Thesis
case

PROGRESSIVE SPEED TRIALS

OF THE

SEA-GOING DREDGE

COMSTOCK

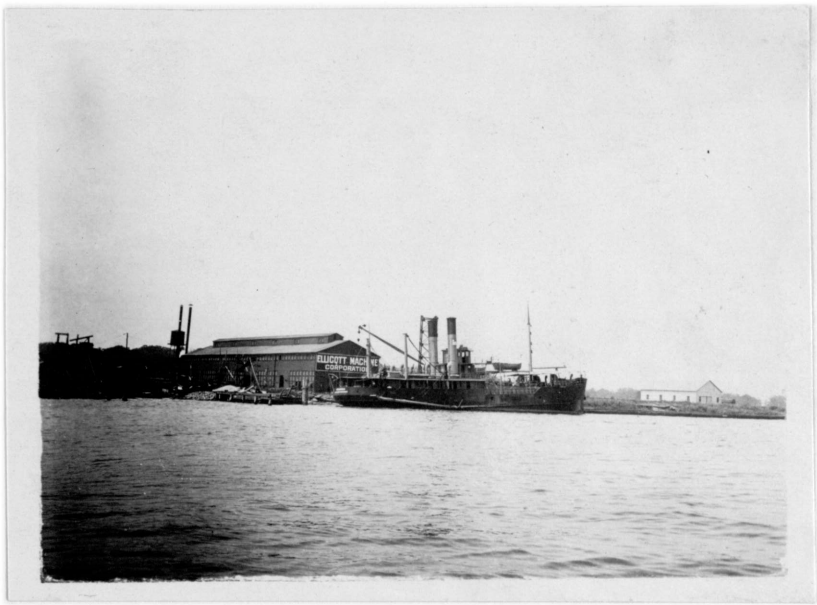
Thesis 1916

Course XIII B

Submitted by

Signature redacted

Massachusetts Institute of Technology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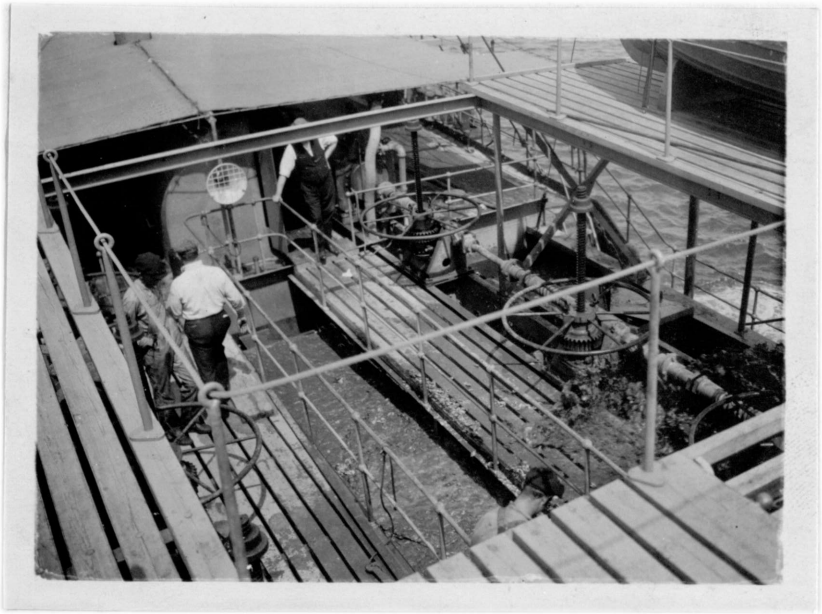
CORPORATION



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Acknowledgment.

Through the kindness of Mr. W. C. McGowan of the United States Army Engineer Corps, and the courtesy of the builders - the Ellicott Machine Corporation - we were permitted to participate in the Government Acceptance Trials of the sea-going dredge "Comstock".

Thanks are also due to Professor C. H. Peabody, Head of the Department of Naval Architecture and Marine Engineering at the Massachusetts Institute of Technology, and to Professor H. A. Everett and Mr. E. Burtner of the same department for their advice and help; . Professor Everett and Mr. Burtner accompanying us on the trials.

General Description of the Dredge "Comstock".

The "Comstock", built for the United States Government service in the Galveston, Texas district, is of the sea-going, hopper, suction type. The material to be dredged is drawn through suction pipes by centrifugal suction pumps and discharged into hoppers. She is a single-screw boat propelled by a compound engine which is supplied with steam by two Scotch boilers equipped for burning oil and fitted with Eckliff circulators.

The pumping machinery, consisting of two compound engines, one for each dredging pump, is placed athwartship at a higher level above the engine room floor.

The principal dimensions of the dredge "Comstock" are as follows:

The Principal Dimensions of "Comstock".

L.B.P.	155' 10"
L.O.A.	163' 10"
Beam Moulded	35' 0"
Beam at L.W.L.	35' 0"
Depth moulded at side	17' 0"
Depth	17' 0"
Draft Loaded	14' 6"
Light Draft	10' 8"
Load Displacement	1600 tons.
Light Displacement	1056 tons.
Wetted Surface, Loaded	8075 sq.ft.
Wetted Surface, Light	6282 sq.ft.
Diam. of H.P. Cylinder, Propelling Engine	18"
Diam. of L.P. Cylinder, Propelling Engine	36"
Stroke of Propelling Engine	24"
Diameter of Piston Rod, Propelling Engine	3-11/16"
Diameter of H. P. Cylinder, Pumping Engine	11"

Diameter of L.P. Cylinder, Pumping Engine	22"
Stroke of Pumping Engine	14"
Diameter of Piston Rod, Pumping Engine	2-13/32"
Diameter of Propeller	8' 6"
Pitch of Propeller	11' 0"
Number of Blades	4
Developed Area	31.234 sq.ft.
Projected Area	24.520 sq.ft.
Swept Area	56.745 sq.ft.
Pitch Ratio	1.292
Projected Area Ratio	0.432

The Scope of the Thesis.

The acceptance trials of the dredge Comstock consist of

1° Progressive Speed Trials,

2° Pumping Engine Tests,

3° Inclining Experiment.

Except the last trial mentioned above, the others were prepared in advance and attained by Messrs. P.T. Mar and T. Yuen and the writers of this thesis under the supervision of Professor Everett and with the assistance of Mr. Burtner. The thesis here presented is, however, only on the progressive speed trials.

Sequence of Trials.

In the preliminary trial at the yard of the Ellicott Machine Corporation, the stern tube bearings were found so tight as to hinder the propeller shaft from turning, and the ship had to be docked. After the docking, the boat left for Annapolis on July 21, 1915.

On the way, the indicator cards of all the engines were taken in order to familiarize the men with their respective positions. The results of this run were, of course, not used in the final computation. Upon the arrival the hoppers were loaded.

