THESIS.

DESIGN OF ATLANTIC COASTING SCHOONER WITH DISESEL ENGINE.

Department
of
Naval Architecture and Marine Engineering.
Massachusetts Institute of Tech.

Submitted by,

INTRODUCTORY.

Any ship hoping to compete successfully in the commercial world of to-day must be the result of years of practical experience and scientific improvement. Records of ships already built form the nucleus about which the skilled naval architect builds a new and better ship. The data concerning this ship, to which I have had access, has been very meagre and unreliable. Consequently, the design is not intended to be an improvement over anything so far built, but rather, my idea of what a ship of this description should be.

I am especially indebted to Professor Jack for his kindly advice on this problem and to Mr. Edson B. Schock, a Vancouver Naval Architect.

Chris. B. Nelson.

CONTENTS

	PAGE
Introductory	3
Preliminary design and choice of type	4
Principal dimensions	11
Curves of Form	12
Resistance and Power	18

THE PRELIMINARY DESIGN.

Requirements.

This schooner has been designed for Atlantic coastwise service in competetion with all manner of slow cargo carriers as well as the seaboard railroads. The requirements are :-

1. Deadweight 900 Tons.
2. Draft 16'-6"
3. Sea Speed 7 Knots.
4. Cruising radius 3000 miles at three-quarter speed.

The type vessel chosen was the steel schooner with a Diesel auxiliary. This combination has many arguments in its favor.

An out and out steam driven vessel was eliminated because the nature of the freight carried is such that a slow sailing vessel can handle the freight more cheaply and hence show to advantage when the competetion becomes keen.

A vessel trading along the Atlantic coast will dock frequently. A sailing ship without andauxiliary must hire tugs to get in and out of harbors.The existance of an auxiliary will justify itself on this score alone.A gasoline engine, while costing far less than a Diesel in first cost and taking up less space is extremely expensive to operate in such a large size. A steam installation is bulky, heavy, and uneconomical in intermittant service. The Diesel is the one power that we have not eliminated. It is reliable for continuous service and instantly available in intermittant service. A large number of schooners are driven ashore each year whereas power might have saved them.

During the war a great many wooden ships were built. They are worthless costing more in repairs, upkeep, and insurancethan a steel ship. It is urgent, therefore, that we decide upon a steel hull.

The method I have followed in designing this ship has not been the usual practice. As I have already stated, there were no lines or data of a type ship available so I have attempted to build up a design on the few technical facts which were known. I will expand upon this later.

DISPLACEMENT.

A fair ratio of deadweight to displacement for moderate sized cargo carriers appears to be .6 On account of the small size of this vessel, I have taken this ratio to be .5 to allow for a reasonable margin. The displacement is, therefore, 1800 tons. This estimate is probably just as close as calculating the net steel from a vessel of dissimilar type.

METACENTRIC HEIGHT.

The V.C.G. is estimated to be .6 of the depth. which is as yet undecided. The BM for the type is not known so it is thought advisable to keep the ratio of breadth to depth within the limits of the type.

BLOCK COEFFICIENT.

The block coefficient permissable by Table One for an approximate length and the required speed is far too great for a satisfactory sailing vessel, being .79 A block coefficient of .65 was decided upon as being low enough a good sea speed and yet give a large cargo capacity.

The femaining principal dimensions were decided upon after a comparison of three sets of dimensions computed from the foregoing data. With the draft and block fixed,the length and breadth alone may be varied. The three ships were computed with length beam ratios of 5, 5.50, and 5.25respectively.

The third ship proved to have the smallest scantlings under Lloyd's rules and so was chosen.

L.B.P. 178.166'

Moulded Draft 16'

Moulded Breadth 34' By shaving off an inch and thereby making the breadth 33'-11" it was possible to reduce some of the scantlings.

LINES.

Freehand sections were drawn in with the general resemblance of a schooner. The sections were faired up and made to coincide with the data on hand.

COEFFICIENTS.

Load water line offsets were obtained from Simpson The corresponding load waterline coefficient is .797 Since the Prismatic coefficient divided by the L.W.L. coefficient is almost always the constant .9 we may obtain the remaining coefficients.

