Wooden Boatbuilding

Or

How to build strong, lightweight, streamlined shapes.

Joint Presentation

- Introduction to Wooden Boat Building (Jerry)
- Wooden Boat Building Methods (Tim)
- Building a Tortured Plywood Boat (Jerry)
- Plywood Lapstrake Boat Joinery (Jerry)
- Building a Stitch and Glue Boat (Nelson)

Wooden vs Fiberglass Boats

- Fiberglass Suitable for Mass Production and Cheaper
  - Often Two Molds: Hull and Deck/Cabin
  - Attach and/or Bond the Deck/Cabin to the Hull
- Wooden Hull Shapes Not Constrained by a Mold
- Wooden Hulls Can Have Better Strength to Weight Ratio

Graham Byrnes' Outer Banks 20

Example of Sheet Plywood Bottom and Ashcroft Sides

Howard Rice’s Southern Cross

Explored Tierra del Fuego in a Modified 12 foot SCAMP

- Survived Rare 70 knot Cyclonic Winds
- Kelp Blocked Two Safe Anchorages
- Abandoned Boat and Swam Ashore
- Rescued by Chilean Patrol Boat
- Southern Cross Rescued 3/5/2017

http://www.mysailing.com.au/cruising/howard-rice-the-end-of-the-south-american-adventure-comes-in-dramatic-fashion

Form Follows Function

- How a Boat is Used influences Hull Shape
- Hull Shape Influences Building Methods
  - Monohulls
    - Displacement
    - Planing
    - Semi-Displacement
  - Multihulls
    - Catamaran
    - Trimaran

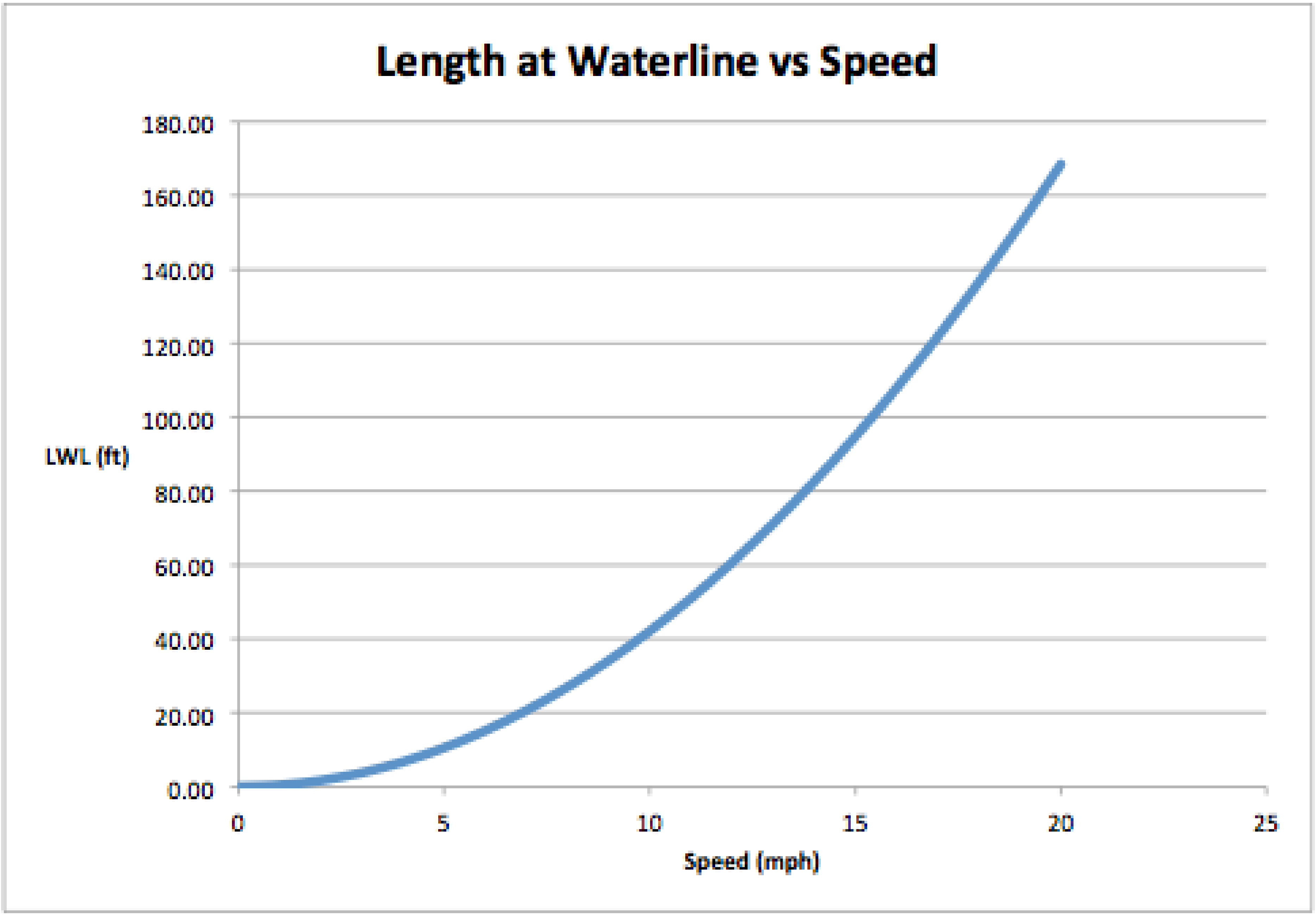
Displacement Hull

- Held Up By Buoyancy, i.e, Static Force
- Not Designed to Exceed Displacement Speed
- Characterized by a Curved Underwater Surface
- Minimize Bow and Stern Waves for Efficiency

Displacement Hull Speed

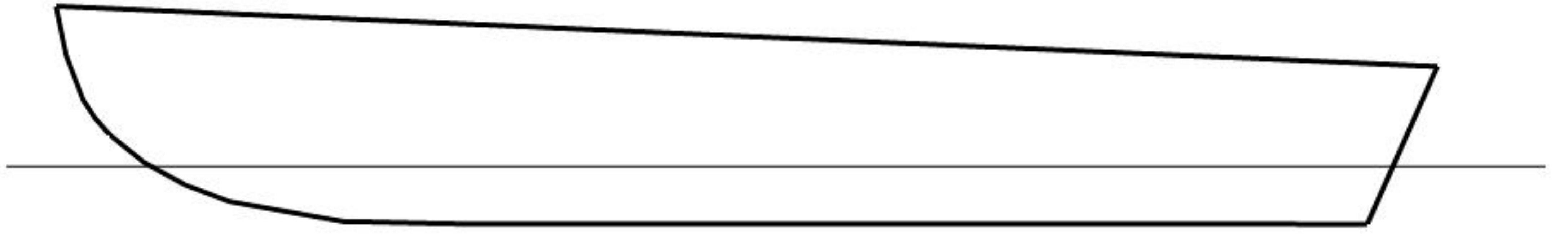
hull speed (knots) = 1.34 x square root of length at waterline (ft)

Speed (mph)	LWL (ft)
0	0.00
1	0.42
2	1.68
3	3.79
4	6.74
5	10.53
6	15.16
7	20.63
8	26.95
9	34.11
10	42.11
11	50.95
12	60.64
13	71.17
14	82.54
15	94.75
16	107.80
17	121.70
18	136.44
19	152.02
20	168.44



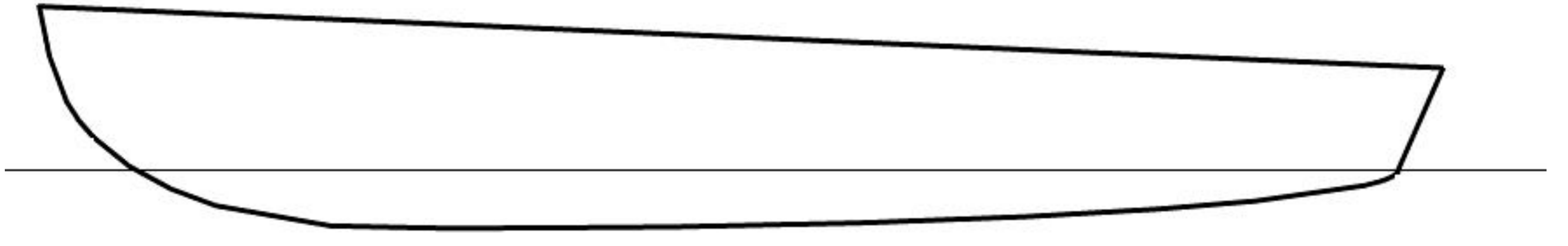
Planing Hull

- Add Hydrodynamic Force
- Characterized by Flat Underwater Surfaces
- Sufficient HP to Overcome Resistance of Bow Wave
- Straight Keel to the Transom



Semi-Displacement Hull

- Can Be Pushed Beyond Hull Speed
- Characterized by Flat Underwater Surfaces
- Keel Curves Up to the Transom