Next morning, July 22nd., the dredge under loaded conditions proceeded to the measured course for its progressive speed trials. Eight runs (Runs Nos. 1 - 8 inclusive) were made, four with and four against, the tide and wind.

During each run, indicator cards for both H.P. and L.P. cylinders were taken simultaneously as many as possible, and the revolutions were recorded by means of an Everett Recording Chronograph placed in the pilot house.

The boiler pressure, the receiver pressure, and

the vacuum in the condenser were all taken both at beginning and at end of each run.

Upon the termination of the loaded speed trials, the hoppers were dumped and the light speed trials then took place. Eight runs (Run Nos. 1-8 inclusive) were made, four with, and four against, the tide and wind. These runs were conducted exactly under the same condition as the loaded runs.

Progressive Speed Trials.

See Tables I - XIV inclusive and PlatesI - VIII inclusive.

The observations taken on these trials are as follows:

1. Indicator cards of propelling engine.
2. Time on course by stop-watch.
3. R.P.M. by chronograph.
4. Note of direction of wind and tide.

The above data and the results computed therefrom are shown in the following tables and plates.

Table I - M.E.P. for all cards of odd numbered runs of loaded trials.

Table II - M.E.P. for all cards of even numbered runs of loaded trials.

Table III - M.E.P. for all cards of odd numbered runs of light trials.

Table IV - M.E.P. for all cards of even numbered runs of light trials.

Tables V & VI- Gage reading for loaded and light trials.

Tables VII & VIII - Reduced M.E.P. of loaded and light speed trials.

Tables IX & X - Reduced M.E.P., R.P.M., I.H.P. and corresponding speeds for loaded and light trials.

Tables XI & XII - Time on course, current, wind, R.P.M. and speeds.

Tables XIII & XIV - Analyses of loaded and light trials.

Plates I & II - Curves of M.E.P. on speed for loaded and light trials. The resultant curves were used for analyses.

Plates III & IV - Curves of R.P.M. on speed for loaded and light speed trials. The resultant curves were used for the analyses. Curves of total I.H.P. on speed.

Plates V & VI - Curves showing distribution of power for loaded and light trials.

Plate VII - Real slip - Propeller efficiency curve plotted from Professor Peabody's table to estimate the propeller efficiency of the dredge Comstock.

Plate VIII - Midship Section.

Analyses of Progressive Speed Trials of Dredge "Comstock"

The analyses of the progressive speed trials were made according to the method used in Professor Peabody's "Naval Architecture". In the Tables XIII and XIV, the speeds (line 1) were taken at integral knots and the corresponding R.P.M. (line 2) and I.H.P. (line 3) were read from Plates III and IV for loaded and light speed trials respectively. In determining the initial friction H.P. (line 4) an initial friction pressure of 1.7 pounds per square inch was assumed, this value being chosen because it commonly lies between 1.5 to 2.0 pounds. At zero speed of the plot of the M.E.P. curve, this pressure was found as the most probable one and, therefore, used in the final computations.

Assuming a mechanical efficiency of 90 per cent at full speed, there will be a loss of

(1 - 0 . 90) X 730 = 73.0 I.H.P. at 8-1/2 kts. for loaded speed trials.

and (1 - 0.90) X 687.8 = 68.8 I.H.P. at 9-1/2 kts. for light speed trials.

The load friction power at full speed is

73.0 - 25.9 = 47.1 H.P. at 8-1/2 kts. for loaded speed trials, and

68.8 - 25.5 = 43.3 H.P. at 9-1/2 kts. for light speed trials.

The load friction power (line 5) at other speeds was obtained by multiplying the difference of the total I.H.P. and initial friction power by the ratio:-

47.1 ÷ (730 - 25.9) = 0.0668 for loaded speed trials, and

43.3 ÷ (688 - 25.5) = 0.065 for light speed trials.

The shaft H.P. (line 6) was found by subtracting the sum of the initial and load friction power (lines 4 and 5) from the indicated horse power (line 3).

The apparent slip (line 7) was computed from the equation

$$1 - s_1 = \frac{101.3\ V}{pr}$$

where s_1 is the apparent slip, V the speed of the ship in knots, p the pitch of the propeller in feet, and r the R.P.M.

The real slip was calculated from the equation

$$1 - s = (1 - s_1)(1 - w)$$

where s is the real slip, s_1 the apparent slip and w the wake factor.

In estimating the wake factor of the slip, various methods were tried.

With a block coefficient of 0.708 for the dredge Comstock, the wake factor was found to be 0.279 from the equation:-

$$w = 0.20 + (\text{Block Coefficient} - 0.55)$$
$$= 0.20 + (0.708 - 0.55)$$
$$= 0.279$$

This was considered much more than the proper wake.

According to Luke's latest experiment, the wake factor for this boat is 0.23, which, although agreeing fairly well with that found in the previous case, was also considered excessive.

In addition the method used by Professor C.H. Peabody in his book "Naval Architecture" page 542 was also tried. According to this a wake factor of 0.10 gives a fair concordance with the performance of the propeller. This value was finally used in the computation of the real slip for the loaded speed

trials. However, in the analysis of the light speed trials, a higher value of 0.12 for w was used.

Knowing the values of projected area ratio, pitch ratio and real slip, the propeller efficiency might be taken from Professor Peabody's table at once. Unfortunately the value of real slip was beyond the range of the table. For this reason a curve (Plate VII) was plotted from the values given by Professor Peabody's Table. From this curve the propeller efficiency (line 9) was estimated as 55 per cent for loaded, and 60 per cent for light, speed trials.

The product of the propeller efficiency and S.H.P. gives us the propeller power (line 10).

Assuming a hull efficiency of unity the E.H.P. (line 11) is numerically equal to the propeller power.

The skin friction power (line 12) of the ship was calculated from the formula:

$$F.H.P. = 0.00307\ f\ s\ v^{n+1}$$

where s is the wetted surface in square feet†

and v is the speed of the ship in knots.

f = 0.00957 and n = 1.829 are taken from Tideman's Table.*

*Professor Peabody's Naval Architecture, p. 407.

†See next page.

The residual H.P. (line 13) is computed by taking the difference between E.H.P. and F.H.P.

The last line (line 14) in the table is the speed length ratio, that is, the ratio of speed in knots to the square root of the length of the ship in feet.

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† The wetted surface used in the computation was calculated with great precision by means of Taylor's method. It may be interesting to compare the accuracy of different formulas with Taylor's method.

The following table shows the error of the different formulas when applied to this particular boat.

Method used.	Wetted Surface in sq. feet.		Percentage Error.	
			Loaded	Light
	Loaded	Light		
Taylor's Method	8075	6282	0	0
Taylor's Formula	7930	6370	- 1.79	+ 1.40
Normand's Formula	8040	6420	- 0.370	+ 2.20
Mumford's Formula	8170	6270	+ 1.17	- 0.19

TABLE I

M.E.P. for Loaded Speed Trials.

