SERVICE TEST and SPEED TRIALS ON THE STEAMBOAT "WHITEBEAR".

by

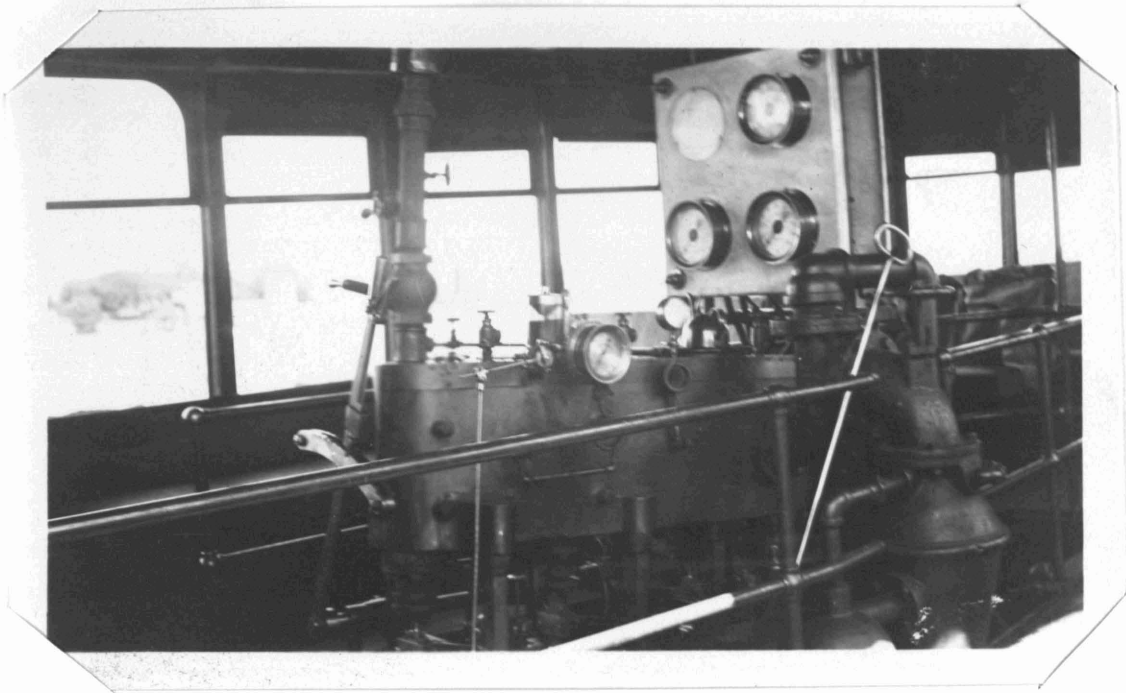
CLIFFORD C. HIELD.

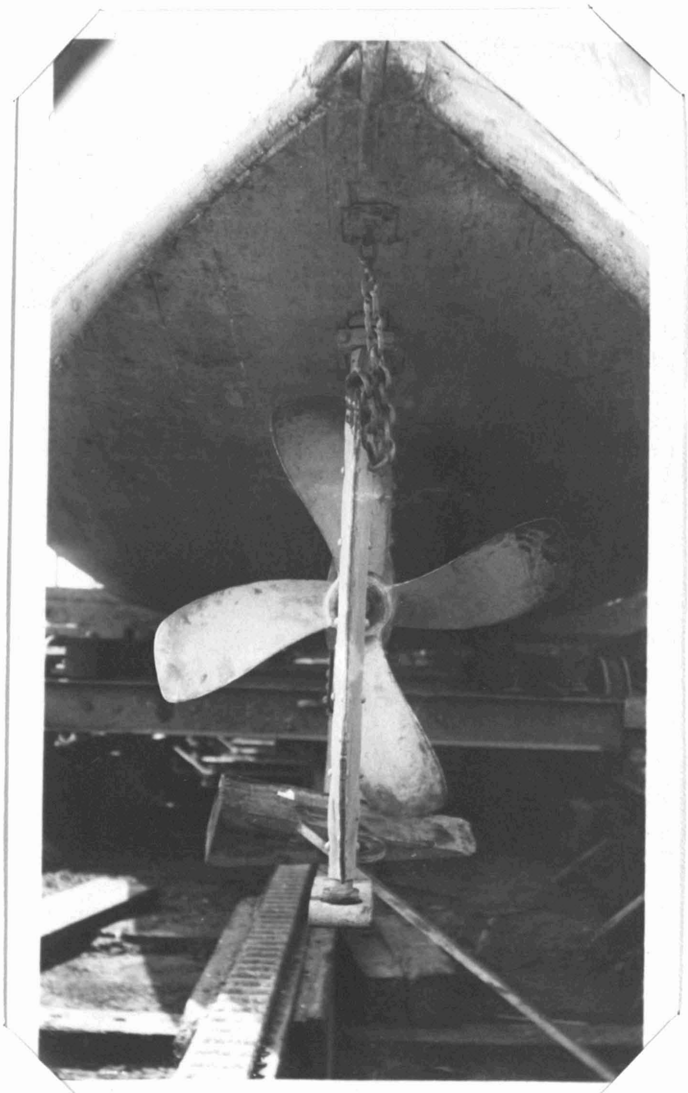
Course II

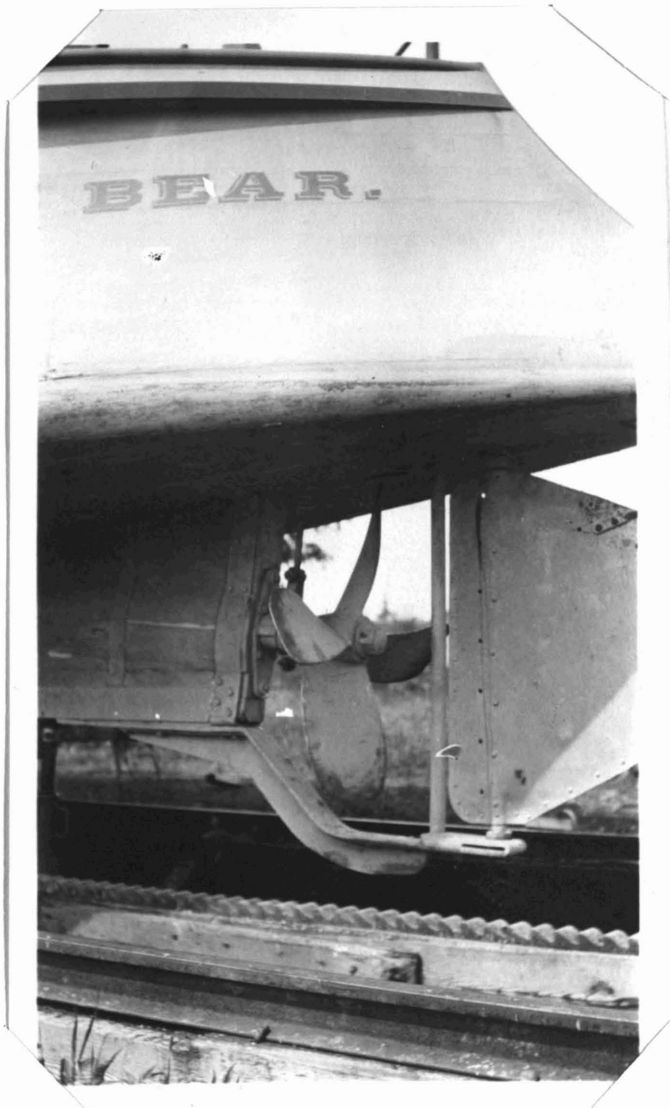
1910

INDEX.


WHITE BEAR.






BEAR.

-PROGRESSIVE SPEED TRIALS-

Progressive Speed Trials of the Steam Passenger Boat "Whitebear."

The steam passenger boat "Whitebear" is a wooden single screw boat designed by Moore of Wazata, Minnesota and built under his supervision in the shops of the Twin City Rapid Transit Company in Minneapolis, Minnesota. She was built for the purpose of carrying passengers on Lake Minnetonka, Minnesota.

Her engine was built by the Marine Iron Works Company of Chicago, Illinois; is triple Expansion, vertical, condensing, fitted with balanced piston valve on the High and Intermediate cylinders and a double ported slide valve on the low.

Steam is furnished by a Roberts Marine Boiler built by the Marine Iron Works Company. The boiler is placed in the same compartment with, but forward of the engine. The draft is natural. The boat is fitted with a Jet condensor, ~~steam~~ fitted withan independently steam driven vacuum air pump, auxiliary steam driven boiler feed pump, hand test pump, and an independent exhaust steam feed water heater. The approximate weight of the plant is 20,500.#

The trials were run in July, 1909 over a measured course, .828 of a knot in length, extending in a straight line from the northern end of Big Island to Ferndale in the lower lake of Lake Minnetonka, Minnesota. The depth was at an average of 80 feet, the Whitebear drawing 5.458 feet to the bottom of her skeg. The course was smooth with very little wind blowing, The trials were run between 10 A. M. and 5. P. M., the breeze freshening a trifle toward the end of the test.

The following observations were taken- the times required to pass over the course, the revolutions of the engine, the boiler pressure, and the engine was indicated by indicator cards- an average of five being taken for each run down the course. Times were taken by a stop watch from the pilot house, the revolutions were taken from a counter on the engine. By means of a three way cock on the cylinders, head and crank end diagrams were taken on each indicator card, one indicator being placed on each cylinder.

The best mean speed obtained was 10.28 knots which is very close to the boat's maximum speed, for she was being pushed nearly to the limit, the engineer having difficulty in keeping her pressure up to 240# at this speed. At 250# pressure, the safety valve blew, so it was thought advisable to keep the boiler pressure below 240#. The boat had just come from dry dock, having had her bottom cleaned, and propeller smoothed up, the supposition being, therefore, that conditions were very favorable to a good performance.

Six runs were made and the results are shown in the following tables. Speeds, revolutions and mean effective pressures (M. E. P.) are shown tabulated. The values were plotted on Plots #3 ~~in table #1~~, and from these plots table #2 was taken. In this table revolutions and mean effective pressures (M.E.P.) are taken off the above mentioned plots at even knots.

The indicated horse power is then figured in the usual manner. In figuring initial friction power, however, a supposition has been made. The initial friction M.E. P. on the plot was assumed as the fairest value under the circumstances and the curve was then fared down to it. In ~~table #3~~ the Analysis these results are seen tabulated as well as the rest of the calculations.

Line 5 gives load friction power which is assumed to be .07 of the difference between the indicated horse power and initial friction power from the formula L.F.P.= .07(I.H.P.- I.F.P.) the symbols being explained in the table.

Line 6 gives gross horse power (G.H.P.) which is found by subtracting the sum of the initial and load friction powers from the indicated horse power for each speed.

Line 7 shows apparent slip S'. This is calculated from the formula $S' = 1 - \frac{V \times 101.3}{PR}$ where R = Revolutions per minute, P = pitch in feet and V = knots per hour.

Line 8 gives true slip - S, calculated by assuming a 10% wake and knowing the apparent slip from the formula $1 - S = (1 - S_1)(1 - w.)$ where w.= wake. Then solving for a constant K from a formula used in conjunction with plots made by M.P. Anderson as part of his thesis, I obtained from these plots the effeciencies of the propeller which appear in line 9. The formula for the constant K is as follows:-

$$K = \frac{10,000,000}{D} \sqrt{\frac{G.H.P.}{R^3P^5}}$$

where D= diameter of propeller in feet.

G. H. P. = gross horse power.

R = Revolutions per minute and P = pitch of propeller in feet.

As a check on assuming 10.% wake the true slips thus solved for were used to take new values of K from the plot and from the above formula the pitch was solved for. This checked to within 3% and as the plot was only good to 2% these values of true slip and propeller efficiency were held.

Line 11 give power applied by propeller to propulsion (E.H.P.) and was found by multiplying gross horse power by propeller efficiency in each case.

Line 10 gives thrust horse power (T.H.P.) calculated from the formula $\frac{E.H.P.}{1 - w.} = T.H.P.$ where w.= wake.

Line 12 gives wake gain and thrust deduction. These two are equal to each other and are found by subtracting E.H.P. from T.H.P.

Line 13 gives power to overcome skin resistance. This is found from the formula $Ps = .00307 f SV^{n+1}$ where f is a constant for hull friction.

V = knots per hour

S = wetted surface of boat

N = exponent   f & n were taken from Tiderman's tables for a 70 ft. boat.

Line 14 gives power to overcome wave making resistance = Pw This is calculated by subtracting skin resistance power Ps from E.H.P.

In line 15 the constant b is found from the formula $Pw = .00307\, b\, D^{2/3} V^{5}$ where Pw is known from the above solution; D = displacement of boat,

L = length of boat in feet.

V = speed in knots.

S P E E D   T R I A L S.

SPEED TRIALS:-

Results:-

Analysis:-

Speed in Knots, V		6.0	7.0	8.0	9.0	10.00	10.28
Revolutions per minute, R.P.M.		124.0	147.5	172.5	199.0	228.0	238.0
Indicated horse power, I.H.P.		15.66	25.42	40.1	61.83	96.5	114.8
Initial friction power, I.F.P.		1.242	1.478	1.728	1.994	2.285	2.385
Load friction power, L.F.P.		1.01	1.68	2.69	4.19	6.60	7.85
Shaft horse power, G.H.P.		13.41	22.26	35.7	55.7	87.6	104.6
Apparent slip, S'		.246	.260	.276	.295	.316	.326
Slip with .10 wake, S		.322	.334	.348	.366	.384	.394
Propeller efficiency, e in %	*1	61.5	60.75	60.0	59.0	58.0	57.5
	*2	57.5	56.75	56.0	55.0	54.0	53.5
Power applied by propeller to propulsion, E.H.P.	*1	8.25	13.55	21.4	32.8	50.9	60.1
	*2	7.72	12.63	20.0	30.6	47.4	56.0
Power to overcome skin Resistance, P_s	*1	4.65	7.21	10.6	14.75	19.9	23.9
	*2	4.97	7.71	11.33	15.75	21.25	25.55
Power to overcome wave making resistance, P_w	*1	3.60	6.34	10.8	18.0	31.0	36.2
	*2	2.75	4.92	8.67	14.85	26.15	30.45
Value of constant, b	*1				.646	.656	.67
	*2				.533	.554	.564

* 1 and 2 are taken under two separate assumptions.
In (1) 5% has been taken from the propeller efficiency for thickness of blade and (f) the hull friction constant is taken as .00983
In (2) 4% more has been taken from the propeller efficiency on account of the wide stern post and the value of f is assumed as .0105

SPEED TRIALS:-

Data:-

Date of Trials -- July 23, 1909.

Boat Constants:-

Displacement,	79,635 lbs.
Draft to bottom of skeg	5 ft. 5 1/2 in.
Length between perpendiculars	70.25 ft.
Wetted surface (including Rudder and Skeg)	967.75 sq. ft.
Diameter of Propeller	43.75 in.
Pitch of Propeller	78.0 in.
Pitch Ratio	1.783

Engine Constants:-

Diameter Low Cylinder	15.0 in.
Diameter of Piston Rod	1 3/16 in.
Stroke	9.0 in.
Diameter of High Cylinder	5 1/2 in.
Diameter of Intermediate Cylinder	9.0 in.

