Chamorro Sailing Canoe Fabrication

Instructional Videos

Version 1.1

500 SAILS

Contents

Introduction

These written instructions, along with the accompanying videos, drawings, and information sheets, are all that someone who has experience building things out of wood and using power tools needs to build a 15-foot Chamorro sailing canoe. Short videos are provided to demonstrate how the activity being described is done. Documents available for download include useful drawings, lists of tools, and lists of materials including where they can be purchased.

While it is possible for a single person to build a canoe, it is far easier to build a canoe as a team of 2 or more people. There are also times when two or more people are needed to move heavy things. Of course, a resourceful person can always figure out a way to do things without help.

These instructions and the accompanying written documentation and illustrations are available free of charge on the 500 Sails website at http://www.500Sails.org with the simplest of registrations – we only ask for a name, location and email address. The registration will give you access to the downloadable materials, allow you to post and reply to messages on the discussion forum, and to provide feedback that will help us improve and expand this work.

These instructions and accompanying materials are also offered without warranty of any kind. Use them at your own risk. We cannot guarantee your success in building a canoe – that depends on you, your abilities, and your determination. Building a sailing canoe is a complex process that is not easy to describe. But every effort has been made to make the instructions as easy to understand and follow as possible. Be sure to read this entire manual and watch the videos before you start to build. Then read each section carefully, ensure that you understand what you'll need to do and have everything you'll need ready, before building what that section describes. If you have questions, we have provided an online discussion forum where you can ask for help and hopefully provide help to others once you've completed your canoe.

The materials that you need can all be purchased online if you don't have suppliers near you. Materials sheets are provided that tell you not only what you need, but also where to buy them. Sails are available from 500 Sails.

We hope you enjoy the process of building your canoe. As you'll soon find out, there is nothing like the thrill of sailing a fast Chamorro canoe built with your own hands!

Acknowledgements

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Historic Context

The Western world first saw a Chamorro proa in the year 1521. An eyewitness on that day wrote of the Chamorro and their proas, *"Their amusement is to go with their women upon the seas with those small boats of theirs. Some are black, some white and others red. At the side opposite the sail, they have a large piece of wood pointed at the top, with poles laid across it and resting on the water...the sail is made from palm leaves sewn together and is shaped like a lateen sail. For rudders they use a certain blade like a baker's peel that has a piece of wood at the end. They can change stern and bow at will and those craft resemble the dolphins which leap in the water from wave to wave..."*

What the Europeans saw that day were sailing vessels that were not less than four times faster than their ships. The Chamorro sailing canoes were unlike anything the Europeans had or had seen anywhere. Time and time again, Europeans would write about how the proas could be sailed in either direction, with two bows and no stern, how the wind was always on the same side of the canoe, now extremely narrow it was and how there was a second, smaller canoe attached to the side. Most of all, they wrote about its amazing speed. The Chamorro proas were so fast that they would hydroplane and fly over the water so fast that they became known as "flying proas".

In the centuries following that first visit, many more Europeans stopped in the Chamorro islands and often they left a record of their visit in their logs, journals and letters. When they wrote about the Chamorro, they always wrote about the flying proa. In the first-contact literature, the Chamorro people and the flying proa are inseparable. This is because the proas were at the heart of Chamorro social structure. They were used for fishing, warfare, travel between the Chamorro islands and for trade overseas. The men who built them and sailed them were highly regarded and admired in Chamorro society. The proas were critical for survival. Young boys learned by building small model canoes, followed by bigger ones, until finally they were allowed to build large canoes that could be sailed. To be involved in building and sailing proas brought prestige. In Chamorro society, only the Matua, the highest-ranking social caste, were allowed to build and sail the proas.

In the 1500s Chamorro society was thriving. An estimated 60 thousand Chamorro were living throughout the 14 Chamorro islands. They traveled at will, up and down their islands in sailing canoes of up to 52 feet in length, from Guahan to Muag, stopping at Luta, Tinian, Saipan, Anatahan, Sarigan, Guaguan, Alamagan, Pagan, and Agrigan along the way. They sailed their canoes far beyond their shores to trade with Carolinians a thousand miles to the south. They built their canoes by hand using stone and shell tools, out of the limited materials found in their island environment. They made the hulls out of lemmai trunks,

masts, booms, amas, outriggers and paddles out of hardwood and bamboo, lines out of coconut fibers, and they sometimes wove their sailcloth so fine that it resembled silk.

To know the history of the Chamorro sailing canoes is to see back into time, to an era when the Chamorro were free and healthy in their own land, and sailed beautiful, fast canoes made with their own hands. In the initial encounters with the Europeans, the arriving ships would be met by hundreds of canoes. When the Spanish ship *San Pedro* stopped at Guahan in 1565, an estimated 400-500 of them surrounded the ship.

The sakman existed in large numbers when the Chamorro formed a nation - before the Spanish turned the Chamorro against each other and managed, with the help of European diseases, to systematically destroy Chamorro society in the name of religious enlightenment. Key to their continued success in suppressing the Chamorro was the suppression of the sailing tradition. The Spanish forbade the Chamorro to venture offshore. They forced them off all their islands except Luta and into designated villages on Guahan where disease and despair killed most of them. The Matua who resisted the Spanish were killed and the knowledge of how to build and sail the flying proa died with them.

Today the Marianas is undergoing a rebirth of maritime traditions. From no Chamorro sailing canoes for over 250 years, today in Saipan alone we have 14 canoes, ranging from 15 feet to 47 feet in length. More are being built every year, and more people are learning to build and sail them. This video series will allow you to build your own Chamorro canoe, a 15-foot duduli. It is the smallest of the Chamorro canoes described in the historic record. In fact, we know very little about the duduli except for its length and the fact that it was a proa. To build a replica of this canoe, we based its design on the sakman design as depicted in the "Anson" drawing of a 40- foot Chamorro Sakman that was captured by the English in 1742, disassembled, measured and drawn in blueprint form by a skilled nautical draftsman. The duduli differs where necessary to accommodate its much smaller length.

The Anson drawing shows a Chamorro sakman that was capable of speeds exceeding 20 miles per hour in the 16th century. It is characterized by a very narrow hull that is asymmetrical, having one side of the canoe severely flattened while the opposite side is well rounded. The sail is unusually large in relation to the hull. The outrigger is also narrow and is attached to the hull with thin spars lashed together using triangular patterns that give it strength and flexibility. The proa has no rudder, but is steered using a long handled steering paddle. There is no stern, but rather two bows. The mast is stepped at the middle point between the two bows but up against the inside of the gunnel on the outrigger side. The mast can be raked forward by adjusting the rope stays that secure the mast to the bows. A third rope stay secures the mast to the outrigger so that it does not fall to leeward, and a wood spar between the mast and the outrigger prevents the mast from falling to windward.

The Chamorro proa, like all Micronesian proas, is sailed with the outrigger facing the wind. To change direction across the wind, the crew moves the base of the forward yard to the opposite bow and they face the new direction and steer from the former bow that is now at the rear of the canoe. This tacking maneuver is unique to proas.

Like the sakman, the duduli has an asymmetrical hull with a more rounded side facing the wind, and a flatter side facing leeward. Under way, the leeward side of the hull acts like a sea anchor to resist downwind drift. The sail shape is different in order to provide more sail area. It is taller and with the mast raked forward, the angle of the clew is greater, allowing for more sail area at the foot. The yard of the sail is set at the extreme edge of the bow allowing for a wider sail. These design changes give the duduli a very large sail to hull ratio, which is needed for a canoe with a small hull.

Like the sakman, the duduli is steered with a paddle, but unlike the sakman where the paddle is braced against the side of the hull, the duduli has a short spar that extends out of the leeward hull to brace the paddle. It also used only two spars to hold the outrigger rather than three. This provides the clearance needed to paddle the canoe when there is no wind.

The duduli can be sailed easily by one person and can carry up to three adults. It is ideal for sailing in protected waters or in the ocean near the shore in fair weather. To build a Chamorro proa with modern materials we will use the KSS method of fiberglass boat fabrication developed by yacht designer and builder Derek Kelsall. KSS uses a flat table to infuse fiberglass panels that can be bent to form hulls and outriggers. This method provides a relatively easy to learn and inexpensive approach to boat building that is well-suited for building a “one-off” canoe.

Definitions

Glass – As a noun, glass refers to fiberglass fibers, rolls, and fiberglass products. As a verb, it means to apply fiberglass and resin to something, usually rigid foam or wood.

Glass panel – A rigid foam panel that has been glassed on both sides to create a strong fiberglass panel that resists bending.

Infuse – To apply resin to fiberglass under a vacuum is referred to as infusing or vacuum infusion.

KSS – “Kelsall Sureswift Sandwich”. Developed by Derek Kelsall in the 1950s, KSS is a method of vacuum infusion on a flat table in order to fabricate 2-dimensional fiberglass panels that can be bent to form 3-dimensional shapes.

Laminate (verb) – To apply resin to fiberglass by brush or roller. Also called hand-laminating.

Laminate (noun) – A laminated surface.

Scratch-sand – To use rough sandpaper to scratch a surface in preparation for lamination. This is routinely done on cured resin surfaces where a chemical bond is not possible. Resins can bond physically to a scratched surface.

Semi-glass panel – A rigid foam panel that has been glassed on one side only, to create a panel that can be bent away from the glassed side. Semi-glass panels are scored and bent to form hulls and luchas.

Special Materials Used in Boat-building

Rigid PVC Foam

Rigid PVC (Polyvinyl Chloride) structural foam is used as a core material between two layers of fiberglass fused to the foam with resin. By itself, rigid foam is extremely resistant to compression but can easily be snapped in two. If a layer of fiberglass is fused with resin to just one side of the foam (semi-glassed), it can be bent away from the fiberglass to a significant degree without breaking. But if both sides are fused with fiberglass, the resulting glass panel is very strong and resistant to both bending and compression.

Rigid foam comes in sheets. We use ½" x 48" X 96"H-80 Divinycell Plain Sheets in most of our canoes. Big canoes need thicker foam. We use 1” thick foam for 40’ and larger canoe hulls and luchas.

Fiberglass

Fiberglass is literally glass fibers. The thicker the fibers, the stronger. The longer the fibers, the more flexible they are before they break. Resins are used to fuse the fibers to materials such as wood or rigid foam to create fiberglass panels, hulls and other objects.

Fiberglass for the most part comes in rolls. Uni-directional rolls have the fiber running the entire length of the roll. Bi-directional and tri-directional fiberglass have fibers laid out in layers with differing orientations. Thin fiberglass thread holds the fiberglass fibers in place within the roll. Chopped strand fiberglass also comes in rolls, but the fibers are short, usually an inch or two long, with each fiber randomly aligned. Fiberglass is described by the fiber orientation and the weight in grams or ounces, e.g., “400-gram uni-directional”. 500 Sails uses four kinds of fiberglass:

Uni-directional

Long glass fibers laid out in one direction only. The fibers resist stretching or compressing in the direction of the fibers, but provide almost no strength against forces that are at 90 degrees to the fibers (sideways). Unidirectional glass is used to give strength strategically, such as along the length of a hull so that the hull has lengthwise resistance to bending. It can also be layered in differing fiber orientations to create bi-directional or tri-directional glass.

Bi-directional

Two sets of long glass fibers laid out to cross each other, usually at 45°, 60°, or 90° degrees. Bi-directional glass provides strength in all directions, but strongest along fibers.

Tri-directional

Three layers of long glass fibers laid out to cross each other. For example, the first layer with fibers that run the length of the roll, a second layer at 90° to the first layer, and a third layer laid out at 45° to both layers. Tri-directional glass provides strength in every direction.

Chopped Strand

Chopped strand fiberglass consists of individual fiberglass strands a few inches in length laid randomly in a styrene binder. It is used for impact reinforcement and as a surface layer in a stack of fiberglass where it serves to conceal fiber orientation patterns below. It is weak as a flat layer because the fibers are short. It is also inexpensive.

Resins

500 Sails uses both laminating and infusion polyester resins in boat building. Laminating resin is a viscous (thick) resin that is applied with a brush. Because it has a syrup-like viscosity, it tends to not drip when applied. Infusion resin is thinner and used in vacuum infusion. Infusion resin is pulled into a vacuum created under the vacuum bag and because it is thin and watery, it moves easily through layers of fiberglass and through holes and channels in rigid foam core materials. Both laminating and infusion resins are liquid until mixed with Methyl Ethyl Ketone Peroxide (MEKP) that causes them to harden. The speed that the resin hardens is dependent upon the temperature of the room and the amount of MEKP mixed in. Hardening time is controlled by using more MEKP for faster set times, and less for slower set times.

Polyester resin can also be mixed with powdery fillers to make thicker resins for different purposes. Hollow glass microspheres (glass bubbles) are added to resin in order to reduce both weight and sanding effort. Fumed silica (marketed as *cab-o-sil* and *aerosil*), is used to create a very strong glue-like resin. Both can be mixed together with resin to create a strong glue-like resin that is less prone to cracking under stress due to the microspheres.

Gelcoat

Gelcoat is a polyester-based final surface coat used like paint. Gelcoat is mixed with a liquid wax that allows it to cure without stickiness. Gelcoat is liquid until MEKP is added to initiate hardening. As with other polyester resins, the amount of MEKP used affects hardening time.

Special Tools Used in Boat-building

Infusion Table

The infusion table is used to fabricate flat fiberglass panels by pulling resin through layers of fiberglass and rigid foam under a vacuum, saturating the fiberglass and bonding it to the panel. The resulting fiberglass panels may be used flat or they may be bent to create shapes. If they are to be used flat, then both sides of the panel are glassed. Bendable fiberglass panels are glassed on only one side of the rigid foam panel. Flat panels are used for seats, decks, bulkheads, and the gunnel. Canoe hulls are made from two bendable panels that are bent into half hull shapes and then connected together to form a full hull.

The table is strong enough to hold the weight of workers who are preparing the table and laying out the layers. It has a stick-resistant surface so that the panels are easy to remove after infusion. The table is also used to support the wooden hull jig that is used to bend semi-glass panels.

Hull Jig

The hull jig is made of a series of rectangular wooden frames called stations, placed next to each other at regular lengths that together are the length of the hull to be built. The stations support plywood shapes that define the inside shape of the hull. Bendable flat panels for each half of the hull are placed in the jig and bent to shape using ratchet straps. Once the shape has been achieved, the inside surface of the bent panel is glassed to hold the shape.

Lucha Jig

The lucha jig is a long rectangular wooden frame that is the same length and width of the lucha. A bendable fiberglass panel is pushed into the jib to form the bottom and sides of the lucha in a U shape and glassed on the inside to hold the shape. This U-shaped panel will be further worked to create the pointed ends of the lucha and a top will be added later.

Vacuum Pump

A vacuum pump is used for resin infusion using vacuum bagging. Vacuum pumps should be able to pull a vacuum of 20 PSI. 500 Sails uses model M60-1515 2-stage rotary vane pumps that operate on 120v purchased from fiberglasssupply.com. We also hook up two pumps on large infusions that involve a lot of set-up and expensive materials, so that if one pump fails the other can be turned on to take over.

Resin Trap

Fiberglass infusion involves liquid resin that moves from a bucket into the piece being infused under a sealed vacuum bag. That piece is in between the bucket and the vacuum pump. Excess resin that leaves the piece and moves toward the vacuum is caught in the resin trap so that it does not enter the pump. A resin trap will have two nozzles, one that connects via PE tubing to the vacuum pump, and one that connects via PE tubing to the vacuum bag. It may also have a vacuum gauge that shows how much negative pressure is under the vacuum bag. 500 Sails uses model M60-3020 1.7-gallon resin traps with a vacuum gauge from fiberglasssupply.com.

Polyethylene Tubing

Flexible polyethylene tubing (PE tubing) is used to carry resin from buckets into vacuum bags and to carry air out of vacuum bags toward the vacuum pump.

Spiral wrap, which is PE tubing with a spiral cut along its length, is used at the end of the PE tubing when it reaches the piece under the vacuum bag. Because liquid resin bleeds out of the cut sides of the spiral wrap relatively slowly, it allows the resin to be distributed over a larger area rather than to just the location at the open end of the PE tube. Spiral wrap is also used under the vacuum bag to direct air and excess resin to the PE tube that connects to the vacuum. This allows for an evenly applied vacuum.

Polyethylene Tees and Connectors

PE tees and straight connectors are used to connect pieces of PE tubing together. Resin does not stick well to these tees and connectors so they can be cleared of residual resin and used again.

Resin Flow Media

Resin flow media is nylon mesh that allows resin to flow across a piece that is being infused under a vacuum bag. It has a weave pattern that is resistant to compression from the vacuum. Resin flows inside the space that the weave creates. Resin flow media is also wrapped around pieces of spiral wrap to ensure that the pressure from the vacuum bag pressing on the spiral wrap does not close the spiral cuts so that resin or air that needs to move through the cuts does not become trapped.

Build the Infusion Table

The table surface is made with two layers of 4’ x 8’ plywood that are joined together to form a large 4’ x 16’ table surface. The top layer is melamine surfaced plywood. Melamine is a good non-stick surface material to begin with and is made even more so through the use of mold wax. The non-stick surface keeps infused panels fabricated on the table from sticking to the table.

The table is supported with wooden legs or it can be supported by a series of sawhorses, but it must be strong and stable enough to support the weight of the wooden hull jig used to bend panels into hull shapes and people working on top of the table. It should be perfectly horizontal and 30 inches off the ground.

Build the table according to the drawing in figure 1. The key to a successful infusion table is ensuring that it does not allow air to escape through the table-top during vacuum infusion. To build an air-tight table top, brush all the plywood pieces clean of dust and grit, and then apply thick lines of gorilla glue in a grid pattern between the top and bottom layers of plywood and in the seam between adjacent sheets of plywood. The glue in the seam should be spread evenly on both edges of the plywood before pushing them together and securing them with wood screws. The glue will act as a gasket, blocking air movement. Screw the two layers of plywood together using wood screws that go through the lower plywood layer and into the top melamine plywood layer. Be sure that the screws go at least half way through the top layer but do not push against or break through the melamine surface. The two layers should be screwed together tightly and while the glue is still soft. The seam between the pieces of melamine plywood in the top layer should be even with the two sides, with no bumps or indentions.

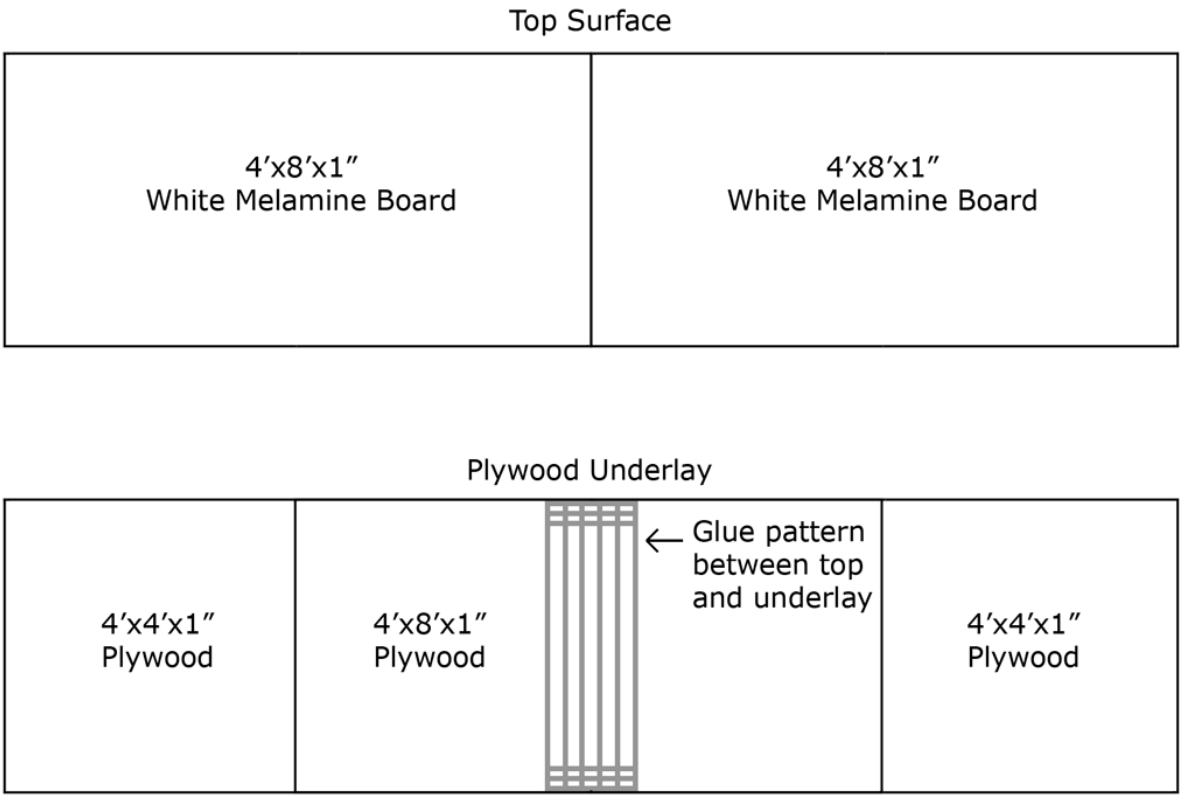


Figure 1- Infusion Table Plan

Draw the Hull Template on the Infusion Table

The *Hull Template Lines* drawing shows the template that is to be drawn on the surface of the infusion table. The red rectangle with numbered parallel lines inside is a reference grid that will be used to locate plot points that will be marked with pencil dots, and lines will be drawn connecting the dots to create the hull template outlines (purple). These outlines show the dimensions of materials that need to be cut and put on the table, as well as triangular areas on the resulting infused panels that will need to be cut away (black) in order to allow some of the bending needed to create a 3-dimensional hull shape.