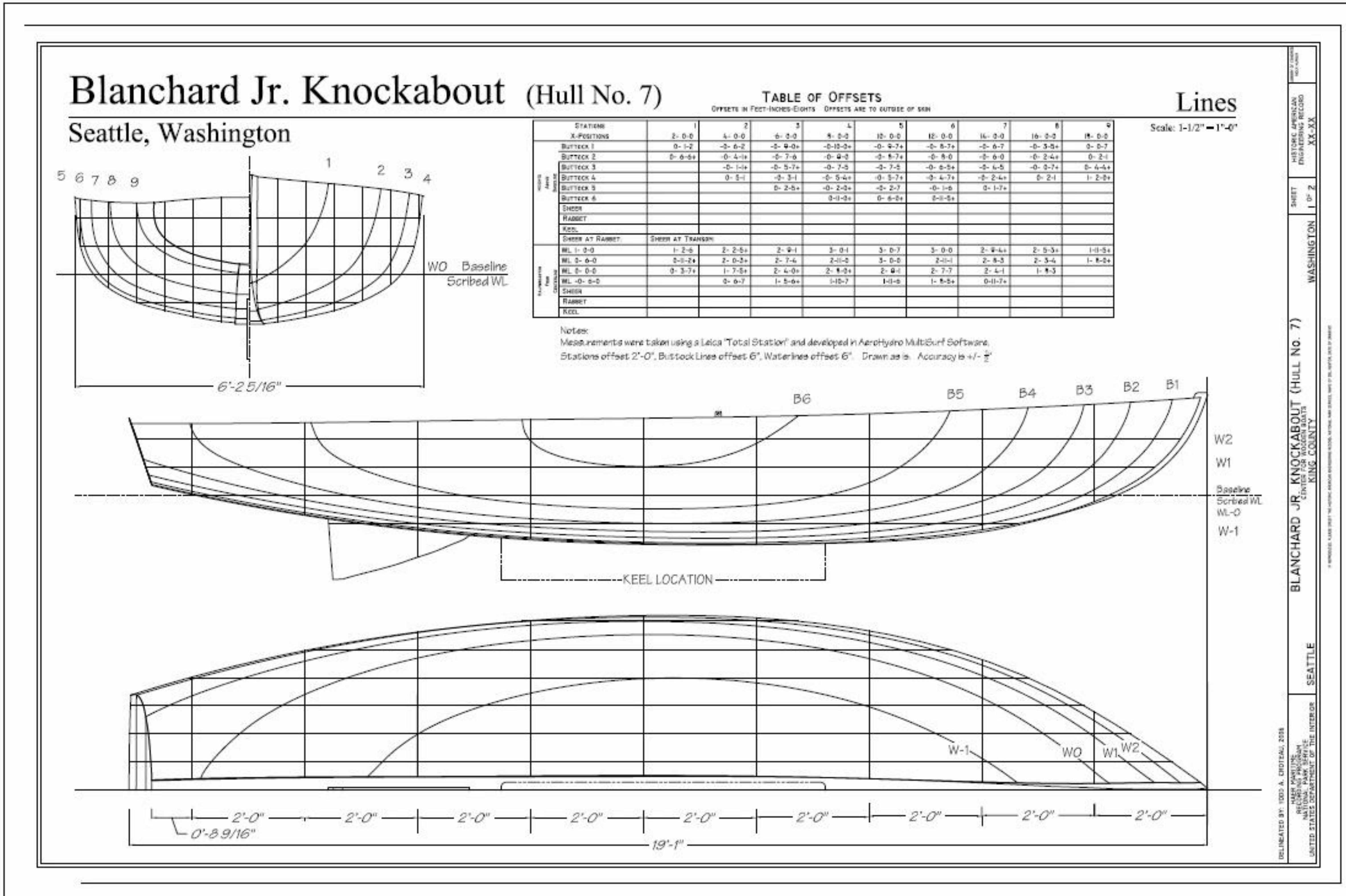


Multihulls

- Catamaran
  - Two Narrow Hulls
  - Each Hull Can Float the Boat (You Can Fly a Hull)
- Trimaran, i.e., A Three Hull Boat
  - Center Hull (Main Hull or Vaka)
  - Outrigger Hulls (Floats or Ama)
  - Typically a Float or Ama <u>Cannot</u> Float the Boat

Building Information

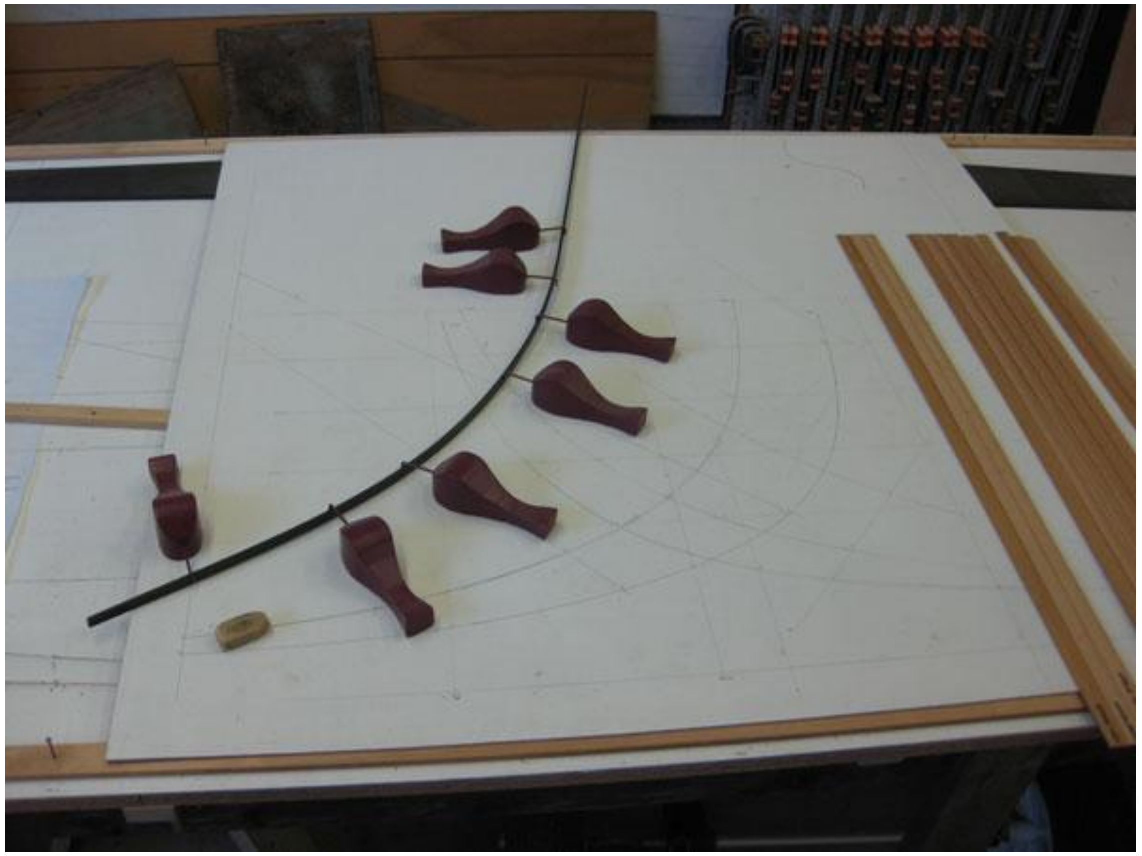
Table of Offsets and Lofting

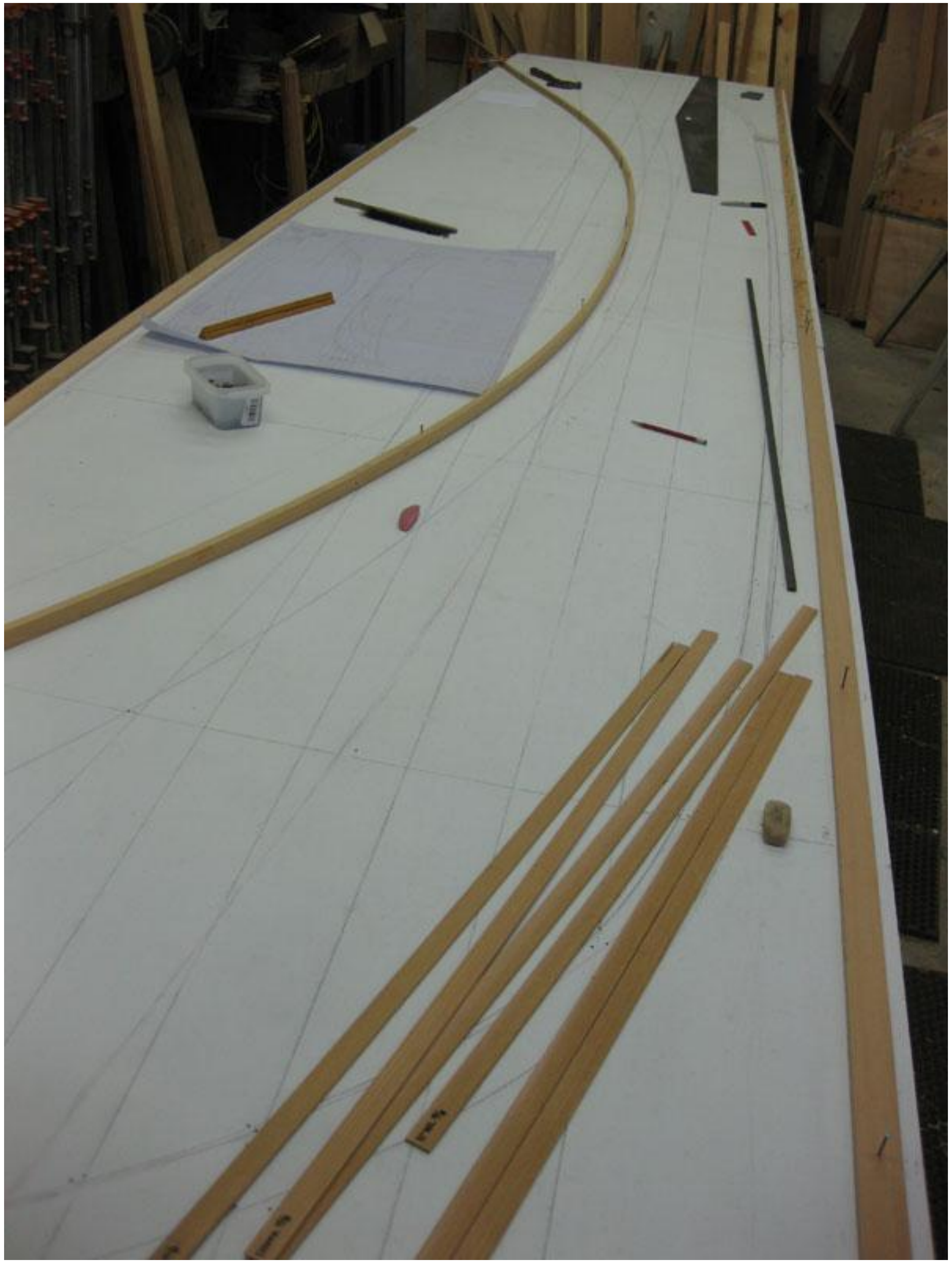


Stations	1	2	3	4	5	6	7	8	9
X-Positions	2- 0-0	4- 0-0	6- 0-0	8- 0-0	10- 0-0	12- 0-0	14- 0-0	16- 0-0	18- 0-0
Buttock 1	0- 1-2	-0- 6-2	-0- 9-0+	-0-10-0+	-0- 9-7+	-0- 8-7+	-0- 6-7	-0- 3-5+	0- 0-7
Buttock 2	0- 6-6+	-0- 4-1+	-0- 7-6	-0- 8-0	-0- 8-7+	-0- 8-0	-0- 6-0	-0- 2-4+	0- 2-1
Buttock 3		-0- 1-1+	-0- 5-7+	-0- 7-5	-0- 7-5	-0- 6-5+	-0- 4-5	-0- 0-7+	0- 4-4+
Buttock 4		0- 5-1	-0- 3-1	-0- 5-4+	-0- 5-7+	-0- 4-7+	-0- 2-4+	0- 2-1	1- 2-0+
Buttock 5			0- 2-5+	-0- 2-0+	-0- 2-7	-0- 1-6	0- 1-7+		
Buttock 6				0-11-0+	0- 6-0+	0-11-5+			
Sheer									
Rabbet									
Keel									
Sheer at Rabbet	Sheer at Transom								
WL 1- 0-0	1- 2-6	2- 2-5+	2- 9-1	3- 0-1	3- 0-7	3- 0-0	2- 9-4+	2- 5-3+	1-11-5+
WL 0- 6-0	0-11-2+	2- 0-3+	2- 7-6	2-11-0	3- 0-0	2-11-1	2- 8-3	2- 3-6	1- 8-0+
WL 0- 0-0	0- 3-7+	1- 7-5+	2- 4-0+	2- 9-0+	2- 9-1	2- 7-7	2- 4-1	1- 9-3	
WL -0- 6-0		0- 6-7	1- 5-6+	1-10-7	1-11-6	1- 8-5+	0-11-7+		
Sheer									
Rabbet									
Keel									