Run and Card	High		Low		
	H.E.	C.E.	H.E.	C.E.	R.P.M.
1-1	33.3	35.6	7.15	7.30	
3	33.4	35.5	6.96	7.29	
5	33.4	33.8	6.98	7.32	
Average	33.4	35.0	7.03	7.30	67.0
3-1	50.2	60.7	10.9	12.0	
3	58.4	60.8			
5	59.7	62.9	11.4	12.5	
Average	56.1	61.5	11.2	12.3	90.0
5-1	75.0	77.2	15.4	16.6	
3			15.2	16.5	
5	75.2	79.8	15.5	16.3	
Average	75.1	78.5	15.3	16.5	103.8
7-1					
3	93.8	97.6	21.7	22.2	
5	94.0	95.2	20.9	22.0	
Average	93.9	96.1	21.3	22.1	117.5

TABLE II

M.E.P. for Loaded Speed Trials

Run and Card	High		Low		
	H.E.	C.E.	H.E.	C.E.	R.P.M.
2-1	32.8	38.6	6.72	7.02	
3	34.5	35.8	6.68	6.87	
5	37.5	41.9	7.07	7.48	
Average	34.9	38.8	6.82	7.12	70.0
4-1	53.6	64.2	11.6	12.5	
3	58.0	60.5	11.8	12.3	
Average	55.8	62.4	11.7	12.4	91.5
6-1	78.4	80.2	15.7	16.1	
3	75.4	75.8	15.4	15.5	
5	76.4	78.6	14.9	16.1	
Average	76.7	78.2	15.3	15.9	105.0
8-1					
3	87.6	93.3	20.9	21.4	
5	90.1	92.9	20.9	21.8	
Average	88.8	93.1	20.9	21.6	114.5

TABLE III

M.E.P. for Light Speed Trials

Run No.1	High		Low		
Card No.	H.E.	C.E.	H.E.	C.E.	R.P.M.
1	36.70	38.45	6.17	6.85	
3	36.25	37.85	8.04	8.21	
5	36.90	38.20	7.70	8.02	
Total	109.85	114.50	21.91	23.08	
Average	36.62	38.17	7.30	7.69	74.14

Run No.3	High		Low		
Card No.	H.E.	C.E.	H.E.	C.E.	R.P.M.
1	53.80	58.70	9.97	10.43	
3	53.15	57.80	9.85	10.66	
5	53.60	56.70	9.85	10.26	
Total	160.55	173.20	29.67	31.35	
Average	53.52	57.73	9.89	10.45	89.73

Run No.5	High		Low		
Card No.	H.E.	C.E.	H.E.	C.E.	
1	70.60	76.10	13.80	15.45	
3	70.40	76.30	14.50	15.20	
5	72.00	75.80	17.27	15.35	
Total	213.00	228.20	45.57	46.00	
Average	71.00	76.07	15.19	15.33	104.1

Run No.7	High		Low		
Card No.	H.E.	C.E.	H.E.	C.E.	R.P.M.
1	92.80	94.75	20.63	21.62	
3	91.75	92.20	20.55	21.45	
5	89.70	92.30	23.62	24.50	
Total	274.25	279.25	64.81	67.57	
Average	91.42	93.08	21.60	22.52	121.30

TABLE IV

M.E.P. for Light Speed Trials.

Run No. 2.	High		Low		
Card No.	H.E.	C.E.	H.E.	C.E.	R.P.M.
1	37.65	38.35	7.51	9.43	
3	36.55	38.90	7.21	7.30	
5	36.85	38.40	7.10	6.85	
Total	111.05	115.65	21.82	23.58	
Average	37.01	38.55	7.27	7.86	74.63

Run No.4	High		Low		
Card No.	H.E.	C.E.	H.E.	C.E.	R.P.M.
1	52.92	55.50	9.79	10.35	
3	53.70	57.10	9.92	10.52	
5	54.35	58.70	10.23	10.78	
Total	160.95	171.30	29.94	31.65	
Average	53.65	57.10	9.98	10.55	90.20

Run No.6	High		Low		
Card No.	H.E.	C.E.	H.E.	C.E.	R.P.M.
1	72.40	77.30	14.70	15.37	
3	71.30	76.50	14.38	15.30	
5	69.60	75.25	---	---	
Total	213.30	229.05	29.08	30.67	
Average	71.10	76.35	14.54	15.34	106.60

Run No.8	High		Low		
Card No.	H.E.	C.E.	H.E.	C.E.	R,P,M.
1	91.90	93.75	20.88	21.30	
3	90.25	91.50	20.55	21.20	
5	90.50	91.65	20.65	21.28	
Total	272.65	276.90	62.08	63.78	
Average	90.88	92.30	20.69	21.26	121.30

General Data for Speed Trials.

TABLE V

Loaded Speed Trials.

Run No.	Boiler Room Gage Lbs.	Engine Room Gage Lbs.	Condenser Vacuum Ins.	Receiver Lbs.
1	152.7	144.2	22.75	0
2	154.3	144.3	22.75	0
3	150.5	140.0	24.50	6.0
4	151.0	140.0	24.00	6.0
5	150.5	141.1	24.00	8.5
6	149.5	140.5	24.00	11.0
7	150.5	139.0	23.00	19.0
8	151.1	139.0	23.00	19.0

TABLE VI

Light Speed Trials.

Run No.	Boiler Room Gage Lbs.	Engine Room Gage Lbs.	Condenser Vacuum Ins.	Receiver Lbs.
1	151.5	143.0	23.9	0.8
2	153.0	143.5	24.8	0.0
3	149.5	140.0	25.3	4.0
4	145.5	140.0	25.3	4.3
5	150.0	140.0	25.6	10.0
6	152.0	142.0	25.5	10.0
7	150.0	138.5	24.8	18.0
8	152.0	140.0	24.8	18.0

TABLE VII

Reduced M.E.P. for Loaded Speed Trials.

Run No.	High H.E.	High C.E.	Low H.E.	Low C.E.	Reduced M.E.P.
1	8.38	8.42	7.07	7.26	15.57
2	8.76	9.32	6.86	7.08	16.01
3	14.09	14.80	11.26	12.22	26.18
4	14.01	15.01	11.76	12.32	26.55
5	18.86	18.88	15.38	16.40	34.76
6	19.26	18.81	15.38	15.80	34.63
7	23.59	23.11	21.50	21.98	45.59
8	22.30	22.40	21.01	21.48	43.60

TABLE VIII

Reduced M.E.P. for Light Speed Trials.