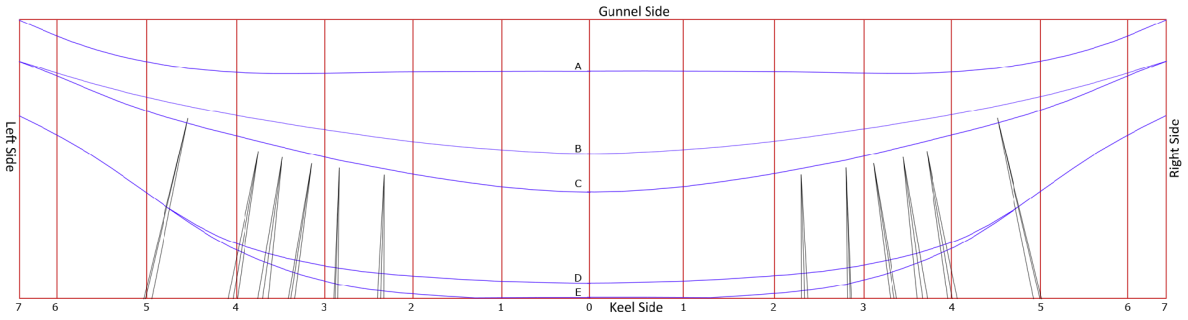


Figure 2 - Hull Template Lines

The Hull Template Lines drawing above is a small version of the drawing in the file *Hull Template Lines.pdf*. Open that file and print it if possible since it shows far more detail.

Before drawing the template pattern on the infusion table top, be sure it is clean and that the seam between the two pieces of melamine plywood is covered with brown plastic packing tape. Do not wax the table before drawing the pattern. Start the drawing with a pencil so that any mistakes can be erased and corrected. When you are sure the drawing is correct, overwrite the pencil lines with a black "sharpie" marker. Do not use color markers to match the colors in the drawing. The colors are only used in the drawing to help explain how to make the template. All the template lines need to be black so that they stand out on the white table and can be seen through fiberglass fabric and traced.

Draw the reference grid (red) on the top of the infusion table

Draw a 15 ft. x 43 ½ in. rectangle in the center of the 16 ft. x 4 ft. infusion table. The rectangle will be 2 ¼ in. from gunnel and keel sides of the table, and 6 in. from the right and left sides of the table. Ensure that the rectangle you draw is perfectly symmetrical by measuring the distances between the two sets of opposite corners. If the two measurements are the same, the rectangle is perfect. If not, the rectangle is crooked and will need to be corrected.

Divide the rectangle in half with a line in the middle, across the width. The line will be 8 ft. from each of the long ends. Then every 14 inches from this center line, draw more lines parallel to the first, in both directions, stopping when you are 6 inches from the end of the rectangle.

Label the middle line 0 (zero). Then moving away from 0 to either side, number the parallel lines 1 through 7, with the last line being the one that closes the rectangle. Do the same in the other direction from the 0 line. When you are done, you will have 15 parallel lines. 1 through 7 to the left, 1 through seven to the right, and 0 in the middle.

Mark the four sides of the table with the labels "Gunnel Side", "Keel Side", "Left Side", and "Right Side" as shown in the drawing.

Mark plot points along the references lines (red) and connect them to create the hull template lines (purple) shown

Using the table below, make a dot on each plot point indicated along each of the 15 rows, using the measurements for the numbered rows. Measure starting from the end of the reference line on the Gunnel Side, toward the Keel Side.

- Use a long, flexible stick aligned along the corresponding dots for each lettered template line to trace a long smooth line that touches each dot (it may take several people to do this). This will create the five template lines shown in the drawing in purple.

Template Line	*Plot points in inches along the numbered reference lines as measured from the gunnel side of the table toward the keel side of the table*

	0	1	2	3	4	5	6	7
A. Edge of gunnel	8 ¼	8 ¼	8 ¼	8 ¼	8 1/8	7 3/4	2 ½	0
B. End of glass area for wide hull	21	20 ¼	18 7/8	16 3/4	14	11	7 3/4	6 ½
C. End of glass area for narrow hull	27	25 7/8	24	21 3/8	18	13 3/4	8 3/4	6 ½
D. Edge of narrow hull keel	40 7/8	40 ½	39 7/8	38 ¼	34 3/4	26 3/4	18	15
E. Edge of wide hull keel	43 3/8	43 3/8	42 5/8	40 ½	35 3/4	26 3/4	18	15

Find and mark the triangular areas (black)

The template shows the location of 12 triangular areas (black) that will need to be cut out of the infused flat hulls so that they bend properly. Each triangle has a line down the middle that will be explained later.

The corners of the triangles, as well as the middle line, can be located using the table below. There are six triangles situated near the Left Side of the table, and six situated near the Right Side of the table. It is best to first plot out and draw the six triangles on one side, and then do the six on the other side. Check your work against the *Hull Template Lines* drawing frequently to be sure you're on track.

All the numbers in the table below are inches, except the reference row numbers.

	Triangle #1	Triangle #2	Triangle #3	Triangle #4	Triangle #5	Triangle #6
Plot point 1	32 ¼	39 ½	46 ¼	50 ½	55 3/8	69
Plot point 2	32 3/4	39 7/8	46 7/8	51 3/8	56 1/8	70
Plot point 3	33 ¼	40	47 ¼	52 1/8	56 7/8	70 ¼
Reference line	2	2	3	3	3	4
Plot point 4	24 ½	23 ½	23 3/4	21 2/3	20 3/4	15 ½
Plot point 5	4	11	1 ½	6 1/8	10	7 ¼

Here are the steps to find the plot points and draw a triangle:

- The starting point for the first three plot points is the end of reference line 0 at the Gunnel Side of the table. Pick a side of the table where you will draw the first set of six triangles. From the starting point, draw a dot at the distance indicated in the Triangle # column for each of the three plot points, measuring toward that side, away from reference line 0.

- Find the reference line number listed in the Triangle # column. There are two reference lines in the *Hull Template Lines* drawing with the same number. Find the one that is on the same side of the table where you just drew the three plot points above. The starting point for plot point 4 is the end of that reference line at the Keel Side of the table. From the starting point, draw a dot at the distance indicated toward the Gunnel Side of the table for plot point 4 in the Triangle # column.

- The starting point for plot point 5 is the dot you just drew for plot point 4. From there, pencil a dot at the distance indicated for plot point 5 in the Triangle # column, measuring toward the side, away from reference line 0.

- Now connect the plot points with lines as follows:

    - Draw a line between plot point 1 and plot point 5
    - Draw a line between plot point 2 and plot point 5
    - Draw a line between plot point 3 and plot point 5

    The resulting triangle should match the one shown in the *Hull Template Lines* drawing.

Build the Hull Jig

The hull jig is used to bend the infused flat panels into the shape of the canoe hull. It is a wooden rectangular frame that contains 13 "stations" that together define the shape of the canoe hull from bow to bow (the Chamorro canoe has two bows, rather than a stern and a bow). The stations are positioned in a row, 14 inches apart, and each station is the exact shape of the inside of the canoe hull at that position.

To create a canoe hull, two flat halves of the hull are glassed on the infusion table and scored (long lines cut at a shallow depth) for bending. These two flat halves of the hull are placed in the jig and bent around the stations to give them their 3-dimensional shape. The two halves are then joined together to form the hull.

The drawing of the jig has all the measurements and dimensions that someone with basic carpentry skills will need to build it. Build your jig on a perfectly flat, horizontal surface. Ideally, build it where you plan to use it. That can be on the infusion table provided that table is strong and perfectly level. Cover the infusion table with light plywood or something similar if you use it as a table for the jig to avoid scratching the melamine surface, and when using the jig, cover the table surface with a disposable tarp or plastic sheeting to catch dripping resin.

The white colored pieces need to be attached using removable bolts with washers and nuts. All other connections should be made with wood screws.

The braces, which are the white pieces that secure the faces of the stations to the sides of the frame, need to be moveable so that they can secure the faces of the stations to either

side. The way to accomplish this is to build the frame as pictured with all the stations braced against the front side, which is the longer distance. Then install them again so that they attach to the back side.

When building the jig, bear in mind that the goal is to place the 13 stations in perfect position in relation to each other so that they accurately define the inside of the canoe hull, and to hold those stations in position against the forces required to bend fiberglass panels around them.

Start by building the base of the jig first, with the 13 bases that will hold the 13 stems that will hold the 13 stations. Stretch a piece of thin string over the 13 bases to indicate where the middles of the 13 stems go and use a thin tip permanent marker to mark where the string passes over the bases. Note that this will not be in the center of the 13 bases, but will be offset because the canoe hull is asymmetrical (one side is narrower than the other).

Make the 13 stems and mark a lengthwise centerline on both sides of all the stems, from top to bottom, with a thin tip permanent marker.

When attached to their bases, the stems must be in perfect alignment with each other so that the center lines are perfectly vertical and the ends of the center lines of all the stems touch the lines drawn on the bases. An easy way to do this is to clamp the stems onto their bases and adjust using either a laser or a level to ensure that the center lines are perfectly vertical while the centerlines touch the marks made on the bases before screwing the stems on permanently.

Again, it is critical that the stems all line up along the same base line and that their centerlines are all perfectly vertical. Once they are in position on the base, build the rest of the jig according to the drawing.

Now make the 13 stations.

Each station is made of 5/8 in. melamine plywood. There are two each of stations 1 through 6, and just one station 0 (zero). Station 0 is the biggest. It has the shape of the inside of the middle of the canoe hull, so it goes in the middle of the jig. The other stations from 1 to 6, are progressively smaller, the smallest one, station 6, having the shape of the inside of the bow. One set of six is positioned on one side of station 0, each 14 inches away from its neighbor, in order from 1 to 6. The other set is similarly positioned on the other side of station 0.

Each station shape will need to be drawn onto a piece of melamine plywood and cut out. The tables below have all the information needed to draw the shapes of all the stations. The best approach is to first draw and cut station 0. Then do one each of stations 1 through 6. When these six are finished, it is easy to trace them one at a time onto the melamine plywood and cut them out creating a second one of each.

Here is the process to draw the outline of a station onto the melamine plywood, using Station 0 as an example. Use a pencil so any errors and be erased and corrected:

Draw the base and the centerline of the station using the *Stations Dimensions* table:

- Find an area on the melamine plywood that has enough space for the station's *Total base width* of 15 3/8 in. and *Height* of 26 ½ in. Either locate the width along a straight edge of the melamine, or draw a straight 15 3/8 in. line.

- Divide the width into two sections where the left section is the *Wide side width* and the right *Narrow side width* by making a dot 10 in. from the left side and 5 3/8 in. from the right side.

- Now draw a 26 ½ in. line from the dot you just made away from the edge line at precisely 90 degrees. This is the *Height* of the station. Use an angle ruler or anything available to ensure that this line is exactly 90 degrees off the width edge. The two lines together form an upside down "T".

Draw the left and right edges of the station using the *Edges of Station from Centerline* table:

- Measuring along the centerline starting from the edge, put a dot at each of the heights indicated in the *Height* column. Label these dots with the reference numbers in the *Reference #* column to the left of each height.

- For each *Reference #*, draw two dots, one the *Distance Left* and the other the *Distance Right*, away from the centerline. Use a framing square or anything available to ensure that the measurements are made at precisely 90 degrees to the centerline.

Connect the edge dots:

- Use a flexible metal ruler to connect the dots in exactly the following way:

    - Place the ruler on the melamine on its side (with one long edge down and the opposite long edge up), using a clamp to hold it in this orientation.
    - Position the clamped end of the ruler so that the ruler edge is exactly at the end of the width on the right side. We will refer to this end as the ruler "base". The other end of the ruler will be parallel to the centerline and oriented in the direction away from the edge.
    - Without allowing the base to shift position in the slightest, bend the other end of the ruler so that it touches each dot marking the right edge of the station through to the highest dot along the centerline. Any dot that is significantly off the edge of the ruler while the other dots are not off, is probably in the wrong position and should be re-measured. It is possible that the rule cannot be made to touch all the dots exactly. If this is the case, average it out so that the rule edge is as close to the series of dots as possible while maintaining a smooth, even bend.
    - Trace the edge of the ruler to mark the edge of the station.
    - Do the same now for the left side of the station.

- Cut the station out of the melamine plywood using a jigsaw. Preserve the centerline by tracing over it with a black permanent marker. Duplicate the centerline on the other side.

Station 0

Station Dimensions (in.)	
Total base width	15 3/8
Wide side width	10
Narrow side width	5 3/8
Height	26 ½

Edges of Station from Centerline (in.)			
Reference #	Height	Distance Left	Distance Right
0	0	10	5 3/8
1	4	10	5 3/8
2	8	9 7/8	5 ¼
3	12	9 5/8	5 1/8
4	14	9 ½	5 1/8
5	15	9 1/8	5
6	17	8 7/8	4 7/8
7	18	8 5/8	4 7/8
8	19	8 ¼	4 3/4
9	20	7 7/8	4 3/4
10	21	7 ½	4 ½
11	22	7	4 ¼
12	23	6 7/8	3 7/8
13	24	5 5/8	3 3/8
14	25	4 5/8	2 ½
15	26	3 ¼	1 ½
16	26 ½	1 3/4	7/8

Station 1

Station Dimensions (in.)	
Total base width	15 ¼
Wide side width	9 7/8
Narrow side width	5 3/8
Height	26 3/4

Edges of Station from Centerline (in.)			
Reference #	Height	Distance Left	Distance Right
0	0	9 7/8	5 3/8
1	4	9 7/8	5 3/8
2	8	9 7/8	5 ¼
3	12	9 5/8	5 1/8
4	14	9 ½	5
5	16	9 ¼	4 7/8
6	18	8 3/4	4 3/4
7	19	8 ½	4 5/8
8	20	8 1/8	4 ¼
9	21	7 5/8	4 ¼
10	22	7 1/8	4
11	23	6 3/8	3 5/8
12	24	5 5/8	3 ¼
13	25	4 ½	2 3/4

14	26	3 3/8	1 3/8
15	26 ½	2 1/8	7/8

Station 2

Station Dimensions (in.)	
Total base width	15
Wide side width	9 3/4
Narrow side width	5 ¼
Height	25 3/4

Edges of Station from Centerline (in.)			
Reference #	Height	Distance Left	Distance Right
0	0	9 3/4	5 ¼
1	4	9 3/4	5 ½
2	8	9 3/4	5 ½
3	11	9 5/8	5 1/8
4	14	9 ¼	5 1/8
5	16	9 ¼	5
6	17	8 3/4	4 3/4
7	18	8 ½	4 3/4
8	19	8 1/8	4 5/8
9	20	7 3/4	4 ½
10	21	7 1/8	4 ¼
11	22	6 7/8	3 7/8
12	23	5 5/8	3 ½
13	24	4 5/8	2 3/4
14	25	3	1 3/4

Station 3

Station Dimensions (in.)	
Total base width	15 ¼
Wide side width	9 7/8
Narrow side width	5 3/8
Height	23 5/8

Edges of Station from Centerline (in.)			
Reference #	Height	Distance Left	Distance Right
0	0	9 7/8	5 3/8
1	12	9 ½	5
2	13 ½	9 ¼	4 7/8
3	15	9	4 3/4
4	16	8 5/8	4 ½
5	17 7/8	8	4 ½
6	19 3/8	6 5/8	4 1/8
7	20 7/8	5 3/4	3 3/8
8	22 ¼	2 ¼	2 ¼
9	23 5/8	1 3/8	1 ¼

Station 4

Station Dimensions (in.)	
Total base width	13 ½
Wide side width	8 ½
Narrow side width	5

Edges of Station from Centerline (in.)			
Reference #	Height	Distance Left	Distance Right
0	0	8 ½	5
1	3 7/8	8 ½	5

Height	20 3/8

2	6 7/8	8 ¼	5
3	9	7 7/8	4 7/8
4	11	7 ½	4 ½
5	12	7 1/8	4 5/8
6	13	7	4 5/8
7	14	6 ½	4 1/8
8	15	6	4
9	16	5 5/8	3 3/4
10	17	5	3 3/8
11	18	4 3/8	2 3/4
12	19	3 3/4	2 3/8
13	20	1 ½	3/4

Station 5

Station Dimensions (in.)	
Total base width	9 ¼
Wide side width	5 ½
Narrow side width	3 3/4
Height	13 3/4

Edges of Station from Centerline (in.)			
Reference #	Height	Distance Left	Distance Right
0	0	5 ½	3 3/4
1	2 ¼	5 3/8	3 7/8
2	3 ¼	5 ¼	3 7/8
3	4 ¼	5	4
4	4 3/4	5	4
5	5 7/8	4 3/4	3 7/8
6	7	4 3/8	3 7/8
7	8 ½	4	3 5/8
8	9 3/4	3 5/8	3 ¼
9	10 7/8	3	2 3
10	12	2 ¼	2
11	13 ¼	1 ¼	1

Station 6

Station Dimensions (in.)	
Total base width	4 3/4
Wide side width	2 3/8
Narrow side width	2 3/8
Height	10

Edges of Station from Centerline (in.)			
Reference #	Height	Distance Left	Distance Right
0	0	2 3/8	2 3/8
1	2	2 3/8	2 3/8
2	3 ¼	2 3/8	2 3/8
3	4 3/8	2 3/8	2 3/8
4	5 5/8	2 3/8	2 3/8
5	7 1/8	2 ¼	2 ¼
6	8 ¼	2	2
7	9 1/8	1 ¼	1 ¼

When all the station shapes are cut out, do an outside tracing of station 3 onto a piece of paper or cardboard. Put this aside to be used when making the hull stand.

Build a Hull Stand

Use the drawing entitled “Hull stand plans.pdf” to build a stand for the hull. As shown in the drawing, both ends of the stand have a wooden cut-out to fit around the hull and hold it upright. When making this cut-out, use the tracing of the hull jig station 3 made in “Build the Hull Jig” section above as a guide, but add ½ inch to the left and the right sides (but not to the bottom or the top edges of the cut-out). Not that these cutouts need to be placed so that the bottom of the cutout (the keel) is several inches above

Put the hull into the stand keel down, gunnel up to work on the top and insides of the hull. When working on the bottom of the hull, turn the hull stand upside down, and place the hull gunnel down on top. Whenever the hull is put on top of the upside-down hull stand this way, attach clamps on the long edges of the stand so that they stick upward and can stop the hull from accidentally being knocked off the stand.

Infuse the Hull

If a complete Chamorro sailing canoe hull were cut into two pieces along the keel line, the two sides would be the same length and height, but one would be wider than the other. This asymmetry is characteristic of Chamorro sailing canoes. When fabricating the hull, we make each side separately and attach them together afterwards to form the hull

The steps for fabricating each side are identical, but the materials used are cut to different sizes (one side being wider than the other). The wider side is called the “windward side” while the narrower side is called the “leeward side”. This is because when the canoe is sailed, the wider side faces the wind, while the narrower side is to leeward (downwind).

