Rules for the Construction, the Scantlings, and the Other Proportions of Wooden Yachts

Nathanael G. Herreshoff

1927

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Adopted By

The New York Yacht Club

January 19, 1928

In Lieu of An Introduction

"Coconut Grove, Fla. N. G. Herreshoff Bristol, R. I. May 7, 1928. Dear Francis, ... Certain influential members of the N.Y.Y.C. suggested that I write out my experience and practice of yacht construction, as a record and to the benefit of those desiring knowledge in that line, and I decided to do so. The title on the manuscript was something like, "Construction Rules for Wood Yachts, as Practiced by the H-M-Co. under N.G.H - supervision." I have not seen the printed matter and it is possible the title has been changed. It was a record of passed designing of yachts that had a world wide reputation for good and durable construction. I certainly have no desire of shutting out any new construction and I maintain that all new constructions or contrivances should be tried out and not condemned until they condemn themselves. Of course any foolish contrivance to be put aside at once. ... Your affect - Father." (Source: Mystic Seaport Museum, L. Francis Herreshoff Collection, Box 17, Folder 4: Letter from N. G. Herreshoff to his son L. F. Herreshoff.)

"Even to this day, yachtsmen speak with awe of the excellence of Herreshoff boats. For a long time they were the best of the best, both in design and construction.

The late Nathanael G. Herreshoff, known as the "Wizard of Bristol," wrote down his rules for the construction of wooden yachts in 1927. Although they are more complicated than Nevins' rules, they will produce a lighter boat. In fact, one should not dare build any wooden boat of lighter construction than they allow lest she break up." (Source: Introduction by Francis S. Kinney to the Herreshoff Rules for the Construction of Wooden Yachts in: Norman L. Skene and Francis S. Kinney. Skene's Elements of Yacht Design, 1973, Dodd, Mead & Company, Inc., New York, NY.)

"Use of these rules soon evolved to guide construction of wooden yachts over the next 50 years. They are equally applicable today for either new construction or as guidance for careful and accurate restoration of Herreshoff or other yachts.." (Source: From the introduction by Halsey Herreshoff to the Herreshoff Rules for the Construction of Wooden Yachts in: Herreshoff Marine Museum (publ.). Proceedings. The 2nd Classic Yacht Symposium. March 31 - April 2, 2006. Bristol, RI, 2006.)

Herreshoff Rules for Wooden Yachts

General Propositions

Frame Spaces:	To be dependent on the displacement of the yacht or boat when at load conditions. Fundamental Factor: (I)
Planking:	Also Decking, Keel, Clamps, Ceiling and all other for and aft members. To be dependent on the displacement of the yachts modified by the ratio of the depth to length of the hull Fundamental Factor: (II)
Stem Siding:	Also Timbers, Floor Timbers, including Plank Floors, etc. To be dependent on the displacement of the yacht. Fundamental Factor: (III)
Deck Beams:	Molded ways to be dependent on the displacement of the yacht modified by the breadth of beam. Sided ways to be dependent on the displacement of the yacht Fundamental Factor: (IV)
House Deck Beams:	Molded ways to be dependent of the displacement of the yacht modified by the length of the longest house beam. Fundamental Factor: (V)

These Fundamental Factors depend upon the special formulas developed at Bristol, and involve the practice of the Herreshoff Manufacturing Company during the years from 1878 to 1918. These formulas have been reduced to tabular form, and the resulting tables for finding these factors, directly from the principal dimensions of the yacht, are provided here within.

Notation and Symbols Used

L.W.L.	Length of the water line at load conditions, corresponding to L.W.L as fixed for Universal Rule[1] by New York Yacht Club in 1913 (same as D.W.L).
O.a.l.	Extreme length of hull as measured for Universal Rule – between plumb lines.
L.	L.W.L. plus 1/3 of overhangs or $\frac{2 \times L.W.L. + O.a.l.}{3}$
B.	Extreme breadth of hull, without moldings, taken at 55% of L.W.L from the for end of the water line. (Generally called "beam")
Q.b.l.	Quarter beam length as used in Universal Rule.
b.	Breadth of hull taken at L.W.L. at 55% of L.W.L. from the fore end of the water line.
d_w or d.	Extreme draft of water.
d_h	Depth of hull from top of deck beams to rabbet line taken at 55% of L.W.L. from the fore end of the water line.
b.c.g.	Depth of outside ballast from top face to center of gravity taken at 55% of L.W.L from the fore end of the water line.
bb	Breadth at top of outside ballast taken at 55% of L.W.L. from the for end of the water line.
D.	Displacement in cubic feet when in load condition. Corresponding to D in Universal Rule.
S or S.a.	Sail area in square feet. Corresponding to Sail area (S.A.) in Universal Rule.

All data dimensions in feet and decimals

[1] Captain Nat was also the author of the "Universal Rule."

Table of the Fundamental Factors Used in Connection With Herreshoff's Rules for the Construction of Wooden Yachts