L.W.L. Coefficient .797

Block Coefficient .65

Prismatic coefficient .717

Mid. Area Coefficient .907

CURVE OF AREAS.

With the prismatic coefficient known, offsets for the corresponding curve of areas were found from Mc-Entee's curves. The lines were made to conform to this curve of areas.

Ordinates of Required Curve of Areas.

Station	Ordinate (In percent)	Required Area (In Sq. feet)	
1	.000	00.0	Afterbody.
2	.130	64.1	
3	.310	153.	
4	.529	261.	
5	.726	358.	
6	.881	434.	
7	.957	472.	
8	.992	488.	
9	1.000	493.	
10	1.000	493.	
11	1.000	493.	
12	1.000	493.	
13	1.000	493.	
14	.992	488.	
15	.960	473.	
16	.883	438.	
17	.760	375.	
18	.592	292.	
19	.391	193.	
20	.184	90.7	Forebody.

FREEBOARD AND SHEER.

The freeboard was estimated, from the freeboard tables, to be 3'-6"

Standard mean sheer $\frac{200}{10}$ 10 30"

Standard mean sheer plus the 50% allowed 45"

Reduction in freeboard ¼(act.mean-stand.mean) 4"

Resulting freeboard 3'-2"
Winter N.Atlantic 3'-5"

The sheer is excessive for a steel ship but protects the quarters in the forecastle. Furthermore, since we have started with our maximum draft, it is more economical to increase the sheer than either the beam or length.

PRINCIPAL DIMENSIONS AND PARTICULARS.

Displacement (Moulded)	1800 Tons
Deadweight	900 Tons
L.O.A.	200 Ft.
L.B.P.	178.166 Ft.
Moulded Breadth	33'-11"
Moulded Depth	16 Ft.
Block Coeff.	.65
Area waterline Coeff.	.797
Mid.Area Coeff.	.907
Prismatic Coeffi	.717
Freeboard.	
Sea speed under power	7 Knots
Horsepower (Brake)	240

CURVES OF FORM.

Bonjean's curves of sectional areas were drawn. The calculations of the hyrostatic curves dependent upon these will not be given. A sample of the computations of the remaining curves is given below. The figures are obtained from the five pages following.

16 ft. Water-plane.

$$\text{Area of w.p.} = \frac{102.44 \times 17.82 \times 2 \times 4}{3} = 4870 \text{ sq.ft.}$$

$$\text{C.F.} = \frac{(111.58-104.08)}{102.44} = 1.305 \text{ ft. abaft station 5}$$

$$I_{5\ (\text{long})} = \frac{2}{3} \times (17.816)^3 \times 617.78 \times 4 = 9{,}250{,}000 \text{ ft.}^4$$

$$I_{(\text{C.F.})} = 9{,}250{,}000 - \frac{2}{3} \times 102.44 \times 17.816 \times 4 \times (1.33)^2$$

$$I._{(\text{C.F.})} = 9{,}241{,}380 \text{ ft.}^4$$

$$\text{B.M.}_{(\text{long.})} = \frac{I}{V} \ \frac{9{,}241{,}380}{1785 \times 35} = 147.8 \text{ ft.}$$

$$I._{(\text{Trans.})} \ \frac{2 \times 17.816}{9} \times 1558.57 \times 4^3$$

$$I._{(\text{Trans.})} = 395{,}000 \text{ ft.}^4$$

$$\text{B.M.}_{(\text{Trans.})} = \frac{395{,}000}{1785 \times 35} = 6.32 \text{ ft.}$$

The V.C.B. was found by taking the moment of the curve of displacement about the L.W.Line.

