four inner jigs. Build them up from several glued thicknesses of the plywood, or use 1/2" or 3/4" plywood scrap if available. The jigs will be cut to squares sized to fit inside the bore at equal lengths along the section, keeping the ones at the ends slightly inside, as opposed to right at the end. Round off the corners of the jigs, to prevent glue from the rabbet joints from touching them. Drill a hole in the center of each inner jig, and pass a length of cord through all of the jigs. Make a knot in the cord on the side of each jig that faces the smaller end of the trapezoids. Keep a small loop in the cord between each jig.

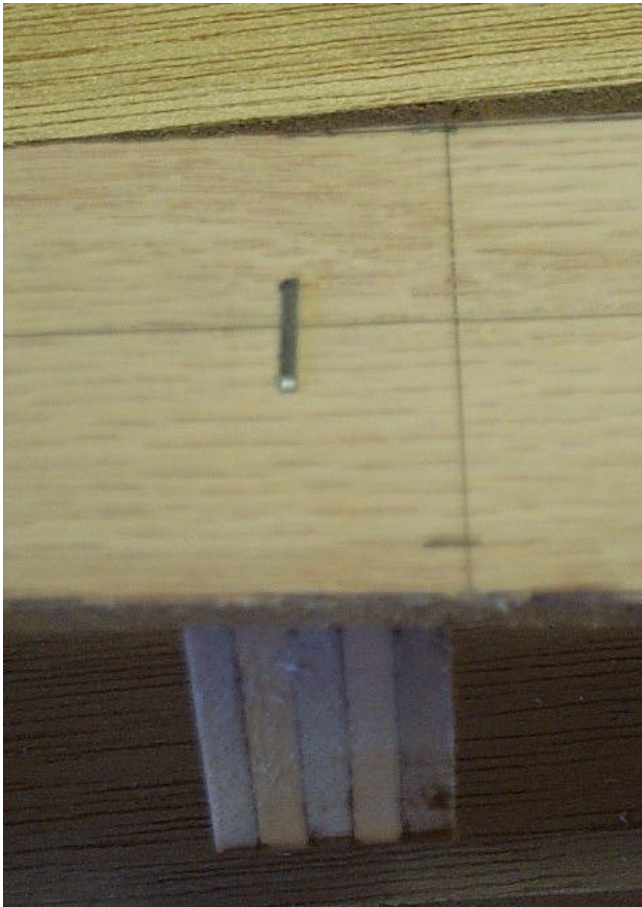
- Test fit three of the four Main section trapezoids, and carefully place the inner jigs between them so that they

Box-O-Cleide Construction

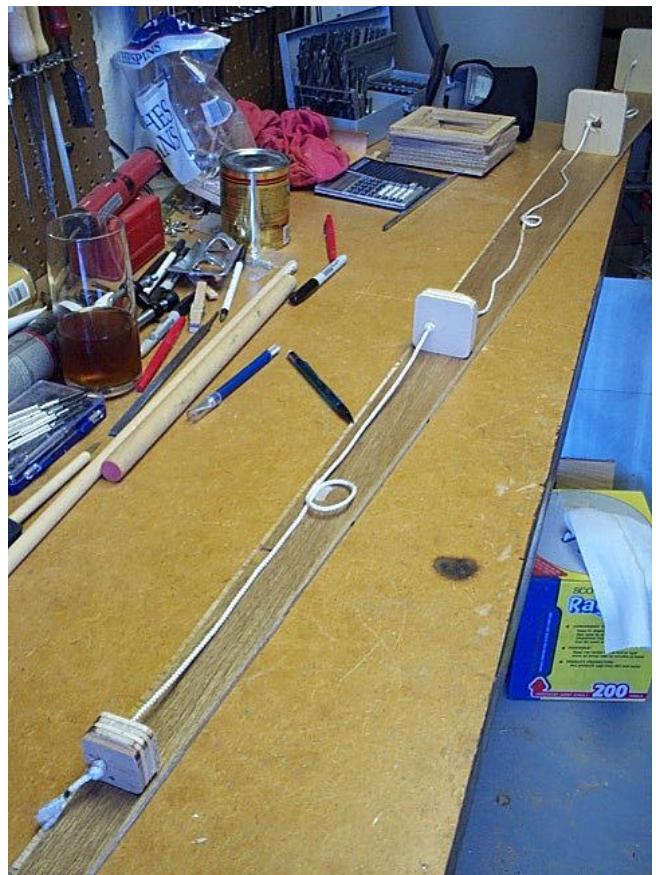
touch. The idea is to position the jigs so that they will support the trapezoids during gluing, yet not get in the way of the pieces fitting together. Use a staple or two small nails for each inner jig, to temporarily secure the jigs to one of the four trapezoids. Note: inner jigs are not needed for the two smaller sections, but cut a length of 1/2" [1.27 cm] dia. dowel and use it on the small end of Bocal-A section to make sure that the trapezoids will fit it after gluing.



typical inner jig (hole should actually be centered)



inner jig stapled to trapezoid



inner jigs with cord, and largest jig inside end of 'tube'



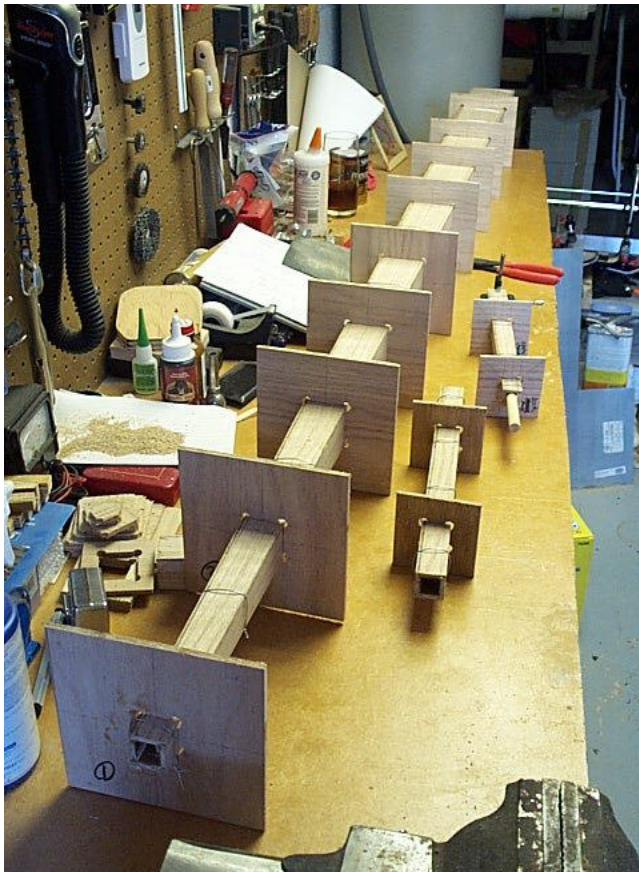
Box-O-Cleide Construction

Sections

Follow this procedure for each of the three sections.

- Lay all four trapezoids down parallel to each other. Lay a bead of wood glue in the rabbet cuts of each trapezoid. With one trapezoid as the base (in the case of the Main section, this will be the trapezoid with the inner jigs stapled to it), position two more trapezoids on edge along the sides of the first one, so that their 'no varnish' edges engage the rabbet cut edges. Make sure that the ends of all three trapezoids are aligned. Fit the fourth trapezoid on top of the first three, and check alignment again. Slide the outer jigs over this assembly, sliding them towards the larger end of the tube until they fit snugly; on the Bocal-B section, use small shims or any wedge shaped pieces of material to get the jigs to fit firmly against the trapezoids.