KSS vacuum infusion is a fabrication process in which a vacuum is used to draw liquid resin onto and through layers of fiberglass fabric and rigid foam on a flat table. This will be done twice to infuse the two flat halves of the hull, creating two flat fiberglass panels. These will be bent into 3-dimensional hull halves later in the fabrication process and then attached to form the hull.

To make a fiberglass panel that can be bent, only one side of a rigid panel is glassed (the outside), leaving the other side of the rigid foam core exposed (the inside). The panel can then be scored lengthwise (parallel shallow cuts made into the foam core) along the inside near the keel to allow a bend toward the inside along the score lines. The scoring only allows bending in one direction and once bent, the newly curved surface prevents bending in another direction.

Subsequent bending is done by cutting “darts” through the bend section. Darts are cuts made completely through the piece, removing material that blocks bending but preserving material that is flat and can be bent.

Once a panel has been bent to the desired shape, the inside of the bent panel is hand laminated to hold the shape.

The steps involved to set up for vacuum infusing of a panel that is to be bent, in this example the leeward side of the hull, are below:

Prepare the table

Start by cleaning the infusion table surface of any residual resin if it has been used before by scraping it clean with a razor tool or a wood chisel. Do not use a solvent to do this. If necessary, use fine sandpaper (120 grit or more) to remove any resin that doesn't chip away.

Wax all areas of the table that will be under the vacuum, using mold release wax. The area under the vacuum extends to 8 inches beyond the outlines drawn on the table. The wax will keep the infused piece from sticking to the table after the infusion so it can be easily removed, and also protects the drawing template outlines since these are used twice for each canoe hull fabricated. Apply five layers of mold release wax to areas of the table that have no residual wax, or three layers to areas that do have residual wax. This is done in the same manner as waxing a car - the wax is wiped onto the surface by hand in a circular motion, allowed to dry to a dull film, and then buffed shiny with a clean cloth.

Cover the entire surface of the infusion table with a clear, thin plastic sheeting using tape to secure the edges of the sheeting in place. This plastic sheeting is used to keep the wax from touching the fiberglass and foam materials while we are marking and cutting them into the pattern shapes on top of the table. After these are cut, the plastic sheeting will be removed and layers of materials, including these, will be laid out on top of the table onto the waxed surface. But for now, we don't want the wax to touch any of these materials.

Cut the fiberglass fabric

Unroll the full hull size tri-directional fiberglass fabric over the template so that it completely covers the pattern of the leeward side, which is made up of lines A (the gunnel), the two bow ends, and line D (the leeward keel). The black lines of the pattern should show through the fiberglass fabric. If not, adjust lighting so that it does.

If a single length of fiberglass fabric does not completely cover the pattern (with the ½ inch added to the edges), you will need to add a piece of fiberglass fabric together so that it does. However, whenever fiberglass fabric is extended like this, the two pieces must overlap by four inches. This overlap is needed so that the two pieces are strongly fused together.

Trace the leeward pattern onto the fiberglass fabric using a black permanent marker, adding ½ inch to the edges so that the fabric is ½ inch wider than the pattern. Once you have the entire pattern marked on the fiberglass fabric, cut it with a pair of heavy-duty scissors. Take care to hold the fiberglass fibers in place with one hand while cutting so that the fibers don't get pulled out of alignment by the cutting action. It helps use a series of short cuts with the scissors, rather than trying to make long cuts along the length of the scissor blades, to avoid pulling the fibers out of alignment.

When the fabric has been cut and laid out over the pattern, it should cover the pattern evenly with a ½ inch extra fabric all around.

Carefully and loosely roll up the cut fiberglass fabric and put it somewhere off the table temporarily.

Lay more fiberglass fabric over the pattern again, but this time it only needs to cover the area from line A (the gunnel) to the line C. Again, if you use more than one piece of fiberglass fabric, be sure that they overlap by 4 inches. Then trace lines A and C, plus the bow ends, onto the fiberglass fabric using a black permanent marker and cut the pattern out of the fiberglass fabric. Move this fiberglass fabric off the infusion table as well.

Cut the rigid foam

Lay pieces of rigid foam on top of the infusion table so that it completely covers the pattern that you just used (the area from line A to line D). The pieces of foam will need to be glued together edge to edge using Gorilla Glue. Put 12-inch strips of plastic sheeting under the two edges to be glued together to avoid excess glue getting on the clear plastic sheeting already on the table. Spread the glue evenly to both edges of foam before pushing them firmly together. Use 6 in. x 3 in. galvanized mending plates to hold the pieces together until the glue dries. Lightly hammer the galvanized mending plates into the two panels to secure them. After the glue is completely dry, pry the plates up to remove them, and sand down any protruding glue from both surfaces of the panels. CAUTION: Take care when handling large glued panels to avoid snapping off the panel corners or snapping the panel in half by always supporting the panel in the middle so that it does not bend and snap, but if it does, just glue it back together.

Unroll the larger cut fiberglass fabric from step 4 on top of the rigid foam, positioning it as close to one corner and one long side of the rigid foam panels as possible. This is so that when the panel is cut to shape, the left-over panel will be as big as possible since it will become a resource for future fabrication.

Mark an outline of the fiberglass fabric onto the panel. Then roll the fiberglass fabric up again and move it off the table. Draw a slightly smaller pattern within the outlined area, so that the new lines drawn are ½ inch from the inside of the outline. This recreates the original pattern on the table (between lines A and C). Use a razor cutter to cut this pattern out of the rigid foam, and discard the remaining ½ edge pieces. Carefully move the newly cut out rigid foam off the infusion table.

Place the layers in order on the table

Remove the clear plastic sheeting so that the waxed surface of the infusion table is exposed.

Now lay the smaller piece of fiberglass fabric that was cut in step 5 above directly on top of the pattern area between lines A and C with the extra ½ inch extending beyond the top of the piece (line A in the drawing) and the bows as well. This is the area of the panel that gets glassed on both sides so that it resists bending. Be sure that only one side of the fabric, the bottom side, ever touches the waxed table surface, with the clean (never touched wax) side facing up.

Carefully lay the cut rigid foam on top of the fabric so that it fits perfectly over the table pattern between lines A (gunnel) and D (keel). ½ inch of fiberglass fabric will extend past line A (away from the panel).

Lay the larger piece of cut fiberglass fabric that was cut in step 4 above on top of the foam, so that ½ inch of fabric extends out all the edges of the panel.

Lay peel-ply over the entire hull shape, including the ½ in. fiberglass fabric that extends beyond the edges of the rigid-foam. Peel-ply may be laid out in pieces with a not more than 1 inch overlap. Small pieces of blue masking tape should be used to hold the peel ply in place at the overlap, but the tape must only be on the top surface of the peel-ply. If underneath, the tape will become caught in the resin. Trim the peel-ply a half inch beyond whatever is below it so that it covers everything below it.

Choose one bow end or the other to be the first resin delivery point. The other bow end will be the vacuum attachment point. When infusing, the air will be removed from the piece by a vacuum pump attached to the vacuum attachment point, and resin will be delivered to the surface of the piece from a series of buckets starting from the first resin delivery point.

Lay resin flow media is over the peel-ply. Trim the resin flow media to just cover the shape of the materials below it including the extra ½ inch of peel ply around the edges. Cut a separate piece of peel ply that is as wide as the bow end of the hull piece and 18 inches in length. Lay it over the bow end of the hull piece and onto the table so that one end extends on top of the resin flow media over the piece, and the other end is laid out over the 18-inch length of peel ply, leaving the last four inches of peel ply bare.

Cut a piece of spiral wrap to a slightly narrower width than the width of the strip of resin flow media and fit a PE tubing T-connector into the middle of the spiral wrap. Wrap it with resin flow media using masking tape, with the T-connector nozzle protruding through a hole in the resin flow media, and tape it on top of the strip of resin flow media on the edge furthest from the edge from the panel, with the T-connector nozzle pointing upward.

A series of short lengths of spiral wrap with a PE T-connector inserted in the middle needs to be laid out from the first resin delivery point toward the vacuum attachment point. These lengths need 3 feet apart from each other, and reach to 1 inch from the sides of the piece width-wise. They must be wrapped in resin flow media with the T-connector extending through a small hole in the resin flow media. Use blue tape to hold the wrapped resin flow media in place.

Lay the first in the series of spiral wrap on top of the piece at the first resin delivery point, and the others 3 feet apart until the last piece is within 3 feet of the vacuum attachment point. Ensure that the protruding nozzle of the T-connectors is pointing straight up, and tape the pieces down with blue tape so that they do not move out of position. It is critical that the spiral wrap does not extend any closer than an inch from the edge of the piece so that it does not deliver resin off the piece.

Add the vacuum bag

Lay out tacky tape around the hull piece, about 4 inches from the edges of the resin flow media. Press the tape against the table until it sticks firmly, but keep the protective white paper in place on the upper surface. When the tape needs to make a sharp turn, it can be either bent around the turn or cut and the next piece of tape can be started on top of the cut end and continue around the hull piece. The tacky tape is what will hold the vacuum bagging material against the table in an air-tight seal.

Pleats are needed in the vacuum bagging material that is to be laid out over the hull piece. The pleats allow the vacuum bag to fit loosely around the hull piece so that it has flexibility and can be pushed into tight corners by the pressure of the vacuum without breaking. To make a pleat, a piece of tacky tape is folded into an upside down T shape. The vertical stem of the upside-down "T" is about three inches tall and the two sides below each extend about an inch. The pleat is created when the vacuum bagging is run up one side of the T stem and down the other side to create a six inch fold of vacuum bagging. Make and place a tacky-tape pleat T on top of the tape on the table at each point where a spiral wrap tube comes up to near the edge of the piece. Put one on the tape at each of the four corners of the bows. Leave the white protective tape on the tacky tape Ts in place.

Cut a rectangle of vacuum bagging that is 258 inches long by 84 inches wide. This will be the vacuum bag that covers the piece and extends beyond the edges to the tacky tape that will seal it to the table. These dimensions also provide the additional bagging material needed for the pleats.

Seal the vacuum bag by removing the protective white paper from the tacky tape, and pressing the vacuum bagging against the tacky tape starting from one narrow end of the table and progressing toward the other end.

Lay the vacuum bag over the piece so that the long sides hang evenly over both sides of the table and one of the narrow sides only extends three inches past the edge of the narrow edge of the tape. This will be the starting point for securing the bag to the tape. The other narrow side will have a lot of extra vacuum bag hanging off the table initially, but most of it will be taken up by the pleats that lie between the starting point and the end.

At the starting point side, make a four inch tear in the middle of the white protective paper strip and press the center of the vacuum bag edge against the tacky tape, positioning the bag so that it extends three inches beyond the tape. Be sure that the bag stays straight so that the edges of the bag are parallel to the edge of the tape.

Using one hand to pull away the white protective strip, press the bag onto the tacky tape from the middle to one corner of the rectangle by sliding a finger top along the bag, pressing firmly along as the tape is being exposed as the white strip is pulled off. Ensure that there are no creases in the bag as it is pressed onto the tape.

As you progress toward the corner, when you come across tacky tape for a pleat, remove its protective white paper and carefully press the bag along the pleat tacky tape, over the top of the tape, and back down the other side, always making sure that there is continuous and uninterrupted contact between the bag and the tacky tape. Continue until you reach the

corner. Then do the same in the other direction, again starting from the middle and moving toward the other corner.

Press the bagging against the tacky tape going from the corner, along the long length of the rectangle, to the far corner, but alternate between the two sides, doing only a foot or two at a time, so that both sides progress evenly. Keep the bag very loose, maintaining the folds created by the pleats as you progress. When closing the bag in this fashion, watch for when the bag covers any of the PE t-connectors. When it does, pause to poke a hole in the bagging to allow the nozzle to poke through the bagging. It works best to do this by holding the nozzle opening against the vacuum bagging, puncturing the bag with a Phillips screwdriver, and forcing the nozzle through the small hole from the screwdriver. Then use a short one and a half inch of tacky tape to seal the base of each of these nozzles to the bag, leaving most of the nozzle stem clear.

When you reach the two far corners of the rectangle, pick one corner and start sticking the bagging to the tacky tape in the direction of the other corner, until you reach the other corner, completing the rectangle. If, when you reach the far corner, there is excess bagging, add pleats to take up the excess bagging material.

At this point, the piece is completely covered by the vacuum bag, and all the nozzles of the t-connectors are sticking out of the bag. Trim excess bagging so that the bag extends no more than 3 inches beyond and outside of the tacky-tape.

Add resin buckets and the vacuum pump

Place one 3-liter plastic bucket on top of the vacuum bagging and between each set of the nozzles on the piece, starting from the first resin delivery point. There will be one extra nozzle at the end which is the vacuum attachment point that is over the 4 inches of peel ply. Cut lengths of PE tubing to run from each bucket to the nozzles next to them so that each bucket feeds two tubes. When cutting the lengths, consider the natural bend in the PE tubing and cut a length that will allow the tube to run from the nozzle to the bottom of the bucket with as little spring that might tip the bucket as possible. Trim one end of the PE tubing twice to form a pointed end. The other end should have a straight cut across the tube. Connect this end to the nozzle by pressing it over the nozzle. Press a one and a half inch piece of tacky tape around the end of the tube and the base of the nozzle to seal it.

If a hose clamp is to be used to control the level of resin flow through the tube, put it in place around the tube now. Position the pointed end of the PE tube in the bucket so that it hugs the inside wall of the bucket and touches the bottom of the bucket. Use a squeeze clamp to hold the tubing in this position.

If hose clamps are not available, vice grips can be used to control flow inside the tube by taping two short lengths of ½ inch PVC piping taped around the two jaws of the vice grips. Put the vice grips in place now, with the jaws of the vice grips set tight enough to completely close the tube.

Cut a length of PE tubing to go between a nozzle and the bucket. If an adjustable hose clamp will be used to control the flow of resin, put it in place around the tube now. Push one end

of the PE tubing over the nozzle at the end of the four inch peel ply at the vacuum attachment point, and the other end over one of the two nozzles coming out of the resin trap. Use a one and a half inch piece of tacky tape to seal the end of the tubes around the nozzles.

Cut a length of PE tubing and push one end over the other nozzle coming out of the resin trap the other to the intake nozzle of the vacuum pump. Use one and a half inch pieces of tacky tape to seal the end of the tubes around the nozzles.

Test and run the vacuum

Turn on the vacuum pump. If all the hoses between the bucket and the bag are closed properly with the vice grips, and the vacuum bag is well sealed, the bag should start to tighten down against the table. If not, then look for leaks.

The first place to look for leaks is the buckets. Cut a three foot piece of PE tubing and press one against an ear and, one at a time, point the other end of the hose at the end of the hoses in the buckets to hear and correct any leaks. The second thing to do is to go all around the piece and press the bag against the tacky tape to ensure a tight seal, while listening for the high sound of leaking air, again with the aid of the PE tube. Common leak areas are the pleats and where nozzles come through the bag to the hoses, but the most common leak area is along the tacky tape seal.

When all the leaks are sealed, the vacuum will build quickly. The negative pressure under the bag needs to be at least 18 HG and not more than 28 HG. Once this level is reached, run the vacuum for at least two hours before beginning the infusion. This is needed to completely remove all the air from under the vacuum bag. It is important to understand that the vacuum pump does not pull resin into the piece, but simply creates, and maintains a vacuum. The resin moves into the piece to fill the vacuum.

Test the infusion resin set time

While the vacuum is running, do a test to find the amount of MEKP that needs to be added to the infusion resin to both ensure that resin hardens and that it does not harden too fast. This test is necessary before each infusion because resin hardens at different rates depending upon the air temperature and humidity, as well as the age of the resin. A good working time is 45-60 minutes.

Test a 1% mix by adding 2 ml of MEKP to ¼ liter of resin and use a stopwatch or clock to time how long it takes to gel. Hardening takes a bit longer, but the set time is when the resin will no longer flow, so we will focus on set time. If the ¼ liter hardens too fast, do another test with less MEKP. If too slow, do another test with more MEKP. Less than .7 % MEKP may be insufficient to trigger the resin to set. Most likely the amount of MEKP needed will be in the 1-2% range.

Once you have found the % of MEKP needed to cause ¼ liter of resin to gel in 45-60 minutes, do another test with ½ a liter. Be careful to calculate correctly to ensure that you get the conversion from % MEKP to ml of MEKP right and that you don't get confused. One way to

do this is to make a chart based on what you found in the ¼ liter test. For example, if you found that 2 ml of MEKP was the right amount to cause ¼ liter of resin to get in 50 minutes, your chart would look like this:

NOTE: THIS IS A SAMPLE CHART - YOUR CHART MUST BE BASED ON YOUR RESIN SET TEST RESULTS

Volume of Infusion Resin	Volume of MEKP
¼ Liter	2 ml
½ Liter	4 ml
1 Liter	8 ml
2 Liters	16 ml
3 Liters	24 ml

The chart is very important because it can save confusion and prevent a mixing error that could lead to the loss of all the materials

The second test with a ½ liter of resin will be a little different. After mixing in the MEKP (in our example it would be 4 ml), pour a small puddle of the mixed resin on a scrap piece of wood or waxed cardboard. Time the gel time. It will likely be longer than the ¼ liter test time because that was done in a bucket where the heat generated builds up inside the bucket and speeds the chemical reaction. When the resin is poured into a puddle to set there is more heat loss into the air above the resin, which slows the chemical reaction. The poured resin is similar to what will happen in the vacuum bag. Again, you just want to be sure that in this second test that setting is not sooner than 45 minutes, and that soon after the gel time the resin becomes completely solid.

Prepare the resin

Preparing the resin is very easy, but requires that everything be in place and ready to go once the MEKP is added since that is when the countdown to gel and then hardening begins. Wear vinyl or nitrile gloves and eye protection. Set up fans so that air moves away from the person mixing and/or wear breathing masks with organic vapor filters. The same with the infusion table – provide ventilation that moves air off the table and out of the area.

Once the infusion process starts, it will be necessary to continuously provide resin that is freshly mixed with MEKP until the entire piece is infused. Do not mix all the resin needed for the infusion at one time. If that were to be done, there is a good chance that the resin would gel and harden before it ever reached the piece. Instead, pour resin into several buckets up to the 2 liter level but do not put MEKP in yet. Just have these buckets standing by for when they are needed. As you use them, prepare more to keep an inventory of at least two ready buckets of unmixed resin as the infusion progresses until you are certain that you will not need any more.

The process will be to add and mix MEKP into one of the ready buckets of resin, and then pour the mix into the prepositioned buckets on the table. (The reason we don't mix the MEKP in the prepositioned buckets is that some of the resin would have flowed into the PE

tube and will not receive any of the MEKP, and also the pouring and stirring put the prepositioned buckets in danger of being accidentally knocked over.)

Run the infusion

The most important things to remember when running the infusion are:

1. The delivery buckets must never run out of resin. If the resin level gets lower than the PE tubes, air will enter the tubes and spoil the piece.
2. Keep the resin flow rate at about 1 inch across the piece per 15 seconds. This gives the resin time to reach the fiberglass fabric on the underside of the piece.

The first bucket to be filled with mixed resin is the bucket at the first delivery point, followed by the other delivery buckets in order as the resin moves through the piece toward the vacuum attachment point.

The process will be to mix MEKP into one of the ready buckets of resin, write down the mix time, and pour the mix into the next bucket on the table that is to deliver the resin into the piece. Then immediately adjust the tube clamp (or vice grip) to allow only enough resin flow to feed resin at the rate of 1 inch of progress across the piece in 15 seconds. If the resin moves too fast, slow it down to a near stop for a while to give it time to reach the fiberglass under the panel, and then increase the flow until it moves at the desired rate of 1 inch across the panel per 15 seconds.

As the moving resin reaches the next line of spiral wrap and nozzle leading to the next bucket, close the PE hose feeding at the resin by tightening the hose clamp or vice grip. The PE hose must be completely closed or resin will continue to move into the piece until the bucket is empty and then air will enter the piece.

When the previous PE hose is closed off, open the next PE host to start the flow into the next line of spiral wrap and onto the piece. Again, be careful to keep the resin moving slowly at 1 in. per 15 seconds.