Enter With	(I)	(III) & (IV) (inches)	a	Enter With	(I)	(III) & (IV) (inches)	a	Enter With	(I)	(III) & (IV) (inches)	a	Enter With	(I)	(III) & (IV) (inches)	a
3.0	5.91	3.35	1.14	6.0	11.03	7.18	1.24	9.0	15.89	11.21	1.31	12.0	20.59	15.38	1.36
3.1	6.09	3.47	1.15	6.1	11.20	7.31	1.25	9.1	16.05	11.35	1.31	12.1	20.75	15.53	1.36
3.2	6.27	3.59	1.15	6.2	11.36	7.44	1.25	9.2	16.21	11.49	1.31	12.2	20.90	15.67	1.36
3.3	6.44	3.72	1.15	6.3	11.53	7.57	1.25	9.3	16.37	11.62	1.31	12.3	21.05	15.81	1.36
3.4	6.62	3.84	1.16	6.4	11.69	7.70	1.25	9.4	16.53	11.76	1.32	12.4	21.21	15.95	1.36
3.5	6.79	3.97	1.16	6.5	11.86	7.84	1.26	9.5	16.69	11.90	1.32	12.5	21.36	16.09	1.36
3.6	6.97	4.09	1.17	6.6	12.02	7.97	1.26	9.6	16.85	12.04	1.32	12.6	21.52	16.23	1.36
3.7	7.14	4.22	1.17	6.7	12.19	8.10	1.26	9.7	17.00	12.17	1.32	12.7	21.67	16.38	1.37
3.8	7.31	4.34	1.18	6.8	12.35	8.24	1.26	9.8	17.16	12.31	1.32	12.8	21.82	16.52	1.37
3.9	7.49	4.47	1.18	6.9	12.51	8.37	1.27	9.9	17.32	12.45	1.33	12.9	21.98	16.66	1.37
4.0	7.66	4.60	1.18	7.0	12.68	8.50	1.27	10.0	17.48	12.59	1.33	13.0	22.13	16.80	1.37
4.1	7.83	4.72	1.19	7.1	12.84	8.64	1.27	10.1	17.63	12.73	1.33	13.1	22.28	16.94	1.37
4.2	8.00	4.85	1.19	7.2	13.00	8.77	1.27	10.2	17.79	12.87	1.33	13.2	22.43	17.08	1.37
4.3	8.17	4.97	1.19	7.3	13.17	8.90	1.28	10.3	17.95	13.01	1.33	13.3	22.59	17.23	1.37
4.4	8.35	5.10	1.20	7.4	13.33	9.04	1.28	10.4	18.10	13.14	1.33	13.4	22.74	17.37	1.37
4.5	8.52	5.23	1.20	7.5	13.49	9.17	1.28	10.5	18.26	13.28	1.33	13.5	22.89	17.51	1.37
4.6	8.69	5.36	1.20	7.6	13.65	9.31	1.28	10.6	18.42	13.42	1.34	13.6	23.05	17.66	1.38
4.7	8.86	5.49	1.21	7.7	13.81	9.44	1.28	10.7	18.57	13.56	1.34	13.7	23.20	17.80	1.38
4.8	9.03	5.61	1.21	7.8	13.97	9.58	1.29	10.8	18.73	13.70	1.34	13.8	23.35	17.94	1.38
4.9	9.20	5.74	1.21	7.9	14.13	9.71	1.29	10.9	18.88	13.84	1.34	13.9	23.50	18.08	1.38
5.0	9.36	5.87	1.22	8.0	14.30	9.85	1.29	11.0	19.04	13.98	1.34	14.0	23.65	18.23	1.38
5.1	9.53	6.00	1.22	8.1	14.46	9.98	1.29	11.1	19.20	14.12	1.34	14.1	23.81	18.37	1.38
5.2	9.70	6.13	1.22	8.2	14.62	10.12	1.29	11.2	19.35	14.26	1.34	14.2	23.96	18.51	1.38
5.3	9.87	6.26	1.22	8.3	14.78	10.26	1.30	11.3	19.51	14.40	1.34	14.3	24.11	18.66	1.38
5.4	10.04	6.39	1.23	8.4	14.94	10.39	1.30	11.4	19.66	14.54	1.35	14.4	24.26	18.80	1.38
5.5	10.20	6.52	1.23	8.5	15.10	10.53	1.30	11.5	19.82	14.68	1.35	14.5	24.41	18.94	1.39
5.6	10.37	6.65	1.23	8.6	15.26	10.66	1.30	11.6	19.97	14.82	1.35	14.6	24.57	19.09	1.39
5.7	10.54	6.78	1.24	8.7	15.42	10.80	1.30	11.7	20.13	14.96	1.35	14.7	24.72	19.23	1.39
5.8	10.70	6.91	1.24	8.8	15.58	10.94	1.30	11.8	20.28	15.10	1.35	14.8	24.87	19.38	1.39
5.9	10.87	7.04	1.24	8.9	15.74	11.07	1.31	11.9	20.44	15.24	1.35	14.9	25.12	19.52	1.39

Rules for the use of the tables

1. Enter the Table with $\sqrt[3]{D}$ and find at once the values of (I) and (III).
2. Enter the Table with L/d_h and find at once the value of a. Multiply this by (III) to find the value of (II). Formula: $(II) = a \times (III)$.
3. Enter the Table with $\sqrt[4]{D \times B}$ and under (III) find at once the value of (IV).
4. Enter the Table with $\sqrt[4]{D \times (length\_of\_longest\_house\_beam)}$ and under (III) find at once the value of (V).

General Rules and Specifications

Frame Spaces

The distance between centers of frames in inches is to be equal to the Factor (I).

Keel

In standard construction, white oak or teak, in as long as lengths as possible.

When it is necessary to be in two or more pieces or where connecting to stem or after overhang timber and deadwood, the scarf or lap joint must extend at least 2½ frame spaces, and be well bolted with Navy or Tobin bronze through bolts having head and nuts, the nuts being exposed in the inside when possible.

Yachts having the main keel cast in lead and included in the outside ballast, the lead is to be in depth not less the 1½ times the depth required for oak or teak and the casting is to be stiffened by containing not less than 5% or more than 7½% of antimony.

Keels for inside ballast yachts or power yachts and launches are to be in siding not less than siding of stem and overhang timber, or less than $0.35 \times (II)$. Molded way or depth to be not less than $0.8 \times (II)$; except near ends of vessels it may be reduced to $0.5 \times (II)$.

Keels in rowboats and centerboard sailing yachts to be not less than $.35 \times (II)$ in depth and not less than $.55 \times (II)$ plus centerboard slot in width, the ends gradually tapering to match siding of stem and sternpost. In case of centerboard yachts having main keel of lead, the lower pieces of centerboard casing (centerboard logs) and arms to bolt timbers to (floor timbers) are to be cast as part of the keel. The top of lead to be able top of floor timbers to give a clear caulking seam. Planking rabbet to be cast into lead.

Keels in sailing yachts as developed by the Universal Rule, having outside ballast bolted on, to be of flat plank type with planking rabbet worked into edges.

When one piece of proper size is not obtainable, make keel in two pieces butted together midships and bolted to a deadwood piece underneath – to be steamed and bent to form. The deadwood where butt is made is to be in depth not less than the keel pieces. Butt to be square-ended and made midway between two consecutive floor timbers and fastened wit bronze through-bolts, with nuts above a bronze plate covering the joint. Or make the keel in three pieces: the middle one running from forward of the outside ballast to the intersection with the sternpost and laying directly on top of the outside lead casting; the forward section of keel to be scarfed on top of middle section, with its aft end molded deep enough to make scarf, and then running to stem piece, which is scarfed on; the after section to run over deadwood and to transom, with transom knee lying on top.

The middle section of the keel may be dispensed with if the outside lead is properly designed with rabbet for garboard planking and satisfactory connection is made with the forward and after overhang pieces and after deadwood. The last plan is preferable in yachts that are hauled out of water for long periods in dry atmosphere.

Stem Pieces

Of white oak or teak as standard woods; but in small classes, of not over 150 cubic feet displacement (row or power boats), hackmatac or other tough and lasting wood may be used. Siding to be $0.5\times(III)$ and molded way over $0.7\times(III)$ as required. In yachts of over 100 cubic feet displacement, the back rabbet is to be wide enough for double fastening of wood ends of planking.

The stem piece is to lap the keel at least 2½ frame spaces and to be well bolted with not less than 4 through-bolts set up with nuts. There must always be a breast hook piece, well bolted to sheer strakes and clamps and having a good for-and-aft bolt through stemhead.

Transom

To be white oak or teak plank in yachts of over 500 cubic feet displacement; in smaller ones may be of lighter wood, as mahogany, butternut, etc. To be steamed and bent to form if curved, and to be reinforced at the edges with white oak in larger, and hackmatac in smaller, yachts. Transom to be rabbeted at edge and reinforcement, making back rabbet to receive fastenings of ends of planks.