Station	Ord. in inches	Simpson's Mult.	Function of Areas	Interval	1st. Moment	2nd. Moment	Ord. cubed.	Interval	Function Ord. cubed.
½	1.61	2	3.22	4½	14.50	65.20	4.17	2	8.34
1	2.87	1½	4.31	4	17.24	68.96	23.64	1½	35.50
2.	3.89	4	15.56	3	46.68	140.04	58.86	4	235.44
3	4.12	2	8.24	2	16.48	32.96	69.93	2	139.86
4	4.17	4	16.68	1	16.68	16.68	72.51	4	290.04
5	4.18	2	8.36	0			73.03	2	146.06
				Sum aft	111.58				
6	4.16	4	16.64	1	16.64	16.64	71.99	4	287.96
7	4.12	2	8.24	2	16.48	32.96	69.93	2	139.86
8	3.77	4	15.08	3	45.24	135.72	53.58	4	214.32
9	2.38	1½	3.57	4	14.28	57.12	13.48	1½	20.23
9½	1.27	2	2.54	4½	11.44	51.50	20.48	2	40.96
	Sum Areas		102.44	Sum For.	104.08	617.78 Sum I.Long.			1558.57 Sum I.Trans.

Calculations for curves of Form.

16 FT. WATER LINE.

Scale ¼" 1'

Station	½ Ord. (in In.)	Simpson.	Funct. Areas.	Interv.	1st. Moment.	2nd. Moment.	Ord. cubed.	Interv.	Funct. Ord. cubed.
½	.72	2	1.44	4½	6.48	29.20	.37	2	.74
1	1.83	1½	2.74	4	10.96	43.84	6.23	1½	9.35
2	3.67	4	14.68	3	44.04	176.12	49.43	4	197.72
3	4.14	2	16.56	2	33.12	33.12	70.96	2	141.92
4	4.19	4	16.76	1	16.76	16.76	73.56	4	294.24
5	4.22	2	8.44	0			75.15	2	150.30
					94.90				
6	4.17	4	16.68	1	16.68	16.68	72.51	4	290.04
7	4.11	2	16.44	2	16.44	32.88	69.43	2	138.86
8	3.62	4	14.48	3	43.44	130.32	47.44	4	189.76
9	2.05	1½	3.04	4	12.16	48.64	8.37	1½	12.55
9½	1.00	2	2.00	4½	49.00	40.50	1.00	2	2.00
			96.76		97.72	568.06			1427.48

Calculations for curves of form.

12 ft. Water-line. Scale ¼" 1'

Station	½ Ord. in Inches.	Simpson's Mult.	Function of Areas.	Interval	1st. Moment	2nd. Moment	Ord. cubed	Interval	Funct. Ord. cubed.
½	.40	2	.80	4½	3.60	16.20	.06	2	.12
1	1.11	1½	1.68	4	6.72	26.88	1.37	1½	2.06
2	3.11	4	12.44	3	37.32	111.96	30.08	4	120.32
3	4.00	2	8.00	2	16.00	32.00	64.00	2	128.00
4	4.13	4	16.42	1	16.42	16.42	70.44	4	281.76
5	4.18	2	8.36	0			73.03	2	146.06
					80.06				
6	4.13	4	16.42	1	16.42	16.42	70.44	4	281.76
7	4.00	2	8.00	2	16.00	32.00	64.00	2	128.00
8	3.22	4	13.12	3	39.36	118.08	35.29	4	141.16
9	1.63	1½	2.44	4	9.76	39.04	4.33	1½	6.50
9½	.78	2	1.56	4½	7.03	31.70	.47	2	.94
			89.24		88.57	440.70			1236.68

Calculations for curves of form.

8 FT. WATER LINE.

Scale ½" 1'

Station	½ Ord. in Inches	Simpson's Mult.	Function of Areas	Interval	1st. Moment	2nd. Moment	Ord. Cubed.	Interval	Function Ord. Cubed
½	.25	2	.50	4½	2.25	10.14	.02	2	.04
1	.60	1½	.90	4	3.60	14.40	.22	1½	.33
2	2.08	4	8.32	3	24.96	74.88	9.00	4	36.00
3	3.49	2	6.98	2	13.96	27.92	42.51	2	85.02
4	3.82	4	15.28	1	15.28	15.28	55.72	4	222.96
5	3.89	2	7.78	0	v	58.87	58.87	2	1117.74
					60.05				
6	3.82	4	15.28	1	15.28	15.28	55.72	4	222.96
7	3.62	2	7.24	2	14.28	28.56	27.44	2	94.88
8	2.68	4	10.72	3	32.16	96.48	19.25	4	77.00
9	1.18	1½	1.77	4	7.08	28.32	1.64	1½	2.64
9½	.53	2	1.06	4½	4.77	21.50	.13	2	.26
			75.83		73.57	332.76			859.65

Calculations for curves of form.