Notes:
Measurements were taken using a Leica "Total Station" and developed in AeroHydro MultiSurf Software.
Stations offset 2'-0", Buttock Lines offset 6", Waterlines offset 6". Drawn as is. Accuracy is +/- $\frac{1}{2}$"

Lofting from Table of Offsets



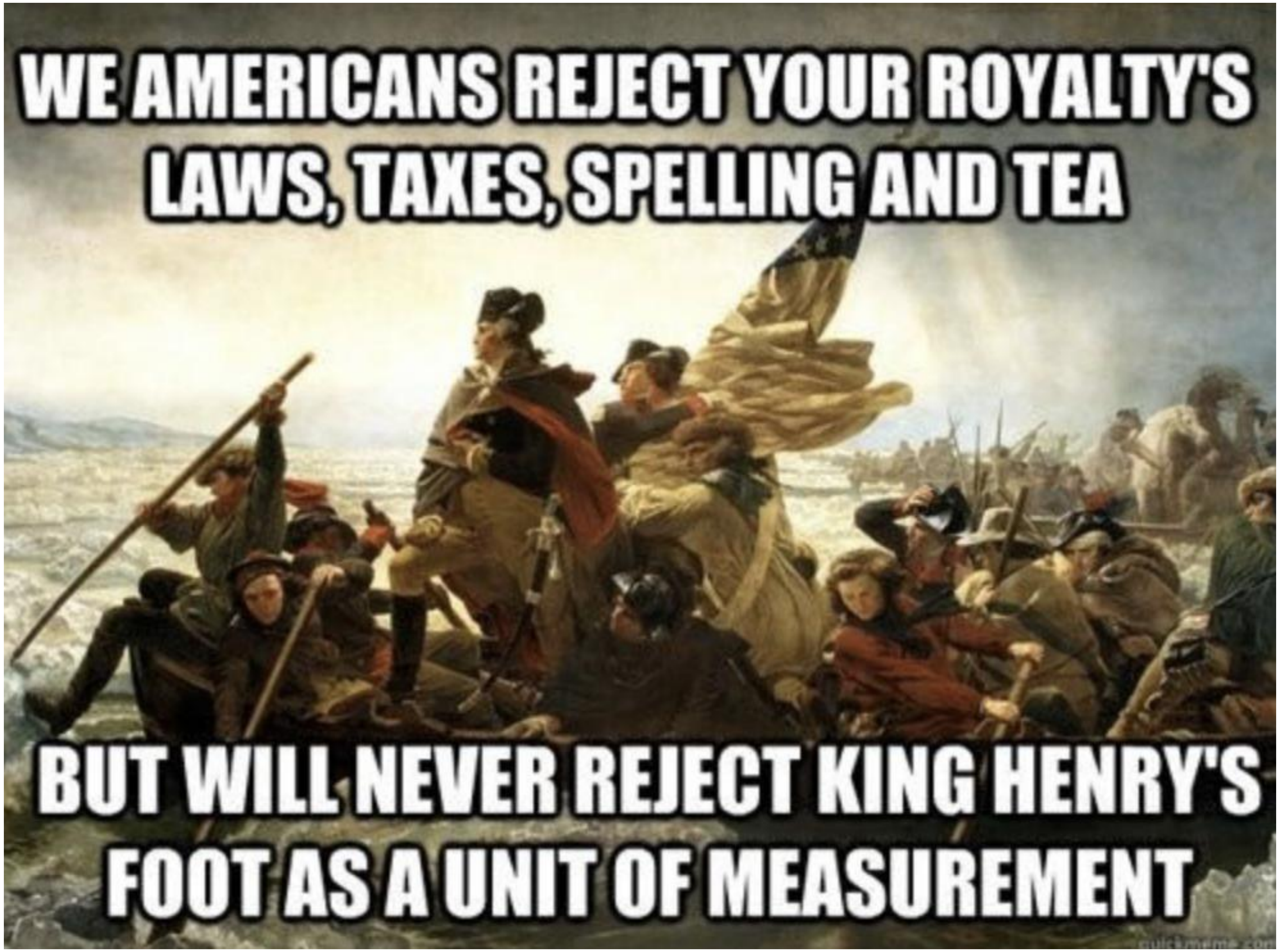


You Can Get Up Off Your Knees
No Lofting Required

- Dimensioned Drawings
- Full Size Patterns
- CNC Kits

Be Prepared to Work in Metric

- Marine Plywood is Metric
- Many Boatbuilding Plans are Metric
- Only Liberia, Myanmar and the USA Haven't Adopted the Metric System



Wooden Boat Building Methods (Tim)

Desired Hull Shape with Little or No Limitations

Cold-Mold

Hull is built up in layers of veneer. Hull can be built over a mold to create a light-weight and accurate hull rivaling most all modern constructions.

Cold-Mold

Each layer of veneer is epoxied to the layer below. Each layer is placed on alternating diagonals. When one layer has cured, another layer is added. Layers are held in place with staples to hold alignment while curing. Far fewer staples are needed if a vacuum bag is added.

Cold-Mold

In addition to using a mold, cold molding can be built over other types of construction.

Cold-Mold

Of course if you have a lot of time and friends:

Desired Hull Shape with Little or No Limitations

Carvel

The toughest and heaviest of constructions. With some work they can be repaired to extend their life. The most complicated shapes can be made. Used on military and work ships that traveled the world; yet can be used on the smallest of boats too.

Carvel

Built over heavy frames that were usually sawn to shape. Frames must not only fit the hull curvature but will need to be beveled to get contact with planks. Planks are typically fastened to frames with screws. Thick planks need to be hollowed on the inner face to make contact at the frames. They also need a bevel between planks to allow space for cotton caulk.

Carvel

Planks are added with clamps and fastened as each plank is fitted. Making patterns, shaping and test fitting planks will be the most time consuming part of making the boat. The number of clamps can limit you.

Carvel

Making a pattern for the end of a simple plank. Some planks will require extensive templating and shaping.

Carvel

Fastening the plank shaped from the pattern. Screws are countersunk and plugged. Cotton caulking is driven between planks to make watertight.

Carvel

Final results for a long lasting work boat.

Desired Hull Shape with Little or No Limitations

Strip Planking

Strip planking uses thin strips glued to each other. They were traditionally nailed to each other but now are most likely glued with epoxy or resorcinol. Aliphatic can be used if you will be covering the final hull with fiberglass.

Strip Planking

Strips need to make good contact at the glue line. Strips need to be beveled and twisted to make contact. As an alternate and to shorten the fitting time, the edges can be routed with a bead and a matching cove.

Strip Planking

Example of the form for building. The ribs were laminated over each section of the mold before the mold was erected. Note that the ribs will stay inside the hull when finished.

Strip Planking

Alternate technique to work with strips. These forms will be removed entirely at the conclusion. Note that the transom and keel will stay with the hull.

Strip Planking

A beautiful example of this technique. Note there are no ribs. It is a pure monocoque construction.

Strip Planking

Once again, if you have a few friends to help.

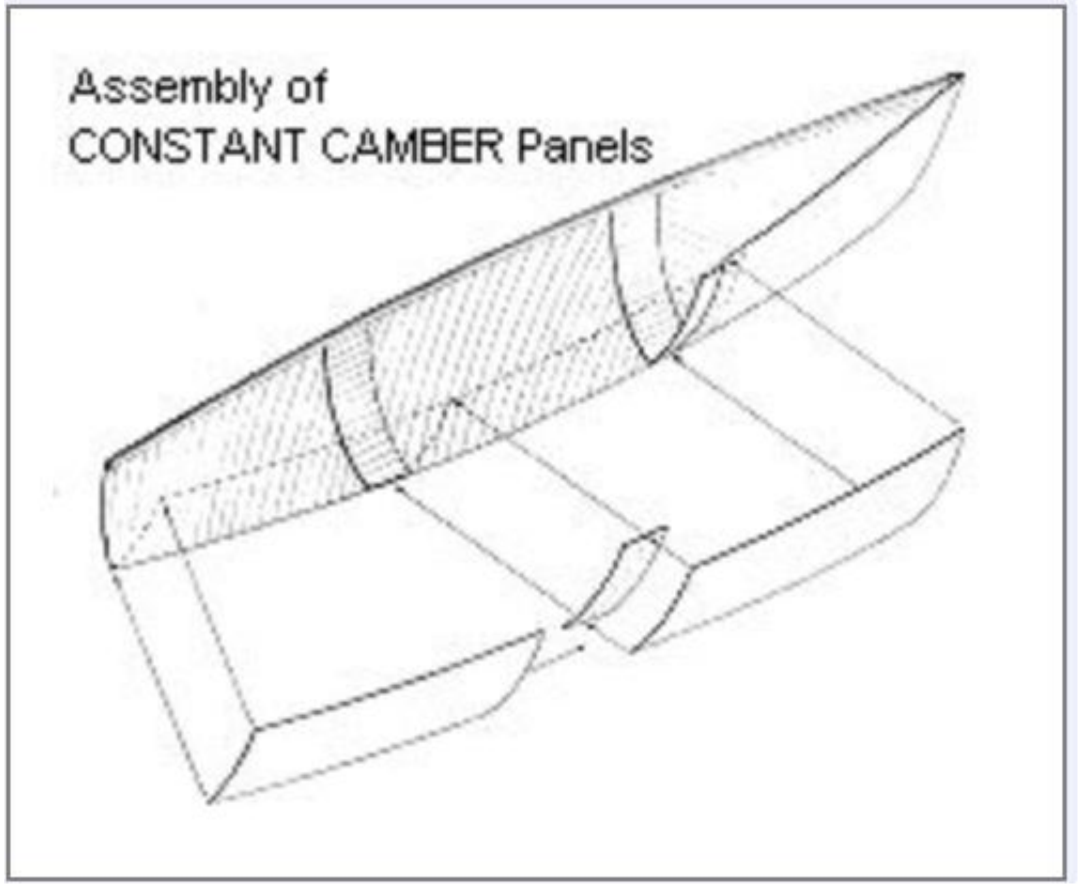
Approximation of Desired Hull Shape
Constant Camber

Constant Camber uses the same technique as Cold Mold, but pre-laminates the plies on a uniformly curved mold to create curved plywood.