To be quarter knees and center line knee on to keel, and framing timbers, if necessary. In small yachts, rowboats, etc., without corner reinforcing, transom plank to be not less than $0.18\times(II)$ and wood-ends of planking exposed.

Timbers or Frames

To be of best quality of white oak selected for ability to bend to required form when steamed. There is comparatively little white oak that has the proper qualities for first-class timbers, but when obtained there is no other wood equal to it for the purpose.

Timbers must be bent over traps or molds and the larger sizes strapped to prevent splitting. They should be square in section, so best side can be selected for bending. This is important. The size to be $0.2\times(III)$ square and from $7.2\times(III)$ below head are to taper to size at head $0.2\times(III)$. Taper equal 0.1 in 36 = $^{1}/_{32}$″ per ft. nearly. Center-board and moderate draft yachts with ballast close to the keel, timbers $0.23\times(III)$ square and from $7.2\times(III)$ below head are to taper to size at head. Taper 0.1 in 24 = $^{31}/_{64}$″ per ft. nearly.

In any case where the curvature of the bilge is too quick for timbers to bend safely without splitting or upsetting grain, it is best to split the timbers down with a fine saw in equal parts as far as bend extends, and have all planking fastening go through both parts.

In power yachts increase the siding of timbers that come in machinery section 50% to 75%.

Floor Timber

To be of white oak or equivalent in strength and lasting qualities. The arms should be long enough to lap the timbers from 6 to 9 times the size of timbers. Thickness of plank floors not less than $0.185 \times (III)$ and not less than 3 times diameter of keel bolts. Knee or crook floors are to be sided not less than $0.28 \times (III)$ with depth in throat not less than $0.32 \times (III)$ and arm ends not less than size of timbers.

There should be not less than 3 timber bolts each side, of diameter $^1/_6$ to $^1/_8$ size of timber, passing through timber and floor timber and set up with nuts. Bronze in smaller sizes, but over $^5/_{16}$″, good galvanized iron or steel may be used.

Keel bolts should always be bronze if they come in contact with lead ballast. If not, sizes over $^3/_8$″ may be good galvanized iron or steel. Have two keel bolts whenever possible, in diameter not less than $^1/_5$ to $^1/_6$ size of timber, but if only room for one bolt into keel to be larger, depending on character of keel and deadrise of hull section.

When floor timber bolts support outside lead ballast they are to be increased in size. Their diameter in inches is to be not less than the square root of weight of outside lead in tons divided by number of bolts supporting lead.

$$\sqrt{\frac{Tons\_lead}{no.\_bolts}}$$

If it is desirable to use bolts of different diameters, proper compensation should be made so the total bolt area is not reduced and when bolts are independent of floor timber bolts, their size is to be equivalent in size to the sectional area of adjacent floor timber bolts, as determined above.

Floor timbers over outside ballast are to be increased in size so their thickness is not less than three times diameter of bolts passing through them and length and depth sufficient to receive four timber bolts, each side.

Lead Bolts and Straps

Their diameter to be determined by the size and number of floor timber bolts as explained above. Always have them carefully distributed and as near each edge as possible, and have nuts at their upper end so they can be tightened up when necessary. One or more bolts at each end should pass way through lead. All others may be screwed into the lead and the threads that go into lead should be similar to those in wood screws and lag screws. The bolts should penetrate the lead 8 diameters and the length threaded 7 diameters. The pitch of threads should be about 1/5 diameter and depth 1/10 diameter.

All outside lead on wood yachts should have straps extending vertically to connect lead directly with timbers and planking. These straps are to be let in flush and to lap on lead about 5 times their breadth and on the timbers and above the keel and deadwood about 8 times their breadth.

Tobin bronze appears to be the best material. There are to be 5 to 8 straps each side placed on consecutive timbers in the middle part and on alternate timbers near ends of lead. Their size to be determined by multiplying weight of outside lead in tons by ratio (depth of lead to center of gravity divided by breadth on top), if over one and if not, by one. Divide by one and eight-tenths times whole number of straps, which will give sectional area in square inches of each strap.

$$\frac{b.c.g}{b_b} \times \frac{Tons}{1.8 \times No.} \text{ or } \frac{Tons}{1.8 \times No.}$$

The breadth to be 4 times and thickness ¼ the square root of area.

Diameter of screws and bolts to be 1/9 breadth of strap and there are to be not less than 8 brass wood screws into lead and not less than 9 bronze through-bolts with nuts through planking and timbers. Countersinking for head of screws and bolts should not be over 1¾ diameter of bolts and the head worked down flush after being set up.

<u>Outside Planking</u>

The thickness to be not less than $0.105 \times (II)$.

White cedar is the best wood for all small craft under 75 to 100 cu. ft. displacement.

In sizes from 75 to 200 or 250 cu. ft. a somewhat firmer wood is preferable, as Port Orford cedar, Mexican mahogany or Douglas Fir. Larger yachts should have planking of woods of still harder texture as Georgia pine, western oak or good quality teak or mahogany of hard texture.

Small lap streaked boats should have the laps well fastened with copper clinch nails or copper through fastenings with bars.

Single planking with square seams should be well and closely fitted and caulked with cotton in small and intermediate sizes. The larger sizes with hard wood planking, okum caulking may be used.

When double planked, it is found most practicable to have both layers parallel and the seams about equally lapped. The layers are to be well cemented together. Shellac is found best, but when there is plenty of time (2 or 3 months setting) white lead is as good, or better in large work. The inner layer should be 3/8 to ½ of total thickness and softer or lighter wood may be used, as cedar or cypress with Mexican mahogany or Douglas fir outside. Have the layers well screw-fastened from inside between the timbers. It is always best to have garboard and sheer strakes single thickness and a good practice is to have a few strakes above the garboards also single.

The edges to receive double planking should be rabbeted to make a lap joint with one of the layers.