Keep the resin level in the bucket feeding the PE hose from running low by adding more mixed resin, and ensure that there are at least two buckets of unmixed resin lined up and ready to be mixed with MEKP. If both PE hoses in a bucket have already been used and closed off, leave the resin in the bucket to avoid handling the buckets and hoses and possibly causing a spill. To avoid excess resin waste, be careful not to overfill. Just keep it at a comfortable margin well above the PE hose intake.

Occasionally check all the delivery buckets with closed PE hoses to be sure that the resin left in the bucket is not being pulled into the piece. If it is, that indicates that the hose is not completely closed off. Tighten the hose clamp until it is. If a vice grip is being used, close if off again with a different vice grip. Then remove the loose vice grip. This will avoid the original vice grip allowing resin into the piece in the time it takes to open the vice grip and tighten it again.

End the infusion

When the resin has reached the end of the piece, it will continue to move across the resin flow media toward the 4 inch stretch of peel ply and the last nozzle that leads to the resin trap and vacuum. Allow the resin to continue until it reaches the peel ply, at which point it will slow down as it continues toward the nozzle. Just before it reaches the nozzle, clamp the PE hose at the last delivery bucket closed. The flow will slow and stop.

Keep the vacuum pump running for at least three hours after the infusion. This is to maintain the vacuum and prevent the vacuum bag from relaxing and allowing air to enter the piece while the last of the applied resin completely hardens and cools. Leave it overnight before removing the finished piece.

Remove the infused piece

Start by removing the pump, resin trap, clamps, tubes, and buckets. The hoses usually need to have the ends around the nozzles cut with a razor cutter to remove them. Be very careful when cutting them because it is very easy to lose control of the razor in this situation. Keep fingers on and behind the cutter and cut slowly to avoid an accident.
The hoses that have hardened resin in them are difficult to clear of resin, but it can be done by shattering the resin inside with a hammer or by slamming the tubes against a solid surface. Be careful not to crush the tube when doing this. Tubes cleared of resin can be reused after trimming back the ends that were cut.

Use a wide wood chisel to remove the bag from the table by repeatedly bumping the chisel against the tacky-tap with the flat cutting edge of the chisel downward and sliding along the table surface. Discard the vacuum bag.

Free the T-connectors and spiral wrap from the resin flow media that they were wrapped in by cutting the resin flow media away. Once removed, clear them of resin. The resin in the spiral warp will fall away when the spiral wrap is twisted and can be reused. The T-connectors can be cleared by clamping them down and carefully drilling out the resin using a drill bit that is smaller than the inside diameter of the T-connectors. The cleared spiral wrap and the T-connectors can be reused.

Peel the resin flow media and the peel-ply beneath it off the surface of the piece. Start from one of the narrower ends of the piece. It can be difficult to remove just by pulling by hand, but pliers can help. Do not pull straight up, but rather twist and pull the layers back, parallel and close to the surface of the piece. Be careful not to accidentally grab any fiberglass fibers or fabric when pulling the layers off. If a piece of fiber is caught and starts to pull out of the resin, cut it at the surface of the piece to stop it from continuing to pull out.

If the removal of the resin flow media and peel ply is very difficult, make a pulling tool out of a metal pipe that is at least two inches in diameter and about 5 feet long. Cut a thin slot that is 12 inch deep in one end of the pipe. Then clear a tab of resin flow materials and peel-ply so that it can be inserted into the slot and twist the pipe around it so that it grabs. The pipe can be twisted by more than one person from the opposite end and it will pull the material off the piece as it travels across the piece from one end to the other.

Once the piece is free from the table and the vacuum bag underneath removed, the edges should be trimmed with a grinder with a cutting blade so that the edges have a clean cut with no sharp protruding fiberglass.

Repeat the infusion process to fabricate the windward half of the hull.

Fabricate a Rigid Panel

Canoe seats, the bow ends, bulkheads, the deck, and the gunnel are cut from a large fiberglass panel that has been glassed on both sides so that it does not bend. In actuality, even flat panels that are glassed on both sides can bend a little when they are long and narrow, and they can be made to bend even more by cutting score lines through both the fiberglass and partway into the underlying rigid foam on one side. This is how the gunnel, which is glassed on both sides, will be bent slightly. Other parts cut from a rigid panel, like the seats, bow ends, bulkheads, and the deck are not bent at all.

The steps to infuse a single large piece of unbendable fiberglass panel are identical to infusing the hull, except that both sides of the rigid foam core will be completely covered with fiberglass fabric.

Connect two 4’ x 8’ panels to make a 4’ x 16’ rectangular panel by following the steps above under “Cut the rigid foam” above in the “. Trim the panel down to 3’ 4” x 15’ 4”. This will fit on the infusion table with four inches to spare around each edge so that there is room for the tacky-tape when sealing the vacuum bag.

- Follow the process above under “Infuse the Hull” with the following differences.
- Use triaxial fabric on both sides of the panel
- Cut the vacuum bag to 4’ 8” x 16’ 8” (this will allow for the two 4” pleats needed at each corner)

Fabricate a Bendable Panel

A large panel that can be bent will be needed to make the lucha. The steps to infuse a single large piece of bendable fiberglass panel is identical to the process to fabricate a rigid panel above except that only the top side of the panel will be covered with fiberglass fabric. Since there is half as much fiberglass to infuse, the amount of resin needed will be half what was used to infuse both sides.

Infuse a 40” x 10’ panel to make the bendable panel for the lucha.

Make a Long Bendable Aluminum Corner

Cut two 8-foot aluminum corners with 1-inch edges as follows:

Starting from one end, measure and mark every six inches with a sharpie along one of the edges. Do the same for the other edge, except start three inches in from the end. This will produce alternating marks every three inches along the piece.

Make cuts with a grinder and cutting blade from the outside edge to the corner at every mark. This will produce 8-foot aluminum corners with alternating cuts every three inches. Those cuts will allow the piece to bend when used in the Hull Jig to guide the panels as they are bent.

Prepare Wooden Battens, Spacers, and Wedges

Wooden battens varying in length from 16" to 60" are used in conjunction with the Hull Jig to bend the hull to shape. They can be cut as you need them, or cut in advance, but it can be hard to judge how many you will need and what lengths are needed, so it is best to have a supply of wood for battens and a chop saw ready to make them as needed.

The wood used for battens should be 2 ½ to 3 ½ inches in width and about 1/8 inch thick. Different kinds of wood vary in flexibility, so choose wood that can bend a little without breaking. A 14" batten that is strong but able to bend 2 inches without breaking is about the right stiffness.

Spacers need to be about three inches long and two inches wide, and of varying thicknesses from 1/16th of an inch to ¼ of an inch. These should be cut in advance. Three 2" x 8' pieces of wood that are 1/16th, 1/8th, and ¼ of an inch in thickness can be cut to make 32 of each which is plenty.

Wooden wedges can be bought or cut. They should be 4-5 inches long, 3/4 to 1 inch wide, and ½ inch tall at the high end.

The Lamination Process

The lamination process differs greatly from the infusion process. It is also used repeatedly during the rest of the canoe fabrication. This section will familiarize you with the process before we continue. Refer back to this section when the instructions call for laminating but do not provide specific steps.

The main difference between lamination resin and infusion resin is their viscosity. Infusion resin is less viscous (thinner) which enables it to pass more easily through holes and channels in core materials and along glass filaments as it moves under a vacuum bag. Laminating resin is more viscous (thicker), which makes it more suitable for application by brush or roller on sloped surfaces since it doesn't drip as easily as infusion resin. Other than these qualities, they are very much the same. However, whereas infusion resin can be used for laminating with or without thickeners, depending on whether or not dripping would be a problem, laminating resin should not be used in infusions as it can lead to dry spots.

The process for laminating is always as follows:

1. Scratch-sand any surfaces that already have a cured resin surface, or that present a smooth surface. Rigid foam that has not been glassed does not need to be sanded because it will bond chemically with the resin. Very recently glassed surfaces also do

not need to be sanded because until the resin is fully cured, it will bond chemically to new resin.

2. Brush or roll resin onto the surface to be glassed.
3. Brush or roll resin onto the surface face of the fiberglass to be laid down resin-face to resin-face on the surface to be glassed. This is only needed IF the fiberglass is heavy or stiff, such as triax. The purpose of this step for heavy fiberglass is to help the resin penetrate and saturate the fiberglass.
4. Lay the fiberglass onto the wet surface and use the tip of a brush to press it into the resin. Brush resin onto the fiberglass so that it becomes saturated with resin and clear. Tap the fiberglass with the tip of the brush to work any trapped air out from underneath the fiberglass. Air can be tapped toward and out the sides of the fiberglass, or it can be forced through the fiberglass by repeatedly tapping directly on the air bubble.
5. Lay peel-ply on top of the fiberglass. The peel-ply should be slightly bigger than the area that has been wet with resin since its main purpose is to be a barrier between the surface resin and the oxygen in the air that would inhibit the surface resin from curing. Resin that is not covered with peel-ply will have a sticky surface even after the resin beneath the surfaces has cured.
6. Brush or roll resin on the peel-ply so that it is thoroughly wet but not to excess so that resin pools on top of the peel-ply or drains off. Use the tip of the brush to tap away any air bubbles beneath the peel-ply.
7. Pull off the peel-ply only after the resin has hardened and cured. Note that this will happen later than when resin remaining in the bucket hardens since the bucket will trap heat which will build and grow, and resin hardens faster at higher temperatures.

Shape the Hull

Mark the flat hull halves

Use a black sharpie to mark the two flat hull halves with the “Hull Template Lines” pattern on the infusion table. The best way to do this is to lay the hull panels on the infusion table exactly within their respective pattern lines. Duplicate all the lines in the pattern exactly where they are.

Also mark the edges of the panels where the 14 reference grid lines reach the edges.

Score the leeward hull half

Use a sharpie to fill the area between lines “B” and “D” with parallel lines, one inch apart, that run from the “left side” to the “right side” as identified in the “Hull Template Lines” drawing. These drawn lines fill the area that needs to be scored so that the panel can be bent.

The score lines need to be cut to a depth of 2/3 into the panel. The cuts can be made with a jigsaw or a multi-tool that as long as the depth of the cut can be set. The width of the cuts should not exceed 1/8 of an inch. Straight lines can be cut easily and quickly by securing a long plank with a straight edge over the panel in position so that the cutting tool can be slid

along the straight edge and over the line to be cut. The plank can be repositioned for each cut.

Take care when cutting to start and stop the cut within the marked area. Also check periodically to ensure that the depth setting of the cut hasn't changed due to downward pressure on the tool.

Make the hull dart cuts

Cuts that go completely through the panel are called "darts". These cuts are needed to allow the panel to be bent in a second direction after it has been bent along the score lines. Why this is needed will become clear as the piece is bent in the jig.

The dart lines are the black triangular lines that extend from the keel edge upward in the "Hull Template Lines" drawing. Each set of dart lines has three lines that mark the long sides of two triangles – one smaller triangle for the leeward hull panel, and a slightly wider triangle for the windward hull panel.

Figures 3 and 4 are close-ups of the dart lines in the "Hull Template Lines" drawing, with color added to indicate the dart shapes to be cut out of the panels. The green area shows the dart to be cut for the leeward hull. The green area combined with the red area show the dart to be cut for the windward hull. Note that in Figures 3 and 4 the red is toward the middle of the canoe and the green is away from the middle of the canoe. It is important to see this difference between the left and right sides when cutting the darts.

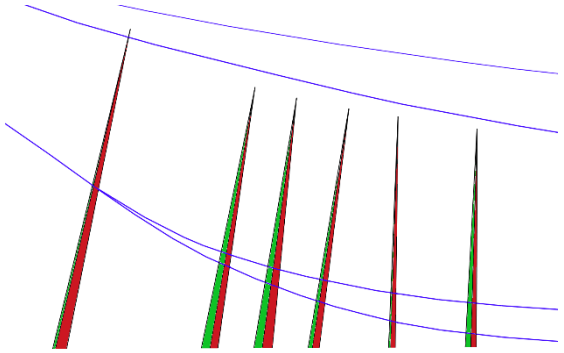


Figure 3 – Left side darts

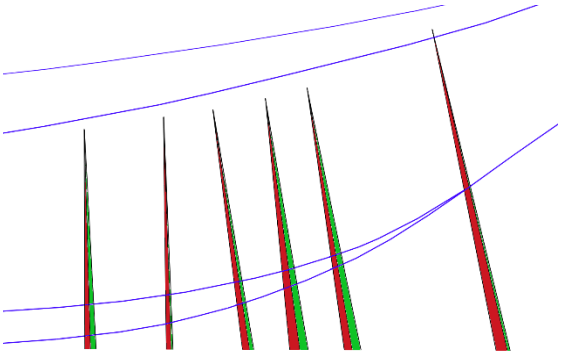


Figure 4 – Right side darts

Prepare the hull jig

Set the jig on its side so that the leeward side of the station is lower. Open the jig on the keel side of the stations by removing lower bolts on the removable braces nearest the keel edge of the stations and swinging the braces up and out of the way. Cover the edges of the leeward stations with brown packing tape. This will prevent resin from fusing the station to the panel accidentally when the panel is hand-laminated later.

Bend the leeward hull half

With the score lines and dart cuts complete, push the leeward hull half into the hull jig, gunnel side first, with the scored side facing edges of leeward stations. Push the panel in as far as it will go, with the panel gunnel pressing against the wood that supports the station at the station gunnel end. Ensure that reference lines drawn on the hull line up with the station edges.

Station 0 and the reference line for station 0 must be perfectly lined up. The other stations should be very closely, if not perfectly, aligned with the stations. Same with the gunnel. If the entire panel does not make contact with the wood supporting the gunnel edge of each station, adjust the panel so that any gaps between the panel gunnel and the jig gunnel are the same for each corresponding station number on both sides. In other words, if left side station 4 has a 1 inch gap between the station gunnel and the panel gunnel, then the right side station 4 should also have a matching 1 inch gap.

Once the panel is in place, put all 13 ratchet straps in place with just enough tightness to hold them in position. The straps in the middle of the jig, from station 0 to about station 3, can easily be positioned so that the straps align along the station edges. However, as the straps move toward the ends (station 6), the curvature of the keel will cause the straps to slide away from the station edges. When this happens, focus on getting the strap positioned at an angle so that the strap crosses the station edges and does not slide out of place. The videos can illustrate how this can be done. Remember, that the goal is to use the ratchet straps to pull the panel against the edges of the stations with few or no gaps between the panel and the stations.

Do not attempt to tighten the straps against the stations all at once, but rather do it slowly, bending the panel a little at a time. Start at station zero, then work through the numbers from 1 to 6, always tightening the 1’s, then the 2’s, then the 3’s, etc. until you've done them all. Then start at station 0 again and tighten them a little more, in order again.

Once the panel is partly bent along the entire hull, add the metal corner to the keel edge of the panel. The alternating cuts every three inches will allow the metal corner to bend as the panel bends. The metal corner will distribute the pressure from the straps along the keel edge, making a smoother curve. It also serves to hold wooden spacers between the panel edge and the metal corner. These spacers add pressure to the panel, forcing more of an outward bend at the point under the spacer. They are used in tandem with the wooden battens that are placed under straps to put pressure against a curved panel, causing it to become straighter. Wooden wedges can be pushed between a strap and a batten to put even more pressure on the panel surface under the batten. Using both spacers and battens, it is possible to force a nice curve in the panel between stations and avoid areas where the sides of cut darts protrude outside the desired surface plane of the hull.

<u>Prep the bent panel surface for lamination</u>

Once the panel is bent to shape, the scored (and now concave) surface needs to be hand-laminated to hold the shape. There may be areas where the edges of the panel jut up outside the plane of the inside surface. These will be where the dart cuts were made. These higher areas must be sanded down until they are level with the surrounding surfaces. If they

jut up very high, you can sand them down partially and use filler later to build the surrounding surfaces up. However you do it, the goal is to create a solid and smooth surface that the fiberglass fabric can lay flat against. Do not worry about the outside of the hull. Just be sure that the inside is solid and smooth. Later, there will be an opportunity to fill and smooth the outside surface if necessary.

Test the laminating resin set time

Follow the instructions above under "Test the Infusion Resin Set Time", but using laminating resin instead, and create a chart for mixing MEKP with laminating resin.

Prepare thickened laminating resin

Estimate the amount of resin you will need to fill the holes and gaps and pour 75% of the estimated amount into a mixing bucket. Add and mix the amount of MEKP needed for a 30 minute set time. After mixing, add a 50/50 mix of aerosil and microspheres that is about half the volume of resin in the mixing bucket and stir it well. Add more microspheres if needed to bring the mix to a consistency like creamy peanut butter. We will refer to this mix as "peanut butter".

Starting from one end of the bent hull, use a spreader to push peanut butter into any of the scored areas that did not close completely and smooth out the surface with the spreader. Also fill any areas where darts were cut but did not close completely when the panel was bent. Again, smooth the surface of the filled areas with the spreader so that it is even with the surrounding panel surface. The goal is to have a filled, flat surface for the fiberglass fabric.

Prepare fiberglass fabric and peel-ply

Cut pieces of triaxial fiberglass fabric to fit between all the stations and between the two station 6s and the end of the hull. These should be cut 1 inch short of the stations so that the fiberglass does not inadvertently get laminated onto the stations. They should reach the edges of the gunnel and the keels.

Cut pieces of peel-ply to be laid over the fiberglass fabric after the fiberglass has been put in place and saturated with resin. The peel-ply pieces should be about two inches wider than the fiberglass fabric on all sides. Use a sharpie to draw a big arrow on the peel ply to indicate both the top and the keel edge of the peel ply so that when it is time to place the peel-ply over the fiberglass it is position correctly since it will have been cut to a shape that can only fit one way.

Place the fiberglass fabric in position where it is to go and secure the gunnel edge to the gunnel with a binder clip. Pull the keel end back and over the binder clip so that most of the panel at the keel side is free and clear. Do not press the pulled back fiberglass fabric down to create a crease.

When this is correctly set up, there will be 13 pieces of fiberglass with the gunnel side held in position by binder clips and the keel side pulled back, and beneath each of the 13 pieces will be the peel-ply that goes over it.

Laminate the panel surface

Mix two liters of laminating resin in a mixing bucket with the amount of MEKP needed for a 45 minute set time. Starting from one end of the piece, use a 3 inch chip brush to apply the resin to the panel starting from the keel. Work down toward the folded back fiberglass. When you reach the folded back fiberglass, brush resin on the folded surface. Then roll the fiberglass back into position up to the keel edge, being careful to keep it in perfect position.

Once the fiberglass is sticking to the panel at the keel edge, remove the binder clip and lift the dry fiberglass fabric off the panel while brushing resin on the dry panel surface. When the surface is completely brushed wet with resin, brush resin on the upward facing fiberglass fabric in your hand. When that has been completely brushed with resin, carefully lay it down in position starting from keel side downward so that the fiberglass fabric that is laid down at the gunnel edge is last.

Brush additional resin onto the fiberglass fabric that is now in position and so that the resin is spread out uniformly and has no dry spots. You can use the very tip of the chip brush to poke down on the fiberglass to force resin into dry spots.

When the fiberglass is thoroughly wetted, carefully take the peel-ply out from under the area you are working and lay it carefully over the fiberglass as indicated by the arrow that you drew on it earlier. It is very important that the peel-ply cover all the fiberglass to avoid sticky surfaces that did not cure completely because they were not covered by peel-ply. Brush more resin on top of the peel-ply until it too is saturated evenly. Again, use the tip of the chip brush to poke at the peel-ply to force resin into it and to force air out of it. Large air bubbles can be carefully poked toward an edge of the peel-ply until it exits there. Small air bubbles can be poked straight down into the fiberglass to force the air to exit through the peel-ply.

Once the peel-ply is thoroughly wetted, it is time to move to the next station. By only mixing 2 liters of resin at a time, you should have time to do each station properly without rushing. Be sure that before you start a new station that you have enough resin left in the bucket to finish that section. If not, mix another 2 liters and have it ready when the first bucket runs out.

Allow at least four hours after the last station is laminated for the resin to harden and then remove the peel-ply.

Mark the keel line

Remove all the battens, spacers, wedges, and the aluminum corners. Remove all the ratchet straps except the ones at station 0 and the two station 6s. The hull should stay in place and not become loose. If it does become loose, re-secure it using ratchet straps.