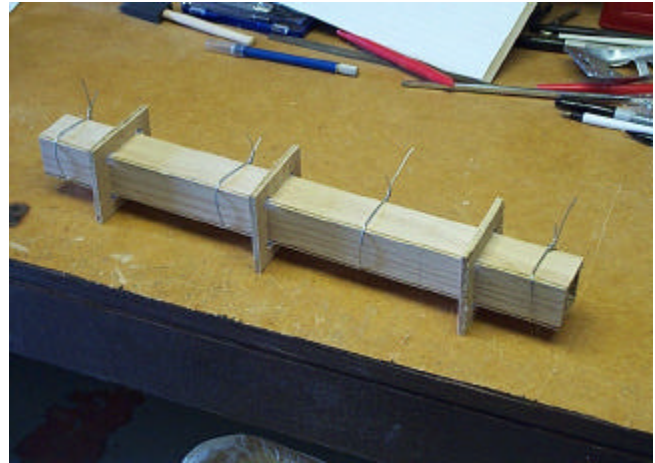
- After another check of alignment, make sure that the rabbet joints are properly engaged over the length of the tube assembly. Cut short pieces of steel wire and wrap them around the tube between the jigs. Use the pliers to twist the wire so that it tightens and pulls the trapezoids firmly together. This should cause excess glue to squeeze from the rabbet joints, so wipe up any visible glue. In the case of the Bocal-A section, remove the 1/2" dowel and wipe off any glue that may have gotten onto it, then put it back into the tube end until the glue in the rabbet joints has dried.



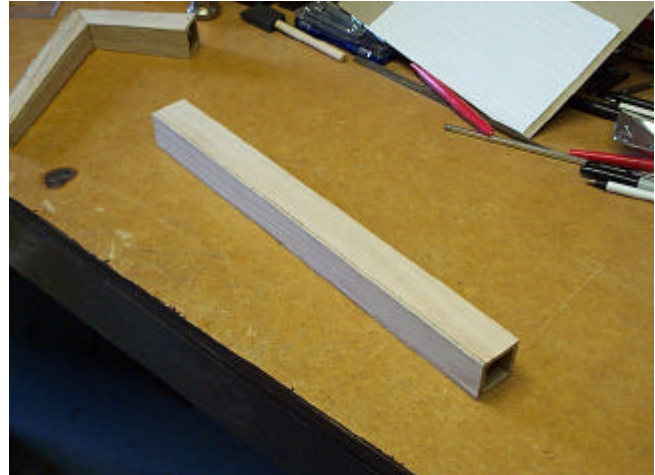
three sections glued with outer jigs visible

- Allow the glued sections to dry overnight.

- Cut the steel wire from the tubes. Remove the outer jigs; this might require light tapping with a mallet or screwdriver handle. In the case of the Main section, remove the staples that secured the inner jigs and pull on the cord from the large end, dislodging the largest inner jig. More pulling will sequentially dislodge the other inner jigs; remove them completely. Rub wood glue into the staple holes and allow to dry. Lightly sand the outer surfaces of the three sections to remove excess dried glue, and sand the edges to slightly round the corners.



Bocal-B section glue-up with outer jigs and wire visible



Bocal-B section with jigs and wire removed

Receiver

- Remove the 1/2" dowel from the small end of the Bocal-A section. Mix sawdust (preferably fine dust from routing the rabbet cuts) with epoxy to make a thick wood-filled paste; the mixture should be about half sawdust.

- Make a mark on the dowel 1/2" [1.27 cm] from one end. Coat this 1/2" section of dowel with the wood-epoxy paste. Use a small screwdriver to fill the inside corners of the

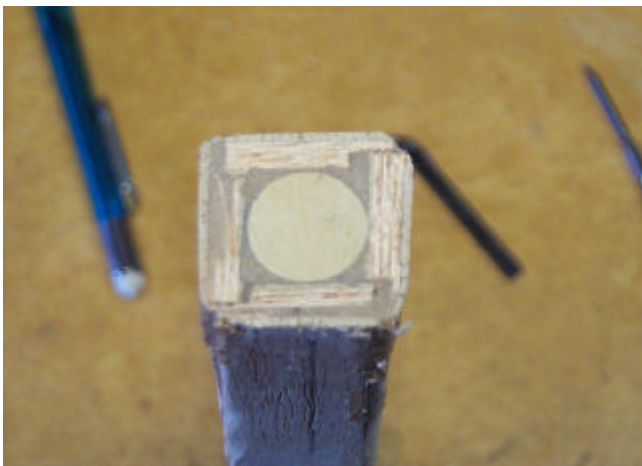
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small end of Bocal-A with the paste, to a point 1/2" inside the tube. Slowly work the dowel into the tube with a back and forth twisting motion. Use the screwdriver to pack more paste into the spaces between the dowel and the inside corners of the tube.



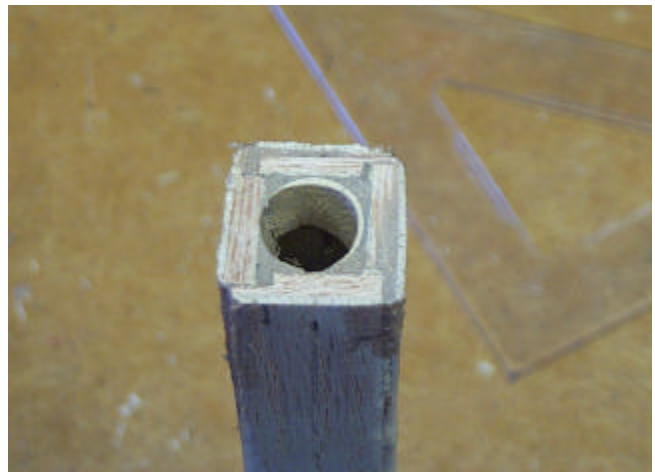
1/2" dowel epoxy-ed inside Bocal-A

- After the epoxy has cured, cut off the extra dowel, taking about 1/16" [0.16 cm] of the tube with it. This will leave a clean cut surface. Drill a small hole in the center of the remaining piece of dowel inside the tube, then drill again with a 1/2" [1.27 cm] bit, completely removing the dowel and leaving the surrounding wood-epoxy resin.



Bocal-A trimmed after epoxy has cured

- The 1/2" hole is the mouthpiece receiver; it will accept the shank of most suitably sized mouthpieces with an airtight seal. Check inside the receiver using a flashlight, and look for any excess epoxy beyond the 1/2" depth of the receiver (where the dowel ended), and trim it away.



dowel drilled from tube, leaving the receiver

Shaping

With all three sections and the receiver formed, the sections will be cut and their pieces rearranged to create the final shape of the BOC.

- Refer to the Section Details diagram, and make pencil marks on the centerlines of each section at the 'bend' points. For example, on the Bocal-A section, measure from the small end (at the receiver) and make a mark at the 12.5" [31.7 cm] point along the centerline. The Bocal-B and Main sections will each have two marks; measure from the end '0' and make the first mark, then make another mark measured from the first mark.