Data from Plate No. 3:-

Table #2

Speed in Knots.	R.P.M.	M.E.P.
6.0	124.0	31.5
7.0	147.5	43.0
8.0	172.5	58.0
9.0	199.0	77.5
10.0	228.0	105.5
10.28	238.0	119.95

Summation - M. E. P'_s reduced to Low Pressure Cylinder.

1st (low) Speed		=	33.49#
2nd	"	=	44.79#
3rd	"	=	55.98#
4th	"	=	66.69#
5th	"	=	102.58#
6th (max)	"	=	119.95#

Speeds, R. P. M's. & M. E. P's.

	Speed	R. P. M.	M.E. P.
1st Speed	6.3725	130.95	33.49
2nd "	7.12	148.9	44.79
3rd "	7.845	168.0	55.98
4th "	8.395	183.1	66.69
5th "	9.89	223.5	102.58
6th "	10.28	238.0	119.95

Horse Power = $\frac{P\ L\ A\ N}{33000}$ where A = mean area of low pressure cylinder.

1. H. P. @ low speed (1st) = $\frac{P\ L\ A\ N}{33000}$ =

$$33.49 \times 9/12 \times \frac{176.45 \times 130.95}{33000} = 17.6$$

1 H. P. @ high speed (6th) = $119.95 \times 9/12 \times \frac{176.45 \times 2.38}{33000}$

= 114.8

CALCULATION:-

1. Indicated Horse Power (I.H.P.) :-

at 6 knots $I.H.P. = 31.5 \times \frac{9}{12} \times \frac{176.45 \times 124}{33000} = 15.66$

Here $I.H.P. = \frac{PLAN}{33000}$ where A = mean area of low pressure piston = 176.45 square inches.

at 7 knots $I.H.P. = 43 \times \frac{9}{12} \times \frac{176.45 \times 147.5}{33000} = 25.42$

at 8 knots I.H.P. = 58 x 172.5 x .00401 = 40.1

at 9 knots I.H.P. = 77.5 x 199.0 x .00401 = 61.83

at 10 knots I.H.P. = 105.5 x 228 x .00401 = 96.5

at 10.28 knots I.H.P. = 119.95 x 238 x .00401 = 114.8

2. Initial Friction Power:-

From M.E.P. curve, plot #3, po = 2.5

at 6 knots $H.P. = 2.5 \times \frac{9}{12} \times \frac{176.45}{33000} \times 124 = 1.242$

at 7 knots H.P. = .01002 x 147.5 = 1.478

at 8 knots H.P. = .01002 x 172.5 = 1.728

at 9 knots H.P. = .01002 x 199.0 = 1.994

at 10 knots H.P. = .01002 x 228.0 = 2.285

at 10.28 knots H.P. = .01002 x 238.0 = 2.385

3. Load Friction Power:-

at 6 knots	H.P. = .07 (15.66 - 1.24)	= .07 x 14.92	=	1.01
at 7 knots	H.P. = .07 (25.42 - 1.48)	= .07 x 23.94	=	1.68
at 8 knots	H.P. = .07 (40.1 - 1.73)	= .07 x 38.37	=	2.69
at 9 knots	H.P. = .07 (61.83 - 1.99)	= .07 x 59.84	=	4.19
at 10 knots	H.P. = .07 (96.5 - 2.29)	= .07 x 94.21	=	6.60
at 10.28 knots	H.P. = .07(114.5 - 2.39)	= .07 x 112.11	=	7.85

4. Gross or Shaft Horse Power (G.H.P.):-

at 6 knots	H.P. = 15.66 - (1.242 + 1.01)	=	13.41
at 7 knots	H.P. = 25.42 - (1.478 + 1.68)	=	22.26
at 8 knots	H.P. = 40.1 - (1.728 + 2.69)	=	35.68
at 9 knots	H.P. = 61.83 - (1.99 + 4.19)	=	55.65
at 10 knots	H.P. = 96.5 - (2.29 + 6.60)	=	87.61
at 10.28 knots	H.P. = 114.8 - (2.39 + 7.85)	=	104.6

5. Mechanical Efficiency of Engine:-

$$\text{Efficiency} = \frac{G.H.P.}{I.H.P.} \times 100$$

at 6 knots $E = \frac{13.41}{15.66} \times 100 =$ 85.8%

at 7 knots $E = \frac{22.26}{25.42} \times 100 =$ 87.0%

at 8 knots $E = \frac{35.68}{40.1} \times 100 =$ 89.0%

at 9 knots $E = \frac{55.65}{61.83} \times 100 =$ 90.0%

at 10 knots $E = \frac{87.61}{96.5} \times 100 =$ 90.8%

at 10.28 knots $E = \frac{104.6}{114.8} \times 100 =$ 91.0%

6. Apparent slip (S_1)

$$S_1 = 1 - \frac{V \times 101.3}{R.P.}$$

where R = R.P.M.
P = mean pitch in feet
V = knots per hour

at 6 knots $S_1 = 1 - \frac{6 \times 101.3}{\frac{78}{12} \times 124} = .246$

at 7 knots $S_1 = 1 - \frac{15.6 \times 7}{147.5} = .260$

at 8 knots $S_1 = 1 - \frac{15.6 \times 8}{172.5} = .276$

at 9 knots $S_1 = 1 - \frac{15.6 \times 9}{199.} = .295$

at 10 knots $S_1 = 1 - \frac{15.6 \times 10}{228} = .316$

at 10.28 knots $S_1 = 1 - \frac{15.6 \times 10.28}{238} = .326$

7. True Slip (S) and Efficiencies of Propeller Corresponding.

Assuming a wake factor of .10 for this boat.

$$(1 - S) = (1 - S_1) \times (1 - w_1)$$

(S with .05 wake)		(S with .10 wake)	Efficiencies.
.284	at 6 knots S = 1-.754x.90 =	.322	66.5-5. = 61.5%
.297	at 7 knots S = 1-.74 x .90 =	.334	65.75-5. = 60.75%
.312	at 8 knots S = 1-.724 x .90 =	.348	65.0 - 5.= 60.0%
.330	at 9 knots S = 1-.705 x.90 =	.366	64.0 - 5.= 59.0%
.350	at 10 knots S = 1-.684 x.90 =	.384	63.0- 5. = 58.0%
.360	at 10.28 knots S = 1-.674 x .90 =	.394	62.5 - 5.= 57.5%

(The propeller efficiencies were found in M. P. Anderson's Plates by means of true slip values and a constant K solved for as follows):-

$$K = \frac{10,000,000}{D} \sqrt{\frac{G.H.P.}{R^3P^3}}$$

Where P = pitch in feet

R = R.P.M.

D = diameter of propeller in feet

K from plot

at 6 knots $K = \frac{10,000,000}{\frac{43.75}{12}} \sqrt{\frac{13.32}{(\frac{78}{12} \times 124)^3}} = 437.$ 425.

at 7 knots $K = 2,743,000 \sqrt{\frac{22.26}{(6.5 \times 147.5)^3}} = 435.$ 427.5

at 8 knots $K = 2,743,000 \sqrt{\frac{35.68}{(6.5 \times 172.5)^3}} = 433.$ 432.

at 9 knots $K = 2,743,000 \sqrt{\frac{55.65}{(6.5 \times 199)^3}} = 440.$ 435.

at 10 knots $K = 2,743,000 \sqrt{\frac{87.61}{(6.5 \times 228)^3}} = 450.$ 440.

at 10.28 knots $K = 2,743,000 \sqrt{\frac{105.2}{(6.5 \times 238)^3}} = 462.$ 445.

8. Power Applied by Propeller to propulsion (E.H.P):-

e = propeller efficiency.

at 6 knots	E.H.P. = G.H.P. x e = 13.41 x .615	= 8.25
at 7 knots	E.H.P. = 22.26 x .6075	= 13.55
at 8 knots	E.H.P. = 35.68 x .600	= 21.4
at 9 knots	E.H.P. = 55.65 x .590	= 32.8
at 10 knots	E.H.P. = 87.61 x .580	= 50.9
at 10.28 knots	E.H.P. = 104.6 x .575	= 60.1

9. Power to Overcome Skin Resistance (P_s):-

$P_s = .00307 \, f \, S \, V^{n+1}$

f = constant for hull friction and from Tideman's tables is .00983
V = knots per hour
S = wetted surface = 967.75 sq.ft.
n = 1.833 from Tideman's tables.
n + 1 = 2.833

at 6 knots $P_s = .00307 \times .00983 \times 967.75 \times 6^{2.833} =$

$.0292 \times 159.3 = 4.65$

at 7 knots $P_s = .0292 \times 7^{2.833} = .0292 \times 247.0 = 7.21$

at 8 knots $P_s = .0292 \times 8^{2.833} = .0292 \times 363. = 10.6$

at 9 knots $P_s = .0292 \times 9^{2.833} = .0292 \times 505. = 14.75$

at 10 knots $P_s = .0292 \times 10^{2.833} = .0292 \times 681. = 19.9$

at 10.28 knots $P_s = .0292 \times 10.28^{2.833} =$

$.0292 \times 818.5 = 23.9$

10. Power to Overcome Wave Making Resistance (P_W):-

$$P_W = E.H.P. - P_s$$

11. Constant b:-

$$P_W = \frac{.00307\ b\ D^{2/3} V^5}{L}$$

Where D = displacement in tons

and L = length in feet

$$= \frac{.00307\ b\ x \left(\frac{79635}{2240}\right)^{2/3} V^5}{70.25}$$

$$= .00307\ b\ x\ \frac{10.8}{70.25} V^5 = .000472\ V^5$$

$$b = \frac{P_W}{.000472\ V^5}$$

at 9 knots $b = \frac{18.0}{.000472 \times 9^5} = \frac{18.0}{.000472 \times 59000} = .646$

at 10 knots $b = \frac{31.0}{.000472 \times 10^5} = \frac{31.0}{.000472 \times 100,000} = .656$

at 10.28 knots $b = \frac{36.2}{.000472 \times 10.28^5} = \frac{36.2}{.000472 \times 114,500} = .67$

Values recomputed taking an additional 4% off propeller efficiencies for rudder post effect and taking a new value of 0.0105 for f the hull friction constant.

7. The assumption was made that 5% should be deducted from the propeller efficiencies as determined from the plots by M. P. Anderson, to allow for the abnormal thickness of the propeller blade. An additional 4% was dropped from the efficiencies on account of the large wake caused by the rudder post of the ship. It was then thought that a true propeller efficiency had been found and the remainder of the test was computed allowing for these losses.

The efficiencies of the propeller stand, then, as follows:-

	Efficiency.
at 6 knots	57.5 %
at 7 knots	56.75%
at 8 knots	56.0 %
at 9 knots	55.0 %
at 10 knots	54.0 %
at 10.28 knots	53.5 %

8. Power Applied by Propeller to propulsion (E.H.P):-

E.H.P. = G.H.P. x e where e = propeller efficiency.

at 6 knots E.H.P. = G.H.P. x e = 13.41 x .575 = 7.72

at 7 knots E.H.P. = 22.26 x .5675 = 12.63

at 8 knots E.H.P. = 35.68 x .560 = 20.0

at 9 knots E.H.P. = 55.65 x .550 = 30.6

at 10 knots E.H.P. = 87.61 x .540 = 47.4

at 10.28 knots E.H.P. = 104.6 x .535 = 56.0

9. Power to Overcome Skin Resistance P_s:-

$P_s = .00307\ f\ S\ V^{n+1}$

f = constant for hull friction and from Tideman's tables reduced to fresh water and a rough wooden surface is .0105

V = knots per hour
S = wetted surface = 967.75 sq. ft.
n from Tideman's tables is 1.833 and
n + 1 = 2.833

at 6 knots $P_s = .00307 \times .0105 \times 967.75 \times (6)^{2.833}$ = ~~.0318~~
= .0312 x 159.3 = 4.97

at 7 knots $P_s = .0312 \times (7)^{2.833}$ =
.0312 x 247.0 = 7.71

at 8 knots $P_s = .0312 \times (8)^{2.833}$ =
.0312 x 363. =11.33

at 9 knots $P_s = .0312 \times (9)^{2.833}$ =
.0312 x 505. = 15.75

at 10 knots $P_s = .0312 \times (10)^{2.833}$ =
.0312 x 681. = 21.25

at 10.28 knots $P_s = .0312 \times (10.28)^{2.833}$ =
.0312 x 818.5 = 25.55

10. Power to Overcome Wave Making Resistance (P_w):-

$$P_w = E.H.P. - P_s$$

(See Analysis plot in Results of Speed Trials)

11. Constant b:-

$$P_w = \frac{.00307\ b\ D^{2/3}\ V^5}{L}$$

where D = displacement of ship in tons

and L = length of ship in feet

$$= \frac{.00307\ b \times \left(\frac{79635}{2240}\right)^{2/3} V^5}{70.25}$$

$$= .00307\ b \times \frac{10.8}{70.25} V^5 = .000472\ V^5 \times b$$

$$\therefore\ b = \frac{P_w}{.000472\ V^5}$$

at 9 knots $b = \frac{14.85}{.000472 \times (9)^5} = \frac{14.85}{.000472 \times 59000} = .533$

at 10 knots $b = \frac{26.15}{.000472 \times (10)^5} = \frac{26.15}{.000472 \times 100000} = .554$

at 10.28 knots $b = \frac{30.45}{.000472 \times (10.28)^5} = \frac{30.45}{.000472 \times 114{,}500}$

$= .564$

BOILER AND ENGINE TESTS.

ENGINE AND BOILER TESTS.

The boat left the dock at 7.45 A. M. on July 27, 1909, and an attempt was made to start the test a few minutes later. Owing to fluctuations of gages, etc., the test was started at 8:15 A. M. The boiler test continued until 8:22 P. M., while the engine test was run between 8:25 A. M. and 2:25 P. M. Owing to the wide fluctuation in the data accumulated for the engine test, the first two hours data was stricken out leaving the actual time as 10:25 to 2:25.

A course was laid in amply deep water throughout the tests. At first the coal clinkered badly and stuck to the grate bars, but this was soon broken up and the readings were found to have varied but slightly.

The following observations were made:- Revolutions were taken from a ratchet counter attached tothe engine, boiler gage readings were taken every five minutes during the engine test and every ten for the remainder of the boiler test. Indicator diagrams were taken from each cylinder, indicators being set so that one sufficed for each cylinder, crank and head end cards being taken by means of a three-way cock. Vacuum and intermediate receiver pressure readings were taken at intervals of ten minutes during engine test. The feed water was measured by means of two barrels containing floating scales graduated in pounds. The condenser discharged into the lake and quantity of condensing water was measured by means of a water metre. Temperatures of this discharge were taken from time to time. Feed water temperature were also recorded. The fuel was put up in 100 pound bags, which had been carefully weighed prior to the test. The bags were weighed before coal had been put into them and also after the coal had been used from them, thus determining the amount of coal clinging to the bags. A sample of coal was taken for analysis for both engine and boiler tests.