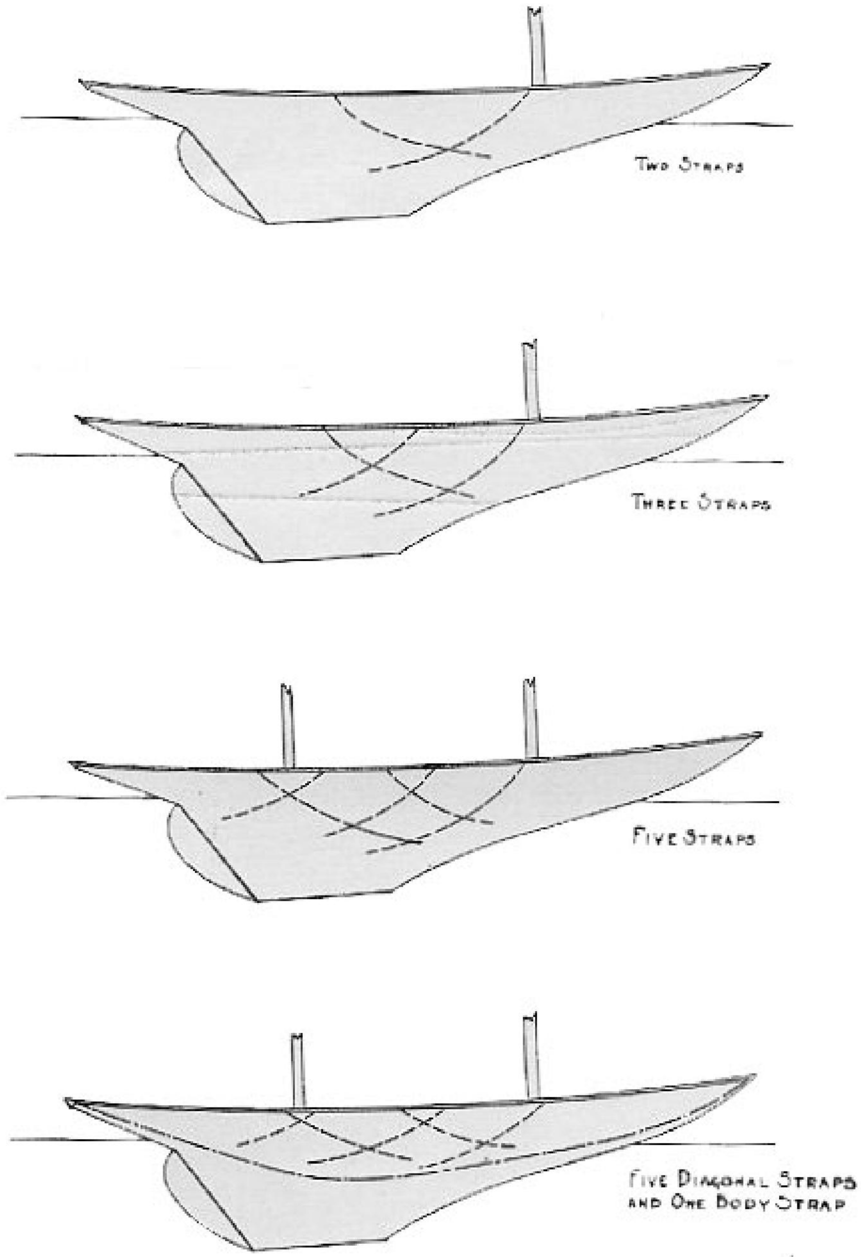
Sheer strakes should be of a hard wood that will well hold drive or screw fastening as white oak, teak, mahogany of hard texture, etc., and to be well seasoned. The molded form is desirable in smaller yachts and the thickness through swell about 1¼ times thickness of planking. Extra thickness in larger yachts than thickness of planking is also desirable – to have more wood for vertical fastening of plank-sheer and rail.

<u>Diagonal Strapping</u>

In small yachts under 100 cubic feet displacement, it is not necessary. In larger ones strap as follows:

Single planked, 100 to 175 cu. ft. disp.:	2 straps
Double planked, 100 to 175 cu. ft, disp.:	2 straps
Single planked, 175 to 200 cu. ft. disp.:	3 straps
Double planked, 175 to 300 cu. ft. disp.:	3 straps
Single planked, 300 to 500 cu. ft. disp.:	5 straps
Double planked, 300 to 500 cu. ft. disp.:	5 straps
Single planked, 500 to 900 cu. ft. disp.:	5 diagonal and body strap
Double planked, 500 to 900 cu. ft. disp.:	5 diagonal and body strap
Single planked over 900 cu. ft. disp.:	7 diagonal and body strap

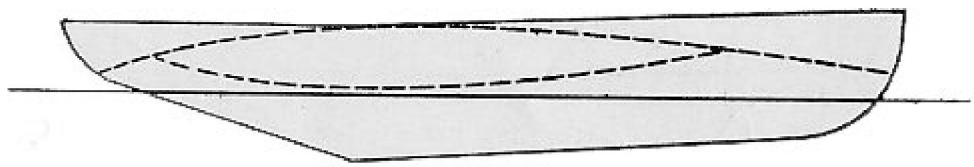
Yachts over 1,200 cubic feet displacement had better be of composite build. The straps are to be arranged as shown in the diagrams below.



DIAGONAL STRAPPING

When body straps are used, the diagonal straps are to be fastened to them.

Light draft sailing yachts and power yachts of any considerable size, say over 300 cubic feet displacement, should be diagonally strapped or stiffened in some way. In hulls of from 300 to 500 cubic feet displacement a very good way is to have arched stringers intersected by short bilge stringers of oak or yellow pine, thus



The arched stringers if in two or more lengths to be well secured at the butts, and the bilge stringers well secured to the arch stringers at their ends. All to be well fastened to the inside of the timbers. Larger yachts to have the regular system of diagonal strapping laid on to the outside of the timbers before planking. Their arrangements depends so much on the character of hull and distribution of weights, it is difficult to formulate a rule, but generally, drooping of ends and sagging at position of machinery have to be looked out for.

In the sailing yachts that have body bands, they should be well secured to the stem near its head and run aft under the lower part of body amidships, finally terminating at the quarters where they should be well secured. The lower end of all diagonal straps should terminate at these bands and be well secured to them. Arranged this way straps do not go into the bilge-water and therefore are not subject to intense corrosion.

The size of straps to be about the same as determined for lead straps, or possibly a little wider and thinner, and body bands about the same thickness but 50% to 75% wider. Screw fastening at each edge into planking and also into timbers. Tobin bronze is standard but in larger sized yachts galvanized steel banding is usual.

Clamps

Clamps for supporting deck beams and making a longitudinal tie should be continuous from breast hook to quarter knees, and if in for more than one length avoid if possible having any butt near amidships. The best practice is to have a long length amidship and butted to two shorter ones at ends. Connection to be made by a short filling piece between the clamp and sheer strake between adjacent timbers (the butt being midway of a frame space) and a long butt piece on the inside of clamp or of galvanized steel angle. Bevel clamps at outside so top surface is level and correctly fays to the deck beams, which are to have a level seating. Their size before beveling should be $0.24 \times (II)$ each way and the inner lower corner may be chamfered away about $0.05 \times (II)$ excepting under butt pieces.

In the smaller classes, spruce or other stiff light wood may be used in larger ones woods of harder texture, as Douglas fir, Georgia pine or oak, and in as long lengths as possible.

In yachts having long cabin trunks, or houses, that cut off the deck beams, it is desirable to have a secondary clamp inside the primary, and well bolted to it.

In many yachts having height topsides and flush decks clamps may be omitted, and the deck beams supported by metallic drop knees of brackets, bolted to deck beam and timber, both being placed in the same plane. If this construction be used longitudinal strength shall the be made up by having a molded or thicker sheer strake and a heavier planksheer or waterway.

Breast Hook and Quarter Knees

There should always be a breast hook to connect the stem, sheer strakes and decking securely together. In the modern sailing yacht it becomes a chunk of wood to receive bolts and fastenings, but it should be selected with care for soundness and durability, and it must be well seasoned. There should be a long fore and aft bolt passing through stem and set up with nut inside. The forward end of clamps should also be bolted to under side of breast hook.