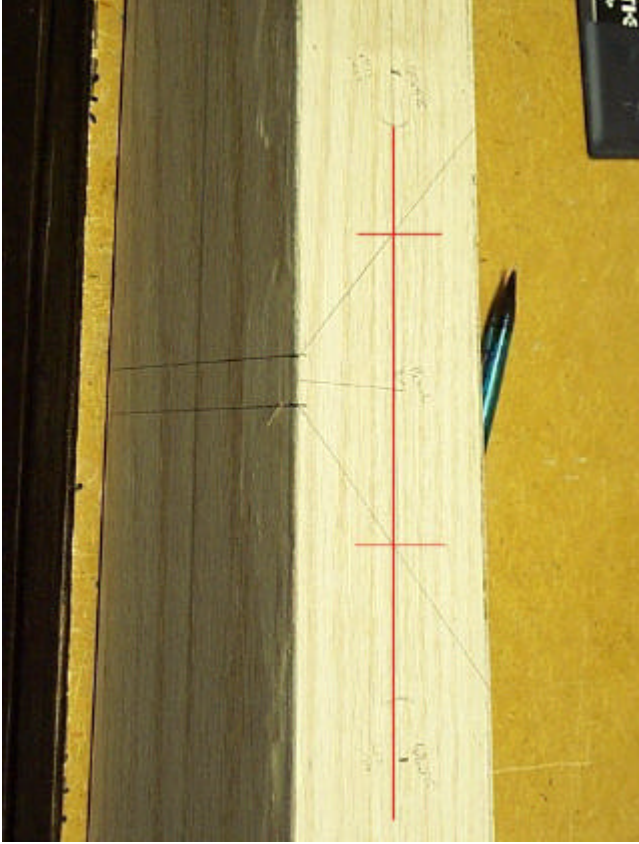
- Mark the cut lines on each section, being careful to use a square aligned to the marked centerline of the bore; do not align to the edge of the tube! Cut lines will all be 45 degrees relative to the centerline, and will intersect the centerline at the measured marks. The cut marks will all be made on only one side of each tube section, and this side will be the top during cutting. On each adjacent side of the tube, extend the cut lines, this time at 90 degrees to the centerlines. The three lines at each location will help in keeping the saw straight during the cuts.

- Use a hand saw or mitre saw to make the cuts. Start the cuts along the top cut line, then continue down through the tube, using the other two lines as a guide. Lightly sand all cuts to remove burrs.

- Refer to the photos and reassemble each section with the cut pieces rotated to make the 90 degree bends. Test fit first, and sand the cuts as required to adjust for a tight joint and

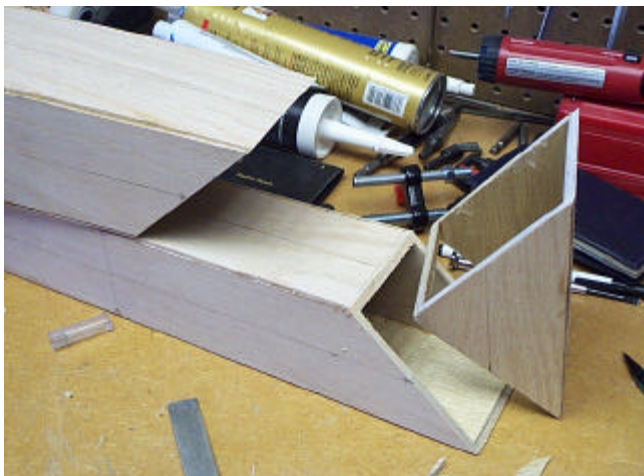
Box-O-Cleide Construction

all pieces in alignment along the centerlines. For Bocal-B and the Main section, cut wafers of 3/4" [1.9 cm] dowel to fit between the parallel pieces; carefully sand for optimum fit. Use wood glue to make these joints and also for the dowels, and block the assemblies until dry. Once dry, trim the ends of Bocal-B for a total centerline length of 13.25" [33.66 cm]. Glue a small wedge of wood at the corner of Bocal-A for reinforcement.



typical cut lines, marks and centerline highlighted

- Assemble the three reshaped sections into the final BOC shape. Once again, use dowel wafers to separate and brace between the various pieces. Without these braces, the BOC's other glue joints will not withstand the strain that will be placed on them.



the three sections after shaping



dowel wafer between pieces of a section



three sections during reshaping

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the three sections assembled into BOC shape

Tuning

The BOC is more difficult to tune than a real ophicleide, since it does not have a tuning slide or adjustable bocal shank, but it is still necessary to tune the 'half step'. The BOC, and ophicleides, are similar to instruments with valves or slides in that the player selects a length for the air column, then uses the lips to select a note from the series of partials afforded by that tube length. Almost all notes are selected by opening one or two (adjacent) holes at a time near the bell to effectively create a new bell closer to the mouthpiece than the normal bell. All holes are normally closed except the one nearest the bell, and in this normal (all fingers off) configuration, the normally open hole is the acoustic bell and the air column stops there; the fundamental pitch will be B-flat. To lower the pitch by a half step, the normally open hole is closed, transferring the acoustic bell from this hole to the normal bell and making the air column long enough to arrive at a fundamental of A.

- On the BOC, all hole positions are determined by measurement, but the total bore length with the normally open hole closed must be adjusted to match the holes by

trimming the bell. Since the holes have not been cut yet, play the BOC and obtain the A pitch below middle C. Compare this to a piano, another instrument or a musical instrument tuner; the A will be flat. Use a hand saw to trim the bell in 1/2" [1.27 cm] increments, trying the A after each cut. If it becomes necessary to trim beyond the top of the Bocal-B, trim by cutting a notch on the player side of the bell only.



bell tuning, with notch visible

Box-O-Cleide Construction

Cutting Holes

Opicleides have between 9 and 11 keys; for simplicity the BOC uses only the minimum of 9. The larger holes are best cut using a hole saw, and the smaller ones using wood-boring bits, but other methods may also work.

- Use a tape measure, and starting along the *side* of the mouthpiece receiver, measure along the centerline past the bend in Bocal-A and the two bends in Bocal-B; be careful to avoid gaining or losing distance when going around the bends! When the tape reaches the joint between the Bocal-B and Main sections, move the tape around to the 'front' side (opposite the player side), again without gaining or losing distance. Continue to measure along the centerline on the front of the BOC, and start making marks on the centerline at the distances shown in the Section Details:Hole Dimensions diagram. After making all nine marks, transfer the marks for holes 5 and 7 around to the side (hole #7) and back/player side (hole #5); the keys for these holes will be operated using the player's thumbs.



typical hole saw bit in electric drill

- Drill a small pilot hole at each mark, then carefully open up the holes with the hole saws and bores; refer to the diagram for the sizes. The prototype was made by rounding the desired hole sizes to the nearest readily available saw/bore inch sizes. If using metric tools, the builder might wish to use the following list of *desired* sizes, and make

his/her own decisions on rounding to available sizes. Be very cautious to avoid letting the saw/bore rip through the wood, damaging the inside edge of the holes.

- Desired hole sizes, 1 - 9: 0.7" [1.778 cm], 0.85" [2.159 cm], 0.875" [2.222 cm], 1.12" [2.845 cm], 1.42" [3.607 cm], 1.52" [3.861 cm], 1.72" [4.369 cm], 1.52" [3.861 cm], 1.92" [4.879 cm].



typical boring bit in electric drill

- After all holes have been cut, sand the entire BOC, taking care to sand the edges of the holes and just inside the tube around the holes. Coat the entire BOC with polyurethane varnish, lightly sand after drying, and apply another thin coat of varnish. When the second coat is dry, use very fine sandpaper to smooth the areas around the holes (about 1" [2.5 cm] on all side of the holes).