Readings taken during boiler test in addition to those above mentioned were feed water temperature taken by means of a thermometer placed in a well let into an elbow in the feed water pipe. The pressure and temperature in the throttling calorimeter were recorded for the purpose of determining the quality of the steam.

The auxiliaries consisted of a feed water pump, and a steam driven air pump, and a feed water heater. The amount of steam used by the pump was assumed to be negligible. The feed water heater used exhaust steam. The barometer was taken from observations made by the government weather bureau.

BOILER TEST.

BOILER TEST:-

Results:-

Date of Test - July 27, 1909.

Heat of combustion of coal as fired..........	13,978,B.T.U
Boiler Pressure (gauge).....................	209.3#
Quality of Steam............................	1.8° super heat
Boiler Horse power developed (A.S.M.E.rating).	58.45
Thermal efficiency of Boiler....................	59.0%
Coal as fired per square foot of grate surface per hour......................	11.05 lbs.
Heat taken up by water in boiler per pound of coal as fired....................	8250.B.T.U.
Actual water evaporated per pound of coal........	7.38#
Total Equivalent Evaporation from and at 212°F	22,150#
Equivalent Evaporation from and at 212°F per square foot of heating surface.......	.795#
Equivalent Evaporation from and at 212°F per pound of dry coal..................	10.45#
Maximum assumed error of test..................	5.97%

BOILER TEST:-

Data:-

Date of Test - July 27, 1909 - 8:15 A.M. - 8:22 P.M.

Duration of Test........................12 Hrs. 7 minutes.

Barometer...............................28.90" = 14.19#

Boiler Pressure (gauge).................209.3#

Temperature of feed water...............46.9°C = 116.42° F

Degrees of superheat in steam. ....1.8° F

Total water fed to Boilers..............21,481.5#

Boiler heating surface (total)..........2300 Sq.Ft.

" Grate surface (total).............21.70

Draft...................................Natural

Kind of Coal used...Virginia Bituminous Screenings

Moisture in coal, by drying test.........2.72%

Coal as fired (total)...................2909.0#

Dry coal burned (total).................2830.0#

Dry Combustible (total).................2690.0#

Ash and Clinker (total).................210.5#

Total ash and clinker in per cent of

total dry coal.................7.44%

BOILER TEST COMPUTATIONS.

Total Equivalent Evaporation from and at 212° F:-

$H_1 = q + r + C_p(Sup) = 363.9 + 837.25 + .5 \times 1.8 = 1202.05$

$H_2 = q_2$ @ temp. of feed water (46.9° C) $=$ 84.40

$H_1 - H_2 =$ 1117.65

$$\frac{1117.65 \times 21,481.5}{969.7} = 22150 \text{ pounds steam.}$$

Equivalent Evaporation from and at 212° F per pound of dry coal:-

$$= \frac{22150}{(1 - .272)2909} = 10.45 \text{ pounds.}$$

Equivalent Evaporations from and at 212° F per square foot of heating surface per hour:-

$$\frac{22150}{2300 \times 12.1166} = .795 \text{ pounds.}$$

Actual Water Evaporated per pound of coal as fired:-

$$\frac{21,481.5}{2909} = 7.38 \text{ pounds.}$$

Coal per square foot of grate surface per hour:-

$$= \frac{2909}{21.70 \times 12.1166} = 11.05\#$$

Boiler Horse Power developed (A.S.M.E. Rating):-

$$= \frac{1117.65 \times 21,481.5}{12.1166 \times 33320} = 58.45$$

Maximum assumed error of test:-

$$\frac{2}{12} \times 21.70 \times 48\# = 173.5\# \text{ error}$$

$$\frac{173.5}{2909} \times 100 = 5.97\%$$

Thermal Efficiency of Boiler:-

$$\frac{1117.65 \times 21,481.5 \times 100}{2909 \times 13,978} = 59.0\%$$

Heat Taken up by Water in Boiler per pound of coal as fired:-

$$\frac{1117.65 \times 21,481.5}{2909} = 8250 \text{ B.T.U.}$$

-ENGINE TEST-

ENGINE TEST:-

Results:-

Pressure at Throttle = 196.#gage = 210.19#abs.

Vacuum = 22.5"

Steam per hour = $\frac{6963}{4}$ = 1740.#

Indicated Horse Power = 92.46

Steam (including auxiliaries) per

I.H.P. per hour = 18.83#

Pounds of steam per lb. of coal = 6.90#

B.T.U. per I.H.P. per minute = 97.5

ENGINE TEST:-

Data:-

Date of Test - July 27, 1909 10:25 A.M. - 2:25 P.M.

Duration of Test.............................. 4.0 hours

Barometer................................28.90" = 14.19#

Throttle pressure..............................196.0# gauge

Vacuum....................................... 22.5" Hg

Total Coal fired...............................1010.#

Total feed water...............................6963.0#

Quality of steam...............................1.8° super heat

Revolutions per minute.........................220.0

Condensing water per hour......................35,100#

Temperature of Condensing water.........50°C = 122.0°F

Temperature of feed water in barrels.......24°C = 75.2°F

Throttling Calorimeter Temperature.....231.7°C = 449.06°F

Throttling Calorimeter pressure (gauge).......7.0#

M.E.P.:-

High	Head End	77.67#
	Crank End	69.25#
Intermediate	Head End	43.4#
	Crank End	51.5#
Low	Head End	24.4#
	Crank End	27.2#

Engine Constants:-

Diameter of high pressure Cylinder............5.5 inches

" " Intermediate pressure Cylinder....9.0 "

" " Low " " ....15.0 "

Piston Rod Diameter........................... 1 3/16 in.

Stroke of piston...........................9.0 "

ENGINE TEST COMPUTATION:-

Indicated Horse Power:-

$$\frac{PLAN}{33000} = H.P.$$

High Pressure Cylinder:-

$$\text{Head} = \frac{77.67 \times 9 \times \frac{\pi \times 5.5^2}{4} \times 220}{12 \times 33000} = 9.23$$

$$\text{Crank} = 69.25 \times \frac{9}{12} \times \frac{\left(23.75 - \frac{\pi\left(\frac{19}{16}\right)^2}{4}\right) \times 220}{33000} = 7.84$$

Intermediate Cylinder:-

$$\text{Head} = 43.4 \times \frac{9}{12} \times \frac{\pi \times 9^2}{4} \times \frac{220}{33000} = 13.80$$

$$\text{Crank} = 51.5 \times \frac{9}{12} \times \frac{(63.6 - 1.11) \times 220}{33000} = 16.10$$

Low Pressure Cylinder:-

$$\text{Head} = 24.4 \times \frac{9}{12} \times \frac{\pi \times (15^2)}{4} \times \frac{220}{33000} = 21.59$$

$$\text{Crank} = 27.2 \times \frac{9}{12} \times \frac{(176.6 - 1.11) \times 220}{33000} = 23.90$$

Total I.H.P. = 92.46

Steam (including auxiliaries) per I.H.P. per hour:-

$= \frac{1740}{92.46} = 18.83^{\#}$

Pounds of steam per pound of coal:-

$\frac{1010}{4} = 252.5\ \# =$ coal fired per hour:-

$\frac{1740}{252.5} \doteq 6.90^{\#}$ steam per #coal

B.T.U. per I.H.P. per minute:-

$H_1 = 69\frac{63}{4}(q_1 + r_1 + C_p$ (superheat) $= 358.5 + 841.2 \times 5 \times 1.8)$
$\times 1740. = 2,180,000.$

$H_2 = 35,100\ (q_2\ @\ 50°C - q_2\ @\ 24°C) = 35,100(90 - 43.4) =$ 1,639,000

$H_1 - H_2 =$ 541,000

Steam per I.H.P. per minute $= \frac{1883}{60} = .314^{\#}$

B.T.U. per I.H.P. per minute $= \frac{541,000}{60 \times 92.46} = 97.5$

Quality of the Steam:-

Data:-
Calor. gage $= 7.0^{\#} = 7. + 14.19 = 21.19^{\#}$abs.
" temp. $= 231.7°C = 449.06°F$
Boiler pressure = average during Calor. reads =
$228.8^{\#}$ gage $= 243.0\ ^{\#}$abs.

$q_b + r_b + C_p(t_{sup} - t_B) = q_c + r_c + C_p\ (t_c - t_s)$

$371.6 + 829.1 + .5(t - 398.5) \doteq 199.6 + 957.4 + .467(218.02)$

$t = 1.8°F$ superheat.

-THE PROPELLER-

PROPELLER:-

In measuring up the propeller a device was used as shown in plate No. 6 A strip of wood was fastened onto a block fashioned like a nut which was fitted to the end of the shaft aft of the propeller after the locking nut had been removed. The block was placed flush with the end of the hub of the propeller and measurements were takenmdown perpendicularly from the stick to the propeller, at the juncture of different radii and radial lines marked on the blade, as shown in table No 1. The radial lines were numbered from 0 to 7 but no readings were taken on the 0 radial line for the reason that this line came off the wheel beyond the 15" radius line. Radii were marked on the wheel from 6" to 21" as shown in table No. 1 ~~it will be~~ and on plate No. 7

Referring to table No. 1 it will be seen that readings were taken on the contour of both edges of the blade at the different radii;- the column (a) under contour representing the distance of the countour out from #1 or #7 radial lines, as the case may be, and column (b) representing distances measured down perpendicularly from the stick at the contour at the radius in question. The radial lines were marked as nearly equally apart on the blade as possible, but varied somewhat as may be seem from the following table

From 0-1=5.5°	from 1-2=5.25°
" 2-3=5.75°	" 3-4=5.25°
" 4-5=5.75°	" 5-5=5.5°
" 6-7=5.0°	

PROPELLER(cont.)

Radii of the wheel were measured on radial lines 1,2 and 4 as may be seen in the last line of table #1.

By taking the differences in perpendicular readings at different radial lines on a given radius, the pitch between each radial line on the wheel was determined, knowing the angle moved through and computing the circumference at that radius. Each radius was computed for pitch in this manner and a mean pitch for the radius computed, giving the results shown in the mean pitch table on the propeller tracing.

Overall pitches were also computed by taking the angle between outside radial lines on a radius. The blade was found to curve up a great deal -- more at some radii than at others -- so that the manner of selecting the radial lines between which the overall pitch should be calculated varied with different radii, and rested with the discretion of the author. On account of the above mentioned curling up of the edges of the blade absurd results would have been gotten by taking the overall pitch from edge to edge.

From the above measurements the projection of the blade was laid out. The development was drawn with the aid of the completed projection and from measurements taken of the widths of the blade at the different radii (see table #2), and faring a curve through the points found.

For the side elevation of the blade, pitch lines were drawn at different angles corresponding to the pitch at each radius. Points were projected over and up from the developed view of the blade. The generating helix was found to be a

PROPELLER (cont.)

curved line, also the blade was found to have a rake aft and side ways.

In table #2 the measurements of thickness of blade at the intersection of the different radii and radial lines, are shown. It will be seen that the thickness was also taken at each radius on the contour of the blade and at the tip. Measurements for thickness at the 12 inch radius were omitted but were computed for the drawing. On the propeller plate are the maximum thicknesses of the blade normal to the face at each radius.

In the end view of the blade, widths of blade were laid off on the various corresponding pitch lines and a curve fared through those points,- the view being competed by transferring the sectional views of the blade to their proper pitch lines and faring in a curve tangent to the backs of these sections, giving the curve of the back of the blade.

The volume of the blade was computed by planimetering the sections and plotting the areas of these sections and planimetering the area of the plotted areas. As this was a four bladed propeller - multiplying the blade volume by four and adding the hub volume the volume of the propeller was obtained, allowing 512# per cubic foot for bronze metal, the blade was found to weigh 251.0

The boat runs at an average speed of ten knots when in service and the I.H.P. and revolutions were taken at this speed, and noted on the drawing.

PROPELLER:-

Results:- (from drawing)

Mean pitch	=	78.0"
Diameter	=	43 3/4"
Projected area	=	592 square inches
Developed "	=	796.8 " "
Weight	=	251.0#
Area Ratio	=	.394
Pitch Ratio	=	1.783

PROPELLER DATA-

Diameter of Hub at ends = 6 5/8"

" " " " centre = 7 3/8"

Length of Hub fore and aft = 7 1/4"

The radius line used as a base of measurment was 3 1/2" aft of after face of propeller hub.

Computation:-

$$\text{Area ratio} = \frac{\text{Projected Area}}{\text{Disc Area}} = \frac{592.0}{\frac{\pi \times 43.75^2}{4}} = .394$$

$$\text{Pitch Ratio} = \frac{\text{Pitch}}{\text{Diameter}} = \frac{78.}{43.75} = 1.783$$

PROPELLER DATA:-

-Table #1-

Radius	After edge of blade contour (a)	(b)	Radians 1	2	3	4	5	6	7	Fore edge of Blade Contour (b)	(a)
6"	3/4"	2 1/2"	2 15/16"	4"	4 7/8	5 3/4	6 5/8	7 11/16	8 3/4	10 5/16"	2"
9"	1 1/8"	1 3/8"	2 1/8	3 5/16	4 7/16	5 7/16	6 7/16	7 9/16	8 11/16	9 3/4	1 1/2
12"	1 1/2"	5/8"	1 5/8	3	4 3/16	5 5/16	6 5/16	7 9/16	8 5/8	8 7/8	3/8
15"	1 3/4"	1/4"	1 3/8	2 3/4	4 1/16	5 3/16	6 1/4	7 9/16		8	9/16
18"	1 5/8"	3/8"	1 5/16	2 11/16	4	5 1/8	6 5/16			6 5/16	1"
21"	1 7/8"	11/16"	1 1/4	2 5/8	4	5 1/8				5 7/8	1"
Radius pf tip of blade			21 11/16"	21 7/8" (~~11/16~~)		21 11/16"					

Table #2

Thicknesses and Widths of Blade

Radius	After Edge	Radians 1	2	3	4	5	6	7	Fore Edge	Widths*
6"	1/8"	9/16"	1 1/16	1 5/16	1 1/2	1 1/2	1 5/16	1 1/16	1/8"	9 3/4"
9	1/8	5/8	7/8	1 1/16	1 1/8	1 1/8	1"	3/4	1/8"	11"
12										11 3/4"
15	1/8	5/8	11/16	11/16	11/16	11/16	7/16		1/8	12"
18	1/8	9/16	5/8	5/8	5/8	1/2				11 3/8"
21	1/8	3/8	3/8	3/8	3/8					9 1/4"

* Widths pf Propeller blade were measured in a straight line from edge to edge.

- OBSERVED DATA:-

-OBSERVED DATA ON BOILER TEST;

BOILER TEST DATA:-

Feed Water Weights

Barrel #1	Barrel #2	Barrel #1	Barrel #2	Barrel #1	Barrel #2
	275	300			
298.5			278		281
	273	301		300	
297			280		280
	275	299		300	
296			280		280
	275	300		302	
294			278		280
	275	300		300	
296			282		280
	279	300		300	
297			280		279
	278	301		302	
298			279		280
	277	302		300	
297			280		280
	281	302		301	
300			280		280
	278	300		300	
301			280		280
	280	300		301	
301			280		80
	278	300		3006	2880
				3872.5	
297			280	3881.0	

BOILER TEST DATA:- (Cont.)