4 FT. WATER LINE.

Scale ¼" 1'

Station	½ Ord. in Inches	Simpson's Mult.	Function of Areas	Interval	1st. Moment	2nd. Moment	Ord. Cubed	Interval	Function Ord. Cubed
½	.18	2	.36	4½	1.62	7.28	.01	2	.02
1	.39	1½	.59	4	2.36	9.44	.06	1½	.09
2	1.22	4	4/88	3	14.64	43.92	1.82	4	7.28
3	2.62	2	5.24	2	10.48	20.96	13.12	2	35/96
4	3.28	4	13.12	1	13.12	13.12.	35.29	4	141.16
5	3.34	2	6.68	0			37.26	2	74.52
					42.22				
6	3/27	4	13.08	1	13.08	13.08	34.97	4	139.88
7	3.00	2	12.00	2	12.00	24.00	27.00	2	54.00
8	1.88	4	7.52	3	22.56	67.68	6.64	4	26.56
9	.83	1½	1.25	4	5.00	20.00	.57	1½	.86
9½	.34	2	.68	4½	3.06	13.78	.04	2	.08
			59.40		55.70	233.26			480.41

Calculations for curves of form.

2 FT. WATER LINE.

Scale ¼" 1'

RESISTANCE AND POWER.

WETTED SURFACE.

$$W.S.\ 1.7\,d + \frac{V}{d} \qquad \text{(Mumford)}$$

V displacement in tons of 35 cu.ft.
d draft (Moulded)

$$W.S. = 1.7 \times 178 \times 16 + \frac{1785 \times 35}{16}$$

$$W.S. = 8750 \text{ sq.ft.} \qquad \text{(Mumford)}$$

$$W.S. = c\sqrt{D \times L} \qquad \text{(Taylor)}$$

c = coef. derived from table dependent upon the ratio $\frac{B}{H}$

$$W.S. = 15.55 \times \sqrt{316000}$$

$$W.S. = 8750 \text{ sq.ft.} \qquad \text{(Taylor)}$$

SURFACE FRICTION H.P. (At 7 Knots speed)

$$R = 8750 \times .2313 \times \frac{35.9}{35} \times 1.34 \qquad \left(R \times A \times f \times \frac{35.9}{35} \times \frac{speed^{1.825}}{6^{1.825}}\right)$$

$$R = 2780 \text{ lbs.}$$

$$S.F.H.P. = \frac{2780 \times 7 \times 6080}{60 \times 33000} = 59.8$$

RESIDUARY H.P.

The $\frac{V}{L}$ ratio = 5.25 Admiral Taylor's curves do not go below .6 so I have used an emperical formula.

$$W.H.P.\ \ .0384 \times V^5 \times \frac{displacement}{L^2} \times f \qquad \text{(Taylor)}$$

$$W.H.P. = .0384 \times 16800 \times \frac{1785}{31750} \times .65 = 23.6$$

F.H.P. + W.H.P. = E.H.P.

59.8 + 23.6 = 83.4

$$\frac{E.H.P.}{Prop.eff.} = \text{Brake H.P.}$$

Assuming a propeller efficiency of .5

$$\frac{83.4}{.5} = 167 \text{ B.H.P.}$$

Allowing a 25% margin for sea speed we have

$$167 \times 1.25 = 209 \text{ B.H.P.}$$

THE ENGINE AND ITS AUXILIARIES.

The two deciding factors in choosing this engine were, first, the clutch which enables the propeller to run idle when the schooner is traveling under canvas, and, second, the small amount of space which the engine occupies. The engine space has been made 13% of the whole so that a reduction of 32% is gained.

The particulars and dimensions of the engine are as follows:-

Nelseco four cycle Diesel using fuel or crude oil.

B.H.P.	240
Number of Cylinders	8
R.P.M.	350
Bore	9"
Stroke	12½"

Dimensions

L.O.A.	15'-1"
Width	3'-0"
Height from centre line	5'-6"
Weight	28200 lbs.

