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NAVY YARD, WASHINGTON, D.C.

REPORT AND ANALYSIS OF STANDARDIZATION TRIALS

S. S. BLACK FALCON

3 SEPTEMBER, 1932

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Abstract.

This report describes the circumstances leading up to the standardization trials of the S.S. BLACK FALCON, the apparatus used for making observations, the procedure and details of the trials, and gives the original data obtained by all the observers.

The data are analyzed by two different methods, to reduce the ship performance to standard conditions, and estimated corrections are made to allow for shaft friction and increase in frictional resistance due to fouling. The corrected shaft horsepowers for the ship are slightly higher than the powers predicted from model tests, although the revolutions are in good agreement.

Introduction.

The S.S. BLACK FALCON is one of a group of six Hog Island Type "A" vessels belonging to the Black Diamond Steamship Corporation, which were altered to increase their loaded sea speed to 13 knots, as required by the terms of the mail contract held by the owners. Fig. 1 is a photograph of the vessel taken on trial after conversion.

The Type "A" Hog Island vessels are single-screw cargo carriers, built during the World War for a loaded sea speed of about 11 knots, having the following approximate dimensions:-

Length	390 ft.	Draft	24 ft. 4 in.
Beam	54 ft.	Displacement	11,180 tons.

The alterations made to these vessels were of particular interest because they included not only an increase in power effected by certain changes to the propelling machinery common to numerous vessels of this type in the hands of other owners but a definite attempt to reduce ship resistance and ship power by extensive changes in the stern. There were varying opinions among naval architects as to the necessity for and the economic value of the drastic and rather costly hull changes undertaken, hence it was important that the performance of the converted vessels be accurately determined. Unfortunately, it was not possible to conduct trials on any vessel of the class <u>before</u> conversion.

The alterations developed and carried out by the Black Diamond Steamship Corporation were considerably more extensive than the modifications which had been made to several vessels of the type belonging to other owners, in which fairing plates and contra-rudder devices were added around the propeller aperture without disturbing the basic ship structure.

The alterations on the Black Diamond vessels included the removal of the original wide, blunt-ended sternpost and its replacement by a new sternpost of thin sections, well faired into the modified stern structure; the replacement of the original thick, built-up rudder by a streamlined spade rudder, underhung from an extension to the stern abaft the old rudder post; the shifting of the rudder stock aft, and the propeller with it, to obtain a better water flow to the propeller; and, lastly, the fitting of a new propeller of modern design. The general shape of the modified stern, with propeller and rudder, is shown in Fig. 2.

In addition, the leading edges of all outside butt straps on the keel and on the "bilge" strakes were chamfered, partly by welding in the fillet and partly by chipping the corners. The trailing edges of the same plates were chamfered by chipping the corners only. The bilge keels were cut back to the toes of the shell angles for their entire length.

The sides of the vessels were scaled to bare metal, but at the time of the trials of the BLACK FALCON, the paint coating was peeling off (down to the steel) above and below the water line in numerous patches and hanging to the side.

The propeller fitted was of a new design, having characteristics especially suited to the increased power and speed expected from the ships of this class. It was a solid, 4-bladed, manganese bronze wheel, with variable pitch (increasing from 9 ft. 2 in. at 0.2 radius to 14 ft. 10-1/2 in. at the tip) and airfoil sections. Its characteristics are as given in Fig. 6. The propeller was carefully measured before installation and was found to be in reasonable agreement with the designed shape and dimensions.

The terms of the agreement by which a loan was made available to the owners for making these changes required for one vessel of the class "A loaded sea trial to Rockland, Maine, at approximately 24 ft. mean draft with about 12 in. trim by stern and approximately full power, and a set of standardization runs over the measured mile off Rockland, Maine, three runs to be made at each speed of eight, ten, eleven, twelve, thirteen knots, and a maximum speed."

The owners, having no personnel or equipment for conducting the standardization trials, arranged through the U.S. Shipping Board and the U.S. Navy Department for the loan of the necessary instruments and personnel from the U.S. Experimental Model Basin. The trials were carried out under the supervision of an officer from the Model Basin staff, assisted by representatives of the Federal Shipbuilding and Dry Dock Company (who had executed the conversion program), the U.S. Navy Department, the U.S. Shipping Board, the Experimental Model Basin and the owners.

Trial Conditions and Schedule.