Feed Water Weights.

	Barrel #1	Barrel #2	Barrel #1	Barrel #2	Barrel #1	Barrel #2
		279	300		4206.0	
					3636.0	
	300			279	2880.0	
		278	301			
Totals	3872.5	3881	4206	3636	21481.5#	

21481.5# total in 12 hrs. 7 minutes

Coal Burned:-

30 bags used containing 100# coal each

wt. 1 empty bag = 1.0#

30 x 100 = 3000#
91
2909# coal burned

4.0# clinging to bags
30.0# wt. of bags
57.0# as a sample
91.0#

Form 142 — T. C. R. T. Co. Coal Analysis.

Lab. No 959 — July 30, 1909

Kind of coal — Coal from steamer

Total lbs. — At Excelsior

% combustible of total	92.51	% Volatile of dry coal	17.78
" Moisture " "	2.72	" Fixed Carbon" "	77.08
" Ash " "	4.77	" Sulphur " "	.24
Total	100.00	" A sh " "	4. 90
		Total	100.00

B.T.U.per lb.Commercial 13,978. Price per ton

" " Dry coal 14,369.

" " Combustible 15,109.

Remarks: Ash Ananlysis
44.90 Combustible
55.10 Ash
100.00

BOILER TEST DATA: (Cont.)

Combustible burned = 2909 - 155.5# Ash x .449

= 2909 - 69.9 = 2839.1#

Temperature of Feed Water at Boiler:-

Readings taken every five minutes.

Temp.	Temp.	Temp.	Temp.	Temp	Temp.
50.0°C	48.5	48.0	46.0	b46.9	51.5
41.7	40.2	40.5	45.0	47.5	45.0
43.8	49.9	46.5	42.5	44.0	49.0
42.5	54.0	43.0	58.0	45.0	51.0
48.0	39.6	51.3	51.5	47.5	42.0
43.3	47.0	44.0	44.0	50.3	61.0
43.0	47.5	43.4	48.0	42.5	47.0
40.8	46.5	48.0	46.2	48.1	43.0
37.0	45.2	49.2	41.5	47.8	6660.0 Total
49.0	49.0	45.0	40.6	51.3	
51.7	45.0	51.5	50.5	43.9	
39.0	50.5	44.7	51.4	45.0	
46.0	44.5	58.0	41.5	47.5	
47.0	44.2	46.5	42.4	52.0	
52.0	47.9	47.2	52.6	48.5	
52.0	47.0	47.8	39.8	48.0	
47.2	49.0	46.0	48.5	47.2	
43.4	48.2	43.4	42.5	44.7	
45.0	50.9	43.5	44.0	54.5	
51.0	43.8	41.0	48.5	44.0	
42.5	44.0	52.5	43.0	52.5	
52.7	50.5	51.0	41.5	54.4	

Average = $\frac{6660}{142}$ = 46.9°C

BOILER TEST DATA: (Cont.)

Temperature of Feed Water at Boiler (cont.)

Temp.	Temp.	Temp.	Temp.	Temp.	Temp.
46.0	50.3	41.8	48.0	44.0	
51.0	49.0	47.5	43.0	49.0	
40.8	46.0	47.8	49.3	47.0	
47.9	46.0	49.7	48.0	47.0	
42.2	50.0	51.7	45.9	51.0	

Boiler Gauge Pressure:-

Readings taken every 5 minutes from 8:15 A.M. to 2:45 P.M.

Pressure	Pressure	Pressure	Pressure	Pressure
225	* 201	210	182	230
230	188	215	*233	230
238	198	200	225	235
223	214	223	230	220
213	223	192	220	220
217	216	178	230	230
203	203	190	230	230
199	182	218	235	230
209	195	202	205	230
229	203	215	211	230
208	196	209	230	210
225	210	200	235	220
208	225	185	225	240
185	196	181	205	230
203	170	187	220	22090 = Total

** Engine Test was run between the two stars.

BOILER TEST DATA

Boiler Gauge Pressure:

Pressure	Pressure	Pressure	Pressure	Pressure
235	200	208	238	
224	175	196	228	
238	203	200	220	
198	193	180	225	
196	180	225		
	201	169	225	
	195	170	225	
	187	180	225	
	187	188	235	

Average= $\frac{22090}{105}$

= 210.4 lbs.

Corrected = 209.3

Absolute Boiler Pressure = 209.3 + 14.19 = 223.49

-OBSERVED DATA ON ENGINE TEST-

ENGINE TEST DATA:

Boiler Gauge Pressure ;

See boiler test data. Total between the two stars =9848. Average = $\frac{9848}{50}$ = 197.

Corrected = 196.0

Throttling Calorimeter:

Time	Temperature	Gage
5.25	226.0° C	7.0 lbs.
;35	225.	7.0
:45	232.	7.0
:55	234.	7.0
6:05	234.	7.0
:15	232.	7.0
:25	234.	7.0
:35	235.	7.0
:45	233.	7.0
:55	233.	7.0
7:05	233.	7.0
:15	230.	7.0
	Totals 2781.	84.0

Average Temperature= $\frac{2781}{12}$= 231.7°C

Averagge GagePressure = $\frac{84.0}{12}$ = 7.0 lbs.

ENGINE TEST DATA:*-

Vacuum in Inches of Mercury.

Reads every 10 minutes from 10:25 A. M. to 2:25 P. M.

Inches	Inches	Inches	Inches
22.9	22.6	22.8	23.1
22.8	23.0	23.6	23.1
22.7	23.0	23.0	23.1
22.8	22.9	22.3	Total = 549.6
23.3	23.2	22.9	
22.7	22.8	22.9	
22.9	22.5	22.7	

Average Vacuum $= \frac{549.6}{24} =$ 22.9" Corrected = 22.5"

Revolutions per minute:-

Reads every 10 minutes.

Rev.		Rev.
2190		2207
2196		2231
2287		2224
2198		2130
2163		2250
2203		2250
2293		2208
2122		2098
2125		2214
2187		2210
2212		2308
2152	Total	2149
		52807

Average Reading $= \frac{52807}{24} =$ 2200

$\frac{2200}{10} = 220. =$ Av.R.P.M.

ENGINE TEST DATA:-

Coal Burned:-

16 bags @ 100# each = 1600#

1600		2.0#	clinging to bags
42		12.0#	wt. of bags
1558#	Burned in 6 hrs. 10 minutes.	28.0#	Sample
		42.0#	

$\frac{1558 \times 4}{6.167} = 1010\#$ in 4 hours.

Temperature of Feed Water in the Barrels:-

Reads taken every 20 minutes.

Temp.	Temp.
24.0°C	24.0
24.0	24.0
24.0	24.0
24.0	24.0
24.0	24.0
24.0	24.0
Total	288.0

Average temp. $= \frac{288}{12} = 24.0°C$

Temperature of Condenser Water.

Reads taken every 20 minutes.

Temp.	Temp.
54.0°C	50.0
50.0	50.0
53.0	51.0
48.0	49.0
50.0	48.0
47.0	49.0
Total	599.0

Average temp. $= \frac{599}{12} = 50.0°C$

ENGINE TEST DATA:-

Feed Water Discharged:-

Test from 10:25 - 2:25

	Barrel #1	Barrel #2	
	297	15	
	300	281	
	301	278	
	301	280	
	297	278	
	300	279	
	300	278	
	301	278	
	299	280	
	300	280	
	300	278	3596
	300	282	3367
		280	
Totals	3596	3367	6963 = total in 4 hrs.

ENGINE TEST DATA:-

M.E.P. Cards taken every 10 minutes.

Card No.	High Head Pounds	High Crank Pounds	Intermediate Head Pounds	Intermediate Crank Pounds	Low Head Pounds	Low Crank Pounds
14	86.0	74.0	42.6	54.8	25.2	28.5
15	82.0	75.0	46.2	56.5	26.2	28.6
16	69.4	62.0	41.4	46.3	23.2	24.8
17	74.5	69.5	44.3	52.8	24.8	27.7
18	83.5	75.0	46.1	53.4	25.6	28.0
19	81.1	72.0	44.3	50.0	25.5	26.7
20	80.0	67.1	44.5	50.7	24.8	26.9
21	81.7	72.6	44.6	53.5	24.7	27.5
22	78.0	68.0	42.8	51.8	23.8	26.9
23	75.0	67.0	43.6	51.5	25.2	28.6
24	74.0	68.4	41.6	49.8	24.2	27.0
25	86.2	76.5	47.3	57.2	26.4	29.1
26	88.8	79.5	49.0	58.9	27.6	30.9
27	79.3	67.0	41.8	50.3	24.9	27.7
28	69.3	64.5	42.1	47.8	23.6	26.7
29	78.6	70.9	44.3	52.5	24.4	27.8
30	82.3	75.0	46.1	56.4	26.0	28.4
31	74.0	66.5	40.6	48.0	23.4	26.3
32	77.5	65.7	41.5	49.2	23.4	26.0
33	77.0	71.1	43.8	50.4	24.4	27.2
34	71.0	67.5	40.5	48.1	22.7	25.4
35	66.6	58.0	39.8	46.5	22.2	24.4
36	73.0	63.9	41.1	49.5	22.6	25.5

ENGINE TEST DATA:-

M.E.P

Cards taken every 10 minutes.

Card No.	High Head	High Crank	Intermediate Head	Intermediate Crank	Low Head	Low Crank
	Pounds	Pounds	Pounds	Pounds	Pounds	Pounds
37	74.4	65.3	41.9	49.9	23.0	26.6
Totals	1863.2	1662.0	1041.8	1235.8	587.8	653.2

Mean Effective Pressure Average:-

High:-

Head Av. $= \frac{1863}{24} =$ 77.67 pounds

Crank Av. $= \frac{1662}{24} =$ 69.25 pounds

Intermediate:-

Head Av. $= \frac{1041.8}{24} =$ 43.4 pounds

Crank Av. $= \frac{1235.8}{24} =$ 51.5 pounds

Low:-

Head Av. $= \frac{587.8}{24} =$ 24.4 pounds

Crank Av. $= \frac{653.2}{24} =$ 27.2 pounds

ENGINE TEST DATA:-

Condenser Water: Metre Readings taken every ten minutes.

Readings	Differences in Cubic Feet
14496	
14594	98
14693	99
14792	99
14890	98
14988	98
15088	100
15188	100
15287	99
15386	99
15483	97
15582	99
15682	100
15780	98
15879	99
15978	99
16077	99
16175	98
16275	100
16373	98
16472	99
16580	108
16670	90
16770	100
Total =	2274 cubic feet for four hours.

$\frac{2274}{4}$ = 568.5 cu. ft. per hr.

Weight of 1 cubic foot of water at 50°C (122°F) = 61.70 pounds.

568.5 x 61.70 = 35,100 pounds of condensing water per hour.

DATA OBSERVED ON THE

SPEED TRIALS.

SPEED TEST INDICATOR CARDS.

Run #1 North bound (1st Speed)

No of Card	High Crank Area	High Crank Leng.	High Head A	High Head L	Intermediate Crank A	Intermediate Crank L	Intermediate Head A	Intermediate Head L	Low Crank A	Low Crank L	Low Head A	Low Head L
1	0.40	2.42	0.60	2.42	1.62	2.40	1.28	2.40	2.22	2.42	2.08	2.42
2	0.35	2.42	0.60	2.42	1.55	2.40	1.30	2.40	2.25	2.42	2.07	2.42
3	0.37	2.42	0.55	2.42	1.69	2.40	1.27	2.40	2.19	2.42	2.04	2.42
4	0.37	2.43	0.55	2.43	1.60	2.41	1.29	2.41	2.16	2.41	2.00	2.41
5	0.40	2.37	0.60	2.37	1.72	2.41	1.30	2.41	2.05	2.41	1.92	2.41
Total	1.89	12.06	2.90	12.06	8.18	12.02	6.44	12.02	10.87	12.08	10.11	12.08
Aver.	.38	2.41	5.8	2.41	1.636	2.404	1.29	2.404	2.17	2.416	2.02	2.416

Spring high cyl. = 40.# M.E.P.(H.C.) = $\frac{AS}{L}$ = 6.3

(H.H.) = 9.64

Spring Intermediate Cyl. = 20.0#

M.E.P.(I.C.) = 13.6

(I.H.) = 10.73

Spring Low cyl. = 10# M.E.P.(L.C.) = 9.00

M.E.P.(L.H.) = 8.38

Run #2 South Bound (1st Speed)

No of Card	High Crank A	High Crank L	High Head A	High Head L	Intermediate Crank A	Intermediate Crank L	Intermediate Head A	Intermediate Head L	Low Crank A	Low Crank L	Low Head A	Low Head L
1	0.78	2.41	0.89	2.41	2.43	2.41	1.91	2.41	2.48	2.43	2.24	2.43
2	0.79	2.42	0.88	2.42	2.39	2.41	1.91	2.41	2.46	2.42	2.20	2.42
3	0.71	2.44	0.81	2.44	2.37	2.40	1.90	2.40	2.37	2.43	2.22	2.43
4	0.73	2.45	0.89	2.45	2.41	2.40	1.88	2.40	2.42	2.43	2.21	2.43
5	0.73	2.41	0.91	2.41	2.37	2.40	1.90	2.40	2.37	2.43	2.23	2.43
Total	3.74	12.13	4.38	12.13	11.97	12.02	9.50	12.02	12.10	12.14	11.10	12.14
Aver.	.748	2.426	.876	2.426	2.394	2.404	1.90	2.404	2.42	2.428	2.22	2.428

Spring High cyl. = 40.#

M.E.P (H.C.) = 12.30

x (H.H.) = 14.44

Spring Inter. Cyl. = 20.#

M.E.P. (I.C.) = 19.9

(I.H.) = 15.8

Spring Low Cyl. = 10.#

M.E.P. (L.C.) = 9.96

(L.H.) = 9.15

Run #3 North Bound (1st Speed)

No. of Card	High Crank A	High Crank L	High Head A	High Head L	Intermediate Crank A	Intermediate Crank L	Intermediate Head A	Intermediate Head L	Low Crank A	Low Crank L	Low Head A	Low Head L
1	0.74	2.43	0.86	2.43	2.38	2.41	1.91	2.41	2.36	2.42	2.20	2.42
2	0.73	2.43	0.89	2.43	2.38	2.40	1.89	2.40	2.39	2.42	2.20	2.42
3	0.72	2.42	1.89	2.42	2.42	2.41	1.92	2.41	2.38	2.42	2.13	2.42
4	0.73	2.42	0.90	2.42	2.40	2.40	1.92	2.40	2.37	2.42	2.19	2.42
5	0.76	2.42	0.87	2.42	2.45	2.40	1.94	2.40	2.39	2.42	2.16	2.42
Total	3.68	12.12	4.41	12.12	12.03	12.02	9.58	12.02	11.89	12.10	10.88	12.10
Aver.	.736	2.424	.882	2.424	2.406	2.404	1.916	2.404	2.38	2.42	2.176	2.42

Spring High Cyl. = 40.#

M.E.P. (H.C.) = 12.13

(H.H.) = 14.52

Spring Inter. Cyl. = 20.#

M.E.P. (I.C.) = 20.00

(I.H.) = 15.90

Spring Low Cyl. = 10#

M.E.P.(L.C.) = 9.84

(L.H.) = 9.00

Run #4 South Bound (1st Speed)

No Of Card	High				Intermediate				Low			
	Crank		Head		Crank		Head		Crank		Head	
	A	L	A	L	A	L	A	L	A	L	A	L
1	0.64	2.42	0.79	2.42	2.33	2.42	1.85	2.42	2.46	2.42	2.36	2.42
2	0.68	2.43	0.80	2.43	2.37	2.40	1.84	2.40	2.41	2.42	2.27	2.42
3	0.70	2.46	0.82	2.46	2.37	2.41	1.92	2.41	2.42	2.42	2.25	2.42
4	0.68	2.44	0.82	2.44	2.42	2.40	1.92	2.40	2.38	2.43	2.19	2.43
5	~~0.68~~	~~2.44~~	~~0.82~~	~~2.44~~	2.46	2.41	1.92	2.41	2.37	2.43	2.20	2.43
Total	2.70	9.75	3.23	9.75	11.95	12.04	9.45	12.04	12.04	12.12	11.27	12.12
Aver	.675	2.44	.807	2.44	2.39	2.408	1.89	2.408	2.408	2.424	2.25	2.424

Spring High Cyl. = 40#

M.E.P.(H.C.) = 11.06

(H.H.) = 13.21

Spring I. Cyl. = 20#

M.E.P. (I.C.) = 10.87

(I.H.) = 15.73

Spring L.Cyl. = 10#

M.E.P.(L.C.) = 9.92

(L.H.) = 9.35

(Runs 5 and 6 were thrown out.)