Constant Camber

Veneers are forced down on a curved form with a vacuum bag to make plywood.

Constant Camber



Here you see a large sheet of custom molded plywood which is one section of the boat's hull. The diagram shows a hull with three sections.

Constant Camber

Some almost finished hulls for a catamaran. Note these still need a transom added before the deck is built.

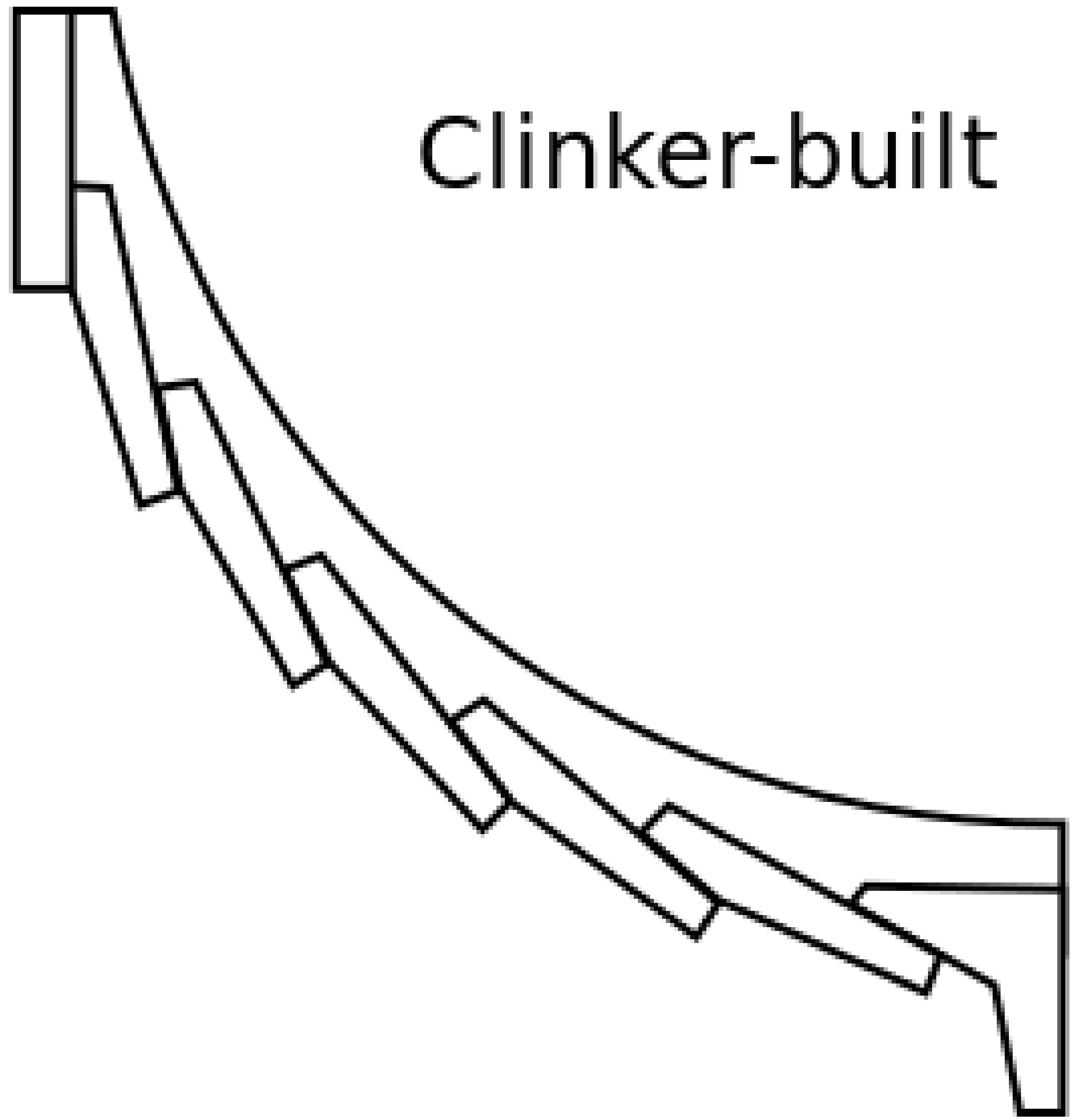
Constant Camber

Chris White’s 52ft ‘Juniper’ hulls built with Constant Camber System

Approximation of Desired Hull Shape

Clinker/Lapstrake

Lapstrake uses thin planks that overlap and are fastened to each other with screws or rivets. The frames can be fastened to the planks or left out for a smoother interior.



Approximation of Desired Hull Shape

Clinker/Lapstrake

A picture of a boat with copper rivets holding the ribs to the lapstrake planking. The ribs can be either laminated or steam bent and were part of the form as the boat was built.

Clinker/Lapstrake

One way to build is to use plywood forms with wood stringers that show where the planks will overlap. When the planks are fastened to each other they can also be fastened to the stringers to strengthen the joint if desired.

Clinker/Lapstrake

Lapstrake makes a beautiful traditional boat shape.

Approximation of Desired Hull Shape

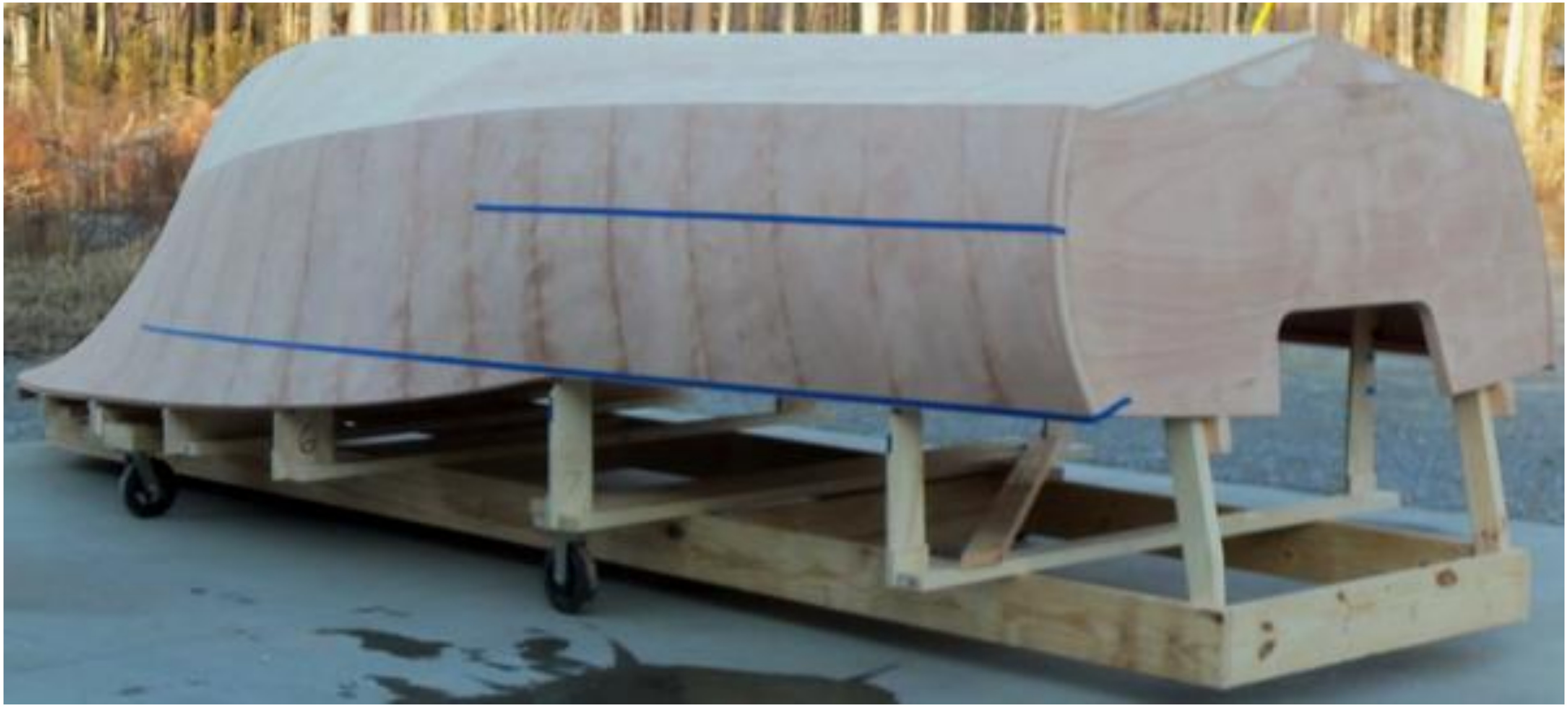
Glued Plywood Lapstrake

A variation of lapstrake using plywood. This allows for fewer wider planks, retaining the traditional look.

Approximation of Desired Hull Shape
Plywood on Frame and Ashcroft Planking Method

Plywood can be fastened to stringers over forms. Forms can be temporary or become bulkheads for the finished boat. This boat appears to be using them for bulkheads.