A 2 to 1 reduction gear is fitted so that a better propeller may be fitted.

Two gasoline engines of 15 H.P. each are installed in the engine room. One of these is connected to a generator which supplies power for the deck winches.

DESCRIPTION.

EQUIPMENT. All equipment is to be of the size and type required by Lloyd's.

Sails. Care has been taken that the centre of effort comes forward of the centre of lateral resistance, so that the sailing qualities of the ship will be good.

Sail Area. Lower sails

Upper sails

Total

DECK HOUSES The after cabin and the Captain's quarters are of teak. The house over the officer's quarters and engine casing is of steel.

MASTS. The masts are of wood and are twenty-six inches in diameter at the base.

APPENDIX.

*Half Breadths L.W.L.

Coefficient L.W.L. .797

Station	Ordinate (In percent)	Ordinate (In feet).
0	Post	Post
½	.407	6.92
1	.678	11.54
2	.898	15.27
3	.965	16.40
4	.992	16.88
5	1.000	17.00
6	.989	16.80
7	.955	16.44
8	.830	14.11
9	.537	9.04
9½	.282	4.79
10	Stem	Stem

*From Sinpson's Handbook.

* Rail Half Breadths

Station	Ordinate (In percent)	Ordinate (In inches) Scale ¼"= 1'.
A.P.O.	.603	2.41
v ½	.730	2.81
1	.810	3.24
2	.910	3.64
3	.967	3.83
4	.979	3.92
5	1.000	4.00
6	.979	3.92
7	.960	3.84
8	.910	3.64
9	.740	2.96
9½	.515	2.06
10	Stem	Stem

* From Sinpson's Handbook.

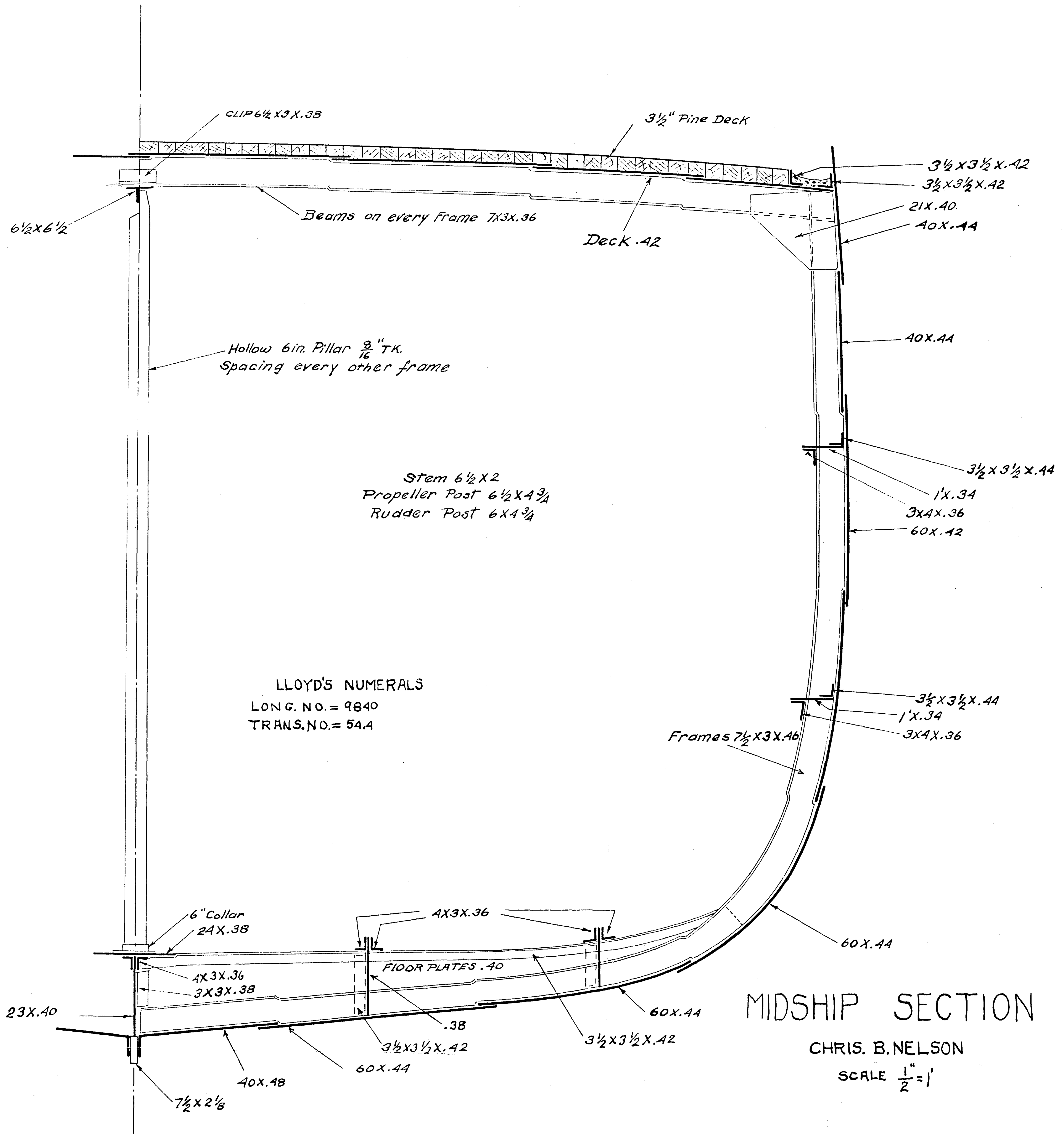
TABEE OF OFFSETS. Half Ordinates (In inches)