Run #7 North Bound (2nd Speed)

No of Card	High				Intermediate				Low			
	Crank		Head		Crank		Head		Crank		Head	
	A	L	A	L	A	L	A	L	A	L	A	L
1	1.58	2.48	1.82	2.48	2.87	2.40	2.27	2.40	2.72	2.42	2.55	2.42
2	1.56	2.46	1.73	2.46	2.87	2.40	2.26	2.40	2.72	2.42	2.58	2.42
3	1.59	2.46	1.87	2.46	2.97	2.40	2.28	2.40	2.74	2.42	2.50	2.42
4	1.59	2.48	1.88	2.48	2.89	2.42	2.30	2.42	2.78	2.42	2.56	2.42
5	1.60	2.46	1.84	2.46	2.90	2.42	2.26	2.42	2.84	2.42	2.55	2.42
Totals	7.92	12.34	9.14	12.34	14.50	12.04	11.37	12.04	13.80	12.10	22.74	12.10
Aver	1.584	2.468	1.828	2.468	2.90	2.408	2.274	2.408	2.76	2.42	2.558	2.42

Spring H.Cyl. = 40.#

M.E.P.(H.C.) = 25.70

(H.H.) = 29.60

Spring I. Cyl. = 20#

M.E.P. (I.C.) = 24.10

(I.H.) = 18.90

Spring L. Cyl. = 10#

M.E.P. (L.C.) = 11.40

(L.H.) = 10.55

Run #8 South Bound(2nd Speed)

No of Card	High Crank A	High Crank L	High Head A	High Head L	Intermediate Crank A	Intermediate Crank L	Intermediate Head A	Intermediate Head L	Low Crank A	Low Crank L	Low Head A	Low Head L
1	1.60	2.46	1.91	2.46	2.95	2.41	2.37	2.41	2.83	2.42	2.64	2.42
2	1.51	2.46	1.84	2.46	2.91	2.40	2.29	2.40	2.78	2.42	2.58	2.42
3	1.51	2.46	1.80	2.46	2.93	2.40	2.30	2.40	2.80	2.40	2.52	2.40
4	1.59	2.46	1.91	2.46	2.95	2.41	2.36	2.41	2.73	2,42	2.59	2.42
5	1.55	2.45	2.76	2.45	2.86	2.40	2.32	2.40	2.70	2.42	2.54	2.42
Totals	7.76	12.29	9.22	12.29	14.60	12.02	11.64	12.02	13.84	12.08	12.87	12.08
Aver	1.552	2.458	1.844	2.458	2.92	2.404	2.328	2.404	2.768	2.416	2.574	2.416

Spring H.Cyl. = 40#

M.E.P.(H.C.) = 25.35

(H.H.) = 30.05

Spring I. Cyl. = 20#

M.E.P.(I.C.) = 24.25

(I.H.) = 19.35

Spring L. Cyl. = 10#

M.E.P.(L.C.) = 11.45

(L.H.) = 10.67

Run #9 North Bound (2nd Speed)

No. of Card	High Crank A	High Crank L	High Head A	High Head L	Intermediate Crank A	Intermediate Crank L	Intermediate Head A	Intermediate Head L	Low Crank A	Low Crank L	Low Head A	Low Head L
1	1.42	2.45	1.69	2.45	2.40	2.40	1.90	2.40	3.24	2.42	3.05	2.42
2	1.42	2.46	1.70	2.46	2.38	2.40	1.90	2.40	3.33	2.42	3.09	2.42
3	1.45	2.46	1.69	2.46	2.38	2.40	1.92	2.40	3.38	2.42	3.08	2.42
4	1.40	2.50	1.69	2.50	2.39	2.40	1.88	2.40	3.38	2.41	3.09	2.41
5	1.43	2.46	1.65	2.46	2.40	2.40	1.95	2.40	3.49	2.42	3.14	2.42
Totals	7.12	12.33	8.42	12.33	11.95	12.00	9.55	12.00	16.82	12.09	15.45	12.09
Av.	1.424	2.466	1.684	2.466	2.39	2.40	1.91	2.40	3.264	2.418	3.09	2.418

Spring H. Cyl = 60#

M.E.P. (H.C.) = 34.70

(H.H.) = 41.00

Spring I. Cyl. = 30#

M.E.P. (I.C.) = 29.85

(I.H.) = 23.90

Spring L. Cyl. = 10#

M.E.P. (L.C.) = 13.94

(L.H.) = 12.80

Run #10 South Bound (3rd Speed)

No of Card	High				Intermediate				Low			
	Crank		Head		Crank		Head		Crank		Head	
	A	L	A	L	A	L	A	L	A	L	A	L
1	1.40	2.46	1.63	2.46	2.30	2.41	1.90	2.41	3.47	2.42	3.13	2.42
2	1.38	2.48	1.60	2.48	2.30	2.40	1.94	2.40	3.48	2.42	3.17	2.42
3	1.35	2.45	1.59	2.45	2.34	2.40	1.94	2.40	3.49	2.42	3.18	2.42
4	1.34	2.45	1.59	2.45	2.43	2.41	1.99	2.41	3.45	2.42	3.17	2.42
5	1.36	2.45	1.62	2.45	2.40	2.42	1.95	2.42	3.51	2.42	3.24	2.42
Totals	6.83	12.29	8.03	12.29	11.77	12.04	9.72	12.04	17.40	12.10	15.89	12.10
Av.	1.366	2.458	1.606	2.458	2.354	2.408	1.944	2.408	3.48	2.42	3.18	2.42

Spring H. cyl. = 60#

M.E.P (H.C.) = 33.40

(H.H.) = 39.30

Spring I. cyl. = 30#

M.E.P. (I.C.) = 29.35

(I.H.) = 24.20

Spting L. cyl. = 10#

M. E. P.(L.C.) = 16.38

(L.H.) = 13.14

Run #11 North Bound (4th Speed)

No of Card	High				Intermediate				Low			
	Crank		Head		Crank		Head		Crank		Head	
	A	L	A	L	A	L	A	L	A	L	A	L
1	1.77	2.46	2.07	2.46	2.75	2.42	2.28	2.42	1.99	2.42	1.80	2.42
2	1.80	2.46	2.08	2.46	2.76	2.42	2.29	2.42	1.96	2.42	1.79	2.42
3	1.80	2.46	2.05	2.46	2.78	2.42	2.30	2.42	1.93	2.42	1.73	2.42
4	1.81	2.47	2.07	2.47	2.80	2.43	2.32	2.43	2.07	2.42	1.80	2.42
5	1.80	2.46	2.10	2.46	2.82	2.42	2.32	2.42	2.03	2.42	1.80	2.42
Totals	8.98	12.31	10.37	12.31	13.91	12.11	11.51	12.11	9.98	12.10	8.92	12.10
Av.	1.796	2.462	2.134	2.462	2.782	2.422	2.302	2.422	1.996	2.42	1.784	2.42

Spring H. cyl. = 60#

M.E.P. (H.C.) = 43.75

(H.H) = 52.00

Spring I. cyl. = 30#

M.E.P. (I.C.) = 34.50

(I.H.) = 28.60

Spring L.cyl. = 20#

M.E.P. (L.C.) = 16.50

(L.H.) = 14.75

Run #12 South Bound(4th Speed)

No of Card	High				Intermediate				Low			
	Crank		Head		Crank		Head		Crank		Head	
	A	L	A	L	A	L	A	L	A	L	A	L
1	1.80	2.48	2.08	2.48	2.77	2.44	2.33	2.44	1.92	2.42	1.70	2.42
2	1.79	2.46	2.03	2.46	2.80	2.42	2.36	2.42	2.00	2.42	1.80	2.42
3	1.86	2.45	2.13	2.45	2.80	2.43	2.35	2.43	1.98	2.42	1.75	2.42
4	1.84	2.45	2.12	2.45	2.83	2.43	2.40	2.43	2.05	2.41	1.80	2.41
5	1.85	2.47	2.10	2.47	2.72	2.42	2.39	2.42	2.00	2.42	1.80	2.42
Totals	9.14	12.31	10.46	12.31	13.92	12.14	11.83	12.14	9.95	12.09	8.85	12.09
Av.	1.828	2.462	2.092	2.462	2.784	2.428	2.366	2.428	1.99	2.418	1.77	2.418

Sprimg H. cyl. = 60"

M.E.P. (.H.C.) = 44.50

(H.H) = 51.00

Spring I. cyl. = 30#

M.E.P. (I C.) = 34.40

(I.H.) = 29.30

Spring L. cyl. = 20#

M.E.P. (L.C.) = 16.50

(L.H.) = 14.70

Run #13 North Bound (5th Speed)

No. of Card	High				Intermediate				Low			
	Crank		Head		Crank		Head		Crank		Head	
	A	L	A	L	A	L	A	L	A	L	A	L
1	1.80	2.48	2.10	2.48	2.13	2.45	1.70	2.45	2.97	2.44	2.59	2.44
2	1.82	2.48	2.07	2.48	2.13	2.45	1.72	2.45	3.06	2.44	2.60	2.44
3	1.80	2.48	2.00	2.48	2.14	2.42	1.72	2.42	3.05	2.42	2.66	2.42
4	1.85	2.50	2.15	2.50	2.10	2.43	1.72	2.43	3.10	2.43	2.70	2.43
5	1.85	2.50	2.14	2.50	2.05	2.42	1.75	2.42	3.12	2.45	2.70	2.45
Totals	9.12	12.44	10.46	12.44	10.55	12.17	8.61	12.17	15.30	12.18	13.25	12.18
Aver.	1.824	2.488	2.092	2.488	2.11	2.436	1.722	2.436	3.06	2.436	2.65	2.436

Spring H cyl. = 100#

M. E. P. (H. C.) = 73.40

(H. H.) = 84.00

Spring I. cyl. = 60#

M. E. P. (I. C.) = 52.00

(I. H.) = 42.50

Spring L. cyl. = 20#

M. E. P. (L. C.) = 25.18

(L. H.) = 21.80

Run #14 South Bound (5th Speed)

No. of Card	High				Intermediate				Low			
	Crank		Head		Crank		Head		Crank		Head	
	A	L	A	L	A	L	A	L	A	L	A	L
1	1.80	2.50	2.01	2.50	2.15	2.43	1.72	2.43	3.02	2.44	2.70	2.44
2	1.80	2.50	2.06	2.50	2.11	2.42	1.72	2.42	3.16	2.45	2.70	2.45
3	1.80	2.50	2.10	2.50	2.14	2.44	1.78	2.44	3.20	2.44	2.73	2.44
4	1.89	2.48	2.13	2.48	2.16	2.41	1.73	2.41	3.20	2.43	2.79	2.43
5	1.82	2.50	2.09	2.50	2.10	2.45	1.70	2.45	3.13	2.43	2.75	2.43
Totals	9.11	12.48	10.39	12.48	10.66	12.15	8.65	12.15	15.71	12.19	13.67	12.19
Aver.	1.822	2.496	2.078	2.496	2.132	2.43	1.73	2.43	3.142	2.438	2.734	2.438

Spring H cyl. = 100#

M. E. P. (H.C.) = 73.10

(H.H.) = 83.20

Spring I cyl. = 60#

M. E. P. (I.C.) = 52.60

(I.H.) = 42.75

Spring L cyl. = 20#

M. E. P. (L.C.) = 25.80

(L. H.) = 22.45

Run #15 North Bound (Max.(6th) Speed)

No of Card	High				Intermediate				Low			
	Crank		Head		Crank		Head		Crank		Head	
	A	L	A	L	A	L	A	L	A	L	A	L
1	1.50	2.50	1.70	2.50	1.91	2.42	1.58	2.42		2.42	3.73	2.42
2	1.42	2.50	1.60	2.50	1.85	2.42	1.52	2.42	3.66	2.42	3.10	2.42
3	1.40	2.50	1.60	2.50	1.71	2.40	1.40	2.40	3.58	2.43	3.08	2.43
4	1.38	2.49	1.62	2.49	1.84	2.40	1.50	2.40		2.43	3.20	2.43
5	1.38	2.50	1.58	2.50	1.97	2.41	1.59	2.41	3.59	2.43	3.12	2.43
Totals	7.08	12.49	8.10	12.49	9.28	12.05	7.60	12.05	10.83	12.13	15.63	12.13
Av.	1.416	2.498	1.62	2.498	1.856	2.41	1.52	2.41	3.61	2.426	3.126	2.426

Spring H. cyl. = 150#

M.E.P (H.C.) = 85.15

(H.H.) = 97.50

SptringI. cyl. = 80#

M.E.P. (I.C.) = 61.50

(I.H.) = 50.50

Spring L. cyl. = 20#

M.E.P. (L.C.) = 29.78

(L.H.) = 25.80

Run #16 South Bound (Max.(6th)Speed)

No. of Cards	High Crank A	High Crank L	High Head A	High Head L	Intermediate Crank A	Intermediate Crank L	Intermediate Head A	Intermediate Head L	Low Crank A	Low Crank L	Low Head A	Low Head L
1	1.39	2.50	1.61	2.50	1.75	2.40	1.42	2.40	3.20	2.44	2.94	2.44
2	1.36	2.48	1.55	2.48	1.93	2.41	1.56	2.41	3.37	2.44	2.99	2.44
3	1.45	2.48	1.63	2.48	1.87	2.42	1.58	2.42	3.54	2.44	3.20	2.44
4	1.54	2.50	1.65	2.50	1.85	2.41	1.56	2.41	3.65	2.44	3.26	2.44
5	1.52	2.50	1.62	2.50	1.90	2.41	1.56	2.41	3.73	2.43	3.38	2.43
Totals	7.26	12.46	8.06	12.46	9.30	12.05	7.68	12.05	17.49	12.19	15.77	12.19
Av	1.452	2.492	1.612	2.492	1.86	2.41	1.536	2.41	3.498	2.438	3.154	2.438

Spring H. cyl. = 150#

M.E.P (.H.C.) = 87.50

(H.H) = 97.00

Spring I. cyl. = 80#

M.E.P.(I.CI) = 61.75

(I.H.) = 51.00

SpringL cyl. = 20#

M.E.P.(L.C.) = 28.72

(L.H.) = 25.92

Average,- Mean Effective Pressures.