Ashcroft Planking Method



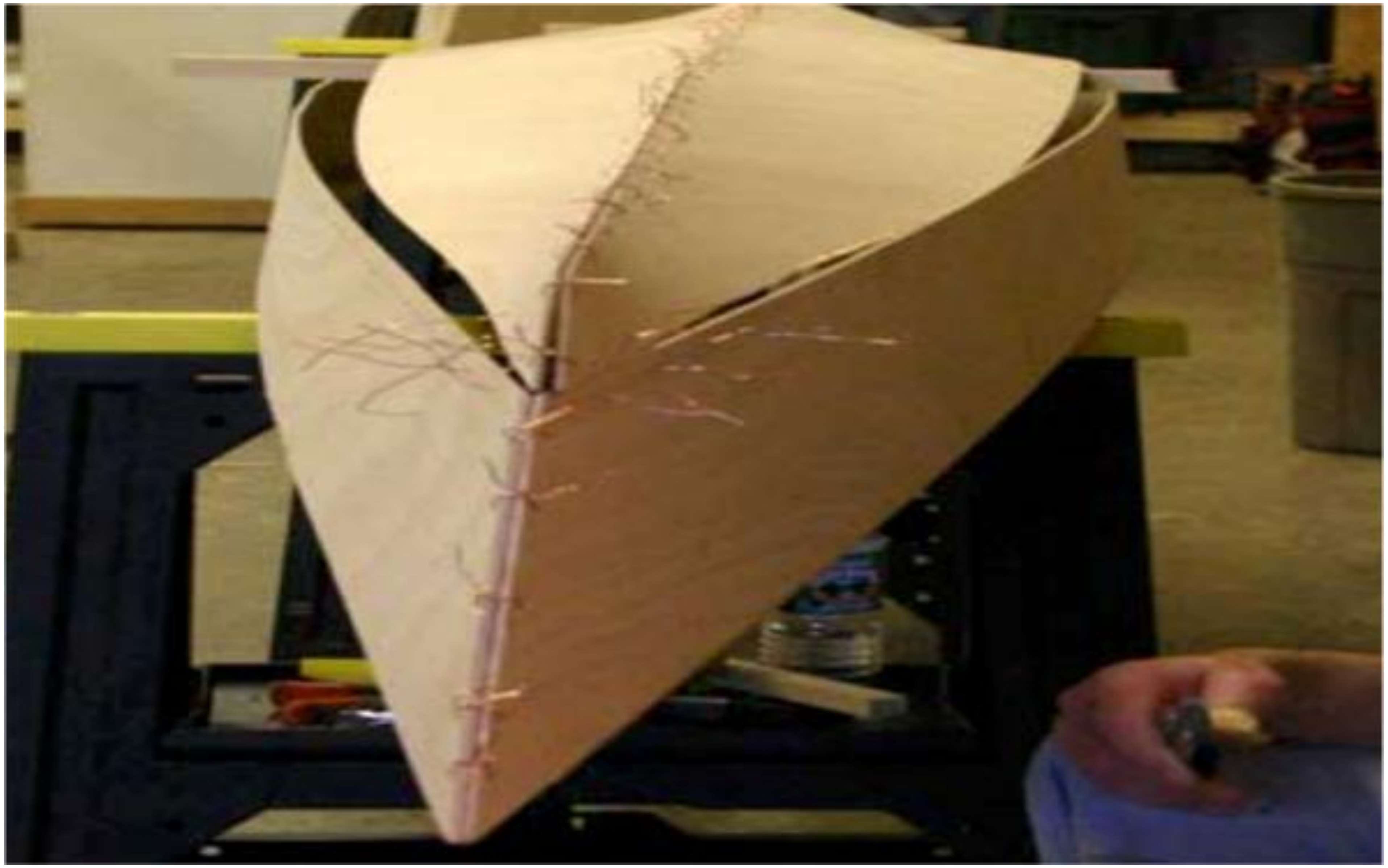
Hulls with complex compound shapes may require using double layers of half thickness plywood where full thickness is too stiff to conform. Strips of plywood are fastened to the stringers, then a second offset layer is laminated over the joint.

Hull Shape Limited by Materials

Sheet Plywood Stitch-and-Glue

Marine plywood is cut to a pattern that will pull into the hull shape when formed. This partial hull has used plastic cable ties to pull the pieces together. A more common method is to use copper wire as a twist tie.

Sheet Plywood Stitch-and-Glue



The separate pieces are pulled together in stages and the full shape develops. When each seam is ready, fiberglass tape is epoxied along the seam on the inside.

Sheet Plywood Stitch-and-Glue

When the complete boat construction is done, it is covered with fiberglass cloth and epoxy.

Hull Shape Limited by Materials
Tortured Plywood

Jerry will talk about this method later.

Building a Tortured Plywood Boat (Jerry)

Wooden Boat Joinery (Jerry)

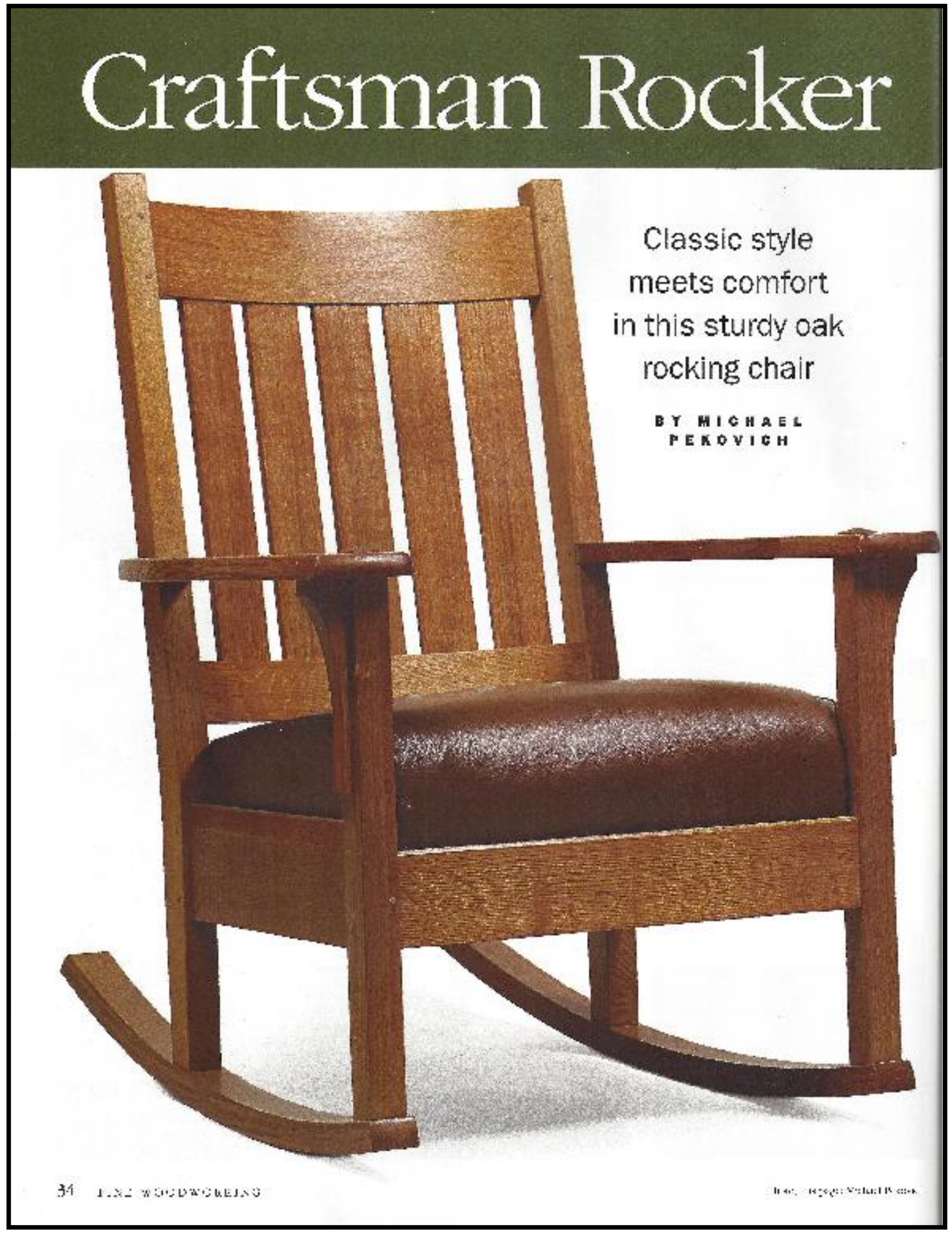
Tortured Plywood

Glen-L's La Chatte

Tortured Plywood
Glen-L's La Chatte

Flat Bottom and Plywood Lapstrake Sides
John Welsford's Pathfinder

Maybe a Rocker is a Better Old Man's Project



Plywood Lapstrake

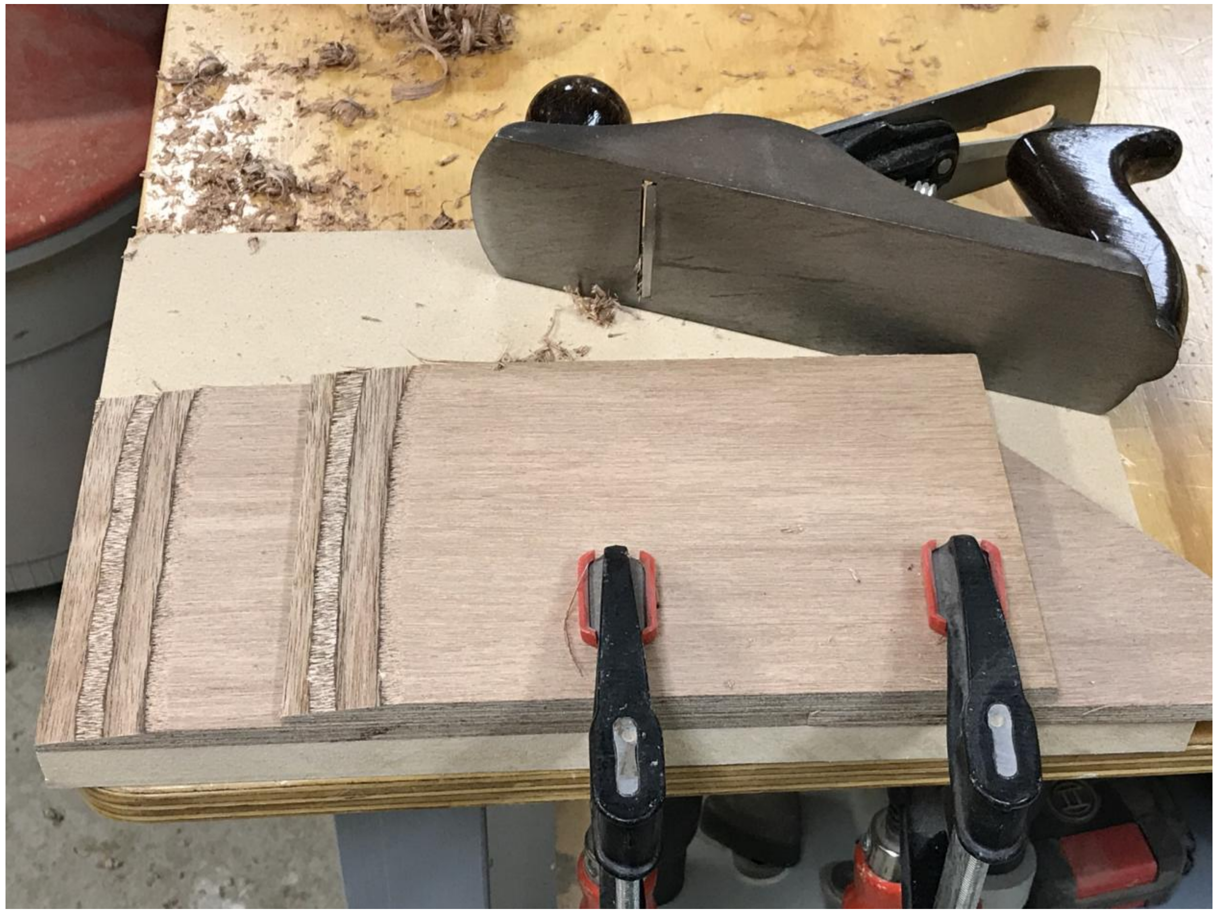
Arch Davis' Penobscot 13 with Stringers Remaining in Boat