The hull has been bent over the stations, past the keel line points that are indicated by the lines drawn on each station. These are the lines that run from the keel tip of the station to the gunnel. Because the assembled hull is not symmetrical width-wise, these lines will be off center in all the stations except stations 5 and 6 where the hull is symmetrical width-wise.

We will need to draw the keel line on the bent panel and cut off the excess panel leaving a straight keel line that runs from one end of the canoe to the other. To do this we will drill a small hole through the panel adjacent to where the keel point lines hit the bent panel.

Before drilling, use a sharpie to mark exactly where to drill. The marks should be as close to the keel point lines as the drill you plan to use will allow, but the thickness of the drill shank will require that the holes you drill be offset by at least an inch. Care must be taken to place the mark for the hole perfectly horizontally off where the keel point line meets the panel. Circle the mark with the sharpie to help you find it as the holes can be hard to see.

Use a small drill bit, not more than ¼ diameter to drill the holes for stations 1 through 5 from the inside out. Then remove the ratchet strap for station 0 and drill that hole. Then remove the ratchet straps from the station 6s and drill those holes. As you drill, take care that the drill stays perfectly horizontal. If it is pointed upward or downward during drilling, it will come out the other side too high or too low.

Draw the keel line

With the braces next to the keel edge once again disconnected at the bottom and swung upward out of the way, use a long, flexible stick to connect all the holes that were drilled using a sharpie. If they do not line up perfectly, average them out so that stick and the line you draw passes around some of them. Do not use a laser to do this because the curved surface of the keel can lead to a curved laser line.

Loosen the leeward hull half

With all the straps off the hull may come loose on its own. If not, loosen it by jiggling the hull and thumping it with the palm of your hand. If it is really stuck, look to find where resin is holding the hull against a station (possibly more than one) and work that it loose by sanding, chipping, or grinding that resin away.

Slide the hull half away from the stations so that it is at least 6 inches away from all the stations. Then use a grinder with a cutting blade to cut along the keel line, take care to keep the blade horizontal so that the cut creates a flat, horizontal surface.

Discard the trimmed away excess panel and move the hull half out of the hull jig and store it temporarily somewhere out of the way.

Score and bend the windward hull half

Clean excess resin from the hull jig and re-tape the edges of the stations with brown packing tape where needed. Resecure the braces and flip the jig so that the windward hull edges of the stations are facing down.

Follow the steps above from “Shape the Hull” through “Loosen the leeward hull half” except for the windward hull half instead of the leeward hull half.

Connect the hull halves

Again, re-tape the edges of the stations where needed, and then slide the windward hull half back into the jig with its gunnel edge all the way in so that it is even with the station gunnel edges. Slide the leeward hull half into the jig over its station edges, until it too has its gunnel edge all the way in so that it is even with the station gunnel edges.

Secure the middle of the two hulls against station 0 using a ratchet strap. Add the other ratchet straps in order from stations 1 to stations 6 alternating between the left and right sides until the hull is back in place with the two hull sides’ keel edges up against each other.

Put brown packing tape on the inside surface of the keel where any gaps exist. This tape will keep the “peanut butter” filler being pushed into the gaps from the outside from spilling through past the gap.

Estimate how much peanut butter will be needed to fill any gaps in the keel and mix the resin, MEKP, and 50/50 aerosil and microspheres to make that amount of peanut butter. Use a spreader to push it into the gaps, but gently so that it doesn’t push past the tape on the inside. Use the spreader to smooth out the peanut butter on the outside surface.

Note that because the ratchet straps are in the way, only the gaps that are not covered by the straps can be filled. Do not attempt to push peanut butter sideways to get the gaps under the straps because it will stick to the straps. These areas will be filled later.

When the peanut butter has hardened, use a sander with 40 grit sandpaper to smooth out the peanut butter on the outside surface of the hull to five inches to each side from the center of the keel and five inches wide. This sanding area of 5” x 10” should be approximately in the middle between straps.

Cut twelve 8 inch long pieces of 3 inch wide fiberglass tape. Laminate these to the hull over the sanded area like tape to hold the two hull halves together as shown in Figure 5 where the brown lines represent straps and the gray lines represent the fiberglass tape placement.

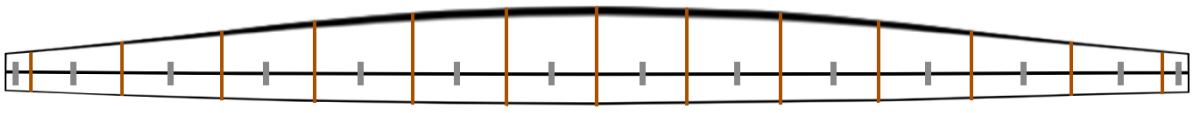


Figure 5 – Fiberglass tape (gray) placement to hold hull halves together

Measure the inside distance between the two hulls’ gunnel edges at station 0, and also at the gunnel edges at end of the two matas that extend past the station 6s. Cut three spacers to these lengths from a 2”x2” or 2”x4”. Secure the spacers in their respective positions between the gunnels using wood screws screwed into the spacer ends from the outside of the hull, through the hull, and into the wood. These spacers will hold the gunnels of the two hull halves so that they do not move while handling the hull. Without the spacers, the keel

might become stressed when being moved and the tape holding the two sides in position could fail.

Laminate the Bottom of the Keel

Turn the hull stand upside down so that the opening faces the floor. Then carefully place the hull on top of the stand, with the keel upward. Cut a 20 inch wide by 94 inch long length of triax and cut two 20 inch wide by 54 inch long lengths of triax.

Lay the larger piece along the keel in the middle of the canoe with 8 inches of width positioned over the leeward side of the hull, and 12 inches over the windward side of the hull. Use a few pieces of blue masking tape to temporarily tape the piece in place. Then use a black sharpie to mark the outline of the fiberglass on the hull so that later it can be removed and put back in the exact same position.

Lay the two shorter pieces of the two mata ends of the keel, again with 8 inches of width over the leeward side and the rest over the windward side, and with a 4 inch overlap on top of the first piece. This 4 inch overlap is necessary so that both pieces of fiberglass are fused together when they are laminated. Failure to do this overlap will result in a weak spot where one piece ends and the other begins. Tape these two pieces in place. Then trim both pieces at their respective matas so that the triax goes all the way to the end of the hull with no triax extending beyond the mata faces.

These two pieces of triax will be much longer on the windward side than on the leeward side at the matas. For both sides, use a black sharpie to mark a point 8 inches from the keel on the windward triax at the mata face. Draw a line between this point to the corner of the triax where it overlaps with the long piece. That corner will be 12 inches away from the keel. Cut along this line and discard the trimmed material or save it for scrap. Trace the outline of the two smaller pieces onto the hull. Draw an arrow on the top of these end pieces, pointing to their respective matas. These arrows will guide you when it is time to put these pieces back on the hull during lamination.

Remove the tape and put the three pieces of triax aside. Sand the area of the hull between the black sharpie marks with 40 grit sandpaper just enough to roughen the surface in preparation for lamination.

Mix 3 liters of infusion resin. Have more resin and some MEKP nearby in case you run out of resin during lamination and need to quickly mix some more.

Start laminating by brushing the center area of the hull between the outlines. Brush resin onto the middle piece of triax and lay it carefully over the keel between the outlines, wet side down. Brush resin into the dry outer surface until it is saturated and clear. For the two mata sides, brush resin onto the hull between the outline and onto the side of the triax that does not have the arrow written on it. Place the triax back on the hull, arrow side up and pointing to the mata, and lay it down starting from the mata end. Brush resin on the top surface until it is saturated.

When both ends of the triax are in place and saturated with resin, lay peel-ply over all the triax on the hull and again brush resin on the peel-ply until all of it is wet.

After the resin has hardened it is okay to move on the next step, but leave the peel-ply on until move the hull of the hull stand, turn the hull stand over, and put the hull inside the stand, keel down. Leave the peel ply on for now.

Laminate the Inside of the Hull

Turn the hull on its side on top of the hull stand. Remove any peel-ply and also the tape that was put over the joint at the bottom of the hull between the two hull halves. This will reveal strips of not glassed areas that could not be glassed since they were up against the edges of the stations and also possible holes in the joint at the bottom. Use a grinder with a 40 grit sanding disk and/or an orbital sander to both smooth out the entire inside surface of the hull that is currently facing up as well as the surface of the joint at the bottom.

Mix peanut butter and spread it over the exposed lines of the not glassed panel to bring these slightly lower areas even with the glassed surfaces on both sides. Also, push peanut butter into any holes found in the joint at the bottom. Use the spreader to smooth the peanut butter out so that a smooth surface remains. When the peanut butter hardens, use a grinder with a sanding disk to sand down any protrusions that would prevent fiberglass from lying flat against the surface.

Cut a piece of biax to shape to fit over the cut areas in the half of the hull that was just prepared, from the keel joint to 4 inches past the end of the cuts toward the gunnel edge of the hull. Also cut pieces of peel-ply to be used to cover the fiberglass after the resin has been applied.

Mix laminating resin and glass the biax. Be careful that the biax is flat against the surface with no dry spots or air bubbles. When it is thoroughly wetted, cover it with peel-ply and wet the peel-ply with resin as well.

When the resin is hardened and the peel ply removed, flip the hull over and glass the other side in the same way. The second biax can go on top of the first biax that was laminated over the keel, but be careful to avoid it going so far in that it turns up and over as it will not bond well to an overhead surface.

When the second side has hardened, remove the peel-ply, put the hull inside the hull stand and laminate a 10 inch wide length of biax along the keel line on the bottom, from mata to mata. Where the fiberglass hits the inside face of the mata, make a cut from the end of the glass toward the other side so that the end to avoid a fold in the biax. Remember to cover the wet biax with peel-ply.

Complete the Hull

Add the Matas

The two ends of the canoe hull need to be closed with pieces of fiberglass panels cut from infused panels with fiberglass on both sides.

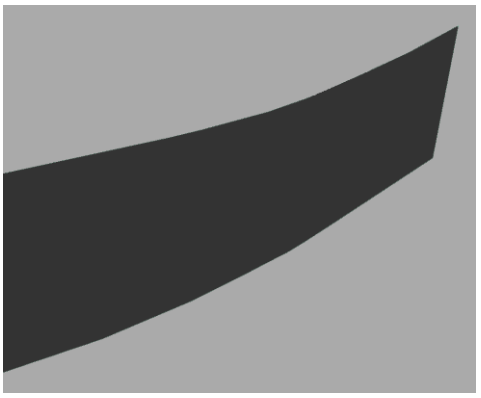


Figure 6 – Angle of the mata

The hull ends where these mata panels go need to be trimmed so that the panels fit flat against them, and with the top of the gunnel extending outward a few inches further than the keel below. *Figure 6* shows how the hull ends should look from the side after trimming. After the ends are trimmed, make a mata pattern for each end by holding a piece of cardboard against the hull end. Ensure that the cardboard fits evenly and straight against the hull end with every edge touching the cardboard and that the surface that the cardboard makes is facing directly away from the canoe. In other words, the mata face should be 90 degrees to the keel line. If it isn't, the canoe will appear to be pointing a little sideways as it sails, like a car with its wheels out of alignment.

Cut the pattern out of the cardboard and use it to trace the mata shape onto a flat piece of fiberglass panel that has been infused on both sides. Cut the mata out of the panel using a jigsaw or a grinder with a cutting blade. Use "peanut butter" to attach the matas to the ends. After the peanut butter hardens, sand the outside surface smooth, both removing excess peanut butter and also rounding the corner edge of the mata panel slightly. Then use a multi-tool to dig out rigid foam from between the two fiberglass sides along the outside edges of the mata panels, to a depth of about ½ inch. Fill this channel created between the two fiberglass sides of the panel with "peanut butter". Use a spreader to push the peanut butter into the channel and to clean away the excess peanut butter.

<u>Trim the Top Edge of the Hull</u>

With the hull seated inside the hull stand with the keel down and the hull edges up, shift the hull as necessary so that it is perfectly straight in the hull stand. Walk around the canoe to view it from different angles to get a sense of whether it appears straight or not. This "eyeball" view is very important and when done along with measuring is very reliable and can catch measurement errors.

With the canoe as straight as possible, use a tape measure to measure the distance from each top corner of the matas to the floor. Assuming that the floor is flat and that the matas are perfectly horizontal, if the four mata corners are the same distance above the floor, then the canoe is straight in the hull stand. If not, consider the possibility that one or both matas was not put in straight. Again, eyeball it and when the canoe looks straight in the stand, trim the matas so that the upper edges are perfectly horizontal. Then measure again until the four mata corners are the same distance from the floor.

Next check if the top edge of both sides of the hull are the same distance from the floor by measuring at parallel points on each side. The two sides are very likely uneven and the higher side will need to be trimmed down to match the lower side. To do this, start by sanding the top edge of the lower side with a grinder fitted with a 40 grit sanding disk so

that it forms a smooth and even arch from one mata to the other. Then make black sharpie marks along the top of this lower gunnel about every two feet, and make matching, parallel marks on the top of the higher gunnel. Measure the distance from each mark on the lower side to the floor and mark the outside of the higher hull side to indicate that same height. After every point has been measured and the outside of the higher hull marked accordingly, line up the outside marks along the edge of a long flexible stick and use a black sharpie to draw a new line connecting the dots. Trim the higher side along this line. Measure again and to ensure the hull edges on both sides are now the same distance from the floor.

Add a Deck to the Hull

With the canoe secured in a straight position inside the hull stand position a laser leveler inside the hull above the keel line and in the middle between the two matas, so that it projects a straight line, that is 12 inches above that keel line, against one side of the hull. Use a black sharpie to mark this level with a series of dots along the laser line. Turn the laser lever to point at the other side of the hull, maintaining that 12 inches height, and mark that side as well. Do a series of tests with the laser leveler to ensure that you did indeed mark a series of dots that form a perfectly horizontal 12-inch high dotted line around the inside of the hull. Remove the laser level and connect all the dots. The resulting line will indicate where the edges of the deck will touch the sides. The line should be in the middle of the hull as well.

To cut a deck to shape that fits perfectly inside the hull at the 12-inch level, measure the distance between where two points where the 12-inch level line crosses the keel line – these will be on opposite sides along the length of the keel. Cut a flat long stick that is about ½ to 1 inch in width to this length. Draw a line down the middle of the top side of the stick and mark this middle line every 6 inches, starting with zero from either end of the stick and progressing toward the other end. Number these lines.

Lay the stick along the keel line with the ends touching the 12-inch level lines at each end. Add support under the stick where necessary to keep the stick from sagging. The support can be anything that works – for instance stacks of small pieces of wood.

When the stick is in place, starting with number 1, measure the distance from the center line at that point to the 12-inch level line on the left side and then from the centerline to the 12-inch level line on the right side. Record the measurements. For instance, if the distance from the center line to the 12-inch level line on the left is 2 inches, and the distance from the centerline to the 12-inch level line on the right is 2.25 inches, record:

#2 L=2 R=2.5

Continue measuring until all the points have been measured and recorded. Circle the middle number in the series on the stick (for instance if there are 30 number points, circle number 15 on the stick).

Remove the stick and lay it down along a length of infused fiberglass panel from one long edge toward the opposite edge, and keeping the stick parallel with the right side (as you are facing the far end of the panel), position the stick so that the centerline at the circled

number is recorded distance to the right edge that was recorded for that number. Look at the distance recorded to the left at the circled point and ensure that there is enough panel to reach that distance to the left.

Then starting with number one, use the measurement recorded to the right and measure that distance to the right and put a dot on the panel at that distance. Do the same to the left using the measurement record to the left. Continue down the stick until you reach the last number.

Mark the panel at point zero, where the centerline starts at the end of the stick. Do the same for the far end of the stick – make a dot on the panel where the centerline reaches the end of the stick.

Remove the stick and connect the dots. The resulting line is the outline of the deck. Cut the deck out by cutting straight down along the outline. Set the deck panel aside for the time being.

Add three bulkheads to the keel to support the deck. Put the first one at the middle point between the two long ends of the 12-inch deck outline, and put the other two half way between the middle bulkhead and the far ends of the 12-inch deck outline. Mark these three locations with a mark along the keel line between the deck outlines.

Each bulkhead will be triangular. The top edge of each bulkhead will be the same length as the distance between the two deck outlines at the location of the bulkhead. For each bulkhead, use a piece of cardboard the width of the top edge and trim it to form a triangular shape that fits in that position. Use this cardboard as a pattern to trace out the triangular shape on a panel glassed on both sides and cut it out to make the bulkhead.

Install the three bulkheads using peanut butter. Ensure that the top edge of the bulkhead runs between and is flush with the two deck outlines. The top edge must not protrude higher or lower than the 12-inch height defined by the outlines. Once the bulkheads are cemented in place with peanut butter use peanut butter for coving along the corners where the bulkheads meet the walls of the hull.

When the three bulkheads are installed and the peanut butter has hardened, test the fit of the deck. Make sure that the deck goes in flat and not slanted. The bottom face of the deck should make even contact with the 12-inch deck outline, leaving a gap between the top face of the deck and the sides. This gap will be filled in with peanut butter when the deck is installed. If necessary, trim the deck so that it fits well and makes contact with the three top edges of the bulkheads and both sides of the hull. Be sure that it is in the proper position in the center of the canoe and not offset. If it is offset or tilted, some of the 12-inch deck outline will be showing. When the deck is in position, trace a new outline on the hull walls at the top level of the deck. This will help you get it back in the right position when it is time to install the deck.

Collect enough empty plastic water bottles to fill the spaces in the hull between the bulkheads. Put a good quality glue around the threads of the bottle top and tightly screw the bottle tops on. Lay the glued closed water bottles in the hull between the bulkhead so that

as many as possible fit, but also so that none of the water bottles are higher than the 12-inch deck line.

Have about 10 cans of expanding sprayable foam ready to be sprayed between the bottles in order to fill most of the remaining air space with foam. The foam and the bottles will provide buoyancy by preventing water from filling the hull under the deck if the hull were to be damaged so that water can get in. The foam also serves to hold the bottles together so that if the hull becomes damaged the individual bottles will not be loose and float out any holes.

Mix two liters of peanut butter and using a spreader scrape peanut butter onto the tops of the three bulkheads in a pyramid shape. Simultaneously if possible, or immediately afterwards if not, spray the foam around and under the bottles until the area below the 12-inch deck line is almost all foam and bottles. Then carefully set the deck into position. Press the deck down firmly against the bulkheads and the hull edges and add weight along the middle of the deck to hold it down. Once this is done start pushing peanut butter into the gap between the deck and the hull walls with a spreader. After the gap has been filled, use the spreader to scrape excess peanut butter off the deck and hull walls.

When the peanut butter has hardened, mix more peanut butter and cove the corners where the deck meets the hull walls. Follow this up by laminating 6-inch wide fiberglass tape over the corners where the hull meets the deck.

Add the Stay Bars and the Paddle Braces

The two stay bars are made of 18-inch long pieces of 1 ¼" Schedule 80 PVC pipe, with caps on the end that bring them to about 19 ½" long. The “1 ¼” refers to the inside diameter of the pipe. The outside diameter is bigger so you will need a 1 5/8 inch drill bit for the holes. Be sure to compare the bit to the end of the pipe to ensure it is the right size before drilling the hole. The holes for the stay bars go through the hull near the matas. The centers of these holes are 3” from the closest edge of the mata face and 5 7/8” from the nearest lower face of the gunnel as shown in *Figure 7*.

The two paddle braces are made of 16 ½” long pieces of 1 ¼" Schedule 80 PVC pipe with no caps. The holes for these go in the hull near both mata ends so that the end on the windward side projects only ¼ inch out of the hull and the other end projects much further. The centers of these holes are 14 ¼" toward the middle of the canoe from the centers of the holes for the stay bars and 3 ½” from the nearest lower face of the gunnel as shown in *Figure 8*.

Before installing the stay bars and the paddle braces, they need to be filled with resin saturated fiberglass so that they are solid and strong. The process can be messy so do it over a piece of plastic sheeting or tarp that you can throw away afterwards.

For each bar, cut a length of biax or triax that is twice the length of the bar plus three inches and about 8 inches wide and roll it tightly length wise. Fold the rolled glass in half. Slide the end of a 36-inch piece of wire around the fold and bend the wire around itself to form a tight collar around the glass at the end of the wire. The folded glass should be thin enough

to fit into the opening of the pipe. If it is too thick, then take it apart, trim some of the width from the length of the glass and try it again.