Run No.	High H.E.	High C.E.	Low H.E.	Low C.E.	Reduced M.E.P.
1	9.21	9.19	7.34	7.65	16.70
2	9.30	9.29	7.31	7.82	16.86
3	13.46	13.90	9.94	10.39	23.85
4	13.49	13.75	10.03	10.49	23.88
5	17.85	18.32	15.27	15.25	33.35
6	17.88	18.38	14.61	15.25	33.06
7	22.98	22.41	21.71	22.41	44.76
8	22.85	22.22	20.80	21.15	43.51

TABLE IX

Reduced M.E.P., R.P.M., I.H.P., and Corresponding Speeds.

Run No.	M.E.P.	R.P.M.	I.H.P.	Speed-kts.
1	15.57	67.0	128.1	3.83
2	16.01	70.0	137.6	5.34
3	26.18	90.0	289.1	5.64
4	26.55	91.5	298.7	6.63
5	34.76	103.8	443.0	6.73
6	34.63	105.0	446.9	7.60
7	45.59	117.5	656.1	7.78
8	43.60	114.5	612.7	8.64

TABLE X

Reduced M.E.P., R.P.M., I.H.P., and Light Speed Trials.

Run No.	M.E.P.	R.P.M.	I.H.P.	Speed
1	16.70	74.13	152.0	5.46
2	16.86	74.63	154.3	6.31
3	23.85	89.73	262.3	6.58
4	23.88	90.20	264.1	7.63
5	33.35	104.10	425.7	7.64
6	33.06	106.60	432.2	9.05
7	44.76	120.30	660.1	8.63
8	43.51	121.30	647.2	10.11

TABLE XI

Loaded Speed Trials.

Run No.	Time on Course.	Current.	Wind.	R.P.M.	Speed.
	Min. - Sec. Min.				
1	15 - 40.40 15.67	Against	Against	67.0	3.83
2	11 - 14.40 11.40	With	With	70.0	5.34
3	10 - 37.80 10.58	Against	Against	90.0	5.64
4	9 - 2.40 9.04	With	With	91.5	6.63
5	8 - 54.40 8.96	Against	Against	103.8	6.73
6	7 - 53.20 7.87	With	With	105.0	7.60
7	7 - 43.0 7.72	Against	Against	117.5	7.18 ?
8	6 - 56.15 6.94	With	With	114.5	8.64

TABLE XII

Light Speed Trials.

Run No.	Time on Course.	Current.	Wind.	R.P.M.	Speed.
	Min. - Sec. Min.				
1	10 - 59.4 10.990	Against	Against	74.13	5.46
2	9 - 31.0 9.517	With	With	74.63	6.31
3	9 - 6.4 9.016	Against	Against	89.73	6.58
4	7 - 51.8 7.864	With	With	90.20	7.63
5	7 - 50.8 7.847	Against	Against	104.10	7.64
6	6 - 37.8 6.630	With	With	106.60	9.05
7	6 - 57.4 6.957	Against	Against	120.30	8.63
8	5 - 56.0 5.934	With	With	121.30	10.11

TABLE XIII

Analysis of Loaded Speed Trials.

1	Speed in Knots	4	5	6	7	8	8-1/2
2	R.P.M.	58.1	73.0	87.5	102.2	117.0	124.3
3	I.H.P.	93.5	164.9	268.5	414.5	611.0	730.0
4	Initial Frict. H.P.	12.1	15.3	18.3	21.4	24.4	25.9
5	Load Friction H.P.	5.05	10.1	16.7	26.3	39.2	47.1
6	Shaft H.P.	76.3	139.5	233.5	366.8	547.4	657.0
7	Apparent Slip	0.366	0.369	0.369	0.369	0.370	0.370
8	Real Slip	0.432	0.432	0.432	0.432	0.432	0.432
9	Esti. Prop. Eff.	0.55	0.55	0.55	0.55	0.55	0.55
10	Propeller Power	42.0	76.8	129.1	202.0	301.5	362.0
11	Effective H.P.	42.0	76.8	129.1	202.0	301.5	362.0
12	Friction H.P.	11.9	22.4	37.4	57.9	84.5	104.8
13	Residual H.P.	30.1	54.4	91.7	144.1	217.0	257.2
14	Speed-Length Ratio	0.32	0.40	0.48	0.56	0.64	0.68

TABLE XIV

Analysis of Light Speed Trials.

1	Speed in Knots	5	6	7	8	9	9-1/2
2	R.P.M.	63.1	75.8	88.6	101.9	115.6	122.6
3	I.H.P.	102.0	161.8	249.4	375.0	565.0	687.8
4	Initial Frict. H.P.	13.2	15.8	18.5	21.2	24.1	25.5
5	Load Frict. H.P.	5.8	9.6	15.1	23.2	35.4	43.3
6	Shaft H.P.	83.0	136.4	215.8	330.6	505.5	619.0
7	Apparent Slip	0.270	0.271	0.273	0.277	0.283	0.287
8	Real Slip	0.358	0.358	0.360	0.364	0.369	0.392
9	Esti. Prop. Eff.	0.602	0.602	0.602	0.600	0.588	0.588
10	Propeller Power	50.0	82.1	129.9	198.4	297.2	364.0
11	Eff. H.P.	50.0	82.1	129.9	198.4	297.2	364.0
12	Friction H.P.	17.1	28.6	43.2	64.5	87.8	105.5
13	Residual H.P.	32.9	53.5	86.7	133.9	209.4	258.5
14	Speed-Length Ratio	0.402	0.482	0.562	0.643	0.723	0.763

ENGINE H SPRING 80

RUN No. 6 CARD No. 5

Trial G

A = 3.19
L = 3.67
M.E.P = $\frac{3.19}{3.67} \times 80 = 69.53$

A = 3.41
L = 3.67
M.E.P = $\frac{3.45}{3.67} \times 80 = 75.20$

ENGINE L SPRING 10

RUN No. 3 CARD No. 1

Trial G

A = 3.69
L = 3.70
M.E.P = $\frac{3.69}{3.70} \times 10 = 9.97$

A = 3.86
L = 3.70
M.E.P = $\frac{3.86}{3.70} \times 10 = 10.43$

ENGINE..H..SPRING..60..

RUN No..3..CARD No..3..

Trial F

H.E. A = 370
L = 372

M.E.P.
$= \frac{370}{372} \times 60$
$= 59.7$

C.E. A = 3.90
L = 3.72

M.E.P
$= \frac{3.90}{3.72} \times 60$
$= 62.90$

ENGINE..L..SPRING..30..

RUN No..5..CARD No..3..