Box-O-Cleide Construction

Key Hinges

- The nine holes on the BOC are covered with keys. Each key consists of a rectangle of plywood hinged to a hinge block, which in turn is mounted to the body of the BOC. Each key is approximately 2.5 times the hole diameter lengthwise, and 2 times the diameter widthwise. The prototype used keys that were slightly trapezoidal, with the longer edges parallel to the edges of the tube, for a better appearance. For hole #3, add an extra 2.5" [6.3 cm] length on the end that will be oriented towards to bocal sections; this will improve the hinge point and lever action (the prototype did not have this refinement!).



typical key and hinge block

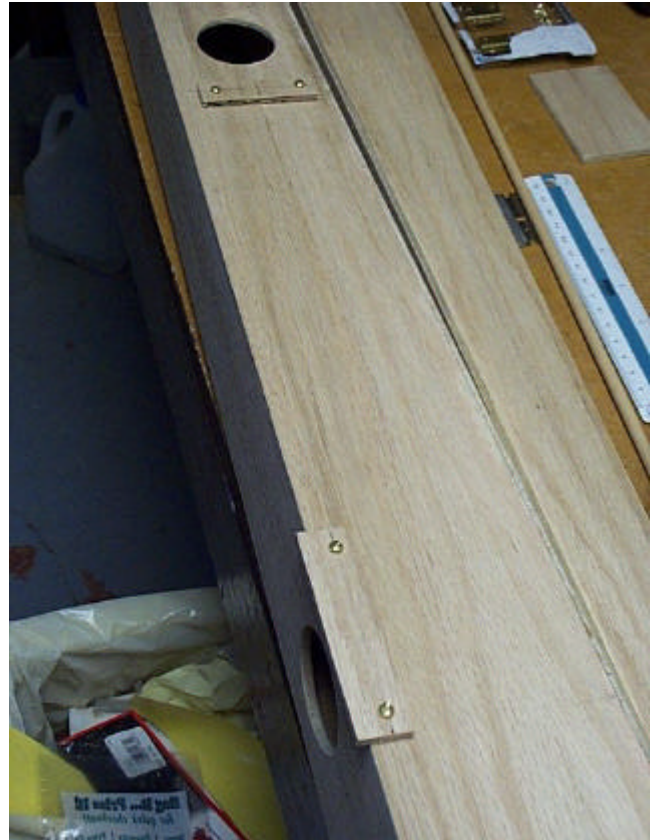
- Each key's hinge block is a piece of plywood, 1/2" [1.27 cm] wide and with a length equal to the key. Note: if the hinges to be used have larger plates, it may be necessary to use hinge blocks wider than 1/2".



typical key, hinge and hinge block

- With the keys centered over the holes, position the hinge blocks and secure to the body of the BOC using two wood screws. Mount the hinge to each key with the hinge plate on the inside surface (the surface that faces the hole), and file or grind off any part of the screws that extend through the

plywood. Mount the remaining part of the hinge to the hinge block. Test the key operation for freedom of movement, and carefully trim the wood if the hinge rubs or binds on the hinge. Note that the keys for holes 2 & 7 will pivot perpendicular to the bore centerline, and their hinge blocks will be different from those of the other keys.



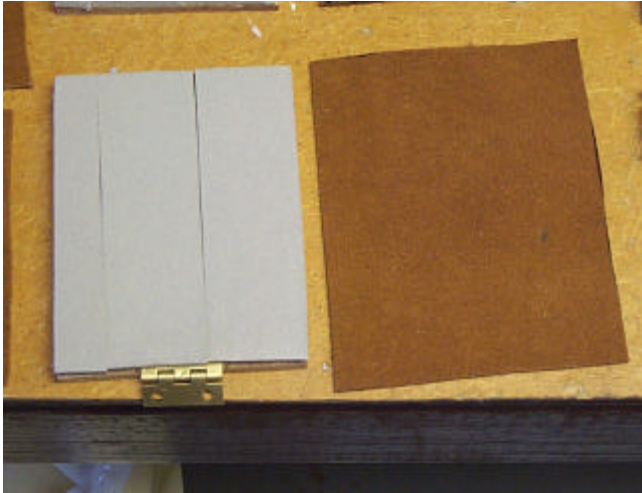
hinge block for hole # 7 (hole #2 is similar)

Key Pads

The keys need pads to form the actual airtight seal with the holes. An ophicleide uses pads similar to those found on saxophones, but these can be hard for most people to obtain, and they also require a sharp edged hole rim to seat against. The BOC uses pads comprised of a simple piece of leather or felt, with an intermediate layer of foam rubber between this and the plywood. In order to fit and seal correctly, the foam should be about the same thickness as the plywood, and the pad material should be slightly thicker than the metal of the hinge plate. This is because the inside surface of the key is separated from the body of the BOC by one plywood thickness plus the thickness of the hinge plate; when the foam and pad are attached to the key, their combined thickness should make the key pivot slightly away from the body of the BOC. When the key is held parallel to the surface of the BOC, the foam should be slightly compressed.

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The BOC prototype used leather obtained at a craft shop; the leather had one side smoother than the other, so the rough side was oriented towards the foam. A piece of thin felt will probably work as well as leather. Obtaining foam rubber in a thickness close to 0.2" [0.5 cm] can be difficult, but the solution in the case of the prototype was the application of foam weather stripping. Some possible alternates to foam rubber are the resilient foam sold by hobby shops for use as rail bed for small gauges of model railroads, or even several thickness of felt.



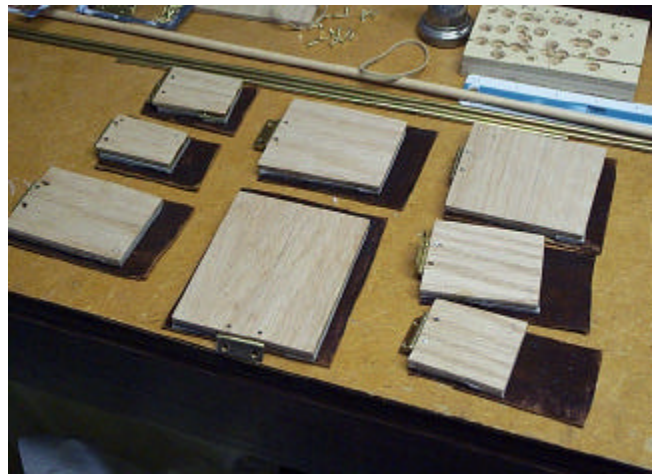
weather stripping on key next to leather pad

On the prototype, the weather stripping had adhesive on both sides, but this adhesive would not adhere to the leather, possibly due to a chemical reaction between the adhesive and the leather treatment. Rubber contact cement was used with good results in this instance.



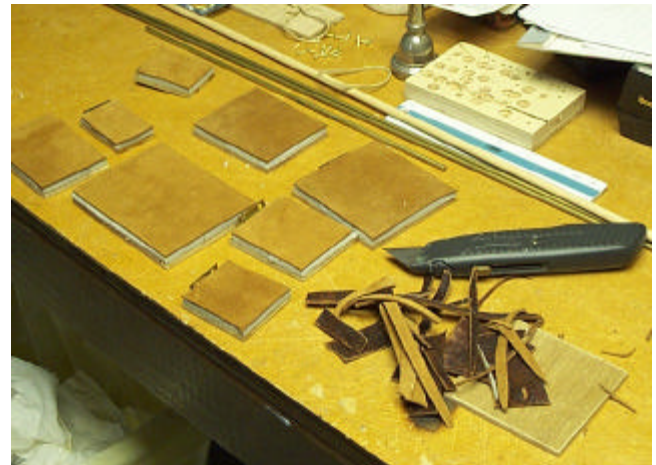
all keys with foam attached, ready for leather pads

- Attach the foam to the key, and then attach the pad material to the foam. Use a razor knife to trim all excess foam and pad around the edges of the key.