When the glass is the right thickness, then working over the tarp, dip the fiberglass that is hanging from the wire into a bucket of resin so that it becomes saturated with resin. Put the other end of the wire through one end of the PVC pipe and out the other and keep pulling the wire until the glass comes an inch out of the opening of the pipe. Then use aluminum foil to tightly wrap the other end of the pipe and the protruding inch or two of glass and run a few winds of tape around the foil to secure it. This will hold the resin in the pipe as it hardens. Allow the resin to harden with the bar in a vertical position with the bottom of the bar with the foil on the ground. When the resin has hardened and the bar has cooled, remove the foil and cut away the resin and wire that is protruding out both sides of the bar with a grinder with a cutting blade. Be sure the cuts are straight across the pipe. Scratch-sand the pipes including the ends.

Cut eight 6-inch squares of triax. On each of them, draw two lines with a black sharpie from opposite corners to make an X on the square. Then draw another X so that the lines of the second X are exactly in-between the lines of the first X (as if the second X was rotated 45 degrees). Draw a 1 5/8-inch circle in the middle of the square where all the lines of the two Xs intersect. Use scissors to cut the lines of the Xs that fall inside the circle so that they become 8 tabs. Trim the corners of the 6-inch square to make it a 6-inch circle. As you make these cuts, try to hold the fibers in place so that they are not pulled out of place by the scissors.

Slide one of the two stay bars through its hole on the windward side of the hull from the outside to half-way through the hull. Then slip one of the circles on it inside the hull so that the tabs point toward the other hole, and slide the second circle on it so that the tabs point away from the other hole. Side the bar through the other hole and out the other side far enough that both ends of the bar are the same distance out of the hull on both sides. Use a black sharpie to outline the bar on both sides of the hull wall so that you can check that the lines haven't shifted when you come back to cove the bar later. Do the same with the other stay bar.

Slide one of the two paddle brace bars through its hole on the windward side of the hull from the outside of the hull to half-way through the hull. Then slip one of the circles on it so that the tabs point toward the other hole, and slide the second circle on it so that the tabs point away from the other hole. Side the bar through the other hole and out the other side, stopping when the back of the bar is ½ inch outside of the hull (on the windward side). Use a black sharpie to outline the bar on both sides of the hull wall so that you can check that the lines haven't shifted when you come back to cove the bar later. Do the same with the other paddle brace bar.

Use peanut butter to cove the outside of all four bars against the outside hull walls. Be sure to check if the bars have shifted before coving.

When the peanut butter has hardened, it is time to laminate the circles onto the bars and the inside hull wall. Cut eight 18-inch lengths of 3-inch-wide fiberglass tape to be used to

wrap around the tabs three times. Cut eight 12-inch lengths of 4-inch-wide peel-ply to wrap around the tabs twice. Cut sixteen 5-inch squares of peel-ply with half of a 1 5/8" circle cut out of the middle of one end (as if a bite was taken out of the side). Two each of these will be used to cover the fiberglass on the inside walls. Put these materials nearby, each set in its own pile so they can be easily accessed.

Do one circle at a time. Start by brushing resin on the inside wall up to 6 inches around the pipe. Then slide the closet circle onto the face of the wall and saturate it with resin, using the tip of the brush to bump the fiberglass firmly against the wall. Brush resin on the tabs. Ensure that every tab is saturated. If the area where the fiberglass bends off the pipes and onto the wall pulls loose, use the tip of the brush to bump it back where it should be – snug against the wall and the pipe. Then wrap the 3-inch-wide fiberglass tape around the tabs, adding resin as you wind so that the tape is saturated. When all the fiberglass tape is one, wrap it with the 12-inch lengths of peel-ply. Cover the fiberglass on the walls with the 5-inch squares of peel-ply, one on each side of the pipe with the half-circle against the pipe.

When the resin has hardened, remove the peel-ply.

Add the Gunnel

The gunnel is a one-piece edge treatment that fits over the hull, with the top edges of the hull fitting up against the bottom surface of the gunnel. For this canoe, the two seats at the two ends of the canoe are incorporated in the gunnel. Part of the rigid panel that was infused earlier is used to fabricate the gunnel.

Measure the outside width of the middle of the hull, between the two matas. This will be the widest width of the hull. Add 9 inches and make a note of the total as the "*maximum width*". Cut a to 15' 4" x "*maximum width*" section from the to 3' 4" x 15' 4" panel.

Use a black sharpie to draw two sets of 6 parallel score lines, 3 inches apart, in the top surface of the panel starting as indicated by the red lines in *Figure 9*. Note that the first score line is 6 inches from the mata edge. The score lines need to cut through the fiberglass and ½ way into the panel. Take care to prevent the score lines from going deeper than ½ way through the panel.

Figure 9 – Gunnel Cut Plan – Top Surface of Panel

Position the scored panel over the top of the hull, with the hull exactly in the middle of the panel. The panel will sit high over the hull as its two ends will be supported by the high ends of the matas. Push down on the panel so that it bends and comes into contact with the hull edge along the entire underside of the panel. Adjust the position of the panel sideways so that the panel edge extends 2 ½ inches beyond the leeward (narrow) side of the hull at the midpoint between the matas. Ensure that the panel remains centered end to end, so that it

extends the same distance beyond both matas, and the edges of the panel beyond the matas are parallel with the matas. Put weight on top of the panel to hold it in place and snug against the top edge of the hull and use a black sharpie to trace the top edge of the outside face of the hull against the underside of the panel.

Remove the marked panel and put it marked side facing up on a table or on the floor. Mark it as shown in Figure 10, as follows:

Use a black sharpie to make a smaller outline exactly ½ inch inside of the black sharpie tracing. This new, smaller outline, indicates where the inside face of the hull meets the panel, while the larger outline around it indicates where the outside face of the hull meets the panel. Together they show where the gunnel will rest along the top edge of the hull.

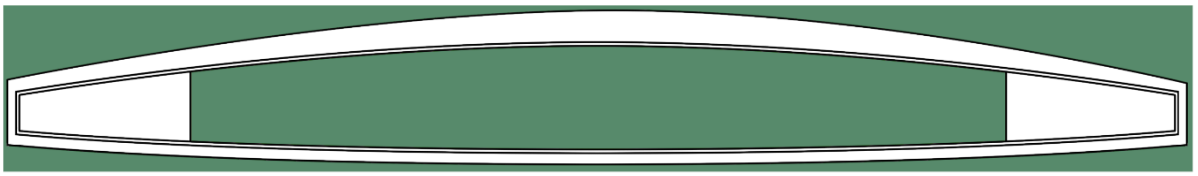


Figure 10 – Gunnel Cut Plan – Bottom Surface of Panel

Draw two lines in-between the smaller outline at 28 inches from each mata edge. These lines indicate the inside edge of the seats on each bow.

Draw another outline that is 2 ½ inches outside of the larger outline, but only on three sides – the two mata ends and the leeward (narrower) side of the hull. This marks the outside edges of the gunnel on these three sides. Part of this 2-inch outline will run along the edge of the panel along the leeward side since the panel was traced with just 2 inches

The gunnel on the windward side is very different from the leeward side. While the leeward edge of the gunnel protrudes 2 inches out beyond the outside of the hull, the windward side of the gunnel protrudes 2 inches out at the mata and gradually becomes wider towards the middle of the windward side where it protrudes 6 ½ inches beyond the outside of the hull. Use a black sharpie to draw this widening edge as shown in the drawing. Ensure that the line you draw is symmetrical so that both ends are mirror images of each other. This line marks the outside edge of the windward gunnel.

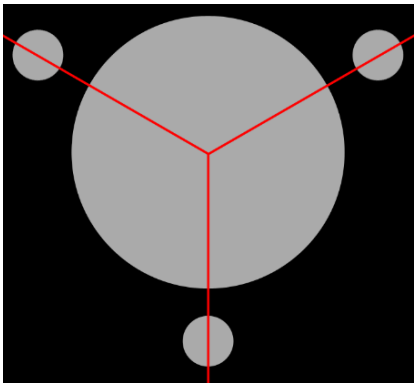
The drawing shows the areas to be cut away in green. The first area to cut is the outside edges of the gunnel. The second area to cut is the middle area between the seat edges and the inside smaller outline.

Make the cut straight down with a jigsaw or sawzall. Do not cut into the middle area since this piece of panel can be used later. Put all the cut-away pieces aside to be used for parts.

<u>Add Holes for the Two Tachong Lahi</u>

Two seats for the lahi need to be added to the top of the gunnel piece near the mata ends. These seats will also need holes for three attach points around them. *Figure 11* illustrates a template that needs to be made in order to locate where holes need to be drilled in the gunnel piece. The black area is the template. The gray areas are cut-outs. The red lines are not part of the template – they are there to show the placement of the holes in relation to each other. Note that the drawing is not to scale. You will need to use the measurements given below to make the template.

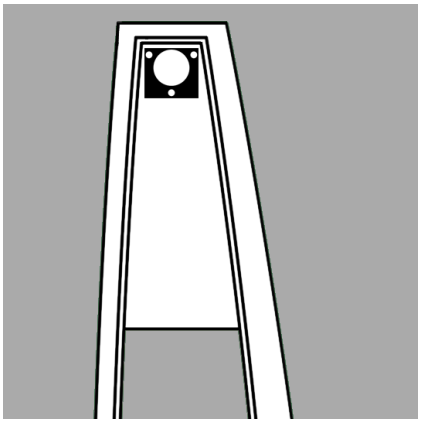
Make the template out of a thin piece of wood and drill out the circles, or use cardstock with a compass to draw the holes and cut them out. There are four holes. The big hole is for the base of the lahi. It will be the outside diameter of the PVC pipe that you will be using for the two tachong lahi. A 4-inch CPVC Schedule 80 slip-slip coupling fitting is recommended. The outside diameter of the fitting is 5 ½ inches, but don't rely on this. Instead, trace the outside of the actual fitting on the template. The three smaller holes are for double-polyester rope that will be used to secure the lahi in the tachong lahi.
These are made from a ½-inch CPVC Schedule 80 pipe. The outside diameter of this size pipe is .84 inch, but again, don't rely on this. Instead, trace the outside of the actual pipe on the template.



The three ½ inch pipe holes are spaced evenly around the big hole and 120 degrees away from each other. They are also ¾ inch away from the edge of the big hole before any coving is added. Note that the two top holes are level with each other.

Use the template on the <u>underside of the gunnel piece</u> as shown in *Figure 12.*

For each mata end, position the template as close to the mata end as possible but no closer than 1 ½ inch to the hull outlines. Be sure to orient the template so that the two small holes at the top are even with each other – the same distance from the end of the mata. Use a black sharpie to outline the holes onto the gunnel piece.



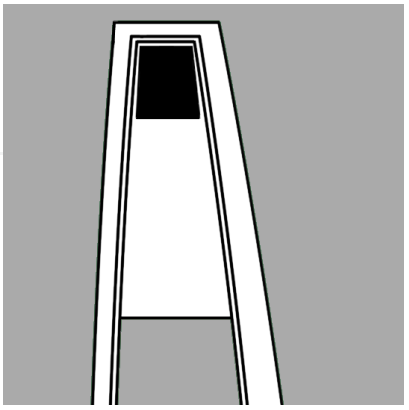
Locate the exact center of each of the four hole outlines on the gunnel piece and mark these center points with the sharpie. Use a 1/8 inch drill bit to drill straight through the gunnel piece to the gunnel piece face on the other side. Before drilling, be sure that there is room below the gunnel piece for the drill bit to exit without damaging whatever is beneath the gunnel piece.

Flip the gunnel piece over and drill out the eight holes, using a circle drill bit. Choose drill bits that fit in the holes that are to be drilled. If you don't have a drill bit that is the right fit, use the biggest drill bit you have that will fit in the hole, and then expand the inside of the hole. There are lots of ways to do this. One way that works well is to use a smaller drill bit (not a circle drill bit) to rub the sides of the hold with in a circular motion around the hole. Don't hurry or use a lot

of force when drilling these holes. Drilling slowly and gently with a fast drill will result in a clean cut with smooth edges and will avoid splintering the fiberglass on the two panel surfaces.

When both sets of four holes are drilled, flip the gunnel over again so that the underside is facing up again. Use a piece of cardstock to cut templates for fiberglass panels to cover both sets of holes as shown in *Figure 13* without getting closer than 1 inch from the double-outline.

Trace the templates onto the surface of the gunnel piece (the underside surface that is currently facing up). Use 40 grit sandpaper to scratch the surface of the gunnel piece inside the outlines made with the templates. This is to prepare the surface for resin.//



Use the templates to cut two panel pieces out of a fiberglass panel that has been glassed on both sides. Ensure that they fit properly where they are supposed to go in their respective ends. Use a multi-tool to remove foam from all the edges to a depth of ¼ inch, leaving a ¼ inch channel between the two surface layers of fiberglass. Fill this channel with peanut butter using a spreader.

When the peanut butter is dry, use a sander with 40-grit sandpaper to scratch both surfaces in preparation for resin. Mix a small amount of laminating resin and brush it on both the surfaces of the gunnel piece that were sanded between the outlines of the templates, and also on the faces of the cut panel pieces that will make contact with the gunnel piece and lay them down in place between the outlines of the templates. Add weight to the top of these pieces so that they are firmly pressed against the gunnel piece.

When the resin hardens, remove the weight and cut pieces of 6-inch wide fiberglass tape to be used to tape the edges of the panel pieces to the gunnel piece wherever there is room, avoiding getting closer to the double outlines than 1 inch. Also cut pieces of peel-ply to go over the tape. Use laminating resin to attach the fiberglass tape, making sure to saturate it. Put the peel-ply over the fiberglass tape and saturate the peel ply too.

Flip the gunnel piece and use the same drill bit used to extend the 6 small holes past the newly added base panel below the holes so that the holes are open all the way through past the base panel. The big tachong lahi holes will now be blocked at the bottom by the base panel, and the ½ inch pipe holes will go all the way through the gunnel piece.

<u>Attach the Gunnel to the Hull</u>

Flip the gunnel so that the scored cuts are facing up and fit it on top of the hull with weight added (cans of paint, cinder blocks, etc. – whatever is handy). Use 6 pieces of 2x4's that are long enough to span the gunnel and spaced evenly across the cut-out in the middle of the gunnel, with the 4" side of the 2x4's facing down. In this cut-out area, put the weights on the 2x4s. This will keep the gunnel edges perfectly level. Without the 2x4s, the weights might

press unevenly and cause the edges to slant downward. In the areas between the cut-out and the matas, put the weights directly on the gunnel face.

Check that the top edge of the hull fits perfectly inside the ½ inch outlined area. If it doesn't, it may be that it is upside down. When satisfied that the gunnel is a good fit, it is time to attach it permanently using "peanut butter".

Have clean and smooth 3 or 4 inch spreaders ready. Remove the weights and remove the gunnel. Prepare 3 liters of peanut butter with at least 30 minutes working time before it hardens.

First, push peanut butter into the score lines and scrape away any excess. This will fill any gaps when the gunnel panel is bent and the score lines close. Then scrape peanut butter off the spreaders and onto the hull edge in a downward motion along both edges to form a "pyramid" of peanut butter along the top of the hull edge. Carefully put the gunnel back on top, starting from one mata, pushing it straight down along the edge to the other mata without allowing the mata to slide out of alignment by holding it in place as the weights and 2x4s with weights are added. When putting weight over the score lines, scrape away any excess peanut butter squeezed out of the score lines first.

When the gunnel and weights are fully in place, use the spreaders to scrape excess peanut butter off the underside of the gunnel and the side of the hull.

<u>Glass the Edge of the Gunnel Area to the Inside Hull</u>

When the peanut butter has hardened, remove the weights. Sand the entire gunnel top surface with 40 grit sandpaper in order to make a scratched surface that resin can stick to. Sand the inside of the hull from the inside edge of the gunnel down 4 inches as well.

Use a grinder with a 60 grit sandpaper wheel to sand the inside top edge of the gunnel, removing about ¼ inch and creating a rounded corner. This is necessary when glassing corners because fiberglass does not lay flat across sharp corners.

Cut two strips of 6-inch wide fiberglass tape to fit along the two inside edges of the cutout where the gunnel meets the hull. Laminate these to the inside edge so that the middle of the tape runs along the middle of the corner and half of the tape width is on the inside hull and the other half of the tape is on top of the gunnel. When applying the fiberglass tape, first wet the corner three inches down and three inches along the top. Then press the tape in place and wet the top, using the brush tip to tap the resin into the tape until the tape is transparent. When the tape is completely wet with resin, cover it with an 8 inch wide strip of peel-ply so that the peel-ply extends one inch beyond both edges. Wet the entire 8 inch wide surface of peel-ply, taping with the tip of the bush to work any air out the sides or through the peel-ply.

<u>Complete the Two Tachong Lahi</u>

Put the hull inside the hull stand with the keel side down.

Cut two 2-inch lengths out of the 4-inch CPVC coupler to make two 2-inch lengths of 5 ½-inch diameter pipe. If any of the inside stop wall is included, trim it away so that the inside of the pipe is smooth and 5 ½-inches in diameter.

Also cut six 1-inch lengths of ½-inch PVC pipe. Scratch-sand all the surfaces of these pieces. Test that all the pieces fit well in their respective holes, being careful not to get them stuck inside the holes. With all the pipes out of the holes, spread peanut butter into the sides of the tachong lahi holes and push the 5 ½-inch pipes firmly into the holes, all the way to the bases of the holes. Spread peanut butter around the inside of holes for the ½-inch pipes and push them all the way in so that they are flush with the surface of the gunnel piece. Clean away any excess peanut butter that pushes out of the holes, both on both top and bottom surfaces of the gunnel.

For both tachong lahis, cut enough fiberglass tape to wrap three times around the outside of the 1 ½ length of the 5 ½-inch pipes that are sticking up beyond the gunnel surface. If necessary, trim one edge of the tape so that when it is wrapped, no tape extends past the top of the PVC pipe. Brush the outside of the pipes that stick up out of the gunnel piece surface with laminating resin, and then wind the fiberglass tape around them while brushing resin on the tape so that the tape is saturated. When all the tape is around the pipes, add a few winds of peel-ply while adding resin to saturate the peel-ply as it goes on as well.

When the resin hardens, remove the peel-ply and use peanut butter to cove the outside bottom of the 5 ½-inch pipe against the gunnel surface. When the coving has hardened, make a mix of loose chop-mat strands and peanut butter and press it into the base of the tachong lahi evenly and to about ½ inch thick.

<u>Add the Tachong Falina</u>

With the hull inside the hull stand with the keel down, measure to locate the middle of the windward gunnel top surface and draw a line from the inside edge of the hull to the outside edge of the gunnel with a black sharpie at that point. This should measure 7 inches. Note: It is extremely important that this line be exactly at the half-way point between the matas. Double-check that it is by measuring from this line to both matas. The two measurements must match.

Cut a piece of 7”x7” square of fiberglass panel that is infused on both sides. Scratch-sand both sides of the panel with 40 grit sandpaper to prepare the surfaces for resin. Draw lines between opposite corners on the panel to create an X. Drill a 5” hole through the exact middle center of the panel indicated by where the lines of the X cross.

Position the panel onto the middle of the windward gunnel, positioning the circle so that the line you made across the gunnel is exactly in the middle of the 5” hole. Use a black sharpie to trace the outside of the panel onto the gunnel. Then scratch sand the inside of the tracing, but preserve the trace lines.

Use laminating resin to glue the panel to the gunnel by brushing resin on both surfaces before putting the panel onto the gunnel inside the tracing. Use clamps to firmly hold the panel against the gunnel until the resin hardens.

When the resin has hardened, scratch-sand the gunnel surface along the outside edge of the panel out to 1 inch toward the matas, and out to the edges of the gunnel. Use a multi-tool to remove ½-inch of foam from between the laminates along the edge of the panel, and replace the foam with peanut butter. Cove all the edges of the panel to the gunnel surface.

Cut a 2-inch piece of 5-inch PVC pipe. Sand all the surfaces of the PVC pipe. Test to ensure that the PVC pipe fits well inside the hole inside the panel. Put peanut butter along the inside corner of the hole and push the PVC pipe firmly inside.