I.- <u>Low</u> (1st) <u>Speed</u>-

$$H.\ C. = \frac{6.3 + 12.30 + 12.13 + 11.06}{4} = 10.50$$

$$H.\ H. = \frac{9.64 + 14.44 + 14.52 + 13.21}{4} = 12.95$$

$$I.\ C. = \frac{13.6 + 19.9 + 20.00 + 19.87}{4} = 18.34$$

$$I.\ H. = \frac{10.73 + 15.8 + 15.90 + 15.73}{4} = 14.54$$

$$L.\ C. = \frac{9.00 + 9.96 + 9.84 + 9.92}{4} = 9.68$$

$$L.\ H. = \frac{8.38 + 9.15 + 9.00 + 9.35}{4} = 8.97$$

2nd Speed-

$$\text{H. C.} = \frac{25.70 + 25.35}{2} = \frac{51.05}{2} = 25.51$$

$$\text{H. H.} = \frac{29.60 + 30.05}{2} = \frac{59.65}{2} = 29.83$$

$$\text{I. C.} = \frac{24.10 + 24.25}{2} = \frac{48.35}{2} = 24.18$$

$$\text{I. H.} = \frac{18.90 + 19.35}{2} = \frac{38.25}{2} = 19.13$$

$$\text{L. C.} = \frac{11.40 + 11.45}{2} = \frac{22.85}{2} = 11.43$$

$$\text{L. H.} = \frac{10.55 + 10.67}{2} = \frac{21.22}{2} = 10.61$$

3rd Speed-

$$H.\ C. = \frac{34.70 + 33.40}{2} = \frac{68.10}{2} = 34.05$$

$$H.\ H. = \frac{41.00 + 3930}{2} = \frac{80.30}{2} = 40.15$$

$$I.\ C. = \frac{29.85 + 29.35}{2} = \frac{59.20}{2} = 29.60$$

$$I.\ H. = \frac{23.90 + 24.20}{2} = \frac{48.10}{2} = 24.05$$

$$L.\ C. = \frac{13.94 + 14.38}{2} = \frac{28.32}{2} = 14.16$$

$$L.\ H. = \frac{12.80 + 13.14}{2} = \frac{25.94}{2} = 12.97$$

<u>4th Speed</u> -

$$H.\ C. = \frac{43.75 + 44.50}{2} = \frac{88.25}{2} = 44.13$$

$$H.\ H. = \frac{52.00 + 51.00}{2} = \frac{103}{2} = 51.5$$

$$I.\ C. = \frac{34.50 + 34.40}{2} = \frac{689}{2} = 34.45$$

$$L.\ H. = \frac{28.60 + 29.30}{2} = \frac{57.9}{2} = 28.95$$

$$L.\ C. = \frac{16.50 + 16.50}{2} = \frac{33.0}{2} = 16.50$$

$$L.\ H. = \frac{14.75 + 14.70}{2} \quad \frac{29.45}{2} = 14.73$$

<u>5th Speed</u>-

$$\text{H. C.} = \frac{73.40 + 73.10}{2} = \frac{146.5}{2} = 73.25$$

$$\text{H. H.} = \frac{84.00 + 83.20}{2} = \frac{167.2}{2} = 83.60$$

$$\text{I. C.} = \frac{52.00 + 52.60}{2} = \frac{104.6}{2} = 52.30$$

$$\text{I. H.} = \frac{42.50 + 42.75}{2} = \frac{85.25}{2} = 42.63$$

$$\text{L. C.} = \frac{25.18 + 25.80}{2} = \frac{50.98}{2} = 25.49$$

$$\text{L. H.} = \frac{21.80 + 22.45}{2} = \frac{44.25}{2} = 22.13$$

6th Speed (Max.)

$$H.\ C. = \frac{85.15 + 87.50}{2} = \frac{172.65}{2} = 86.33$$

$$H.\ H. = \frac{97.50 + 97.00}{2} = \frac{194.50}{2} = 97.25$$

$$I.\ C. = \frac{61.50 + 61.75}{2} = \frac{123.25}{2} = 61.63$$

$$I.\ H. = \frac{50.50 + 51.00}{2} = \frac{101.5}{2} = 50.75$$

$$L.\ C. = \frac{29.78 + 28.72}{2} = \frac{58.50}{2} = 29.25$$

$$L.\ H. = \frac{25.80 + 25.92}{2} = \frac{51.72}{2} = 25.86$$

Reduction of M. E. P.$_s$ to Low Pressure Cylinder.

Data:-

Diameters of Cylinders,-

High = 5-1/2 "

Intermediate = 9 "

Low = 15 "

Stroke = 9 " for all pistons

All Piston rods = 1•3/16 " diam.

M. E. P. reduced to L. P. Cyl. = summation of all 6 M.E.P.$_s$ x each area.÷(Mean area of low pressure cylinder).

Mean Area of Low Pressure Cylinder

$$= \frac{11.15^2}{4} - \frac{\frac{11 \times 1\ 3/16^2}{4}}{2} \qquad 177.00 - \frac{1.11}{2}$$

$$= \begin{array}{r} 177.00 \\ -.55 \\ \hline 176.45 \end{array} \text{ sq. inches.}$$

High Pressure Cylinder;-

$$\text{Head end area} = \frac{5.5^2 \times 11}{4} = 23.75$$

$$\text{Crank end area} = 23.75 - 1.11 = \begin{array}{r} 23.75 \\ -1.11 \\ \hline 22.64 \end{array}$$

Intermediate Pressure Cylinder:-

$$\text{Head end area} = \frac{9^2 \times 11}{4} = 63.6$$

$$\text{Crank end area} = 63.6 - 1.11 = \begin{array}{r} 63.6 \\ 1.11 \\ \hline 62.49 \end{array}$$

Low Pressure Cylinder

$$\text{Head end area} = \frac{11 \times 15^2}{4} = 177.0$$

$$\text{Crank end area} = 177.0 - 1.11 = \begin{array}{r} 177.00 \\ 1.11 \\ \hline 175.89 \end{array}$$

Reducing M.E.Ps to low Pressure Cylinder.

1st Speed

$$= \frac{10.50 \times 22.64}{176.45} + \frac{12.95 \times 23.75}{176.45}$$

$$+ \frac{18.34 \times 62.49}{176.45} + \frac{14.54 \times 63.6}{176.45} + \frac{9.68 \times 175.89}{176.45}$$

$$+ \frac{8.97 \times 177}{176.45} = \begin{array}{r} 1.35 \\ 1.74 \\ 6.50 \\ 5.25 \\ 9.65 \\ \underline{9.00} \end{array}$$

Average = 33.49 #

2nd Speed

$$= \frac{25.51 \times 22.64}{176.45} + \frac{29.83 \times 23.75}{176.45}$$

$$+ \frac{24.18 \times 62.49}{176.45} + \frac{19.13 \times 63.6}{176.45} + \frac{11.43 \times 175.89}{176.45}$$

$$+ \frac{10.61 \times 177}{176.45} = \begin{array}{r} 3.28 \\ 4.01 \\ 8.55 \\ 6.90 \\ 11.40 \\ \underline{10.65} \end{array}$$

Average = 44.79 #

3rd Speed

$$= \frac{34.05 \times 22.64}{176.45} + \frac{40.15 \times 23.75}{176.45}$$

$$+ \frac{29.60 \times 62.49}{176.45} + \frac{24.05 \times 63.6}{176.45} + \frac{14.16 \times 175.89}{176.45} + \frac{12.97 \times 177}{176.45}$$

$$= \begin{array}{r} 4.37 \\ 5.40 \\ 10.45 \\ 8.66 \\ 14.10 \\ \underline{13.00} \\ 55.98 \end{array}$$

55.98 = 55.98 # = Average

4th Speed

$$= \frac{44.13 \times 22.64}{176.45} + \frac{51.5 \times 23.75}{176.45} + \frac{34.45 \times 62.49}{176.45}$$

$$+ \frac{28.95 \times 63.6}{176.45} + \frac{16.50 \times 175.89}{176.45} + \frac{14.73 \times 177}{176.45}$$

= 5.65
6.93
12.51
10.40
16.40
14.80

Average = 66.69 #

5th Speed

$$= \frac{73.25 \times 22.6}{176.45} + \frac{83.60 \times 23.75}{176.45} + \frac{52.30 \times 62.49}{176.45}$$

$$+ \frac{42.63 \times 63.6}{176.45} + \frac{25.49 \times 175.89}{176.45} + \frac{22.13 \times 177}{176.45}$$

= 9.40
11.25
19.00
15.33
25.40
22.20

Average 102.58

6th Speed:

$$\frac{86.33 \times 22.64}{176.45} + \frac{97.25 \times 23.75}{176.45}$$

$$+ \frac{61.63 \times 62.49}{1.76.45} + \frac{50.75 \times 63.6}{176.45} + \frac{29.25 \times 175.89}{176.45}$$

$$+ \frac{25.86 \times 177}{176.45} = 11.06$$

13.09

22.40

18.30

29.15

25.95

Average = 119.95

I

REVOLUTIONS

(1) Low (1st) Speed North Bound = N. B.

1048 Rev. in 8 : 05 : 4

8 : 05 : 4 = 8.0966 minutes

$$\text{R.P.M.} = \frac{1048}{8.0966} = 129.5$$

(2) 1st Speed South Bound = S. B.

992 Rev. in 7:33

7:33 = 7.55 min.

$$\text{R.P.M.} = \frac{992}{7.55} = 131.3$$

(3) N. B.

1050 Rev. in 8 : 0 : 4

8 : 0 : 4 = 8.013 min.

$$\text{R.P.M.} = \frac{1050}{8.013} = 131.0$$

(4) S.B.

1000 Rev. in 7:35

7:35 = 7.583 min.

$$\text{R.P.M.} = \frac{1000}{7.583} = 132.0$$

129.5	131.0	130.4
131.3	132.0	131.5
2)260.8	2)263.0	2)261.9
mean = 130.4	mean = 131.5	130.95

130.95 = R.P.M. of 1st (Low) Speed

II.

(2nd) Speed

7 N. B.

1064 Rev. in 7 : 10 : 1

7 : 10 : 1 = 7.17 min.

II

(2nd) Speed (cont.)

7. N.B.

$$R.P.M. = \frac{1064}{7.17} = 148.5$$

8. S.B.

1018 Rev. in 6 : 48 : 3

6 : 48 : 3 = 6.81 min.

$$\frac{1018}{6.81} = 149.3 = R.P.M.$$

148.5
149.3
2)297.8
Mean = 148.9

148.9 = R.P.M. of 2nd Speed.

III.

(3rd) Speed

9. N. B.

1082 Rev. in 6 : 29 : 1

6 : 29 : 1 = 6.487 min.

$$R.P.M. = \frac{1082}{6.487} = 167.0$$

10. S.B.

1046 Rev. in 6: 11 : 3

6 : 11 : 3 = 6.1935 min.

$$R.P.M. = \frac{1046}{6.1935} = 169.0$$

167
169
2)236
mean = 168.0 = R.P.M. of 3rd Speed

IV **4th Speed**

11 N.B.

1104 Revs. in 6:04

6:04 = 6.066 min.

$$R.P.M. = \frac{1104}{6.066} = 182.0$$

12 S.B.

1063 Revs. in 5:47

5:47 = 5.784 min.

$$R.P.M. = \frac{1065}{5.784} = 184.2$$

```
   182.0
   184.2
2) 366.2
   183.1
```

183.1 = R. P. M. of 4th Speed.

V 5th Speed.

13. N.B.

1139 revs. in 5:05:1

5:05:1 = 5.0866 min.

$$\text{R.P.M.} = \frac{1139}{5:0866} = 224.0$$

14. S.B.

1109 revs. in 4:58:1

4:58:1 = 4.97 min.

$$\text{R.P.M.} = \frac{1109}{4.97} = 223.0$$

223.5 = R.P.M. of 5th Speed.

VI. 6th(Max.) Speed

15. N.B.

1163 rev. in 4:53:4 = 4.897 min.

$$R.P.M. = \frac{1163}{4.897} = 238.0$$

16. S.B.

1137 rev. in 4:46

4:46 = 4.767 min.

$$R.P.M. = \frac{1137}{4.767} = 238.0$$

238.0 = R.P.M. of 6th Speed.

SPEEDS

Measured Course = 5035.3 feet long = .828 knots

1 Knot = 6080.0 feet

I Speed 1. (Low)

1. N. B.

Time = 8 : 05 : 4 = 8.0966 min.

$\frac{6080}{5035.3} \times 8.0966 = 1.207 \times 8.0966 = 9.76$ mins. per Knot.

$\frac{60}{9.76} = 6.15$ Knots per hour.

2. S. B.

Time = 7:33 = 7.55 min.

$\frac{60 \times 5035.3}{6080 \times 7.55} = \frac{49.69}{7.55} =$ Knots per hour. = 6.59

3. N. B.

Time = 8 : 0 : 4 = 8.013 min.

$\frac{49.69}{8.013} = 6.20$ Knots per hour.

4. S. B.

Time = 7:35 = 7.583 min.

$\frac{49.69}{7.583} = 6.55$ Knots per hour.

	6.15	6.20	6.37
	6.59	6.55	6.375
	2) 12.74	2) 12.75	2) 12.745
mean=	6.37	m= 6.375	m Of m= 6.3725

Speed on Low 1st Speed = 6.3725 Knots per hour.

II 2nd Speed.

7. N.B.

Time = 7:10:1 = 7.17 min.

$$\frac{49.69}{7.17} = 6.94 \text{ K. per H.}$$

8. S.B.

Time = 6:48:3 = 6.81 min.

$$\frac{49.69}{6.81} = 7.30 \text{ K. per H.}$$

```
          6.94
          7.30
        2)14.24
mean =    7.12
```

∴ Speed on 2nd Speed = 7.12 Knots per hour.

III 3rd Speed.

9. N.B.

Time = 6:29:1 = 6.487 min.

$$\frac{49.69}{6.487} = 7.66 \text{ K. per H.}$$

10. S.B.

Time = 6:11:3 = 6.1935 min.

$$\frac{49.69}{6.1935} = 8.03 \text{ K. per H.}$$

```
      7.66
      8.03
    2)15.69
mean =  7.845
```

∴ Speed of 3rd Speed = 7.845 Knots per hour.

IV 4th Speed.