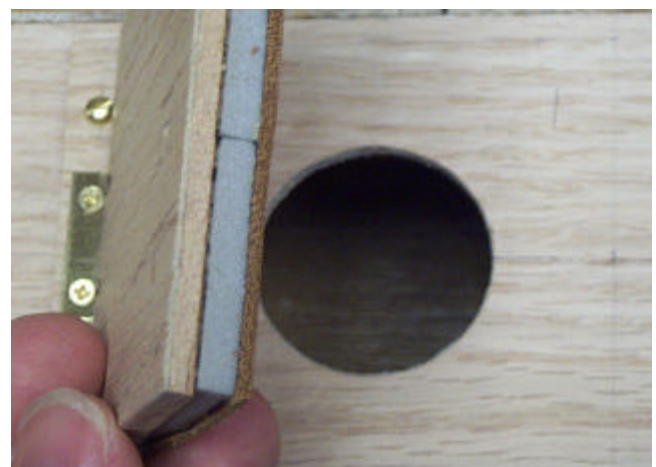


leather pads glued to keys

- Note: If the locally available plywood and foam thickness do not match up as required, the space between the hinge plate and the hinge block can be either built up with thin cardboard, etc; or trimmed as required to adjust the key-to-BOC body distance.



leather pads and foam after trimming



completed key, showing foam and pad layers

Box-O-Cleide Construction



varnished BOC body, hinge blocks mounted & ready for keys
- Note that this photo shows the hinge block for hole #2 in its original orientation; it was later moved perpendicular to the bore centerline and mounted to the side of the 'Up Tube'

- Apply a coat of varnish to the top and edges of the keys, being careful to avoid getting varnish on the foam, pads or hinges.



varnished keys, ready for mounting to BOC

Levers

Each key is operated by a lever, with the exception of the key for hole #9 which is operated by an articulated pair of levers. The levers can be made in many ways, but the BOC prototype used brass rod with a diameter of 5/32" [0.4 cm].

This size rod can be bent fairly easily using pliers and a vise, or even two pliers, and yet is thick enough for small wood screws to pass through holes drilled in it and is stiff enough to resist unwanted bending during use. Steel wire or copper wire might also be suitable.

- Make each lever by laying the rod flat against the key, with the end of the rod aligned with the end of the key opposite the hinge; note that for holes 2 & 3, the rod must extend beyond the edge of the key to overhang the side of the BOC body by about 1/4" [0.63 cm]. Mark the rod at two points just to either side of the edges of the hole. Use the edge of a file to make small flat spots on the rod where the two marks are. Drill holes through the rod at these points; the flat spots will help the drill get started without slipping off of the curved surface. Use the smallest diameter wood screws available, with enough length to go through the rod and penetrate the entire thickness of the plywood; it is OK if the screws extend slightly into the foam. The prototype used extra screws that came with the hinges. The holes in the rod should be just barely large enough for the screws to pass through.



typical key lever, showing its mounting to the key

- Mount the rod to the keys with the two screws (in order to establish the threaded holes), then remove the screws in preparation for bending the rod to shape.

- Mark the front surface of the BOC body between holes 6 & 8, at a position 83.125" [211.14 cm] from the receiver, or

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3.5" [8.9 cm] towards the bell from the center of hole #6. This will be the location of the 'button' on the lever for key #6. Make two more marks 1" and 2" [2.5 cm & 5 cm] towards the bell from the first mark; these will be for the buttons on the levers for keys 8 & 9. The lever for key #7 will wrap around the back of the 'Up Tube' and its button will be centered over player side of the 'Down Tube' at a point 1" [2.5 cm] towards the bell end from the center of hole #7. The button location for key #5 will be the back side of the 'Up Tube', towards the edge of the side that hole #7 is on, at a point 3.5" [8.9 cm] towards the bell from the hole's center. The buttons for keys 1 - 3 will be 3/4" [1.9 cm] apart, centered with hole #2, along the centerline of the 'Up Tube'. The button for key #4 will be towards the edge of the side that hole #7 is on, and about 3/4" towards the 'Bottom Bow' from the position of the button for key #3. Hold the BOC and see if these button marks can be covered with the fingers, and adjust slightly as required. Buttons 1 - 4 are operated by the fingers of the right hand, and button 5 by the thumb of the right hand. Buttons 9, 8, 6 are operated by the first, second and third fingers, respectively, of the left hand, and button 7 is operated by the thumb of the left hand.

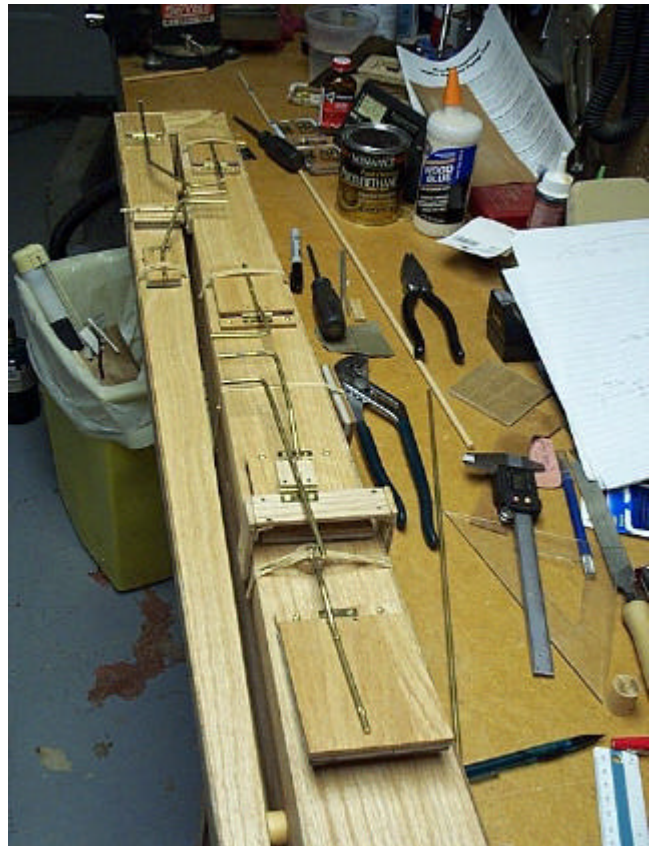


positions of the levers for the right hand

- Note: A less common, yet historically valid, alternate fingering system has the lever for key #7 wrapping around the front of the instrument, instead of the back, with the button between those for keys 6 & 8; in this case all four

buttons are operated by the fingers of the left hand and the thumb does nothing except hold the instrument.

- For the levers of keys 1 - 8, the rods will be bent as required to reach from the keys to the marked button positions, with the buttons about 3/4" [1.9 cm] above the surface of the BOC. Start by holding a lever's rod against the key so that the drilled holes are aligned with the threaded holes in the wood, and determine where the first bend should be; the first bend will always be even with the center of the hinge's axis. Using pliers and a vise or a second pliers, bend the rod at this point so that it angles up slightly from the key. The idea is to figure out what angle will have the key's pad move at least 1/4" [about 0.6 cm] away from the surface of the BOC when the lever is pressed down about 1/2" [about 1.3 cm] from its normal position. The angle will be similar for most keys. For some keys such as 1, 4, 5 and 7, it will also be necessary to bend the lever sideways at this same point. Once the first bend is made, determine any other bends as needed, mark their locations, and bend to suit until the proper shape is achieved. Note: for all levers, estimate the overall length of rod required and cut to suit; after all bends have been made, trim off any excess length at the button ends.



positions of the levers on the front of the BOC

- Mount the levers to the keys, and slip 1/2" [1.3 cm] of rubber or plastic tubing over the button ends until even with the end of the rod. The tubing will provide a larger and more comfortable surface for the fingertips to press against,