Cut enough fiberglass tape to wrap three times around the outside of the 5 ½-inch CPVC pipe that is sticking up out of the panel. If necessary, trim one edge of the tape so that when it is wrapped, no tape extends past the top of the CPVC pipe. Brush the outside of the CPVC pipe that sticks up out of the gunnel piece with laminating resin, and wind the fiberglass tape around the PVC while brushing resin on the tape so that it is saturated. When all the tape is around the PVC pipe, add a few winds of peel-ply while adding resin to saturate the peel-ply as it goes on as well.

When the resin hardens, remove the peel-ply and use peanut butter to cove the outside bottom of the PVC pipe against the panel surface, and the inside bottom of the PVC pipe against the panel surface below.

<u>Add The Sagan Gahet</u>

The two sagan gahet are made of 4-inch IPS Schedule 80 PVC pipe. These must be installed perfectly or the lucha could be out of alignment. To get them perfect, start by marking the exact middle of the hull between the matas and marking this point on the outside edges of both sides of the gunnel.

Securely attach a piece of string between the middle of the two matas. Then use a measuring tape to find the midpoint in the string and mark it with a black sharpie. Use a framing square with the longest side at least 24 inches long. We will refer to this side as “side A” and the other side as “side B”. Hold the framing square so that the outer edge of side A is touching (but not moving) the marked midpoint of the string, and the outer edge of side B is parallel with the string. Rotate the framing square so that the 24-inch side touches the outside edge of one gunnel. Ensure that side A is still at the mark on the string, and that side B is still parallel with the string. Mark the gunnel where the outer edge of side A is touching the gunnel. Do the same for the other side. The two marks are both at the midpoint of the hull.

Now make sure that the hull is perfectly straight in the hull stand by measuring the distance from the middle of both matas to the floor. If the measurements are the same, the hull is straight along the plane from mata to mata (in other words the hull is neither point up or pointing down). Next at the midpoint marks on the outer edge of the gunnels, measure from the top of each gunnel to the floor. If the measurements are the same, the hull is straight along the plane from side to side (in other words, the hull is neither tipping to the left or the right).

The two sagan gahet are 37-inches apart measured from their centers. To mark the points on the hull where the holes for the sagan gahet need to be drilled, use a black sharpie to make dots exactly two inches below both the leeward and the windward gunnels at the midpoint of the hull. Then, with the hull straight in the hull stand, measure exactly 18 ½ inches sideways from these dots toward each mata and mark the location with a dot, making four dots total. Measure the distance of each dot to the floor to ensure that they are all at the same height. These dots mark the middle point of each sagan gahet hole to be drilled.

Use a circle drill bit that drills a hole that fits the outside of the PVC pipe. Usually a 4-inch Schedule 80 pipe requires a 4 ½ inch hole. Drill the holes from the outside of the hull. Circle drill bits have a small drill bit in the center of the circle drill bit that sets and holds the cutting edge of the circle drill bit in position. That smaller drill bit must drill through the dot you made that marks the middle point of the sagan gahet hole. Then the wider 4 ½-inch circle drill bit will cut the hole in the right place. After all four holes are cut, scratch-sand one inch around the outside of the holes on the outside of the hulls, and 6 inches around the holes on the inside of the hull.

Cut four 11-inch squares of triax. On each of them, draw two lines with a black sharpie from opposite corners to make an X on the square. Then draw another X so that the lines of the second X are exactly in-between the lines of the first X (as if the second X was rotated 45 degrees). Draw a 2 ½-inch circle and also a 5-inch circle around the middle of the square, where all the lines of the two Xs intersect. Using scissors, Cut the smaller circle out and discard it. Then cut along all the lines of the Xs from the hole to the 5-inch circle. Last, trim the corners of the 11-inch square to make it an 11-inch circle. As you make these cuts, try to hold the fibers in place so that they are not pulled out of place by the scissors.

Measure the width between gunnels above the holes, and cut four 5-inch diameter PVC pipes to that length. Sand the outside of all four pipes with 60-grit sandpaper.

Slide each pipe into one of the holes from the outside of the hull so that it is part way inside the hull. Slide two of the 11-inch circles onto the pipe on the inside of the hull. The tabs in the middle of the first circle will bend away from the inside wall as the circle is pushed onto the pipe. Then slide the second 11-inch circle on the pipe, but manipulate the tabs so that as the circle slides onto the pipe the tabs point toward the first circle.

When the two circles are around the pipe with their tabs pointing at each other, put the pipe the rest of the way in. Position the pipe so that each end of the pipe is flush with the outside edge of the gunnel above it. Then use peanut butter to cove the outside of the pipes against the outside hull walls. Be sure the pipes do not shift, but remain exactly flush with the outside edges of the gunnels above them.

When the peanut butter has hardened, it is time to laminate the circles onto the pipe and the inside hull wall. Cut four 45-inch lengths of 3-inch-wide fiberglass tape to be used to wrap around the tabs three times. Cut four 30-inch lengths of 4-inch-wide peel-ply to wrap around the tabs twice. Cut eight 9-inch squares of peel-ply with half of a 5-inch circle cut out of the middle of one side (as if a bite was taken out of the side). Two each of these will be used to cover the fiberglass on the inside walls. Cut eight 3” x 7” pieces of peel-ply. These

will be used to cover exposed fiberglass between the 9-inch squares of peel-ply. Put these materials nearby, each set in its own pile so they can be easily accessed.

Do one circle at a time. Start by brushing resin on the inside wall up to 6 inches around the pipe. Then slide the closet circle onto the face of the wall and saturate it with resin, using the tip of the brush to bump the fiberglass firmly against the wall. Brush resin on the tabs. Ensure that every tab is saturated. If the area where the fiberglass bends off the pipes and onto the wall pulls loose, use the tip of the brush to bump it back where it should be – snug against the wall and the pipe. Then wrap the 3-inch-wide fiberglass tape around the tabs, adding resin as you wind so that the tape is saturated. When all the fiberglass tape is one, wrap it with the 30-inch lengths of peel-ply. Cover the fiberglass on the walls with the 9-inch squares of peel-ply, one on each side of the pipe with the cut-out edge against the pipe. If these squares don't completely cover the fiberglass, use the 3"x7" pieces of peel-ply to cover the exposed fiberglass.

When the resin has hardened, remove the peel-ply.

Round the Outside Gunnel Edges

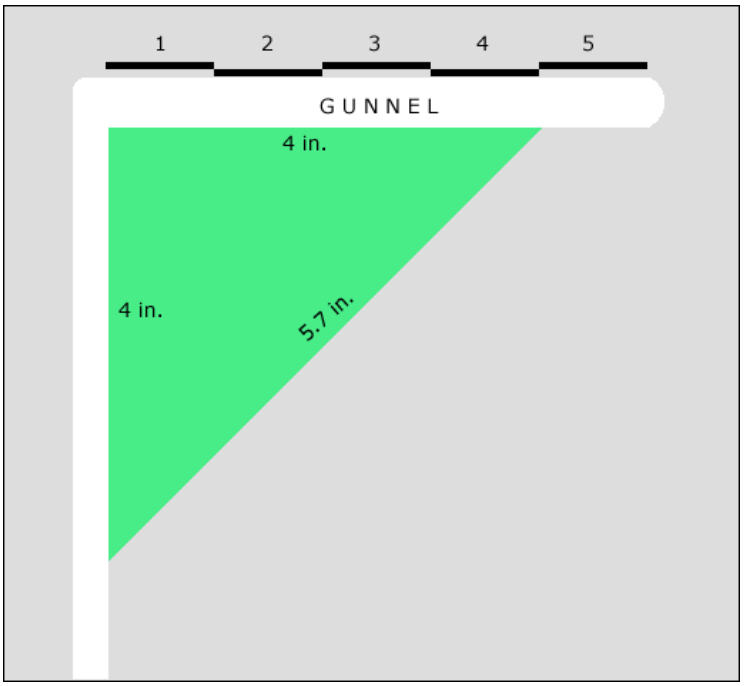
Use a grinder with a 60-grit sanding disk to even out the outside edges of the gunnel all around the hull, so that when viewed from the bows, the edges look smooth and even. Then using a multi-tool, remove foam from between the laminate along the edges of the gunnel to a depth of ½ inch and replace it with peanut butter. Scrape excess peanut butter off the edge so that the peanut butter forms a straight edge between the top and bottom laminates. Then use an orbital sander with 60-grit sandpaper to sand the top and bottom corners of the gunnel edge to shape a slightly curved edge. Be careful to sand only enough of the corners to round the edge and not to remove peanut butter from the middle of the edge.

Add the Gunnel Braces

The wider gunnel over the windward side of the hull is supported by a series of triangular braces. There are 11 of them, centered below the gunnel and spaced evenly 10 inches apart. Use ½-inch pieces of tape on the edge of the gunnel to work out where these braces go. Start by putting a piece of tape in the mid-point of the gunnel between the two mata. Then add five more pieces of tape on both sides, all 10 inches apart. When all the pieces of tape are on the gunnel, double-check that they are all 10 inches apart and number them 1 to 11 from left to right as you face the canoe from the side.

Scratch-sand below each piece of tape where the braces will go.

Below each piece of tape, measure the distance from where the hull touches the gunnel, to 1 inch from the tip of the outward reaching gunnel edge. Write that measurement on the piece of tape. Then, from a fiberglass panel that is glassed on both sides, cut 11 small triangular braces with each being a right-angle with the two equal sides of the triangle being the measured distance for that number. For example, in the drawing below, the gunnel extends 5 inches from the hull, so the triangle is 4" x 4" x 5.7".



Write the number of each triangle on the face of the triangle.

Trim each triangle so that it fits perfectly in its place below the gunnel with the right-angle corner touching both the underside of the gunnel and the hull, and the top edge of the triangle flush against the underside of the gunnel. Trim any that don't fit perfectly by sanding the edge of the triangle that is against the hull with 40-grit sandpaper. Note that since the braces are placed at 90 degrees to the underside of the gunnel that curves slightly upward at each end, the braces will follow that curve and tilt accordingly with the bottom of each brace a bit closer to the matas than the top. As each brace is trimmed to fit perfectly, use a black sharpie to trace all the edges against the hull and underside of the gunnel to mark the exact position.

Use a multi-tool to remove ½-inch of foam from between the fiberglass along the long edge of the triangles and fill these channels with peanut butter. Use a spreader to trim excess peanut butter off the edges so that each triangle has flat edges again.

Use peanut butter to glue each triangle in its place inside the black traced outlines. Cove the inside corners over the traced outlines.

Build the Lucha Jig

Cut and Score Two Panels

Cut two rectangular pieces of fiberglass panel that has been glass on one side, one for the sides and bottom of the lucha hull and one for the top of the lucha, which we'll call the "hat". The piece for the lucha hull should be 10 feet long and 22 inches wide. The hat should

be 10 feet long and 12 inches wide. After these pieces are bent to shape, attached, and trimmed, the new outside dimensions for both will be 9' 10" long and 8 ¾" wide.

Cut parallel score lines along the length of the lucha hull on the unlaminated side. Cut the first score line in the exact middle, between the long sides. Add four score lines on each side of the first score line, space ½-inch apart. Add four more score lines on each side, with 3/4-inch between the lines. Add three more score lines on each side with 1-inch between the lines.

Cut parallel score lines along the length of the hat on the unlaminated side. These score lines should start 1 inch from the long edges and be space ½-inch apart.

Shape the Lucha

Use the lucha jig to bend the lucha hull panel by positioning the panel on top of the jig and pressing the middle down and into the jig until the middle of the panel is touching the bottom of the jig and top edges of the panel are even with the top of the jig. Because of the spacing of the score lines, the bend will be most acute at the bottom, gradually straightening toward the top. Be sure that both sides bend evenly. It may be necessary to push the sides in with pieces of wood clamped to the sides of the jig to hold their position. Ensure that the panel's top edges are even with the top edge of the jig, and put a wood screw through the exact middle of the panel near each end and into the exact middle of the jig below. This will prevent the panel from shifting inside the jig.

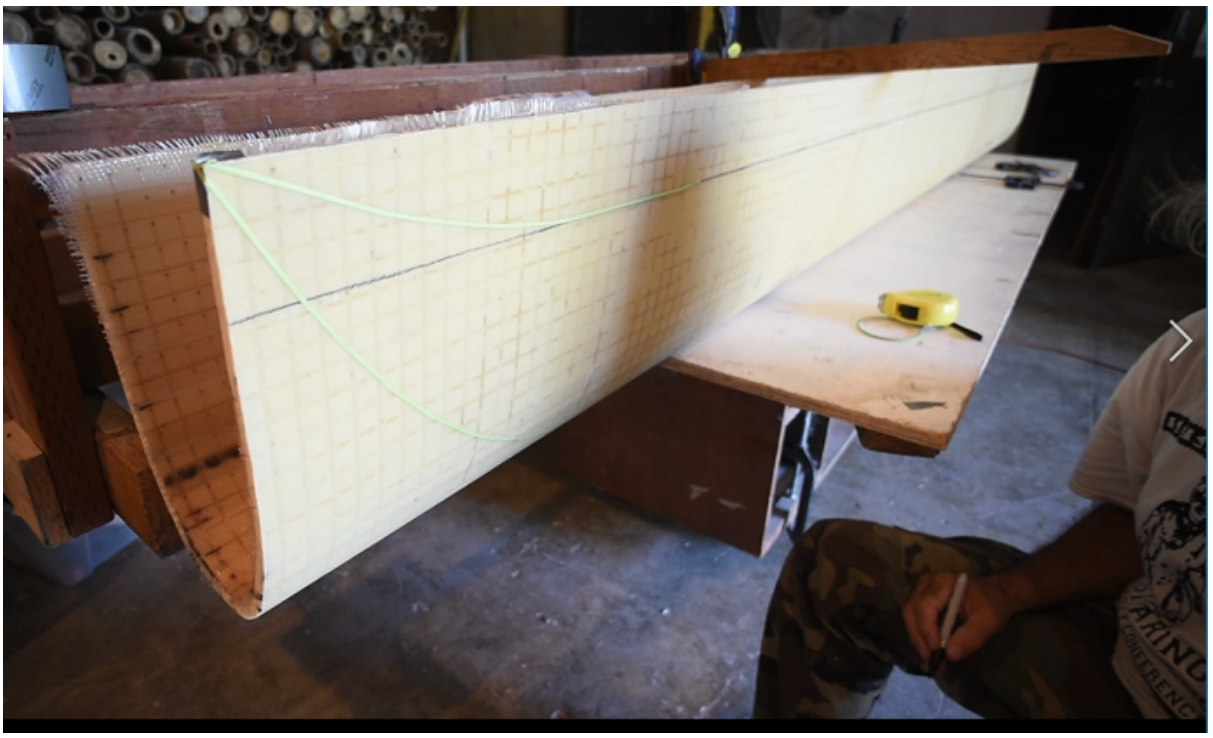
Fill any gaps in the score lines with peanut butter, taking care to scrape any excess peanut butter off the surface of the panel. When the peanut butter has hardened, use an orbital sander to smooth and scratch-sand the inside surface of the panel.

<u>Trim the Lucha Hull</u>

Place the lucha hull keel-down on a flat table, using blocks and clamps to brace the sides so that the lucha hull is straight. Draw "reference lines" on both outside surfaces from bow to bow, 4 inches from the upper edge.

Determine the profile of the lucha by marking out two lines starting from the upper left corner of the lucha body. Do this only on that corner since the profile shape that you mark out will be duplicated exactly at the other corners later.

The first line you draw should curve gently down and to the right until it is horizontal and even with the reference line. It represents the top edge of the lucha when viewed from the side. The second line should curve gently down and to the right until it is horizontal with the table top. It represents the bottom edge of the outrigger when viewed from the side. Use 1/8th inch wide masking tape to make these lines, adjusting the tape as needed until you get the curves that you want. Make lines that form a pleasing shape with smooth curves. As you work, step back 8 feet or so occasionally to see how the profile you're marking will look at the end of a 10-foot long lucha.



When you’re satisfied with the profile you marked out, trace the two lines with a black sharpie and remove the tape. Now duplicate the lines at the other three corners as follows:

Working from left to right along the reference line, measure the distance down to the second curve and write the measurement below the curve at that point. Continue to the point where the curve ends at the table-top level. Do the same for the first curve, measuring up from the reference line.

Duplicate the two curves on the other three corners by measuring up and down along the reference lines at 1-inch intervals, and marking the point at the distance recorded with a dot. Then connect the dots to make the curves.

Use a grinder with a cutting disk to cut along the curved lines. The bottom curved lines will meet on the other side. The top curved lines will end at the reference line. For the top, continue cutting along the reference line until you reach the other curved line. Discard the cut-out pieces.

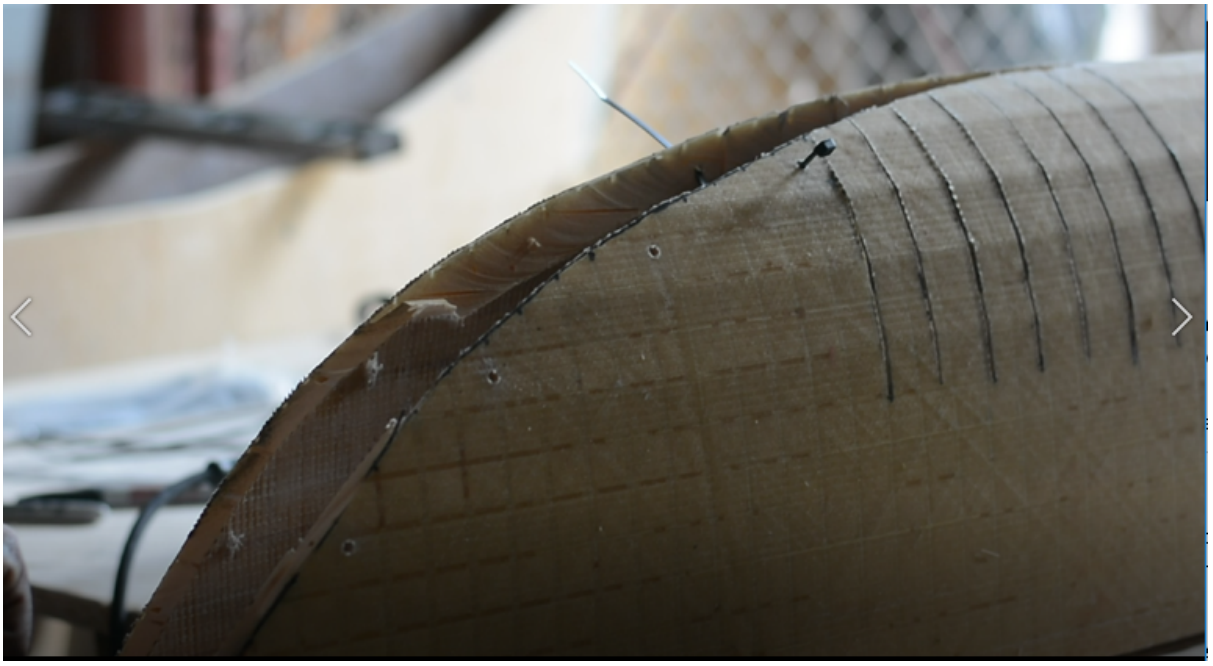
Place the lucha hull on a table with the ends hanging below the table and the keel of the lucha hull facing up. Use ratchet straps to secure it in place.

Use a grinder with a cutting disk to trim the final 3 inches of the inside edges where the two cut edges meet at the keel, so that the faces of those edges are vertical. This trimming will help the two sides bend towards each other in the next steps. Extend the cut into the keel about an inch. The end of this cut is the “starting point” of a series of cuts downward along the sides that will be made to allow the ends of the lucha hull to be bent towards each other and connected at the keel.

Make the first cuts at the starting point. The cuts are made with the grinder with a cutting disk. They go straight down both of the lucha hull sides. Cut only the curved surface, stopping when the curve straightens out.

After the first cut, push the ends of the hull towards each other so that it bends along the first cut and starts to close. The two sides near the starting point will come together. Where they stop coming together, make another set of cuts down the sides, again stopping when the curves straighten. Push the sides together again, and the two sides will come together even further. Where they stop coming together, make another set of cuts down the sides, again stopping when the curves straighten. Push the sides together again, and the two sides will come together even further. Keep doing this until the two edges come together all the way to the end.