Quarter knees must be fitted to securely connect the sheer strakes, clamps, and transom, and also a ledge piece to receive wood ends of deck. Take particular care that the quarter knees and other pieces in the vicinity are of thoroughly seasoned wood that is not subject to dry rot.

Deck Beams

The most desirable wood is white oak or yellow-bark oak, in the larger sizes. Yellow-bark oak, white ash or chestnut in intermediate sizes, and white ash, chestnut or butternut in smaller. It is recommended they be placed on large side of every frame space, the timbers being on the small, or side towards ends of vessel, excepting at frames where there are hanging knees or when there is no clamp, but knee brackets, then they should be in same plane as timber.

The molded size to be $0.28 \times (IV)$. Camber for both top and bottom sides should be the same, for all beams, and between $^1/_3$″ and $^1/_2$″ per foot of beam of vessel, or between $^B/_{36}$ and $^B/_{24}$. The radius of curvature between 9B and 6B. Make the depth of end of all beams $0.20 \times (IV)$, and the under side on level line until intersected by molded or cambered part, as below.

The regular size for siding of deck beams to be $0.17 \times (III)$. Beams each side of mast, and each side of hatches with not more than two beams cut, and at position of belt frames, to be sided $0.23 \times (III)$. At hatches cutting more than two beams, and at breaks of deck, to be sided $0.30 \times (III)$.

Half beams with inboard end supported by hatch coaming or cabin house side may be molded $0.20\times(IV)$ and sided $0.17\times(III)$, there are to be wedge shaped shims between under sides and clamps.

Deck Diagonal Strapping

In yachts over 175 and under 350 cubic feet displacement have one pair running from gunwale to gunwale and crossing new mast partners. Yachts between 300 and 700 cubic feet displacement 2 pairs, and over 700 three or more pairs – all placed where they can best run from gunwale to gunwale and not be cut by hatchways or other deck openings. The angle with center line between 30E and 45E. The size to be about the same as for planking straps. They may be cut into deck beam and flush or fairing pieces, thickness of straps placed on top of beams laid in white lead. To be fastened into deck beams and also into deck beams, with brass screws.

Margin Plank or Planksheer

To run continuously from stemhead over sheer strakes and deck beam ends, to and around transom and return on other side. To be worked in long lengths as possible with butts on butt blocks between timbers, and shifted two or more frame spaces from butts of sheer strakes and clamps. The thickness to be not less than main deck and more is better if deck is bright for holystoning. Breadth to be $0.38\times(II)$. To be screw fastened into sheestrake and beam ends. If deck planks are to be laid straight, make breadth $0.42\times(II)$ to allow nibbing in ends of decking. Best woods are teak, white oak, mahogany of hard texture, in larger; and mahogany, Georgia pine or Douglas fir, in small yachts.

Main Deck

The best wood is clear white pine free from sap and shakes. If a deck is to be canvas covered, which is always recommended in decks less than 1¼″ thick, other light woods are good, as Washington spruce, Port Orford cedar, white cedar, etc.

The best practice is to lay with square seams of thoroughly dry stock and to be tightly caulked with cotton. Bare decks to have seams filled with marine glue after caulking. When canvas covered, seams putties flush.

In the heavier decks a good practice is to get the stock out square so to be able to select the best side to be up, which must always show edge of grain. Such a deck has one fastening to each beam. For two fastening, breadth should be from 1¾ to 2½ times thickness $0.185\times(II)$ to $0.260\times(II)$. Standard thickness to be $0.105\times(II)$, and if canvas covered, thickness may be reduced to $0.1\times(II)-0.05''$. If teak is substituted for white pine in the larger sizes, thickness to be $0.75\times(II)$. It is generally desirable to lay deck parallel to the margin plank, with ends nibbed into a king plank when approaching centerline.

Cabin Trunks, or Houses

If sides are of plank of soft wood, thickness to be $0.11 \times (II)$, and if mahogany, $0.10 \times (II)$, or if teak, $0.095 \times (II)$. The sides should be edge bolted at spacing not over 2 frame spaces.

The house deck beams should be secured to house sides either by a white oak lining strip in width1¾ times molded size of beams and thickness $0.1 \times (II)$. The beams to be dove-tailed into it. Or by metal brackets or clips, securely fastened.

If the sides are framed and with glass or wood panels, frame to be either mahogany or teak $0.12 \times (II)$ in thickness, and glass not less than $^{7}/_{32}$" thick or $0.18 \times (II)$, and with wood panels $0.16 \times (II)$.

House deck beams may be dove-tailed into upper rail of frames side provided it is increased in thickness to $0.175 \times (II)$ and not cut through, but leaving not less than $0.70 \times (II)$ of wood at end of beam.

The molded depth of house or trunk deck beams to be $0.28 \times (V)$: where the factor (V) is taken from Table III by entering with $\sqrt[4]{D \times length\_of\_longest\_beam}$ (square root of the square root); but not less than $^{2}/_{3}$ molded depth of main deck beams. The spacing, -siding of deck beams and thickness of deck, to be in proportion to corresponding scantling of main deck as the square root of the ratio of length of house to the mean length of hull (L), but not less than 2/3 of corresponding dimensions of the main deck, and to be of equivalent grade of wood. Beams each side of mast, hatches, etc., are to be increased as in main deck beam.

Camber to be between $^{1}/_{24}$ and $^{1}/_{36}$ of length of length of longest house beam.

House deck to be laid in same manner as main deck, and same allowance of thickness for canvas to be made.

When the house deck extends forward of a mast it must be diagonally strapped as thoroughly as the main deck.

Mast Partners and Steps

At the position of each mast, bitts, capstan, mooring cleats, etc., the deck should be reinforced between deck beams by a well seasoned hardwood plank run thwartships, - in thickness $0.125 \times (II)$ and length equal to 2½ frame spaces, for mast, bitts and main capstan, and not less than 1½ frame spaces for other major deck fittings. Each side of a mast or bitt hole should be edge bolted, passing through adjacent deck beams and set up with nuts.

Mast steps should be of hard wood – white oak is best – and well supported against the intense thrust of the mast. They should rest on 3 or 4 floor timbers of extra size, and in large sizes of racing yachts, extra timbers and intermediate timbers or straps connecting with chainplates and passing down under mast step is desirable.

Inside Ceiling

Every wood framed yacht should be ceiled from the cabin sole to within a frame space length of the deck beams, or higher, and for at least ¾ length (¾ L) in middle part, but to extend as much farther as is necessary to reach by any sleeping berth. The thickness of ceiling to be $0.20"+0.25\times(II)$. To be laid in reasonably long lengths, seams close and to be well fastened to timbers. Use cedar in smaller sizes and harder woods in larger, ranging up to Douglas fir of Georgia pine in the largest.