11. N.B.

Time = 6:04 = 6:066 min.

$$\frac{49.69}{6.066} = 8.19 \text{ K. p. H.}$$

12. S.B.

Time = 5:47 = 5.784 min.

$$\frac{49.69}{5.784} = 8.60 \text{ K. p. H.}$$

```
        8.19
        8.60
     2)16.79
mena =  8.395
```

$\therefore$ Speed of 4th Speed = 8.395 knots per hour

V 5th Speed.

13. N.B.

Time = 5:05:1 = 5.0866 min.

$$\frac{49.69}{5.0866} = 9.78 \text{ K. p. H.}$$

14. S.B.

Time = 4:58:1 = 4.97 min.

$$\frac{49.69}{4.97} = 10.00 \text{ K. p. H.}$$

```
   9.78
  10.00
2)19.78
   9.89
```

∴ Speed of 5th Speed = 9.89 Knots per hour.

VI 6th Speed

15. N. B.

Time = 4 : 53 : 4 = 4.897 min.

$\frac{49.69}{4.897}$ = 10.15 Knots per hour.

16. S. B.

Time = 4:46 = 4.767 min.

$\frac{49.69}{4.767}$ = 10.41 Knots per hour.

```
   10.15
   10.41
2) 20.56
   10.28
```

Speed of 6th (Max.) Speed = 10.28 Knots per hour.

PLATES

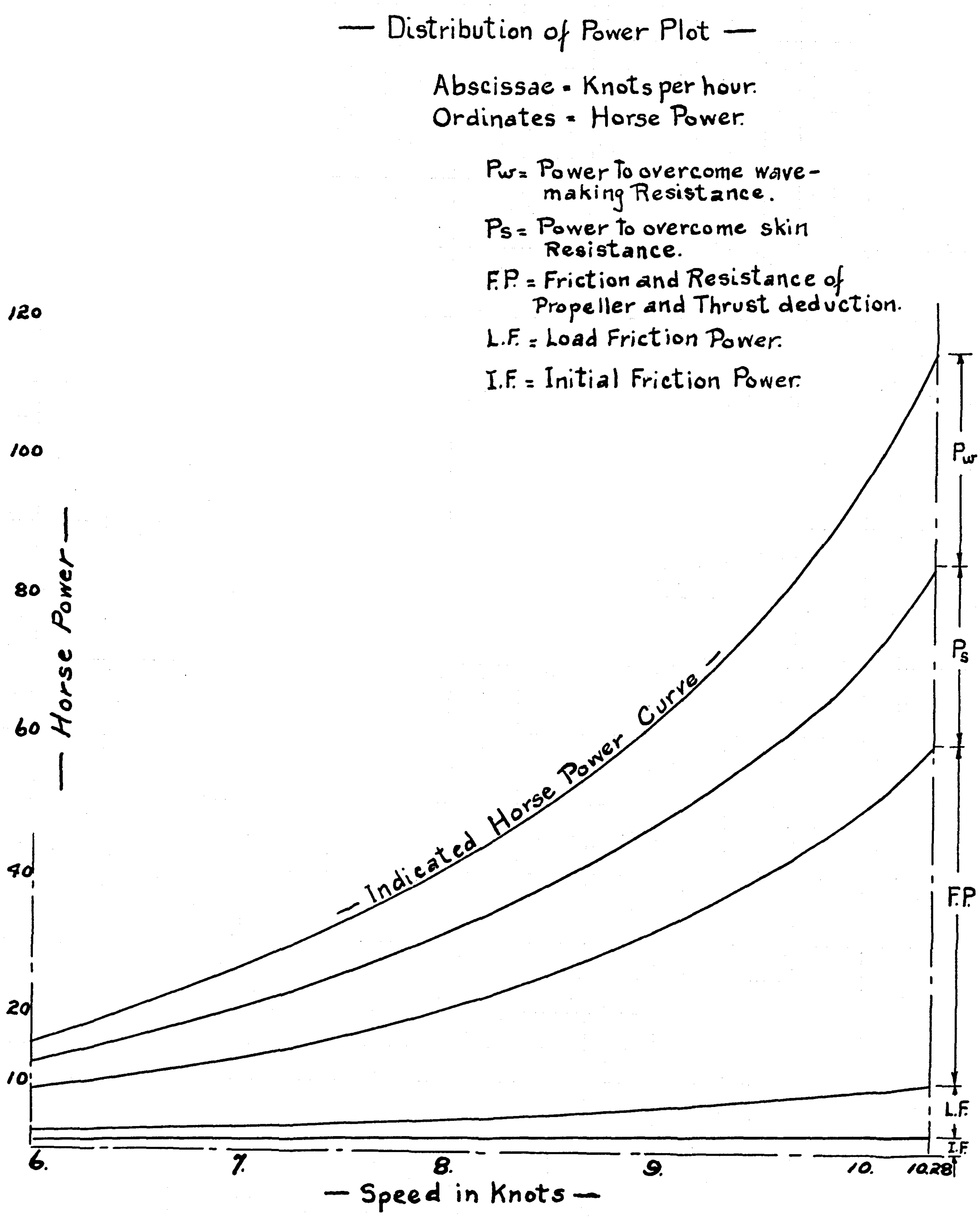

— Distribution of Power Plot —
Abscissae = Knots per hour.
Ordinates = Horse Power.
Pw = Power to overcome wave-making Resistance.
Ps = Power to overcome skin Resistance.
F.P. = Friction and Resistance of Propeller and Thrust deduction.
L.F. = Load Friction Power.
I.F. = Initial Friction Power.
— Horse Power —
120
100
80
60
40
20
10
— Indicated Horse Power Curve —
Pw
Ps
F.P.
L.F.
I.F.
6.
7.
8.
9.
10.
10.28
— Speed in Knots —

Plate #2

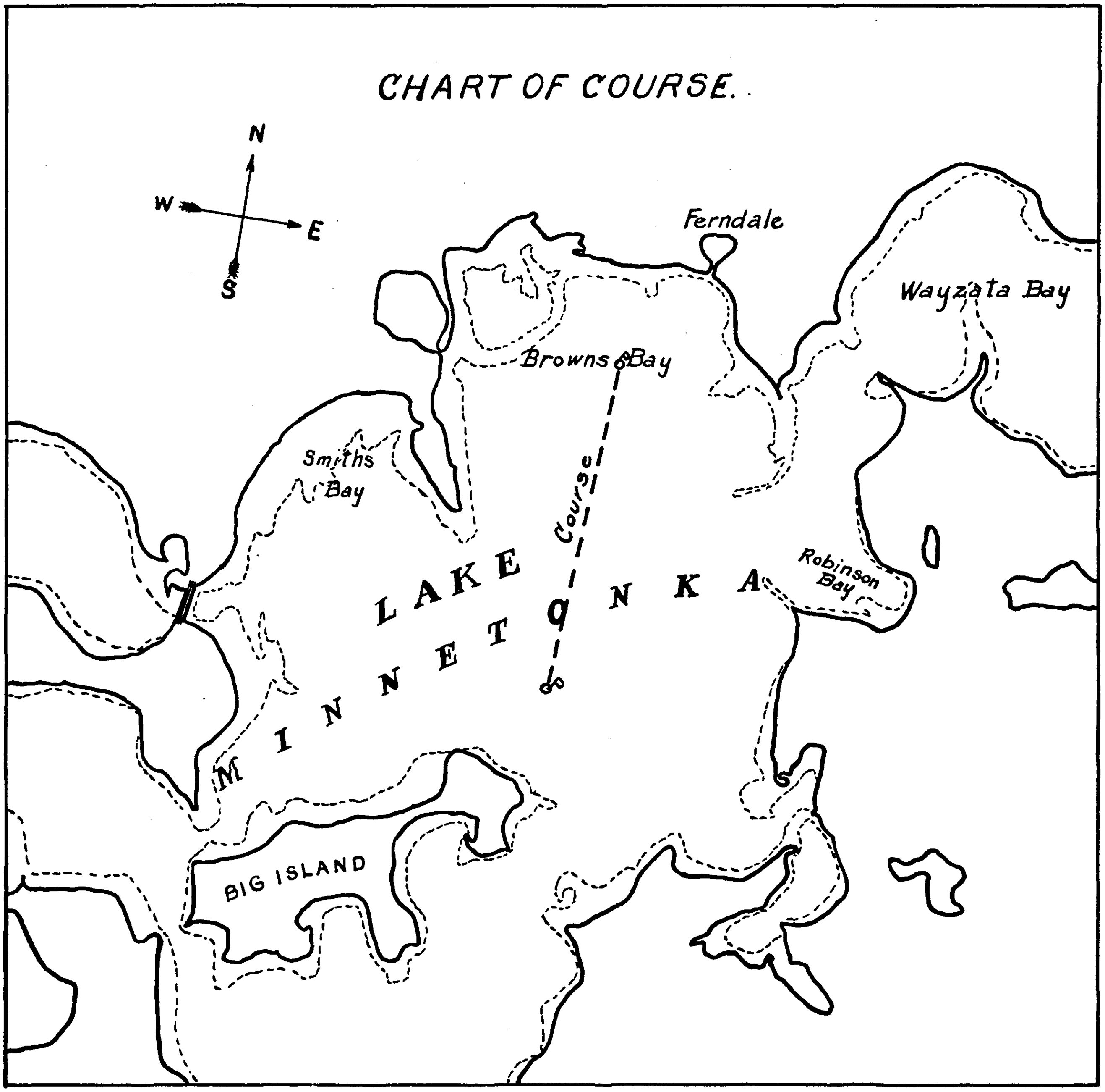
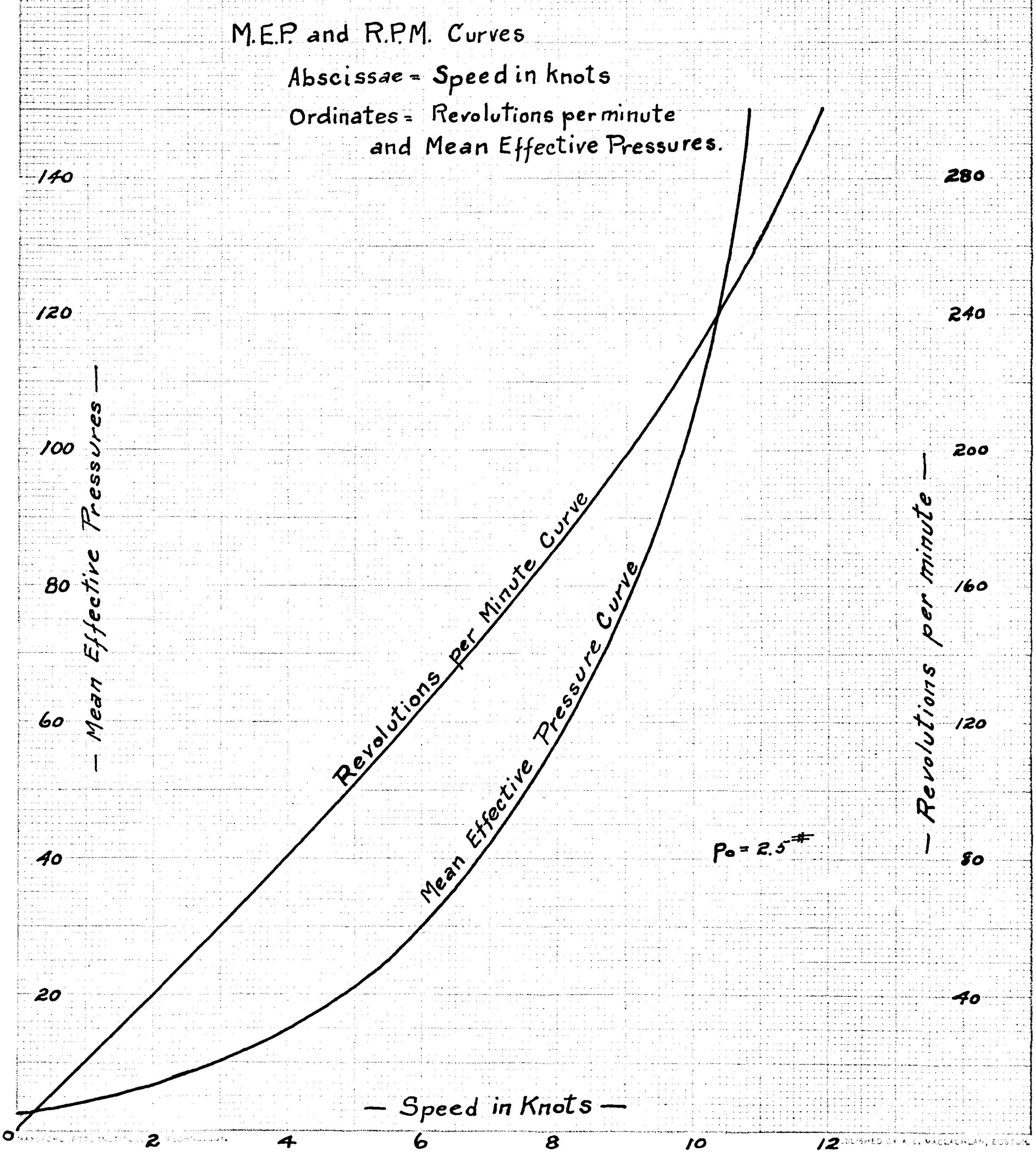


CHART OF COURSE.
N
W
E
S
Ferndale
Wayzata Bay
Browns Bay
Smiths Bay
Course
LAKE MINNETONKA
Robinson Bay
BIG ISLAND

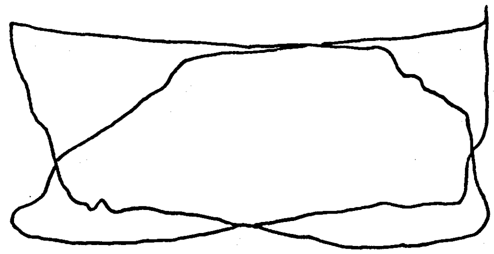
Plate #3



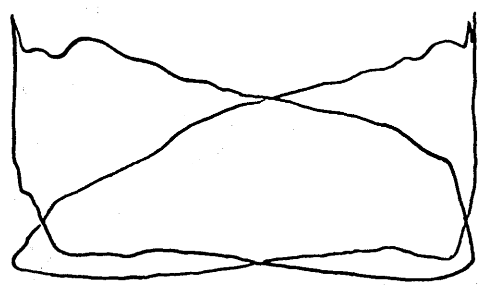
M.E.P. and R.P.M. Curves
Abscissae = Speed in knots
Ordinates = Revolutions per minute
and Mean Effective Pressures.
Revolutions per Minute Curve
Mean Effective Pressure Curve
Po = 2.5#
— Mean Effective Pressures —
— Revolutions per minute —
— Speed in Knots —
140
120
100
80
60
40
20
280
240
200
160
120
80
40
0
2
4
6
8
10
12

Plate #4

Run #13 High Card #4



Run #13 Intermediate.



Run #13 Low.