Trial F

H.E. A = 270
L = 362

M.E.P
$= \frac{270}{362} \times 30$
$= 14.9$

C.E. A = 393
L = 362

M.E.P
$= \frac{393}{362} \times 30$
$= 16.10$

Sample Chronograph Record

START

Run #4

R.P.M. = 89.2 (Run #4)

R.P.M. = 89.9 (Run #4)

R.P.M. = 91.5 (Run #4)

FINISH

PLATE II

Light Speed Trials

Curves showing

M.E.P. — Knots per hour

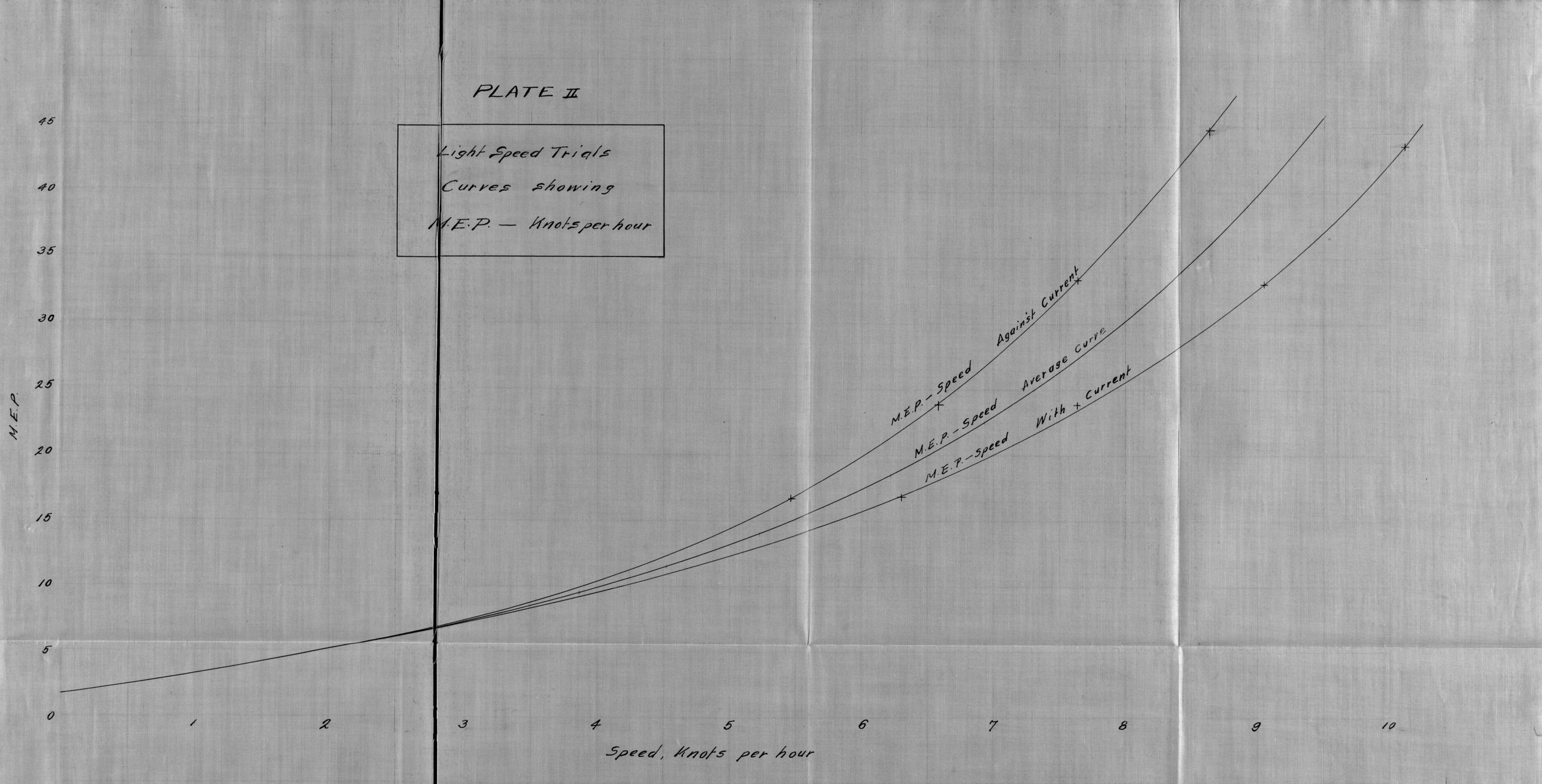


PLATE III

Loaded Speed Trials
Curves showing
Revs. per min. — Knots per hour
Total I.H.P. — Knots per hour