Bilge Stringers

Are not necessary in any yacht that is well ceiled as directed. In cases where a yacht is liable to lay aground and over on her bilge, it is well to have outside protection in the form of one or two or three thick bilge strakes of planking for the middle $^1/_3$ length, or a bilge keel in lieu of it.

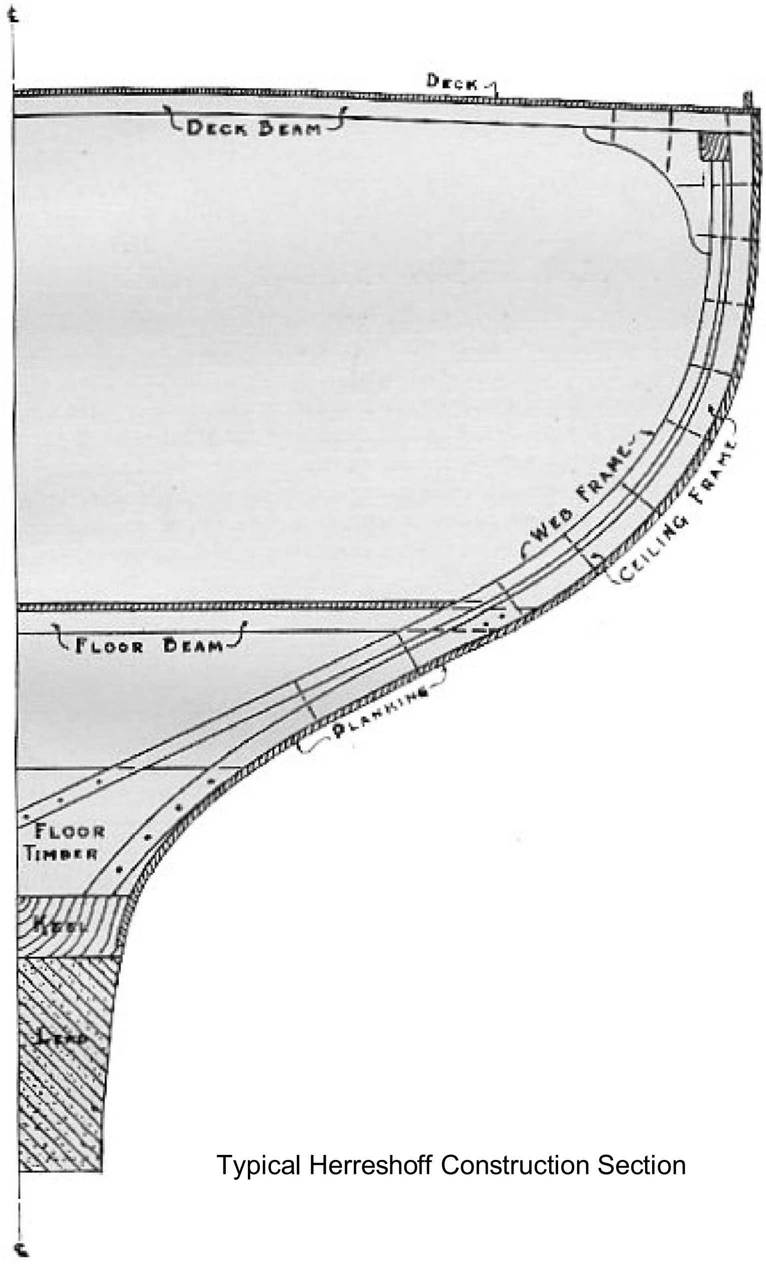
Hanging Knees and Belt Frames

In larger sizes of sailing yachts – over 500 cubic feet displacement with outside ballast – they should be strengthened by belt frames and hanging knees. They can generally be placed at frame spaces that will not interfere with berth spaces, and at partitions, and not closer than 6½ to 8 feet apart. Have two on each side on yachts between 500 and 900 cubic feet displacement and 3 or 4 each side on yachts over 900 cubic feet displacement. The belt timber to be $0.23\times(III)$ square of best white oak, steamed and bent to place. These timbers should be fitted inside the ceiling and not cut it, and hanging knees should connect them to the deck beams of same siding as belt frames: having through fastenings of size for lead straps, with heads bunged into outside planking and passing through timber, ceiling, and belt timber, with nuts inside and not over $1\times(III)$ apart.

The lower end of belt frames to be well fastened to face of plank floors, as are the main timbers.

Cabin Floor, or Sole

Should be laid on oak beams, spaced same as main timers and substantially secured to them, and to be stanchioned to floor timbers where necessary to prevent vibration. Floor may be cedar in small boats, ranging up to Douglas fir and Georgia pine in the largest. The thickness to be $0.20"+0.35\times(II)$. Beams to be sided $0.20"+0.55\times(II)$ and depth 2½ times siding.

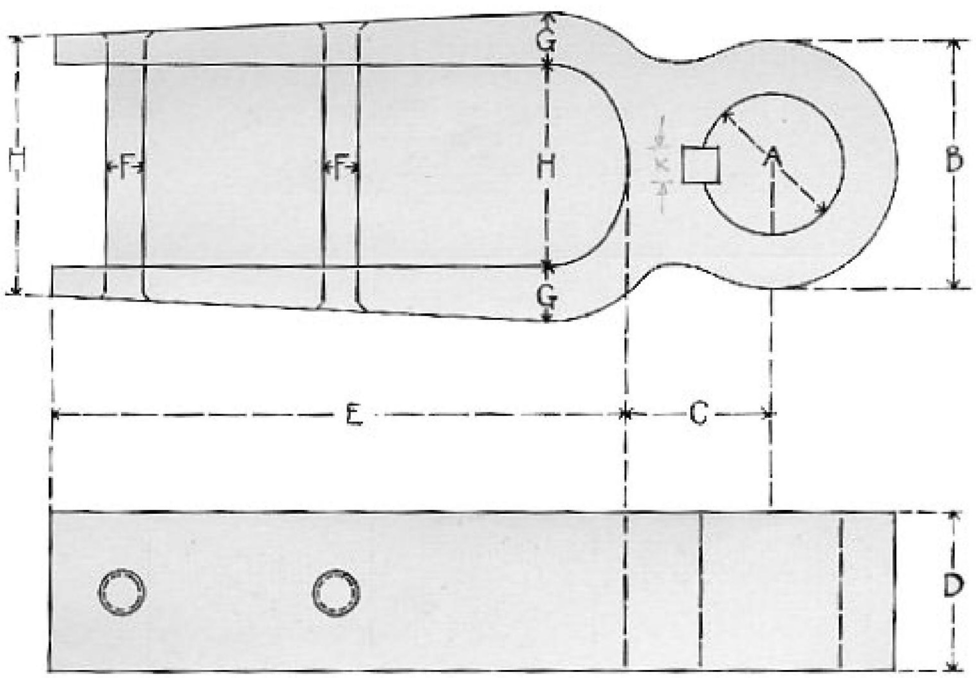


Typical Herreshoff Construction Section

Rudder Stocks

Tobin bronze is standard material for all wood constructed yachts. The diameter in inches for sailing yachts not to be less than 0.155 times breath of yacht in feet, (0.155B) and also not less than the fourth root of 2% of the distance of center of area of rudder blade from axis, times area of blade, times mean length of vessel, all in feet. ($\sqrt[4]{0.02 \times v \times a \times L}$)

The connection of ruder blade to stock to be by two bronze castings with double arms in the general form as shown. To be fitted and keyed tight to stock, and held to blade by two or three copper rivets.