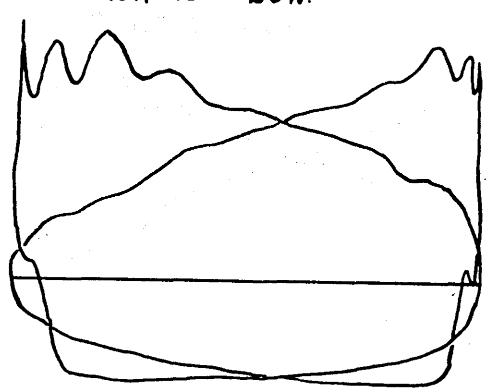
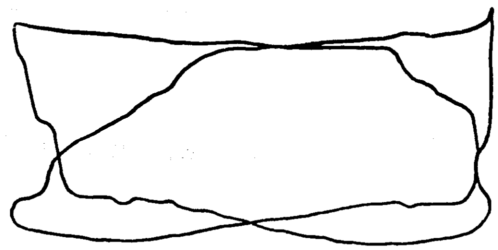
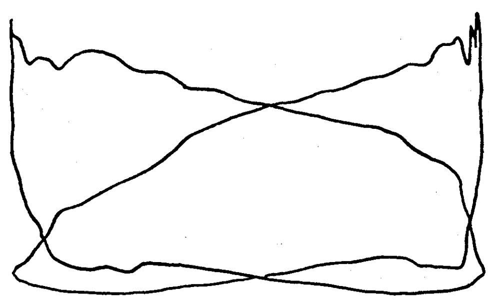


Plate #5

Run #14. High.



Run # 14 Intermediate



Run #14 Low

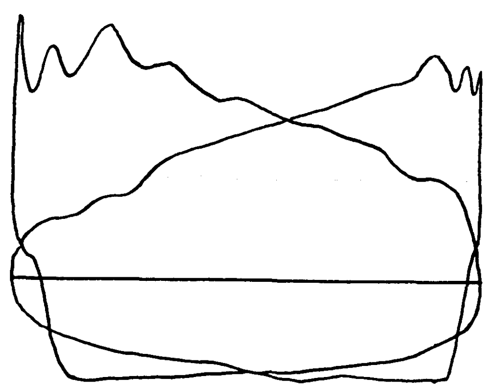


Plate #6

MEASURING THE BLADE.

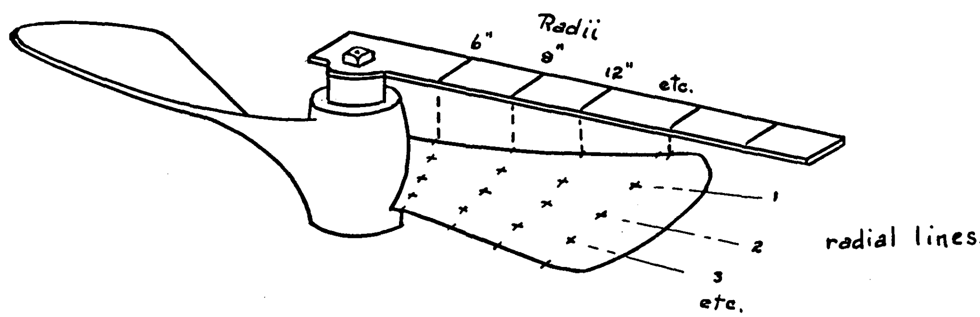
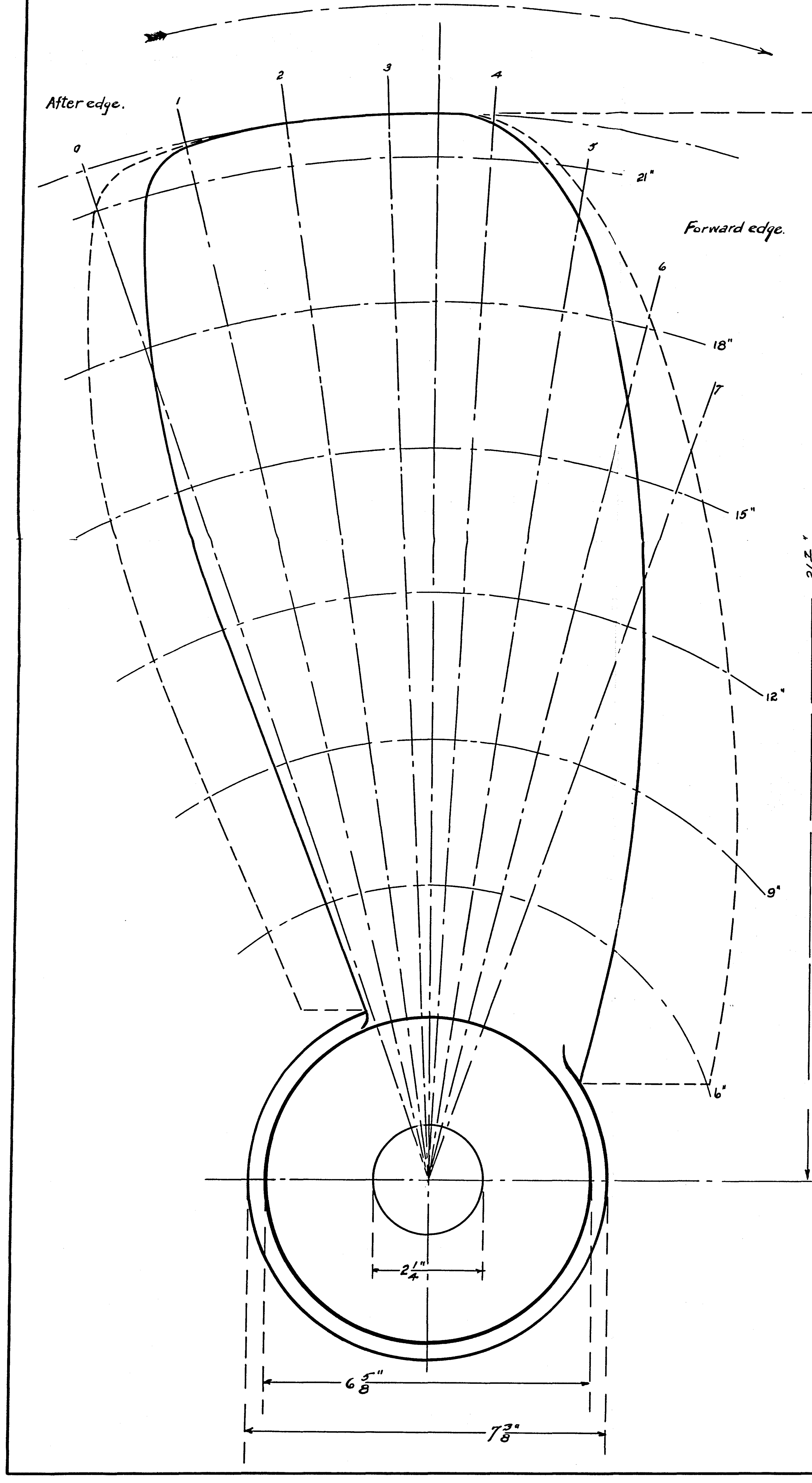
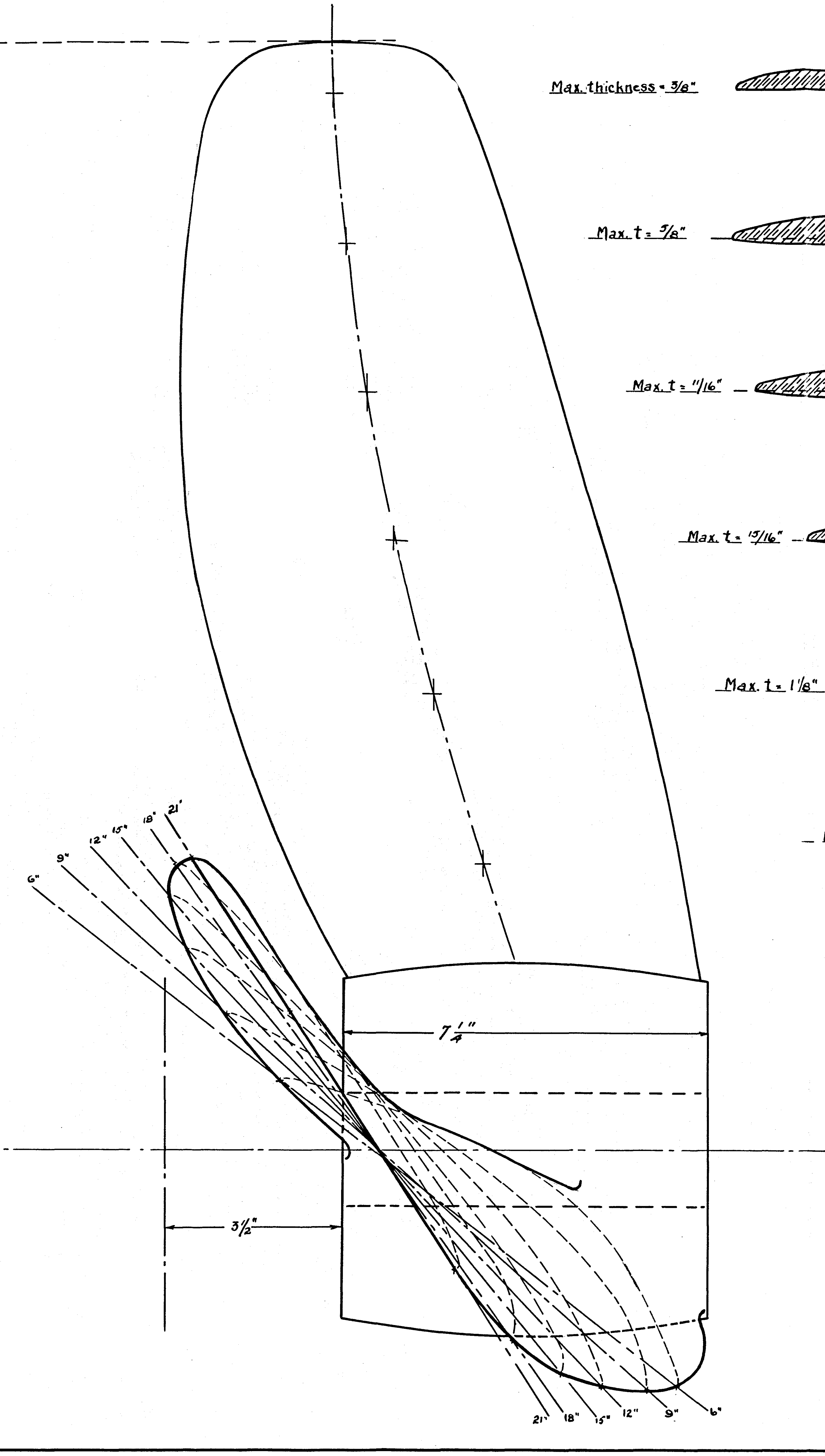
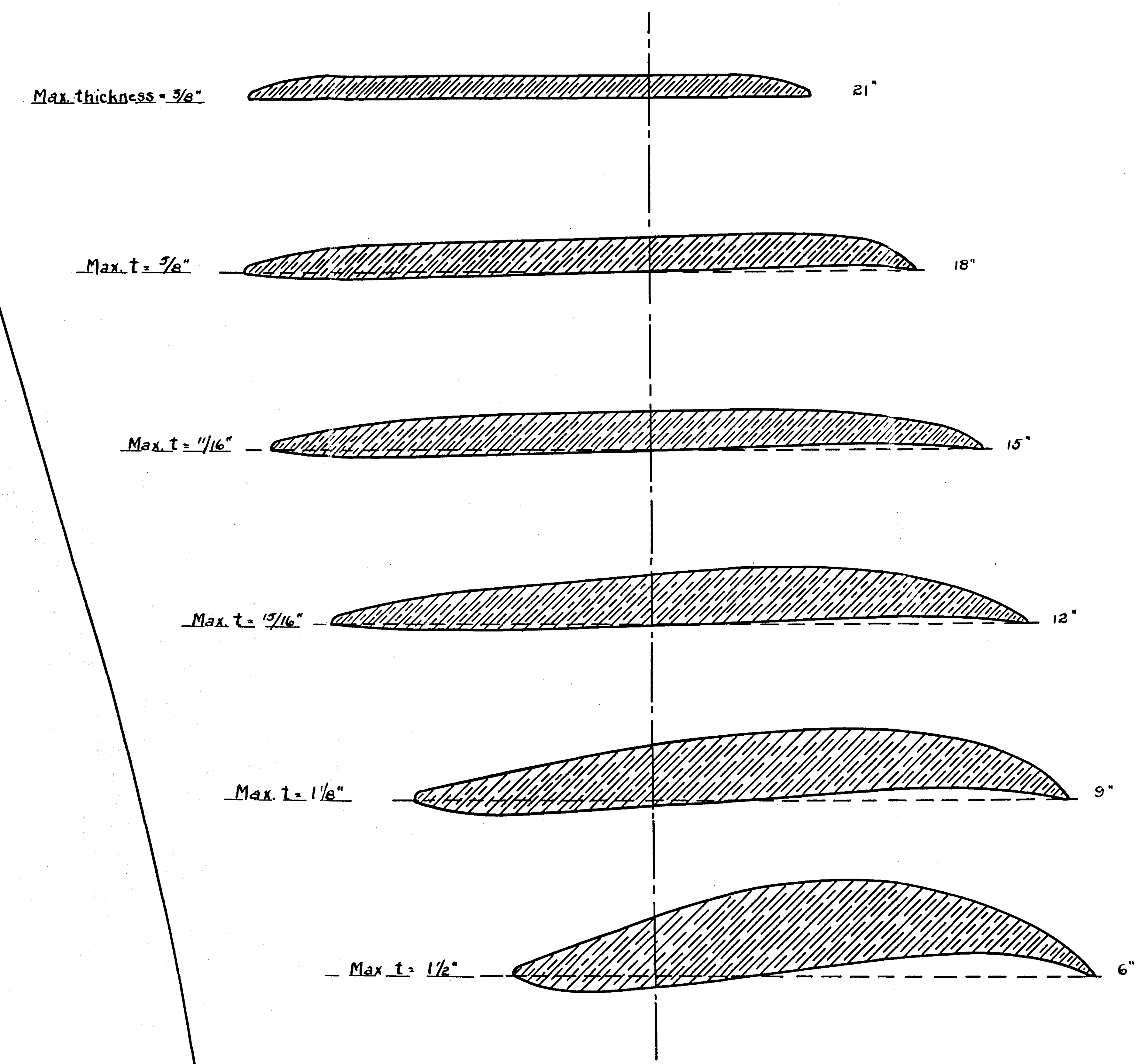


Plate #



Over All Pitch	Mean Pitch
85.0"	85.7"
81.0"	79.2"
77.75"	77.7"
72.0"	73.8"
64.0"	67.7"
49.5"	59.0"





PITCH .... 78.0"
DIAMETER .... 43 3/4"
R.P.M. 220.0
I.H.P. 92.46
PROJECTED AREA .. 592.0 sq ins.
DEVELOPED AREA .. 796.8 sq ins.
WEIGHT ...... 251 #

FOUR BLADE PROPELLER

FOR - 5 1/2" X 9" X 15" ENGINE.

MASS. INST. OF TECHNOLOGY

Scale - 1/2 Size

Date - March, 17, 1910

Made by - Clifford C. Hield.