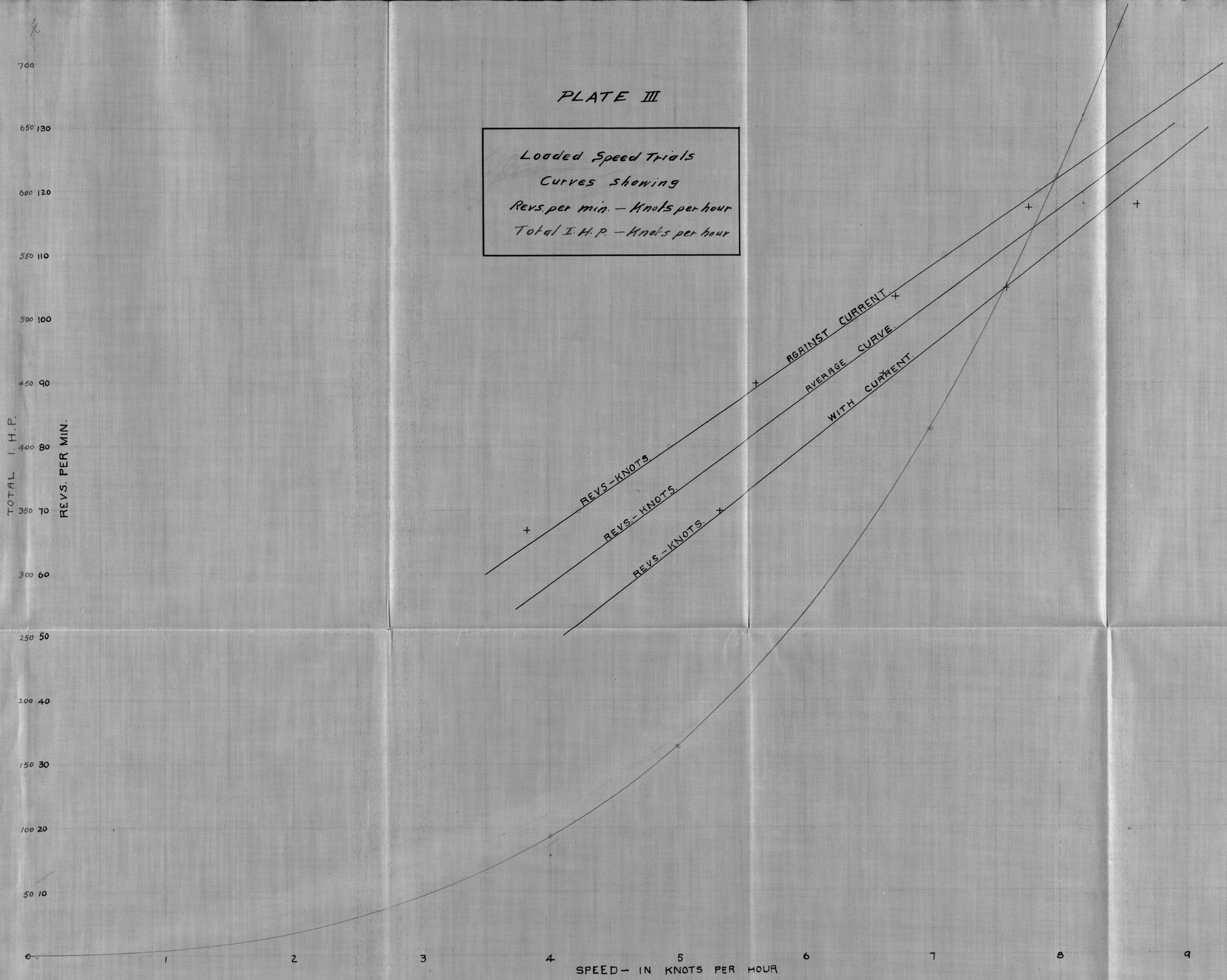


PLATE IV

Light Speed Trials
Curves showing
Revs. per min. — Knots per hour
Total I. H. P. — Knots per hour

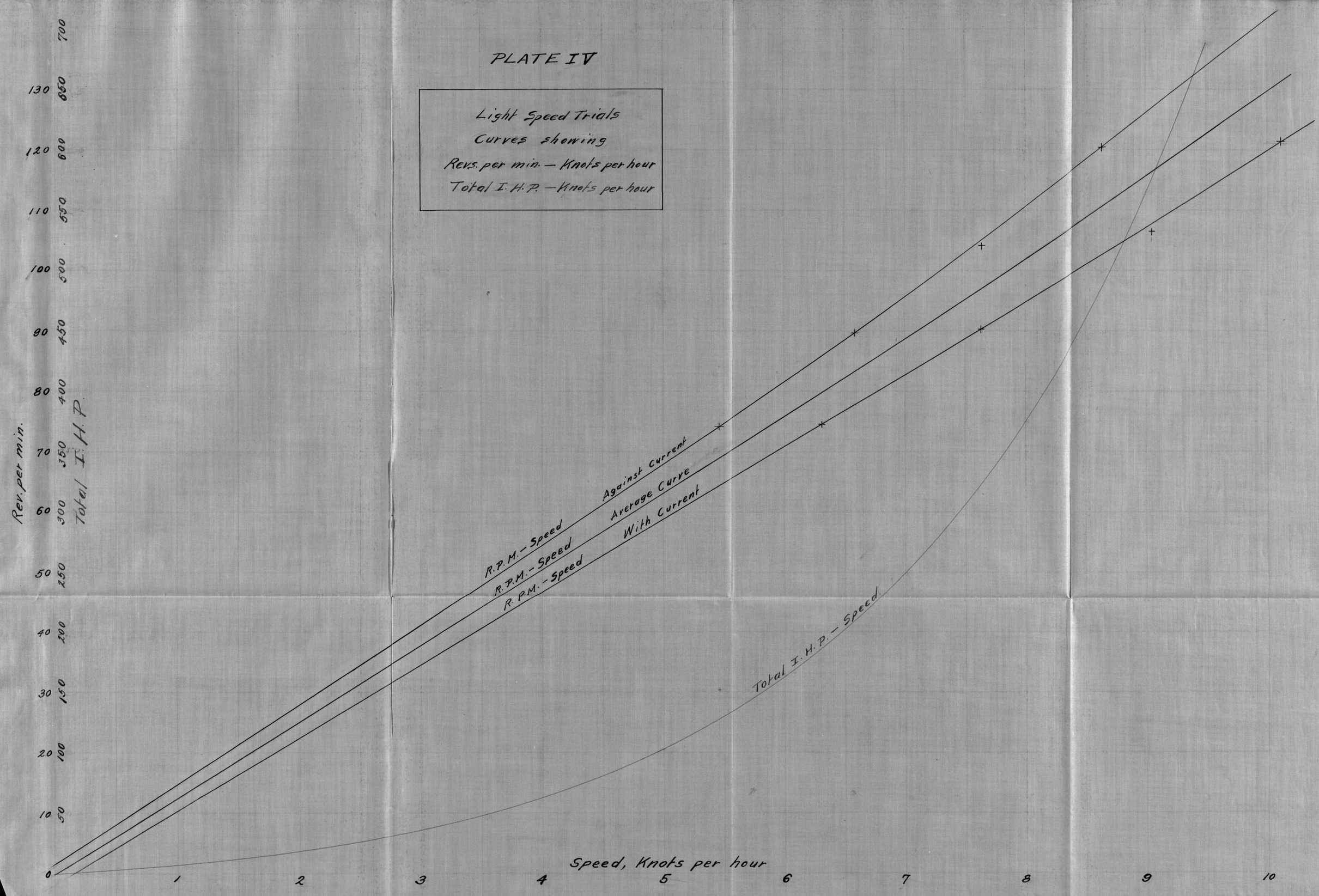


PLATE V.

Loaded Speed Trials

Curves Showing

Distribution of Power.