Proportions:

If the diameter of the stock A is 1, then the other dimensions should be:
B = 1 1/4 C = 1 D = 1 1/8
E = 4 G = 3/8 K = 1/4
F = 1/4 or 7/32 if 3 bolts.
H and H' are required for the thickness of the blade.
K is the size of the key.

It is difficult to make a close rule for stocks to rudders of power vessels. As a rough rule: When blades are supported by a step or pintles. Diameter in inches not less than $0.18 \times (III)$, and not less than $0.85 \times (dia.\_of\_prop.\_shaft)$.

If blade is pendant, then stock to be not less than $0.225 \times (III)$ and not less than $1.25 \times (dia.\_of\_prop.\_shaft)$ and if twin screw, $1.5 \times (dia.\_of\_shafts)$.

Planking and Deck Fastenings

Brass wood screws are usually used and give good results generally, although occasionally there is trouble from electrolysis, and a different composition then that usually used in wood screws the is not subject to it would be better. For the special purpose, screw that are threaded but six-tenths length, so the body part will extend into timber to give better sheer resistance, is better. Care should be taken to bore correct sizes for screw end – body and bung, and special bitts that will bore three sizes at once are desirable. The sizes of screws under No. 10 – it is generally more practical to putty or wax the heads instead of bunging, and in that case 1/8 inch longer screws can be used and not counter bored, but the head set in a short distance.

Table of Sizes of Screws for Planking and Deck Fittings

Planking Thickness	Approximate Diameter	Screw Gauge Numbers	Length	Diameter of Bung
3/8"	9/64"	6	3/4"	5/16"
7/16"	5/32"	7	7/8"	5/16"
1/2"	11/64"	8	1"	3/8"
9/16"	3/16"	9	1 1/8"	3/8"
5/8"	3/16"	10	1 1/4"	7/16"
3/4"	7/32"	12	1 1/2"	7/16"
7/8"	1/4"	14	1 3/4"	1/2"
1"	17/64"	16	2"	9/16"
1 1/8"	19/64"	18	1 1/4"	5/8"
1 1/4"	5/16"	20	2 1/2"	11/16"
1 1/2"	11/32"	22	2 3/4"	11/16" or 3/4"
1 3/4":	3/8"	24	3"	3/4" or 13/16"
2"	13/32"	26	3 1/2"	13/16"

For double planked yachts use table sizes for inner plank fastening to timbers and same gauge but length as required for fastenings between timbers. For outer plank use sizes for total thickness of both inner and outer planking.

Table of Dimensions in Terms of the Fundamental Factors

	Inches and Decimals		
	Deep Keel	*Moderate Draft, Center-Board: Outside Ballast*	*Inside Ballast Sailing Yachts: Power Boats*
FRAME SPACES:	(I)	(I)	(I)
KEEL:			
Depth, or thickness at ends:	0.28(II)	0.35(II)	0.80(II)
Width:		0.55(II) +c.b. slot	0.55(II) +c.b. slot
STEM PIECE:			
Sided:	0.50(III)	0.50(III)	0.50(III)
Molded:	0.70(III)	0.70(III)	0.70(III)
TRANSOM:			
Thickness:	0.95(II)	0.95(II)	0.95(II)
Reinforcing thickness:	0.18(II)	0.18(II)	0.18(II)
	Deep Keel	*Moderate Draft, Center-Board: Outside Ballast*	*Inside Ballast Sailing Yachts: Power Boats*
TIMBERS:			
At head (square):	0.20(III)	0.20(III)	0.20(III)
Maximum (square):	0.24(III)	0.23(III)	0.22(III)
Length of taper:	7.20(III)	7.20(III)	7.20(III)
Taper (per foot):	1/16"	3/64"	1/32"
FLOOR TIMBERS:			
Plank Floors: thick	0.185(III)	0.185(III)	0.185(III)
Crook Floors: thick	0.28(III)	0.28(III)	0.28(III)
deep	0.32(III)	0.32(III)	0.32(III)
OUTSIDE PLANKING:			
Thickness:	0.105(II)	0.105(II)	0.105(II)
CLAMPS:			
Before beveling:	0.24(II)	0.24(II)	0.24(II)
Chamfer (not over):	0.05(II)	0.05(II)	0.05(II)
DECK BEAMS:			
Molded: maximum:	0.28(IV)	0.28(IV)	0.28(IV)
at ends:	0.20(IV)	0.20(IV)	0.20(IV)
Sided: regular	0.17(III)	0.17(III)	0.17(III)
at mast & small hatches:	0.23(III)	0.23(III)	0.23(III)
at large hatches:	0.30(III)	0.30(III)	0.30(III)
Half Beams:			
Molded:	0.20(IV)	0.20(IV)	0.20(IV)
Sided:	0.17(III)	0.17(III)	0.17(III)
PLANKSHEER:			
Thickness:	same as deck	same as deck	same as deck
Breadth:			
Curved deck:	0.38(II)	0.38(II)	0.38(II)
Straight deck:	0.42(II)	0.42(II)	0.42(II)
MAIN DECK:			
Thickness: Pine:	0.105(II)	0.105(II)	0.105(II)
Teak:	0.075(II)	0.075(II)	0.075(II)

Canvas:	0.100(II) -0.05"	0.100(II) -0.05"	0.100(II) -0.05"
CABIN TRUNKS:			
Solid Plank:			
Soft wood:	0.110(II)	0.110(II)	0.110(II)
Mahogany:	0.100(II)	0.100(II)	0.100(II)
Teak:	0.095(II)	0.095(II)	0.095(II)
Glass or Paneled:			
Frame (Mahogany or Teak)	0.120(II)	0.120(II)	0.120(II)
Panels	0.060(II)	0.060(II)	0.060(II)
Deck Beams:			
Molded Depth:	0.28(II)	0.28(II)	0.28(II)
MAST PARTNERS AND DECK FITTINGS:			
Thickness:	0.125(II)	0.125(II)	0.125(II)
INSIDE CEILING:			
Thickness:	0.025(II) +0.20"	0.025(II) +0.20"	0.025(II) +0.20"
	Deep Keel	*Moderate Draft, Center-Board: Outside Ballast*	*Inside Ballast Sailing Yachts: Power Boats*
BELT TIMBERS:			
Square:	0.23(III)	0.23(III)	
CABIN FLOOR, OR SOLE:			
Thickness	0.035(II) +0.20"	0.035(II) +0.20"	0.035(II) +0.20"
Beams:			
Sided:	0.055(II) +0.20"	0.055(II) +0.20"	0.055(II) +0.20"
Depth:	2.5 x siding	2.5 x siding	2.5 x siding

Example

The method of using these Rules and Tables is shown in the following example of finding the required scantlings of a 30-foot deep keel yacht.