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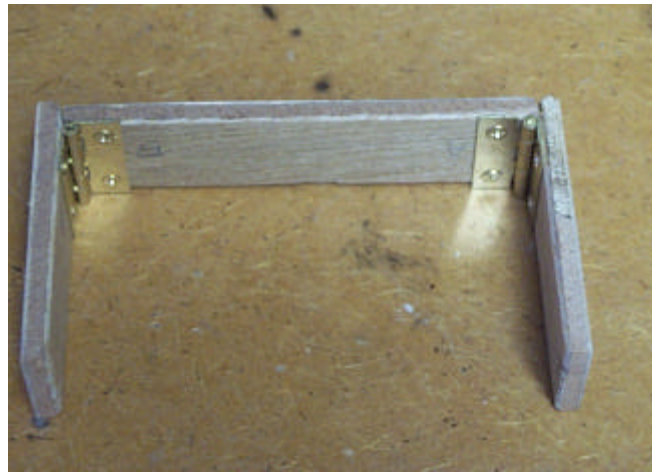
and will also act as bumpers where the buttons contact the surface of the BOC when they are pressed. Double check all lever action, finger positions, and minimum required key opening clearances, and make adjustments to the levers as required.



positions of the levers on the back of the BOC

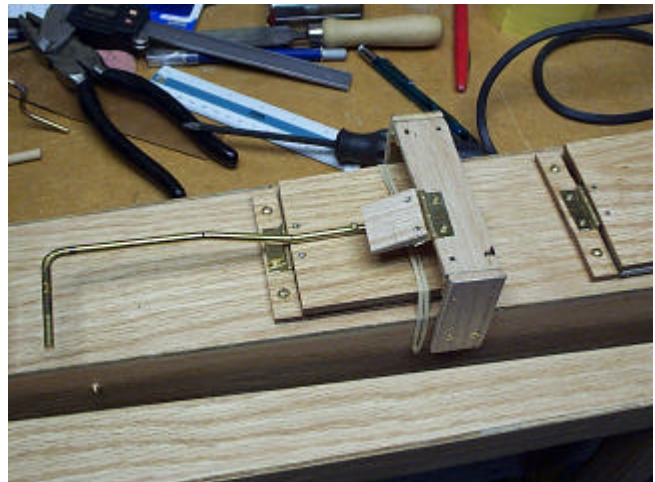
- The lever for key #9 will not be operated directly by a finger. Bend it so that it ends about $\frac{3}{8}$ " [1 cm] above the surface of the BOC, at a point 4.25" [10.8 cm] towards the bottom bow from the center of hole #9, when the non-hinge end of key #9 is about $\frac{3}{4}$ " [1.9 cm] away from the surface of the BOC. Use a stack of felt furniture pads, or similar material, as a bumper under the end of the lever. Drill a small hole sideways through the lever at a point about 1" [2.5 cm] from the end; the hole should be sized to accommodate a small wire paper clip or similarly sized piece of steel wire (the wire used when assembling the trapezoids into the tube sections is a good choice). Note that this lever must be offset from the center of the key by about $\frac{1}{2}$ " [1.3 cm], so that it would pass parallel to the lever for key #8 if it were longer.

- The second lever for key #9 will pass over the key for hole #8, and its pivot point will be above that key. Make a 'bridge' from 1" [2.5 cm] wide pieces of plywood, so that the bottom side of the bridge passes 1" above the surface of the BOC. Use wood screws to secure the bridge to the body of the BOC, so that it can be easily removed should it



bridge for the second lever of key #9

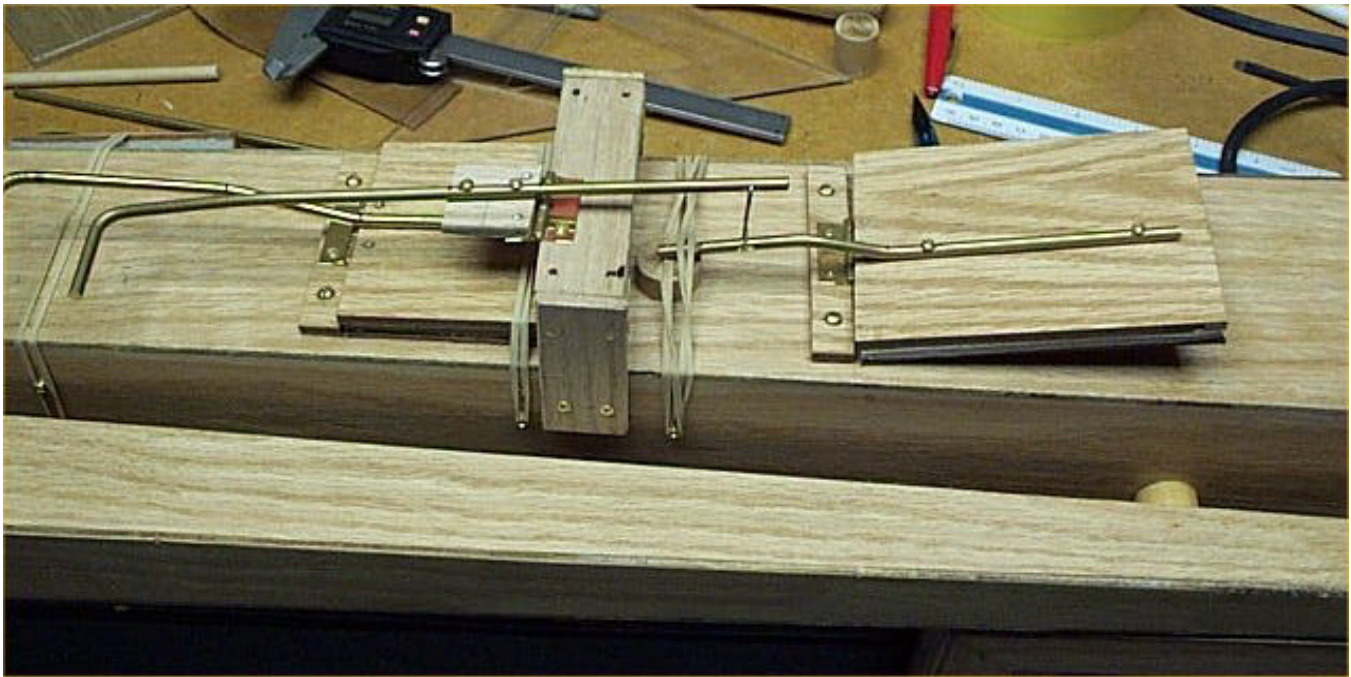
become necessary to service key #8. The prototype used two extra hinges as brackets at the corners of the bridge, but any small 90 degree metal brackets will work. Make a 1" [2.5 cm] square piece of plywood (the 'flap') and attach it to the bridge with a hinge, using the same method as with the key hinges. The second lever can be a simple straight piece with a 90 degree bend at one end for the button. Position it over the flap so that the lever's button end is aligned with the button mark on the body of the BOC, and the other end is in line with the short lever attached to key #9. Attach the lever to the flap with two screws in the same manner as the levers were attached to the keys.



key #9 bridge with 'flap' attached via a hinge

- Observe the location of the hole in the short lever attached to key #9, and make a mark on the second lever immediately above that hole. Cut off any excess length of the second lever $\frac{1}{4}$ " [0.6 cm] beyond mark, and drill a similar hole in the second lever at the mark. With the key's lever touching the felt pads and the button of the second lever the same distance from the surface of the BOC as the adjacent buttons, measure the distance between the drilled holes in the two levers. Bend a piece of wire to pass through the holes and keep the two levers this distance apart. Bend

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detail showing levers for key #9

the wire over so that it cannot come out of the holes. With the two levers for key #9 articulated in this manner, press the button and observe the movement of the pad towards the surface of the BOC; the pad should contact the surface completely with the button still about 1/4" [0.6 cm] above the surface of the BOC, and when released the button should be the same height as the adjacent buttons when the key's short lever is touching the felt pads.