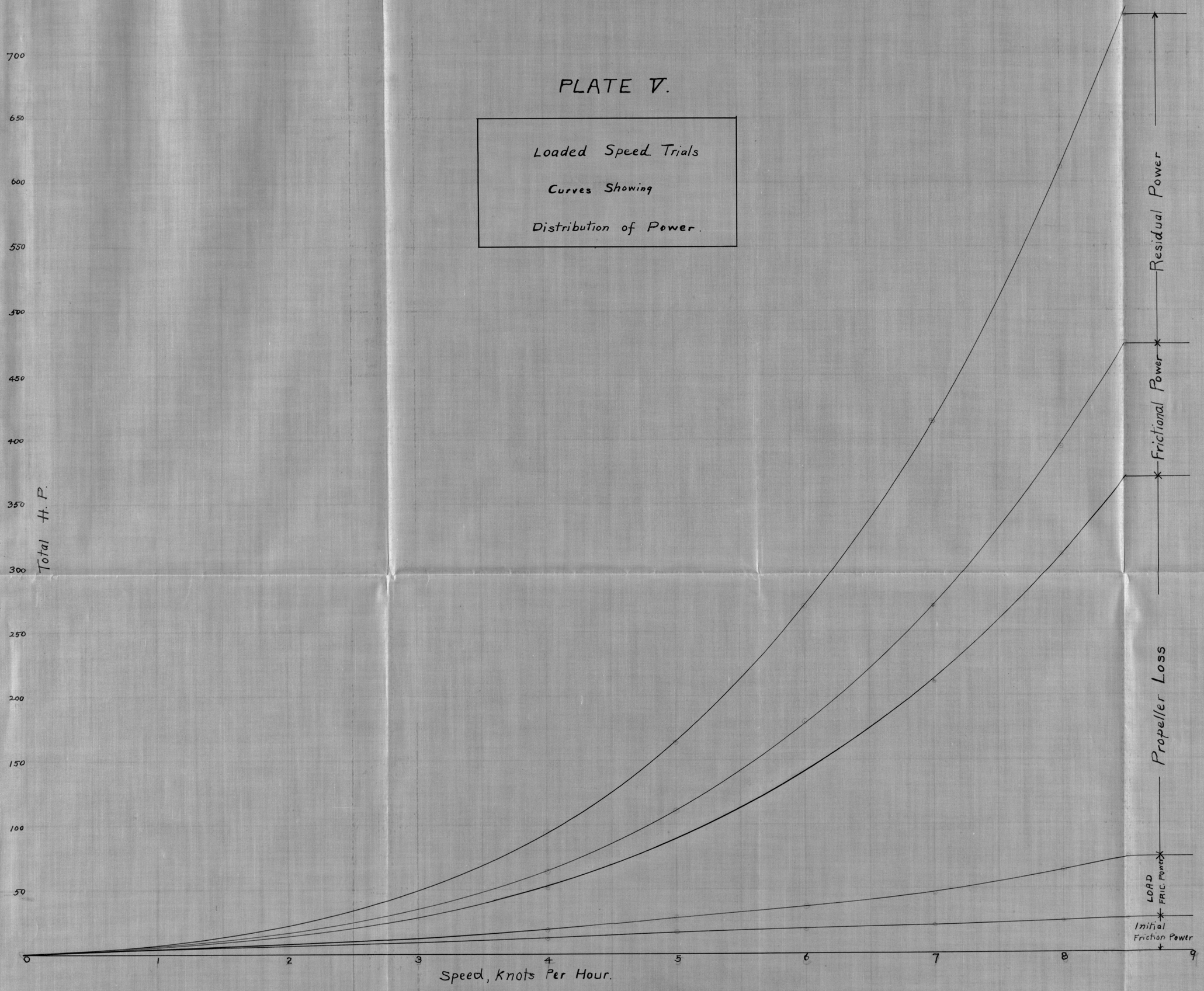


PLATE VI

Light Speed Trials

Curves showing

Distribution of Power

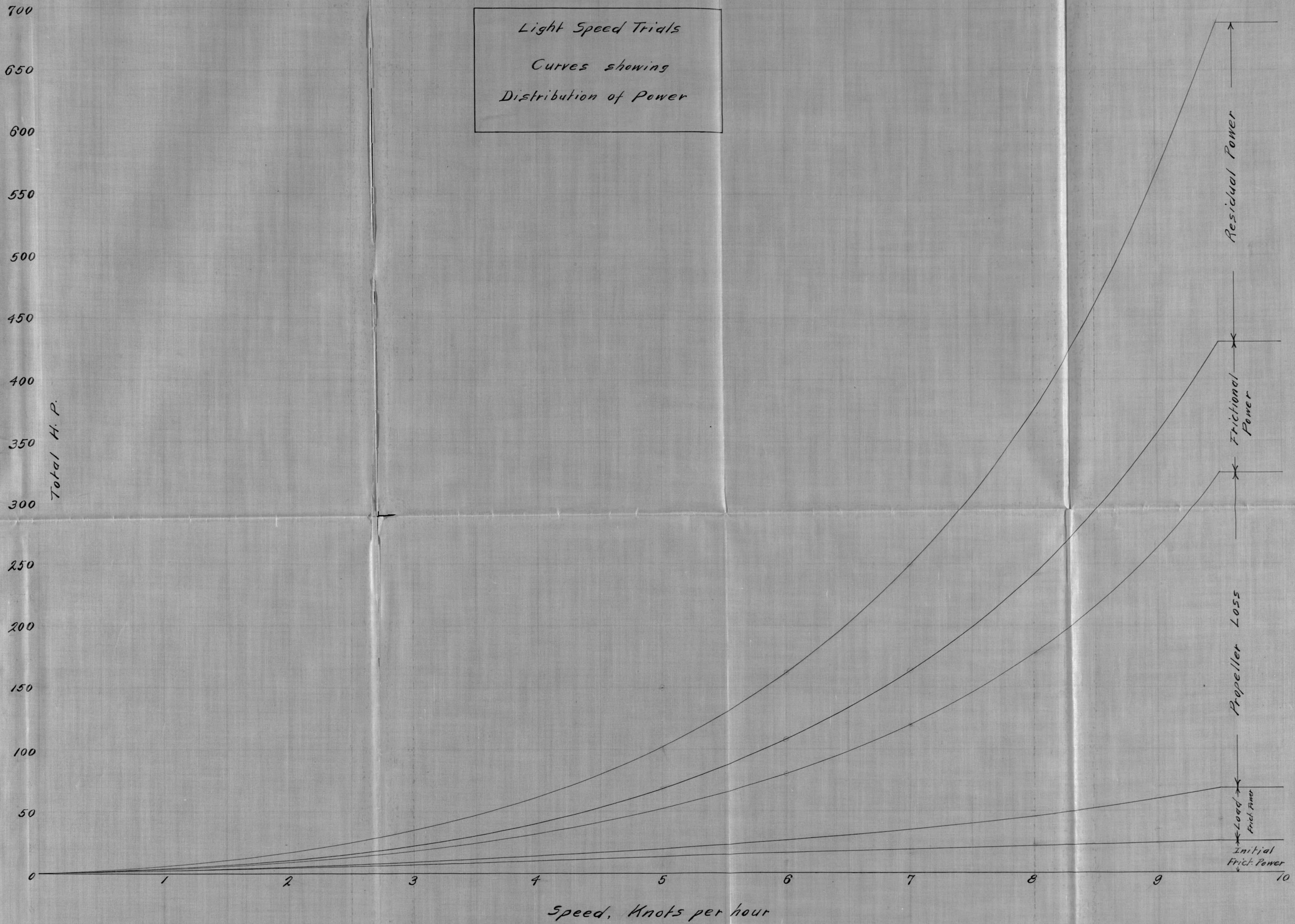
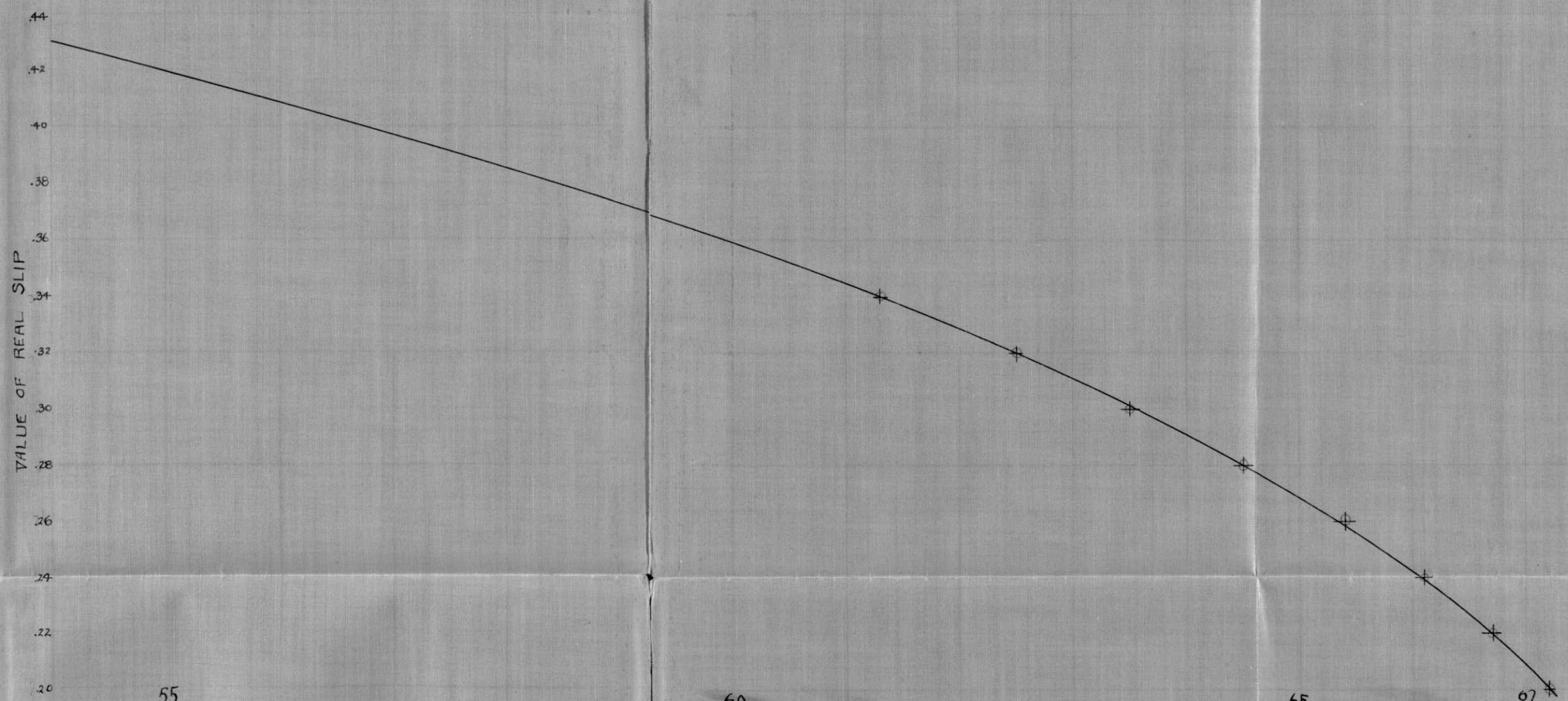