Scale $\frac{1}{4}$" = 1'

L.W.L.	½	1	2	3	4	5	6	7	8	9	9½
16'	1.61	2.87	3.89	4.13	4.17	4.18	4.16	4.13	3.77	2.38	1.27
12'	.72	1.83	3.67	4.14	4.19	4.22	4.17	4.11	3.62	2.03	1.00
8'	.40	1.11	3.11	4.00	4.13	4.18	4.13	4.00	3.28	1.63	.78
4'	.25	.60	2.08	3.49	3.82	3.89	3.82	3.62	2.68	1.18	.53
2'	.18	.39	1.22	2.62	3.28	3.34	3.27	3.00	1.88	.83	..34

INDEX.

	PAGE.
BM	6
Curves of form (Calculations)	12
Coefficients	6
Deadweight	4
Displacement	6
Depth	7
Draft	7
Freeboard	12
Horsepower	18
Length	6
Metacentric Height	6
Resistance	18
V.C.G.	6
Wetted Surface	18
Tables.	
Curves of form	13
Appendix.	
Tables of Half breadths	23
Table of Rail offsets	24
Offsets	25



MIDSHIP SECTION

CHRIS. B. NELSON

SCALE $\frac{1}{2}'' = 1'$

16'L.W.L.
12'W.L.
8'W.L.
4'W.L.
2'W.L.
L.W.L.16'
12'W.L.
8'W.L.
4'W.L.
2'W.L.
Vertical Centre of Buoyancy "KB"
Transverse Metacentre "KM"
Moulded Displacement in Salt Water
Area of Water Planes
Block Coef. Moulded
Prismatic Coef.
Mid Ship Area Coef.
Midship Area
Vertical Centre of Buoyancy "KB"
Centre of Flotation of Water Planes
Long. Centre of Buoyancy
LONG. "KM"
DIESEL SCHOONER
CURVES OF FORM
CHRIS. B. NELSON.
DISPLACEMENT IN TONS
VERTICAL C.B. AND TRANS. METACENTRE
AREA OF WATER PLANES IN SQ.FT.
COEFFICIENTS
MIDSHIP AREA IN SQ.FT.
LONG. METACENTRE AND VERT. C.B. IN FT.
C.F. OF WATER PLANES AND LONG. C.B.
STATION 5
AFT.
FOR.

DIESEL AUXILIARY SCHOONER

INBOARD PROFILE

CHRIS. B. NELSON

SCALE $\frac{3}{16}$" = 1'

LINES

DIESEL SCHOONER

CHRIS. B. NELSON
SCALE 1/4"=1'