Plywood Lapstrake
Iain Oughtred's Arctic Tern with Stringers Removed

Plywood Lapstrake
Shop Made Deep Clamps

Joinery

Scarf Joint to Extend Length



Joinery

Gain at Bow to Change from Overlap to Flush

Bird’s Mouth Spar Calculator

http://www.duckworksmagazine.com/10/howto/birdsmouth/index.htm

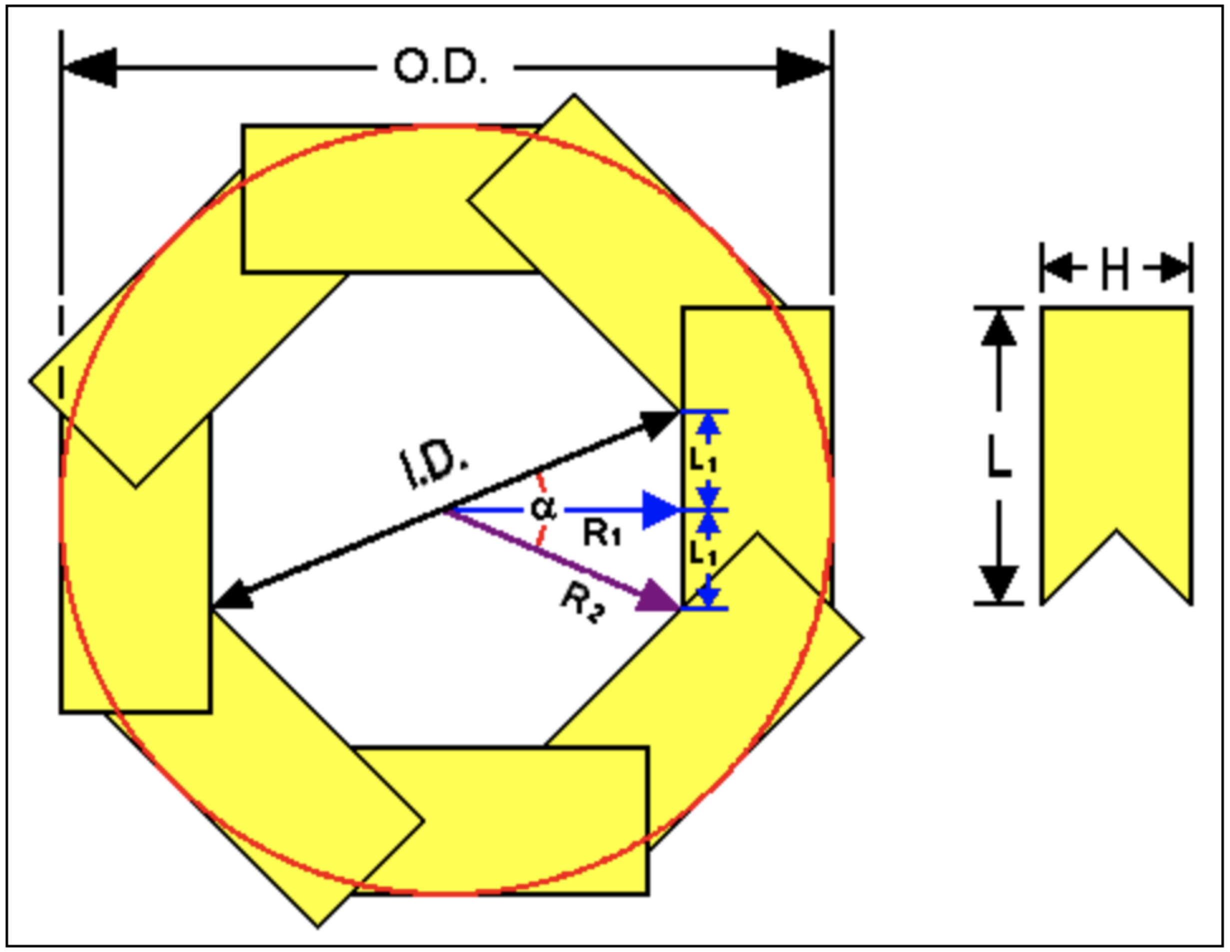


Figure 1- Bird's Mouth Spar : Definitions

O.D. is the outside diameter
I.D. is the largest inside diameter
$\mathbf{R_1}$ is the shortest inner radius
$\mathbf{R_2}$ is the largest inner radius or half **I.D.**
N is the number of sides (eight in this case)
a (alpha) is the angle between adjacent staves or **360° / N**
L is the width of material
H is the thickness of material

Important Ratios

K is the thickness to width ratio of staves or **(H / L)**
M is the "conversion factor" or **(O.D. / L)**
A is the inside to outside diameter ratio or **(I.D. / O.D.)**

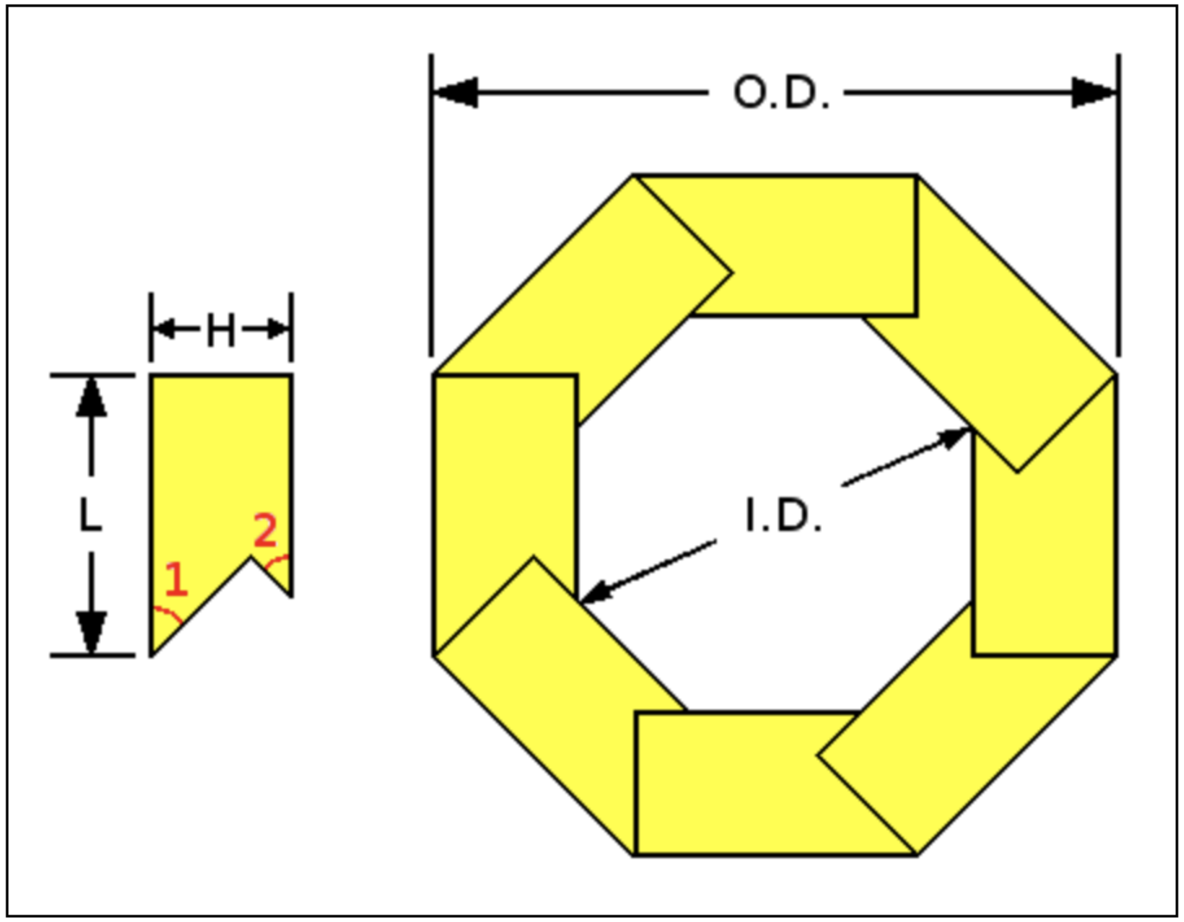


Figure 2- Modified Bird's Mouth Spar : Definitions

O.D. is the outside diameter
I.D. is the largest inside diameter
1 is the first angle of the stave
2 is the second angle of the stave
L is the width of material *measured on the outside*
H is the thickness of material

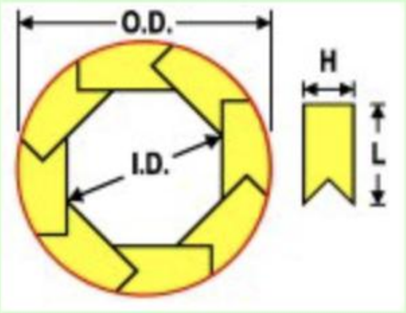
Bird’s Mouth Mast
Calculator for Tapered Mast

Calculator 4: Given N, O.D. and H, calculate L, I.D. and K

Inputs

N : 8
O.D.: 2.5
H : .5

Calculate!



Results

L : 0.974873734
I.D.: 1.623588300
A : 0.649435320
K : 0.512886933
M : 2.564434667

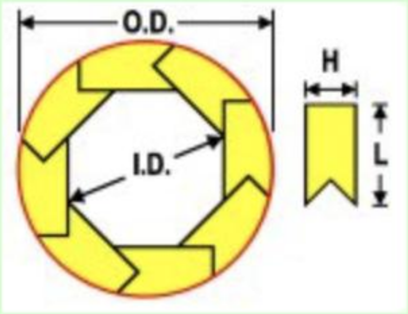
Status :

Calculator 4: Given N, O.D. and H, calculate L, I.D. and K

Inputs

N : 8
O.D.: 3.5
H : .5

Calculate!