The vessel had been loaded with cargo, fuel and water, especially for this trial, to bring her as near to the required displacement as possible. The re-

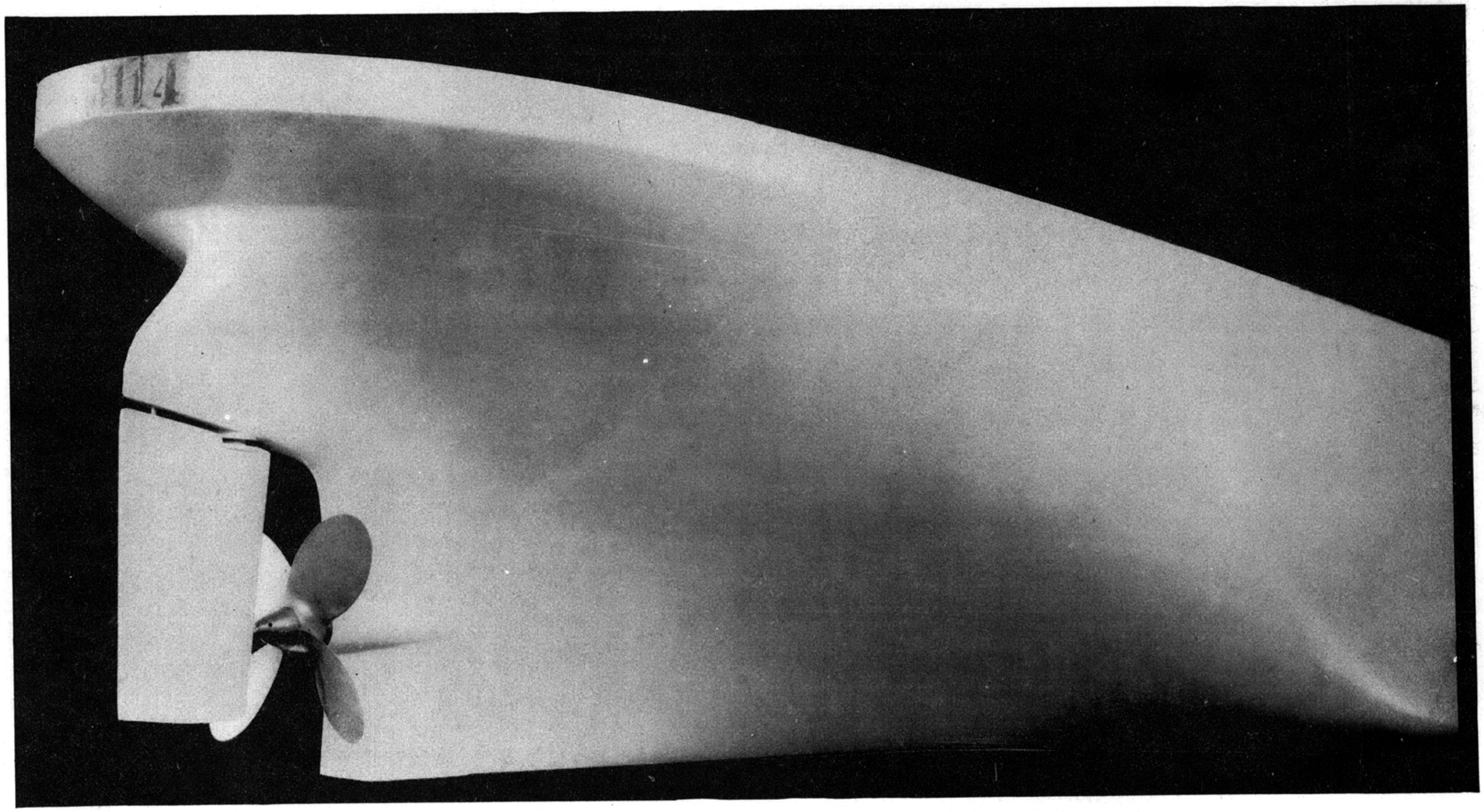

FIG. 2. STERN OF MODEL SHOWING STREAMLINE RUDDER AND NEW PROPELLER.