Now secure the two sides tightly together with zip ties. Drill holes for the zip ties about ½ inch from the edges of the two sides.



Use peanut butter to fill the gaps along the outside keel edges where the two sides come together, forming a new edge that is smooth and even after sanding. Do the same over the outside surfaces over the cuts to form a smooth surface over them. When the peanut butter hardens, turn the lucha hull over and use peanut butter on the cut surfaces there as well, again creating smooth surfaces.

Shape the Hat

Lay the hat on a table with the scored surface facing up. Scratch-sand the scored surface.

Cut two 10 foot long wooden or metal corners with ½-inch edges and fit them along the long edges of the hat. Put 5 evenly spaced ratchet straps around the hat width-wise, with the ratchets on top, close to one of the long edges.

Position a 10 foot by 4” diameter pipe in the middle of the hat lengthwise and under the straps. If you don’t have one, use something similar that can raise the middle of the straps at least 4 inch off the scored surface.

Tighten the ratchet straps one at a time to slowly bend the hat along the score lines. Keep bending until the two long edges are 8 ¾ inches apart. Both sides of the hat should be bent evenly to produce a smooth, round arc. Remove the 10’ pipe.

Measure the concave surface with, and cut a piece of triax that is that width by 10 feet long. Cut a piece of peel-ply that is 4 inches wider and 4 inches longer. Mix some peanut butter and use it to fill any open gaps in the score lines. Then mix 1 ½ liter of resin and laminate the scored surface.

When the resin has hardened, remove the straps and peel-ply and flip the top over so that the convex side faces up. Use a black sharpie to draw a dividing line exactly down the middle of the hat from end to end. Cut the hat in half along this line so that you have two long 10-foot halves. Turn them both over again so that concave surfaces are facing up again.

Our goal now is to bring the two pieces together lengthwise so that where they meet forms a peak and the outside edges of both exactly 9 ¾ inches apart. This is easily done by blocking the outside edges so that they cannot slide outward, using weights, clamps, or tape to hold outside edges in place. Adjust the two halves so that they slope upward evenly to the peak.

Use peanut butter to both glue the two touching halves together at the top of the peak, and to build the peak up to a smooth rounded edge along the top of the hat. When the peanut butter has hardened, turn the hat over and cove on the other side.

Complete the Lucha

Make two Gu'ut Lucha

Two V-shaped *gu'ut lucha* will hold the lucha in position under two bamboo poles called *gahet* that are attached to the canoe hull. The lower part of the gu'ut lucha (the lower part of the V) is permanently attached deep inside the lucha, while the upper part (the top two ends of the V) is lashed to the gahet.

To fabricate the gu'ut lucha, cut one ¾ inch length and four 3-foot lengths of 1-inch Schedule 80 PVC pipe. Scratch-sand the outside surfaces of all of them.

Using the image and measurements in the file "gu'ut lucha frame.jpg" as a guide, build a frame for attaching two pipes together for the gu'ut lucha. Start by attaching two 13" x 4" pieces of wood on a piece of plywood with the inside faces of the top ends 6 ½ inches apart, and the inside faces touch on the bottom. Then use the 1" PVC pipes as spacers and attach two more 13" x 4" pic two pieces of wood on the outside.

Use the frame to make the two gu'ut lucha one as a time using the image in the file "gu'ut lucha use.jpg" as a guide as follows:

Cut a 2-foot square piece of vacuum bagging and position it over the frame so that the frame is covered with about six inches of vacuum bag extending past the end of the frame where the channels come together. Push the vacuum bag evenly into the two channels. The purpose of this vacuum bagging is to keep the peanut butter that will be applied to the pipes inside the channel from sticking to the frame.

Put one pipe on each channel so that their ends touch evenly on the end where the channels come together. Cut away about ¾" of the edge the ¾-inch long 1-inch ring and push the ring into the ends of the two pipes to clip them together.

Mix a small amount of peanut butter and push it into the ends of the pipes and around the ¾-inch long ring, and also between the two pipes at the "inner elbow". The purpose of the peanut butter is to hold the two pipes together. When the peanut butter has hardened, carefully remove the gu'ut lucha and use a grinder with a 40-grit sanding disk to sand away any excess peanut butter so that the gu'ut lucha lays flat on the table on either side.

When both gu'ut lucha have been fabricated and trimmed so that they lay flat, put them both in the frame, one on top of the other and sand off any rough edges. Sand the ends of the joined pipes so that they are the same length and shape, and straight and parallel with

the nearest edge of the frame. Do not sand the ¾" ring that holds the two pipes together inside the peanut butter.

Remove the two gu'ut lucha from the frame.

Add Bulkheads to the Lucha

Bulkheads inside the lucha make it stronger and also hold the gu'ut lucha in its position. Each bulkhead is comprised of two parallel rigid panel walls sandwiched around the bases of the gu'ut lucha. The area between the panels and around the bases is filled with bits of rigid panel encased in resin, creating a solid foundation that holds the gu'ut lucha in place.

To install the bulkheads, start by locating where they go inside the lucha hull. Mark the midpoint of each side of the lucha hull at the top of the sides. Measure horizontally away from the midpoint in both directions and mark the top edges at 18 ½ inches. Label one "1", and the other "2", for bulkhead #1 and bulkhead #2.

The bulkheads go between these two lines. Double-check that these marks are correct. The matching numbers should be across from each other so when the bulkhead is installed between them their flat surfaces are at right angles to the inside of the lucha hull.

Use card-stock to cut a template for bulkhead #1. The top edge of the bulkhead needs to be even with the top edge of the lucha. The lower edges need to run along the inside face of the lucha hull. Once you've got the pattern drawn, trace its outline onto a piece of fiberglass panel that has been glassed on both sides, and cut it out. Test how it fits inside the lucha hull and trim it if necessary until it fits well. Then make another one, since each bulkhead needs two panels. They will be installed with the gu'ut lucha sandwiched in-between.

Try one of the #1 bulkheads in position #2 to see if it fits. If it does, just make two more. If not, modify the template that you made for #1 to fit in position #2 and cut out the panels for position #2.

It is important to understand that the panels are not the bulkheads. Bulkheads are the combination of two panels with a set of gu'ut lucha between them. Temporarily assemble the two bulkheads by clamping the pieces firmly together with a clamp over the top edge. The faces of the panels should be in full contact with the pipes on both sides.

Lower each bulkhead into the lucha hull between the 18 ½" marks, with the top edge flush with the top edge of the lucha hull, and the middle of the gu'ut lucha pipes lined up with the 18 ½" marks. Use two more clamps, one on each side to hold the bulkheads in position. Now get them perfectly aligned so that the faces of the bulkheads are perfectly vertical, the edges of the panels are all in contact with the inside walls of the lucha hull, and the top edges of the panels are even with the top edges of the lucha hull. Now use a black sharpie to trace the outlines of the outside edges of the two outside panels (the panels further from the middle) onto the walls of the lucha hull. Mark the outside face of one of the panels with the letter A, and the wall next to it with the letter A. Likewise trace the other panel edge and mark the outside face of that panel and adjacent wall with the letter B.

Take the temporarily assembled bulkheads out of the lucha hull and disassemble it. Scrape peanut butter over the outside edges of the panels marked A and B (but not the top edge) and push them back in their marked positions (next to their respective A and B marked outlines inside the lucha hull. Be sure they are exactly in the same positions with the edges lined up with the outlines, then cove along the edges where the panels meet the wall. Only cove the outward facing panels (the side facing away from the middle). Scrape away any peanut butter on the inside faces of the panels.

When the peanut butter has hardened, put the two gu'ut lucha back in position, using clamps to hold them against the panels. Ensure that the middle of the gu'ut lucha pipes line up with the 18 ½" marks on the lucha hull top edge. Adjust the gu'ut luchas so that their V shape is straight (not tilted to one side). To be sure that the two gu'ut lucha are perfectly aligned with each other, clamp a plank to the left pipe of one gu'ut lucha and the left pipe of the other gu'ut lucha, and another plank to the right pipe of one gu'ut lucha and the right pipe of the other gu'ut lucha.

When the gu'ut luchas are straight and aligned with each other, use peanut butter to attach them to the panels by pressing peanut butter into the space between the pipes and the panel. Do not get peanut butter on the surface of the pipe facing away from the panel since this would interfere with the next panel that needs to sit flat against the pipe.

When the peanut butter has hardened, install the two remaining panels, again by scraping peanut butter on the out edges (but not the top edge) and press the panels into place, up against the gu'ut luchas. Cove along the outside edges where the panels meet the wall.

When the peanut butter has hardened, fill the middle spaces of the bulkheads between the panels to the top with small pieces of rigid foam, The pieces should be about a square inch each or smaller and should not stick up beyond the top edges of the panels. Mix a liter of infusion resin and pour half over the rigid foam pieces in each of the bulkheads. The resin will flow to the bottom of the bulkheads where it will harden. Give it time to cool, then add more resin, but never more than ½ liter in each bulkhead at a time. Always give the resin time to cool before adding more resin. The reason for this is that the resin heats up as it hardens, and too much resin could get so hot that it can cause the materials in contact with it to melt.

<u>Attach the Hat to the Lucha hull</u>

Cut holes on the edges of the hat where the four stems of the gu'ut lucha need to pass through the hat and set the hat on top of the lucha hull.

On both bow ends of the lucha, use a black sharpie to outline the top by holding the length of the sharpie against the lucha hull and sliding it on the lucha hull surface, drawing the outline against the underside of the top. Then take the top off, turn it upside down, and cut off the excess by cutting straight down along the outline. Put the top back on top of the lucha hull.

Use a grinder with a sanding disk to sand along the top of the lucha hull, and along the bottom of the hat on each end, removing material from both surfaces that stops the bottom

of the top from reaching all the edges of the top of the lucha hull. You will need to move the hat away to make room to sand, sand a bit at a time off the hat and lucha hull, test for fit, and do it again until the hat fits. Put six to eight ratchet straps in place around the lucha (be sure not to wrap them around whatever is holding the lucha in place on the table) and tighten them to test that the hat pulls flat against the lucha hull. It is okay if there are small gaps (1/4" or less) in some of the edges. Loosen and unhook the ratchet straps, but leave them in position to be secured and tightened again in the next step.

Remove the hat and fill the spaces inside the lucha hull with empty plastic bottles with their caps glued and tightly closed. Use "big gap filler" spray foam to fill in between the bottles by using the long spray applicator to shoot the foam below and between the bottles. The foam will rise and fill gaps as it expands so be careful not to use so much that it pushes the bottles up past the lucha hull edge. If there are lots of hands to help, adding the foam can be done simultaneously with scraping peanut butter along the top edges of the lucha hull and the bulkhead panels and closing the top while the foam is still rising. Otherwise, add the foam first, being careful to not put too much under the bottles so that it pushes them above the lucha hull edge, and filling in the open areas next to the bottles at the top so that the bottles appear to be floating in a sea of foam. Then you'll have more time to scrape the peanut butter in place over the edges and add some more foam above the bottles, before closing the top. Once the top is in place, secure it tightly against the lucha hull and use a spreader to scrape off any excess peanut butter that was squeezed to the outside of the hull. This will be along the seam between the top and the lucha hull, and at the base of the gu'ut lucha where the holes were cut.

<u>Glass the Seam and the Gu'ut Lucha</u>

Cut four 6-inch squares from a 6" role of fiberglass tape. Place the end of a 1" PVC pipe in the center of each 6-inch square and trace the outside edge with a black sharpie. Make three evenly spaced scissor cuts across the middle of the circle to form six triangular tabs. These squares will be slid onto the four gu'ut lucha pipes and down against the top face of the hat later. For these, cut four 3" x 6" squares of peel-ply with a one-inch scissor-cut in the middle of one 6-inch edge. Put these materials nearby, ready for use, and label them "6-inch squares"

Do a test wrap of 2-inch fiberglass tape around one of the gu'ut lucha pipes, starting with about 2 inches on the lucha at the base of the pipe, and winding it up the outside of the pipe so that the edges touch but don't overlap, to a distance of 18 inches above the lucha, then cut it off at that level. Measure it and cut seven more lengths of the same size. Cut lengths of peel-ply that are 3-inches wide, and six inches longer than the pieces of tape. These materials will be used to wrap the four gu'ut lucha pipes later. Put them nearby, ready for use, and label them "gu'ut lucha".

Cut two lengths of 6-inch-wide fiberglass tape to fit between the gu'ut lucha pipes. Cut two lengths of peel-ply that are two inches wider and two inches longer than the two pieces of fiberglass tape. These materials will go along the upper edge of the lucha hull later. Put them nearby, ready for use, and label them "in-between".

Cut four lengths of 6-inch-wide fiberglass tape to fit from the edge of the gu'ut lucha pipes to the bow end of the lucha. Cut four lengths of peel-ply that are two inches wider and two inches longer than the two pieces of fiberglass tape. These will go along the upper edge between the hat and the lucha later. Put them nearby, ready for use, and label them "bows".

Use an orbital sander with a 60-grit sanding disk to round out the top edge of the lucha on all sides.

The lucha is ready for the edges and the gu'ut lucha pipes to be laminated. Start at one bow and work one side to the other bow, then back along the other side to the first bow as follows:

1. Brush resin along the edge where the six-inch wide tape will go, from the bow to the gu'ut lucha. Use the materials labeled "bows" Lay down the fiberglass tape, saturate it, and cover with peel-ply.

2. Peel back the peel ply from the base of the gu'ut lucha. Brush resin around the base of the gu'ut lucha to a distance of 3 inches out from the pipe in all directions. Use the materials labeled "gu'ut lucha". Slide one of the 6-inch squares onto the pipe and down onto the wetted surface of the lucha and the end of the fiberglass tape from the previous step. Saturate the square with resin. Brush resin onto the gu'ut lucha pipe surface up to 18 inches above the lucha face. Wind one of the 2-inch lengths of fiberglass tape up the pipe, starting with 2 inches of the tape on the lucha face at the base, and winding clockwise upward, keeping the edges of the tape touching as you wind, until the tape runs out. Saturate the tape with resin. Wind another of the 2-inch lengths of fiberglass tape up the pipe, starting with 2 inches of the tape on the lucha face at the base, and winding counter-clockwise upward with the middle of the tape over the edges of the first tape, again keeping the edges of the tape touching as you wind, until the tape runs out. Saturate that tape with resin. Wrap the gu'ut lucha with peel-ply. Fold the peel-ply that was peeled back, back into place.

3. Brush resin on the edge between the just laminated gu'ut lucha and the next one. Use the materials labeled "in-between" to laminate this area, and cover it with peel-ply.

4. Laminate the 2nd gu'ut lucha the same way as in step 2.

5. Laminate the to the bow and back around the other side to the 3rd gu'ut lucha as described in step 1.

6. Laminate the 3rd gu'ut lucha as described in step 2.

7. Laminate between the 3rd and 4th gu'ut luchas as described in step 3.

8. Laminate the 4th gu'ut lucha as described in step 2.

9. Laminate the final edge between the 4th gu'ut lucha and the first bow as described in step 1.

After the resin has hardened, remove the peel-ply and sand the surfaces smooth where needed. Note that the tops of the gu'ut lucha that are not laminated will be cut off later when lashing the lucha.

Fair and Gelcoat

Gelcoat is a form of polyester resin that is used as a surface paint for boats. The gelcoat will be applied over all fiberglass surfaces, which means the entire hull, both inside and out, and the entire lucha, including the gu'ut lucha.

Prepare the surface by sanding it smooth. Where there are pits or slightly shallow areas in the surface, fill them with Bondo and sand them smooth. Problem areas that are deeply indented need to be addressed with layers of chop-mat, after scratch-sanding the surface with 40 grit or rougher sandpaper.

Gelcoat is added by brush and foam roller. The brush is used for areas that the roller cannot reach. Do the areas that require a brush first. Then follow with the roller. Two coats will be required. Do not try to do one thick coat instead since the gelcoat will drip and there will still be places where the hull surface shows through. Do one coat, let it harden, then do another coat over the first. By allowing the first coat to harden, it will seal the surface so that dark areas of the underlying hull do not show through after the second coat.

The process for gelcoat is to mix the gelcoat in the 5 gallon bucket it comes in, using a paint mixer and a heavy-duty drill until all the gelcoat is an even, white color.

Always do a test to see how fast the gelcoat will harden with a set amount of MEKP. Test a ¼ liter batch using the same % MEKP as you would use for a ¼ liter of resin and see how long it takes to set. If necessary, do additional tests to find out what percentage MEKP is needed for a 40 minute working time. You will also be adding a surfacing agent (called "wax") with the gelcoat to keep it from being sticky after hardening. Try adding the percentage recommended on the can. If there is no information on the can about this, try 3". For both this set-time test and when mixing for painting the canoe, always mix in this order:

1. Pour the gelcoat into a mixing bucket
2. Add the MEKP, mark the start time, and stir.
3. Add the wax and stir.

After mixing for a working time test, brush some gelcoat onto a scrap fiberglass surface. Make a note of when the gelcoat in the bucket sets. The gelcoat on the scrap surface will usually take longer to set since it will stay cooler than gelcoat trapped in a bucket. An hour or more after the test gelcoat has hardened, test it for stickiness. If it is sticky, test again with more wax until you've determined what percentage of wax is needed so that your gelcoat will not be sticky.

When painting the canoe, mix only enough gelcoat that your painters can apply before it sets. This is about 1.5 liters per person.

The moment that a painter notices that the gelcoat is beginning to gel, stop all the painters and discard the remaining gelcoat. Mix more and continue.

By lining paint trays with aluminum foil, the hardened gelcoat can be easily removed and the tray re-lined and ready for use again. Have replacement foam rollers nearby and ready since the rollers usually soften and disintegrate in 30 minutes or less.

Assemble and Lash the Lucha to the Canoe

Cut the bamboo pieces to length as follows:

Sand the surfaces and paint them with marine spar varnish. It usually will take 24 hours for the varnish to dry. The bamboo must be dry before proceeding.

Put the hull inside the hull stand, keel down. Measure to ensure that the distance from the gunnel to the floor at both matas and both sides to on four sides is the same so that the hull is straight.

Put the two bamboo gahet through the sagan gahet so that one end pokes out of the sagan gahet on the leeward side. Lash them in place using ¼-inch double-braid polyester line.

Put the lucha below the ends of the two bamboos with their gu'ut lucha up against the sides of the bamboo. The outer pole of the gu'ut lucha should cross the bamboo with 4 inches of clearance before the end of the bamboo. Measure from the mata ends of both the lucha and the hull and adjust the position of the lucha so that they measure the same. This ensures that the lucha is parallel with the hull. Lash all four gu'ut lucha to the bamboo.

The canoe must be put in the water to see how it floats. Make a note of how the lucha may need to be moved higher or lower so that the gahets are parallel to the surface of the water with two passengers.

Remove the canoe and remove the lucha. Put the hull back into the hull stand and ensure that it is straight again. Raise or lower the platform according to what was observed in the water test and put the lucha back on the platform.

Mark cut points on the gu'ut lucha for a cut parallel to the underside of the bamboo gahet. The goal here is to cut all four gu'ut the same length and side them into place beneath the bamboo so that they are exactly in the middle of the width of the bamboo. Trace the around the gu'ut pipes to mark their edges onto the underside of the bamboo. For each gu'ut, sit along the side with your eyes at the level of the bamboo, and mark the surface of the bamboo to show where the gu'ut would exist if it were to pass through the bamboo. The goal here is to find where to drill holes in the bamboo for a wood pole that is the width of the inside of the gu'ut pass through two holes in the bamboo and go inside the gu'ut all the way to the bottom of the lucha.

Drill these holes very carefully using a flat circle bit (the kind with a small threaded point to contact the wood. Hold the drill in the same plane that the wooden pole will be on as you drill. Drill from outside to inside on both sides. Do one hole first, then check to see if any adjustments will be necessary for the second hole. This can happen if the first hole was not cut exactly where it was marked, or if the marks were off.

Be careful that you are drilling at the correct angle. It is extremely easy to forget and start the hole with the drill be slanted in the wrong direction. This is important because the walls of the bamboo are thick and a hole drilled the wrong way will not fit.

When all four wooden poles have been put in place and pushed to the bottom of the lucha, cut the tops of the wooden poles off three inches from the hole. Make that cut so that it is parallel to the top of the bamboo.