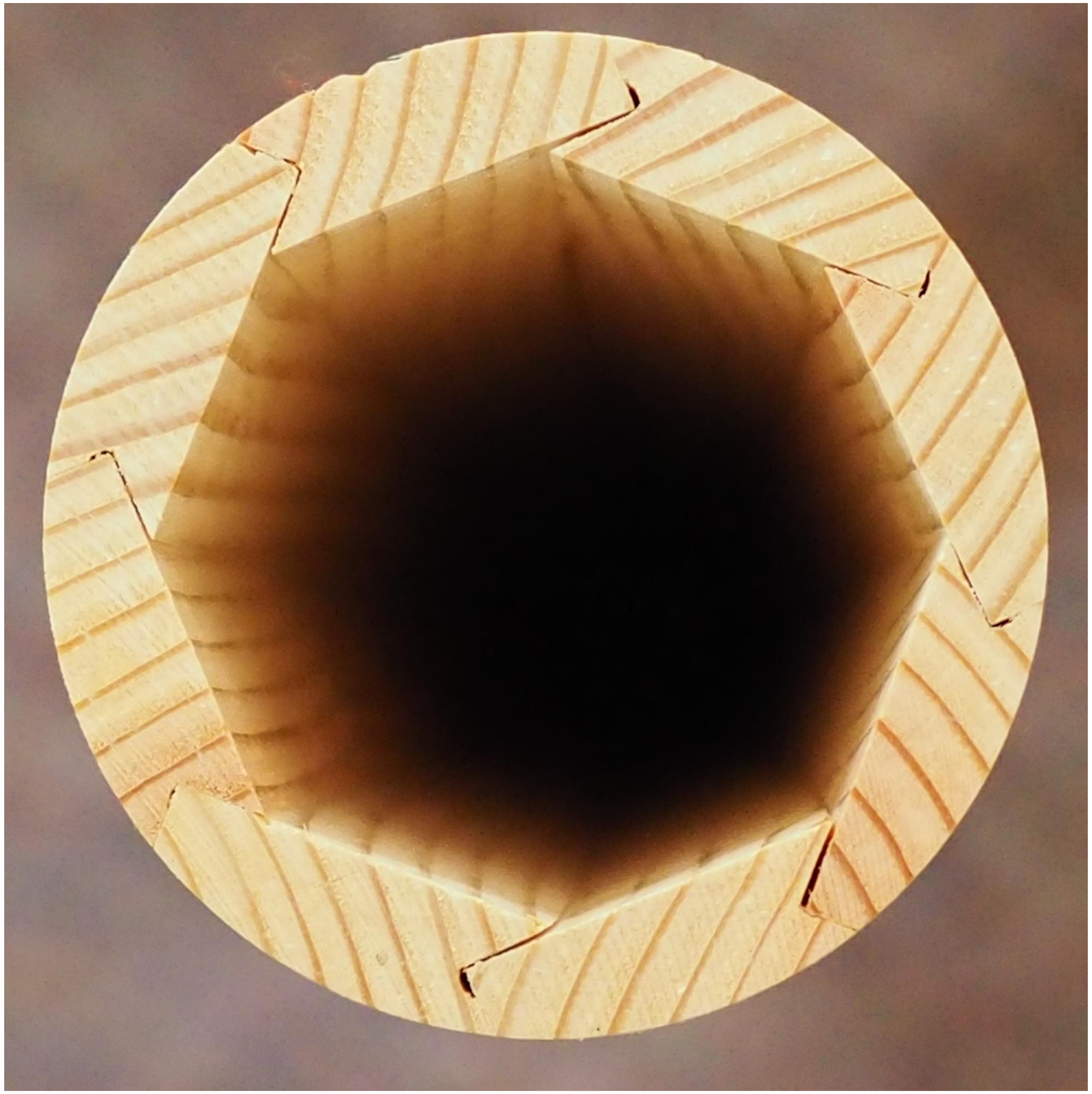
Results

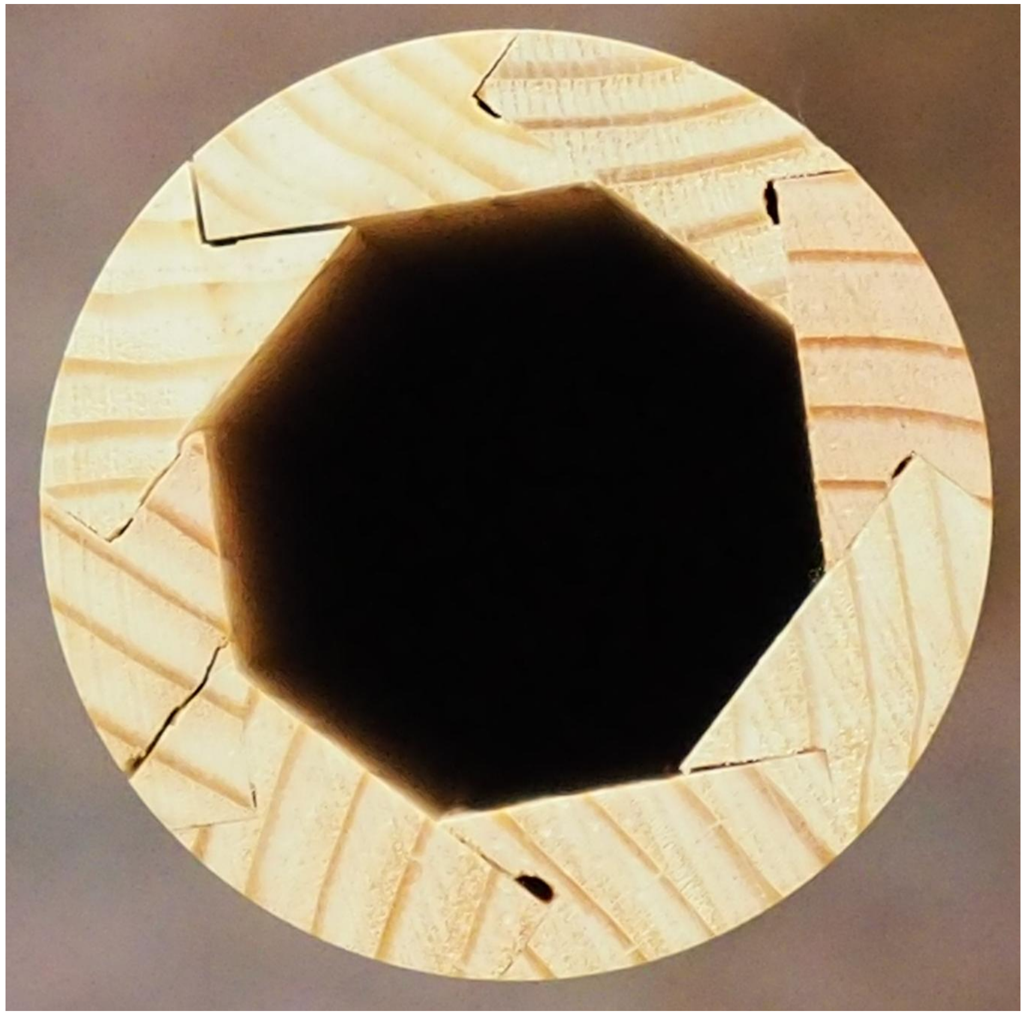
L : 1.389087296
I.D.: 2.705980500
A : 0.773137285
K : 0.359948580
M : 2.519640060

Status :