- Fit the rubber bands to the keys, finding a balance between the tension required to hold the pads flat against the surface of the BOC and the fingertip pressure required to move the keys. For keys 1, 4, 5, 6 and 8 the rubber bands will simply pass over the key near the non-hinge end and wrap around the sides of the tube. For keys 2 & 3, the rubber bands will hook into a notch filed into the end of the lever where it passes beyond the edge of tube, and will continue down the side of the tube and possibly wrap around to the next side as required. Key #7 will be sprung similarly, with the rubber band being hooked into the lever or around a screw placed in the key itself. For key #9, the rubber band will pass over the first lever where it rests on the felt pad (it may be necessary to file a notch on the rod to prevent the rubber band from slipping off), and will then wrap around the body of the BOC just as with the majority of the other keys. All rubber bands should be test fit, marking the tube at the ends of the bands, and then placing small screws to anchor the ends.

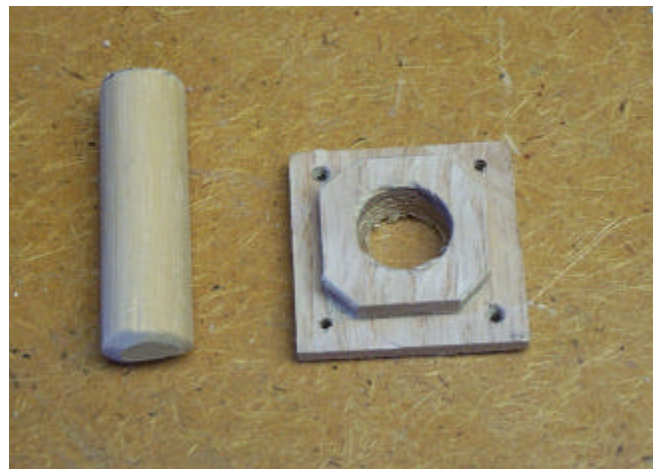
- The BOC will be playable at this point in its construction.

NOTE: for a nicer appearance, remove the rubber band screws and replace them with small dowels glued into the drilled out screw holes.

Attachments

To facilitate playing of the BOC, three small assemblies must be made and attached to the instrument; the neck strap hook, the thumb rest/hook, and the bottom bow bumpers.

- The thumb rest/hook attaches to the 'Down Tube' adjacent to the button for key #7, and allows the player's left hand to support much of the BOC's weight and to stabilize the instrument during playing. It is comprised of a 1.25" [3.17 cm] square piece of plywood, and another piece 7/8" [2.22 cm] square, plus a 1-3/4" [4.44 cm] long piece of 1/2" [1.27 cm] diameter dowel. Cut the corners off of the smaller square in order to allow enough room for the four mounting holes and the heads of the screws that will pass through them. Glue the two square together. When dry, drill a hole through their center to accommodate the dowel, then glue



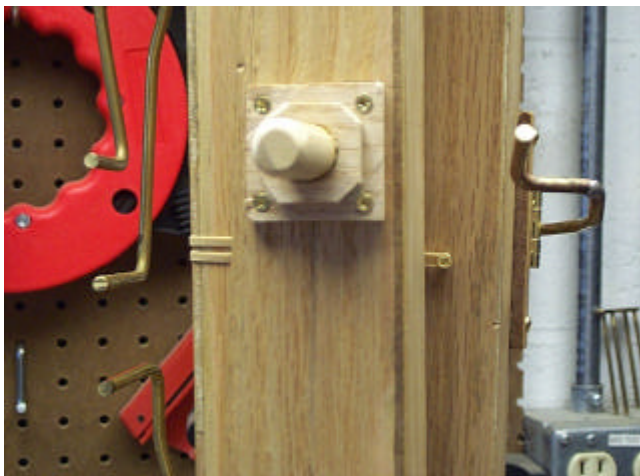
pieces of thumb rest/hook prior to assembly

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the dowel into the hole. Mount the assembly to the 'Down Tube' at the position indicated above and in the photos; make sure to test the fit while holding the instrument before committing to the final position.



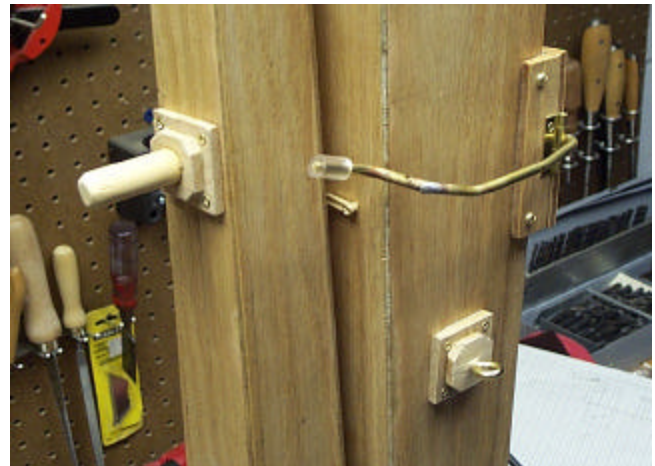
thumb rest/hook prior to mounting on BOC



thumb rest/hook mounted on BOC

- The neck strap hook is almost the same as the thumb rest assembly, except a brass eye hook is screwed into the wooden squares in place of the dowel. A neck strap such as might be used for a saxophone or bass clarinet will attach

here and can help take the most of the weight of the BOC off of the player's left hand. Mount it to the player side of the 'Up Tube' at a point 3-1/4" [8.25 cm] below (towards the bottom bow) the center of hole #7.



thumb rest/hook and neck strap hook

- The bottom bow bumpers provide protection for the instrument when the player rests it on the floor, and they also protect the end of the lever for key #3 where it extends beyond the body of the instrument. Make two bumpers, each from two layers of plywood, glued together and then glued to the bottom of the instrument. Note that the BOC will barely balance on the bumpers if the mouthpiece is removed. For more stability, the builder may choose to make the bumpers longer so that they extend beyond the instrument by a couple of inches to either side.



bottom bow bumpers

Playing the BOC

- The BOC plays just like an ophicleide, and for the most part uses the same fingerings as any historic example. However, as with most ophicleides, there are some notes that just are not quite right with the conventional fingerings. In such cases, the player must experiment with alternates

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and cross fingerings to get the notes into correct pitch or to improve the timbre of certain slightly muddy sounding ones. The prototype has problems with the range of notes between the E and C in the middle of the bass staff; the commonly published fingerings just do not produce the right notes. The author has resisted making adjustments to the holes associated with these notes, since common alternate fingerings that have proven useful on other ophicleides also bring these troublesome notes reasonably into tune (relative to the instrument). The player is advised to experiment with opening one or more of the left hand operated keys in conjunction with these notes.

- The prototype BOC plays well enough in tune with itself to be useful in learning to play the ophicleide, and also as a demonstration and/or educational instrument. It's overall intonation, coupled with its inability to be tuned to a given pitch standard, makes it unsuitable for use with other instruments.