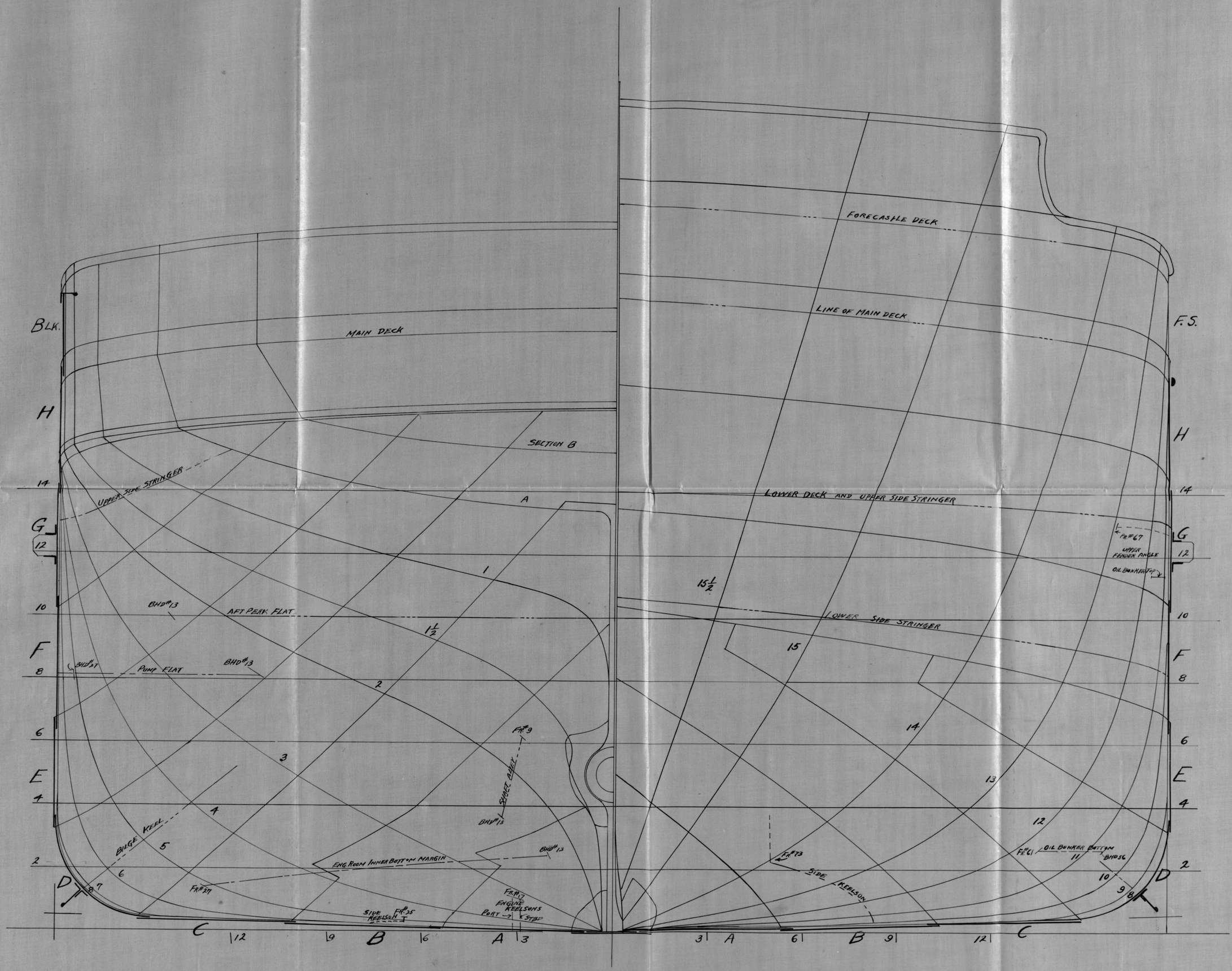


PLATE VII



PROPELLER EFFICIENCY INTERPOLATED FROM PEABODY'S TABLE.

PLATE VIII



BODY PLAN OF DREDGE COMSTOCK

SCALE ½" = 1'