Bird's Mouth Mast

Eight Sides with Exaggerated Taper





Bird's Mouth Mast

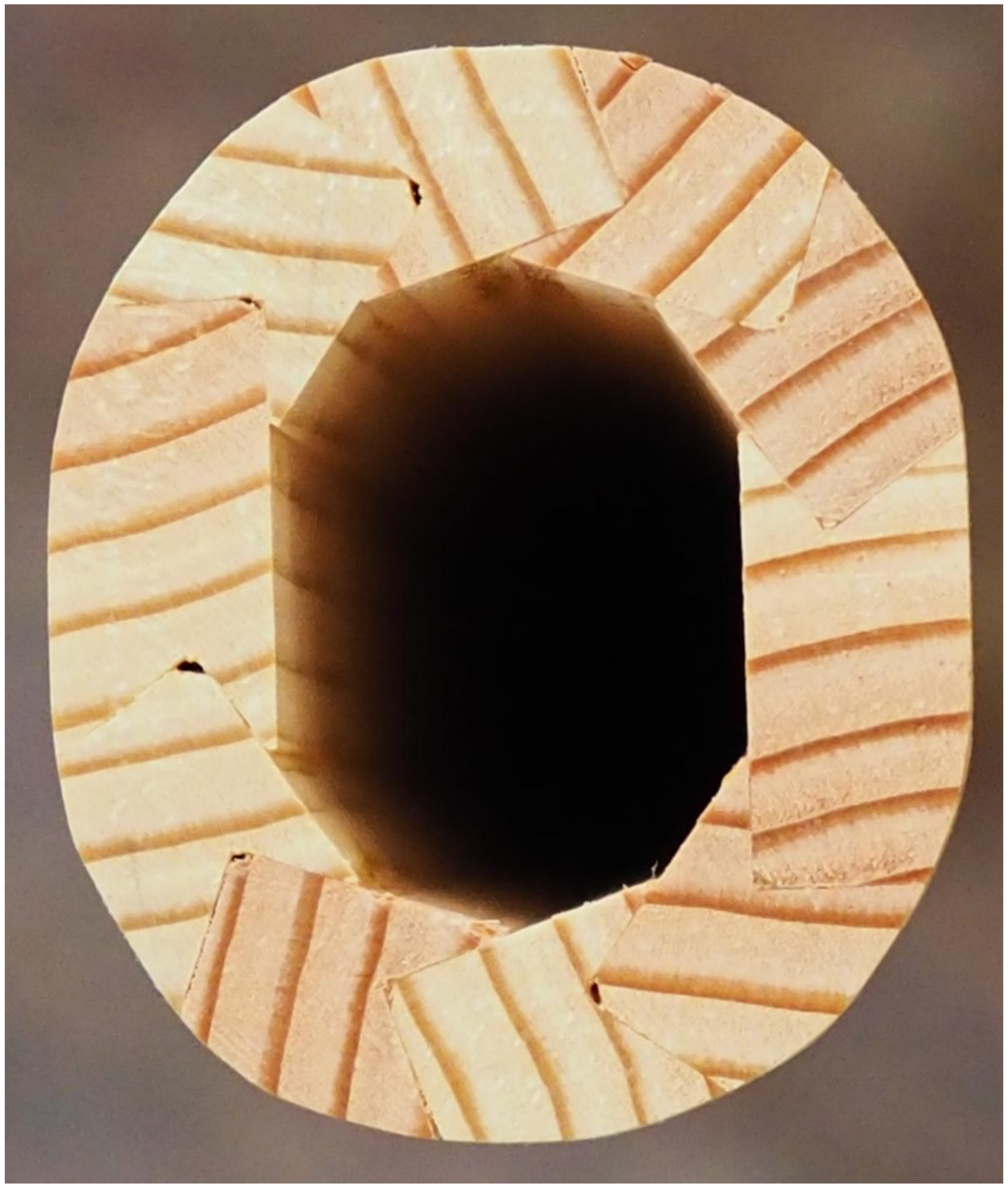
Glue Up with Cable Ties for Clamps

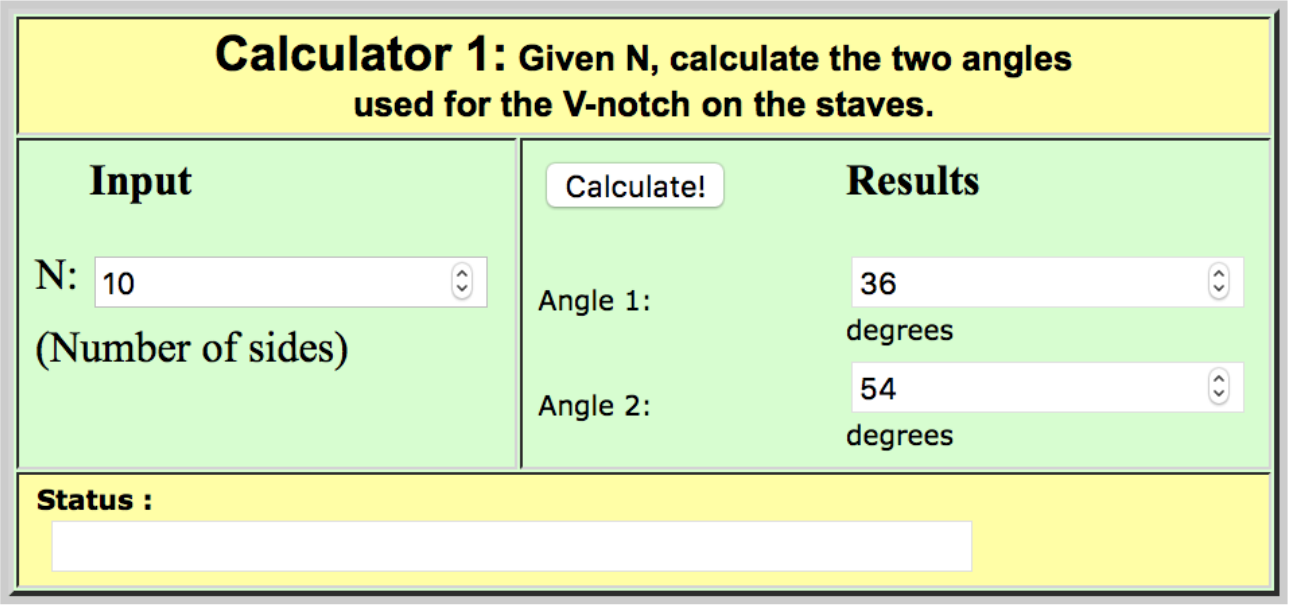
Bird’s Mouth Mast
Building Method

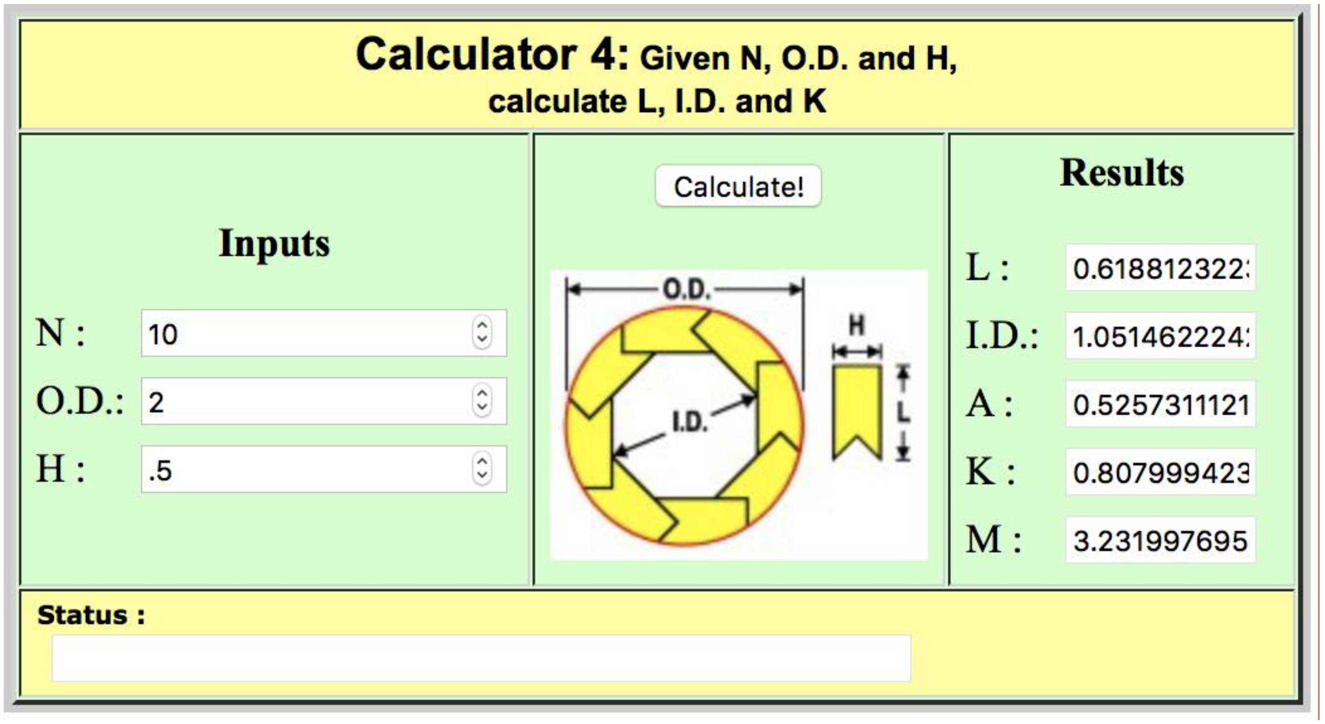
- Scarf Staves to Length of Mast
- Cut Staves with Bird’s Mouth on One Edge
- Taper Edge Opposite Bird’s Mouth for Tapered Mast
- Epoxy Staves Together with a Slow Hardener
- Up to Four Hour Working Time
- Plane to Approximate Round
- Rig a Powered Mast Turning System
- Sand Mast to Smooth Round
- Fiberglass the Mast

Bird’s Mouth Boom

Ten Staves with Two Wider Staves to Form an Oval

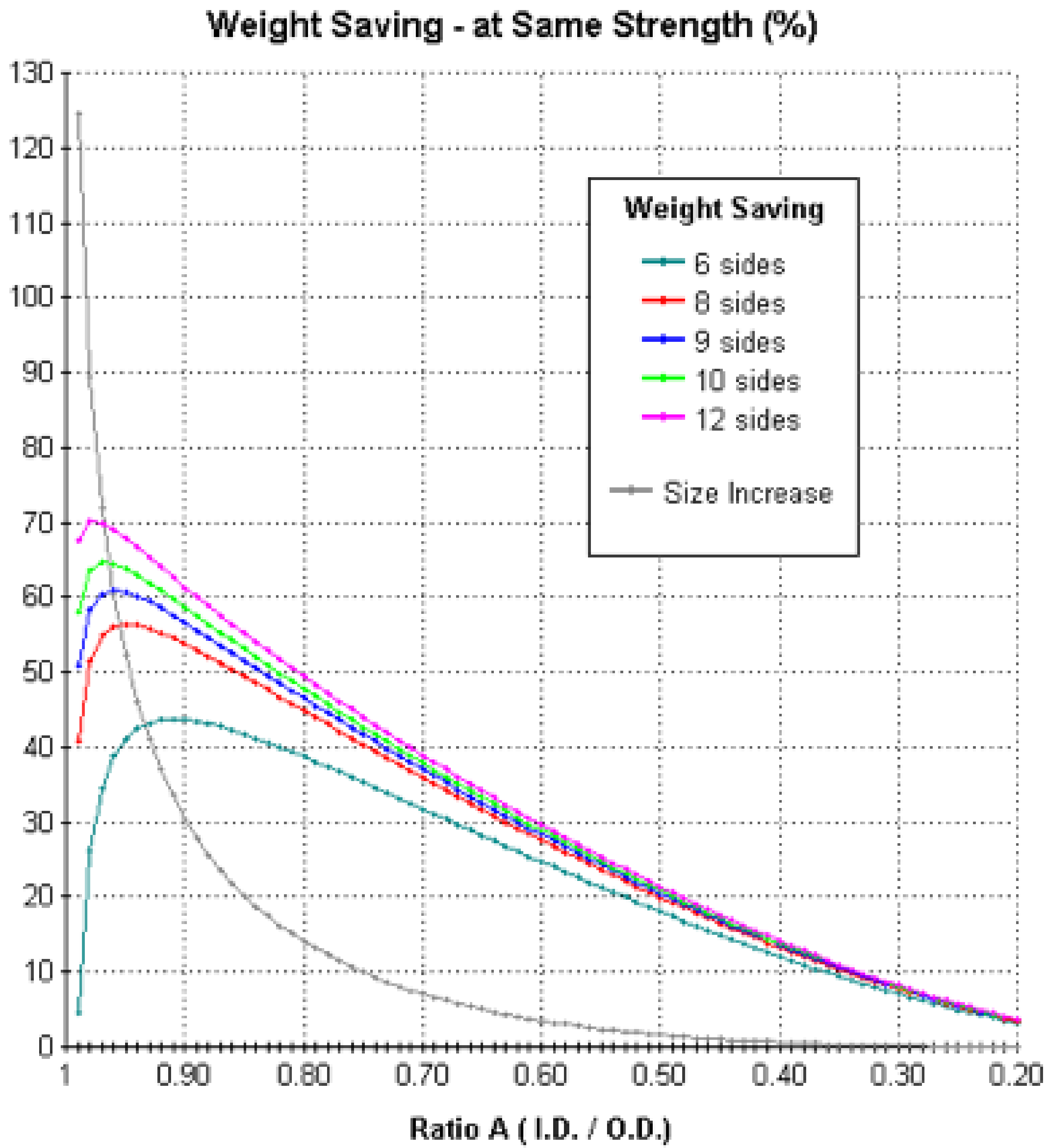






Bird's Mouth Spar

Weight Saving - at Same Strength



Building a Stitch and Glue Boat (Nelson)