1. Dimensions of Yacht.

Length over all:	42'3"	O.a.l.
Load water-line length:	30'0"	L.W.L.
Beam:	9'2"	B.
Depth of hull:	6'0"	d_h
Depth of outside lead:	2'5"	b.c.g.
Breadth of outside lead:	1'1"	b_b
Weight of outside lead:	5 tons	
Displacement:	275 cu. ft.	D

2. Calculations of Fundamental Factors.

a. From the above dimensions find (to nearest tenth).

$$L = \frac{42.25 + 60.00}{3} = 34.1$$

$$L/d_h = \frac{34.1}{6} = 5.7$$

$$D \times B = 275 \times 9.18 = 2525$$

b. From tables of square and cube roots, take out at once:

$D = 275$ $\quad \sqrt[3]{D} = 6.5$

$D \times B = 2525$ $\quad \sqrt[2]{D \times B} = 50.3$

$\sqrt[2]{D \times B = 50.3}$ $\quad \sqrt[4]{D \times B = 7.1}$

c. From the Tables of Fundamental Factors:

Enter with 6.5 and find:	(I) = 11.86
	(III) = 7.84
Enter with 5.7 and find:	a = 1.24
Thence: 1.24×7.84 =	(II) = 9.72
Enter with 7.1 and find:	(IV) = 8.64

3. Calculations of Scantling and Dimensions

Frame Spaces:

Equal to (I), or to 11.86 inches:
Use 11 ¾" or 12"

Keel:

Thickness equals 0.28(II) = 28*(9.72) = 2.72 inches
Use white oak plank 2 ¾”

Stem Piece:

Sided:	0.50(III) = 0.50*(7.84) = 3.92 inches
Molded: not less:	0.70(III) = 0.70*(7.84) = 5.49 inches
Use white oak:	3 $^{7}/_{8}$” by 5 ½” or more.

Transom:

Thickness:	0.95(II) = 0.95*(9.72) = 0.92 inches
Reinforcing:	0.180(II) = 0.180*(9.72) = 1.49 inches

Use oak or hackmatac:
Thickness: $^{15}/_{16}$”
Reinforcing: 1½”

Timbers:

At head:	0.20(III) = 0.20*(7.84) = 1.57 inches
Maximum:	0.24(III) = 0.24*(7.84) = 1.88 inches
Length of taper:	7.20(III) = 7.2*(7.84) = 56.45 inches

Use selected white oak:
1 $^{9}/_{16}$” square at head: increasing for 56 ½” to 1 $^{7}/_{8}$” square.

Floor Timbers:

Plank:

Thickness:	0.185(III) = 0.185*(7.84) = 1.45 inches
Use oak plank:	1 $^{3}/_{8}$” and for floor timbers over outside lead, thickness not less than 3 times size of bolts or 1 $^{7}/_{8}$”.

Outside Planking:

Thickness:	0.105(II) = 0.105*(9.72) = 1.02 inches

Suggest lower third, Georgia pine and remainder double thickness: - Mexican mahogany $^{9}/_{16}$” outside; White cedar or cypress $^{7}/_{16}$” inside.

Clamps:

Before beveling:	0.24(II) = 0.24*(9.72) = 2.33 inches
Chamfer	0.05(II) = 0.05*(9.72) = 0.48 inches

Use Douglas fir or Georgia pine:
2 3/8” square before beveling: chamfer not over ½”

Deck Beams:

Molded:	0.28(IV) = 0.28*(8.64) = 2.42 inches
At ends:	0.20(IV) = 0.20*(8.64) = 1.73 inches
Sided: regular:	0.17(III) = 0.17*(7.84) = 1.33 inches
at mast:	0.23(III) = 0.23*(7.84) = 1.80 inches
large:	0.30(III) = 0.30*(7.84) = 2.35 inches

Use white or yellow bark oak:
Molded maximum 2 $^{7}/_{16}$": depth at ends 1 ¾"
Regular beams to be sided 1 $^{3}/_{8}$"
Two beams at mast partners, two at hatch, and one at aft end of cockpit to be sided 1 $^{3}/_{4}$"
Beam at forward end of companion to be sided 2 $^{3}/_{8}$"
Half-beams:

Molded:	0.20(IV) = 0.20*(8.64) = 1.73 inches
Sided:	0.17(III) = 0.17*(7.84) = 1.33 inches

Half-beams at side of hatch, main companionway, and cockpit to be molded 1 ¾"; sided 1 $^{3}/_{8}$"

Planksheer:

Breadth: 0.38(II) = 0.38*(9.72) = 3.69 inches
Use long mahogany or Georgia pine if deck is bright; Georgia pine or Douglas fir if canvas covered: Breadth to be 3 ¾"

Main Deck:

Thickness: pine 0.105(II) = 0.105*(9.72) = 1.02 inches
White pines, Port Orford cedar, or Washington spruce if canvassed, and $^{15}/_{16}$" thick.
Breadth of plank: 0.22(II) = 0.22*(9.72) = 2.13 inches
Use 2 $^{1}/_{8}$" or 2 ¼"

Ceiling:

Thickness: 0.025(II) + 0.20" = 0.25*(9.72) + 0.20" = 0.44"
Use $^{7}/_{16}$"

Cabin Floor:

Thickness: 0.035(II) + 0.20" = 0.035*(9.72) + 0.20" = 0.54"
Use white pine of Douglas fir, $^{9}/_{16}$" thick
Beams: thick 0.055(II) +0.20" = 0.055*(9.72) + 0.20" = 0.73"
To be ¾" thick and 1 $^{7}/_{8}$" deep.

Lead Bolts:

There should be 12. $Diameter = \sqrt{5tons \div 12} = 0.65''$. Hence make 5 pair of side bolts 5/8" diameter, and 2 center bolts going way through ¾" diameter. Side bolts may be lag-screw type, threaded about 4 ½" and screwed into lead about 5"; with machine screw and nuts at head end and set down tightly on packed washers on top of keel.

Lead Straps:

There should be 5 on each side. Then sectional area in square inches is $Tons \div 1.8 \times number$, or 5/8, which is .278 sq. in. The square root of this is .527: hence,

Breadth of strap is $4 \times (0.527) = 2.11''$: use 2 ¼"
Thickness is $0.25 \times (0.527) = 0.13''$: use 1/8"

Screws and bolts ¼" diameter. Straps to lap on lead not less than 11" and on timbers above keel not less than 17". For length add depth of deadwood, keel, and 11 and 17.

Diagonal Straps:

To be 2 on each side of lead straps and in position covering mast and greatest section, as shown in diagram.

Rudder Stock:

Tobin bronze, not less than 0.155B in diameter, or 0.155(9.2) = 1.42 inches. Use 1 $^{7}/_{16}$", or 1 ½" Tobin bronze shafting.