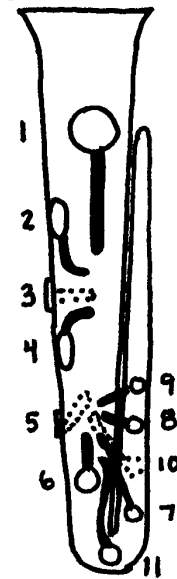
- Don't stop with the BOC! If you find you like playing an instrument of this type, look into acquiring a real historic or replica ophicleide. Refer to the Serpent Newsletter or the Serpent Website for information on finding makers and dealers. Ophicleides are also often found for sale on the Internet, through auctioneers such as eBay.



detail of key #9 lever pads and articulation

B \flat Ophicleide Fingering Chart

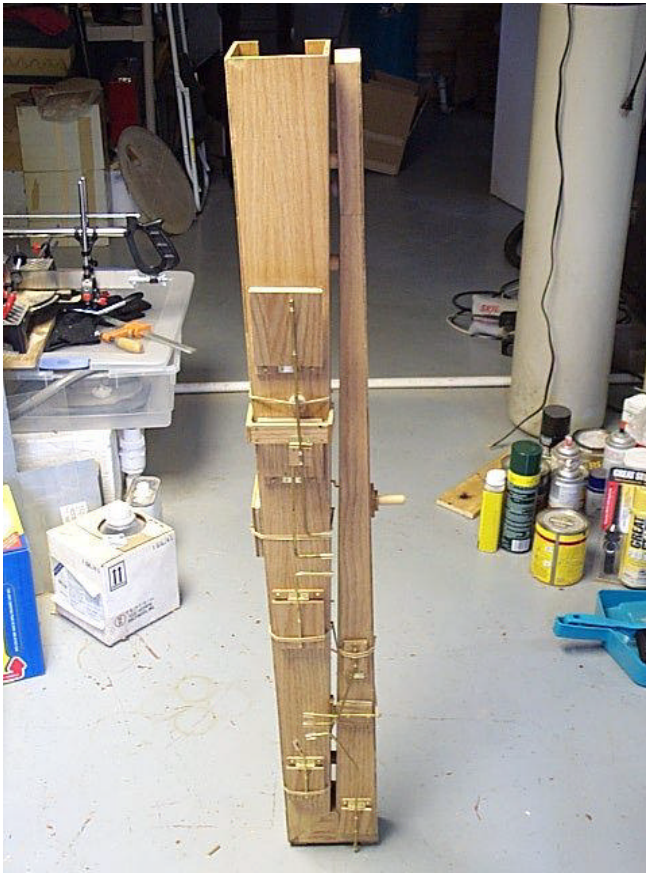
A	B \flat	B	C	D \flat	D	E \flat	E	F	G \flat	G	A \flat
1	0	2	2 3	2 3 4	5	5 6	5 1 6 5 7 6 7	7	5 7 7 8 8	8 10	9
A	B \flat	B	C	D \flat	D	E \flat	E	F	G \flat	G	A \flat
1	0	2	2 3	2 3 4	5 2 3 3 4 4 5 5	5 2 6 3 4 4 5 6	1	0	2	2 3	2 3 4
A	B \flat	B	C	D \flat	D	E \flat	E	F	G \flat	G	A \flat
0	2	3 2 3	1 2 3 3 4	0	2 2 5	1 2 3	0 7	2	2 3	2 3	2 3 4



All Ophicleides have at least 9 keys. Some have 10 or 11. Where a number is listed in this chart, it means to press the key. This opens the hole, except for key #1 where the hole closes when the key is pressed. For the ophicleide in C, shift fingerings right by two pitches, e.g; no keys pressed for low C.

*ophicleide fingering chart taken from the Serpent Website. **Note that the key numbering is reversed** from the rest of this article, and that alternate fingerings applicable only to 11 key instruments are also shown*

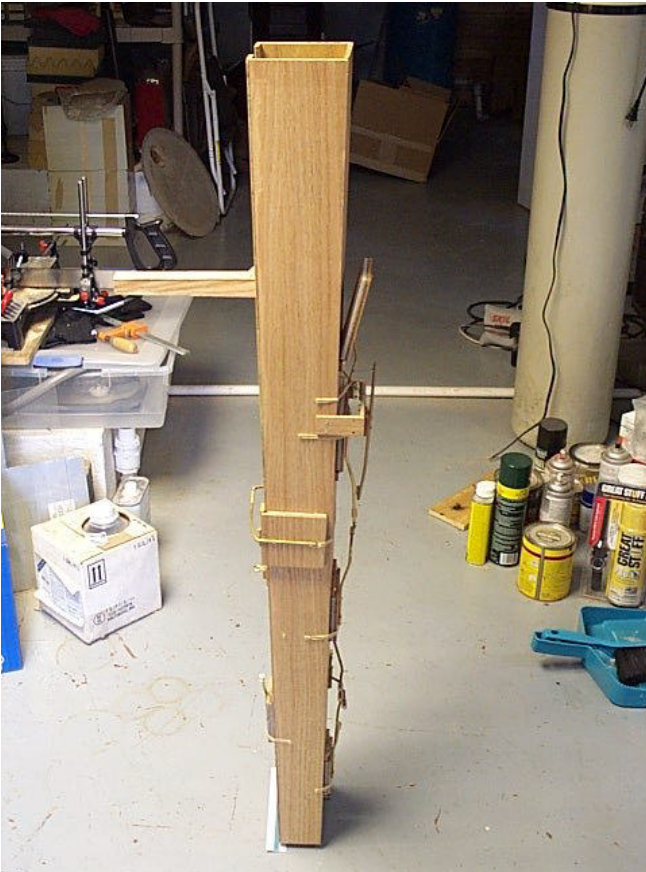
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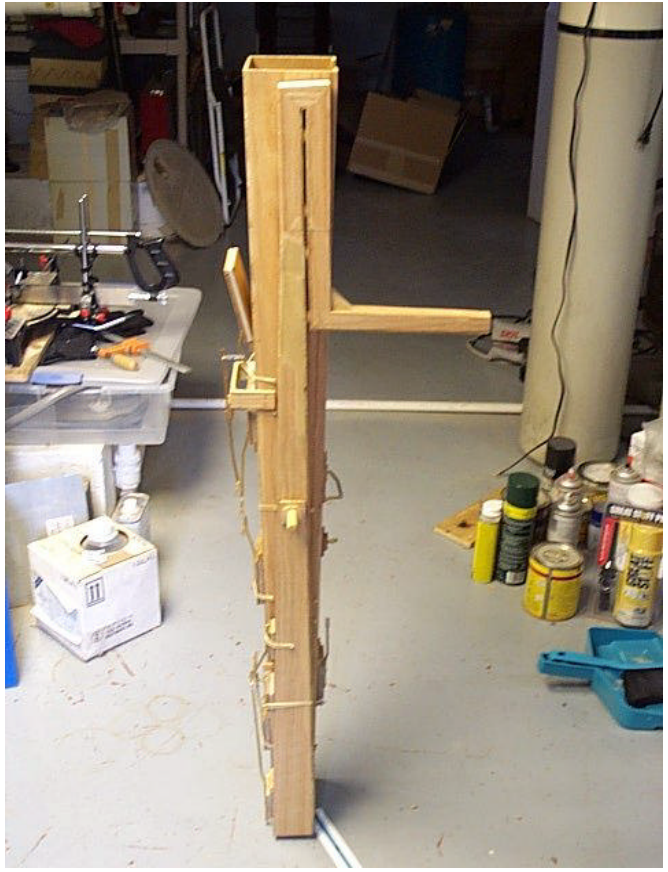
front view of completed BOC



back view of completed BOC



right view of completed BOC



left view of completed BOC

Box-O-Cleide Construction

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