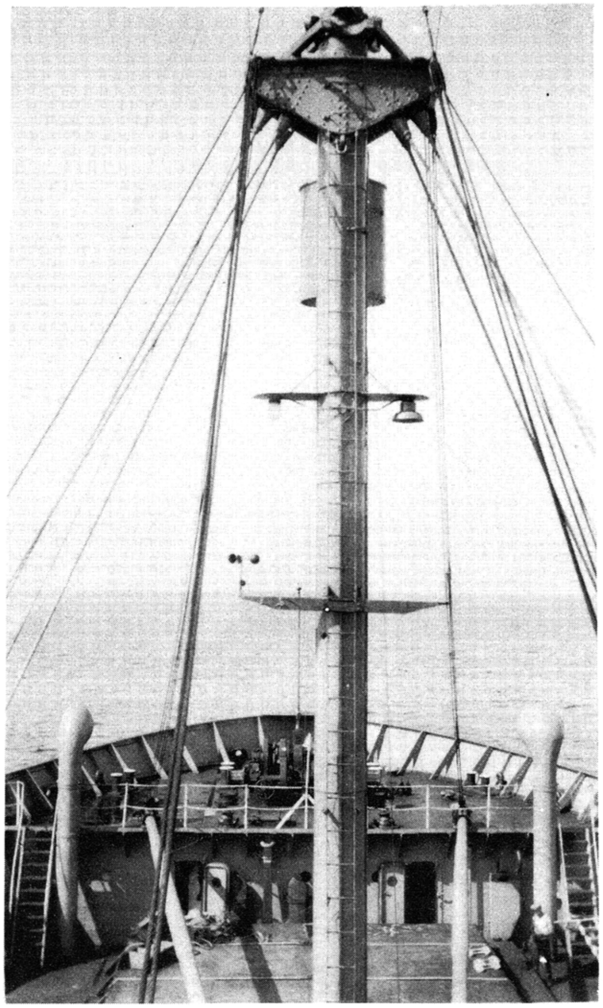

FIG. 3

3-Cup Anemometer and Win

Direction Indicator Moun

on Cross Arm of Foremast.

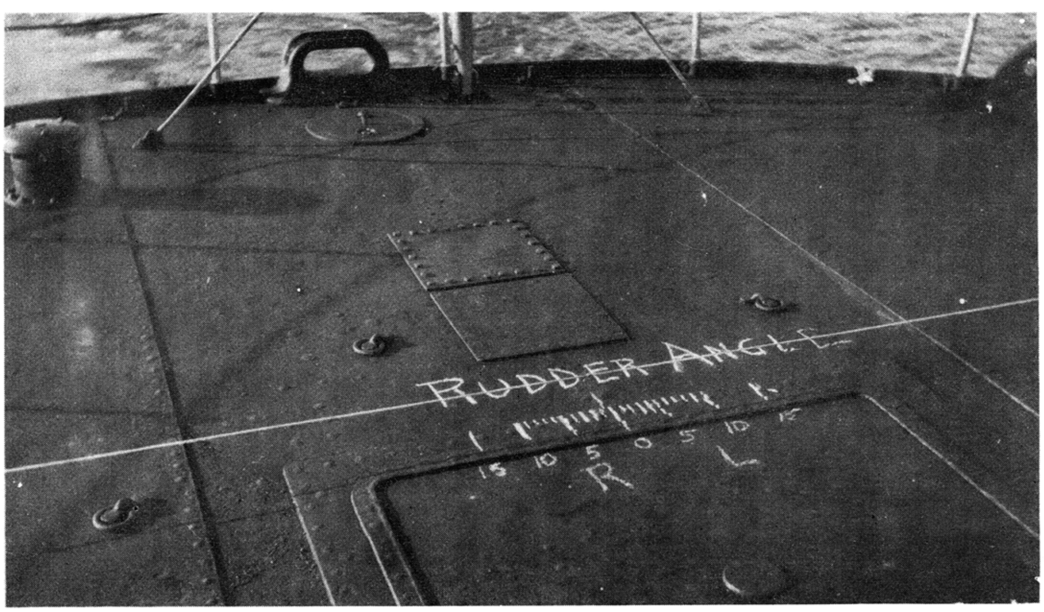

FIG. 8 Improvised Rudder Angle Indicator on Poop Deck.

quired and actual trial conditions are given in the following table:-

	Required	Actual
Displacement . .	11,200 ts.	11,112
Draft, Ford . .	23 ft. 6 in. . . .	23 ft. 3 in.
Mean . .	24 ft. 0 in. . . .	23 ft. 10 in.
Aft . .	24 ft. 6 in. . . .	24 ft. 5 in.
Trim, by stern . .	12 in.	14 in.
Specific gravity of sea water		1.0244
Temperature of sea water		58 deg. F.

Six spots on the standardization curves were to be established, by three runs each at the following revolutions per minute: 60, 72, 81, 88, 95 and 99.5; a total of eighteen (18) runs. It was decided just prior to the trials to omit the spot at 60 RPM and to run a spot at about 107 RPM, or at the greatest revolutions per minute that could be maintained at a constant value for three runs.

Enroute to Rockland, the vessel was operated for a period of 20 to 30 minutes at each of the above revolutions per minute, to establish the steam pressures and the nozzle openings required for these values.

During the standardization trials, steering was by hand (telemotor gear to steering engine); no gyro compass and no automatic steering equipment was installed. Five different helmsmen were at the wheel during the trials.

The vessel was in normal sea-going condition in all respects; in fact, the ship was diverted to Rockland on a regular voyage from New York to Rotterdam.

The ship had been undocked on 10 August 1932 and had been at sea for one day on builders' trials; for the remainder of the period (23 days) until 3 September, the date of the trials, the ship was lying at piers in and around New York harbor or enroute to Rockland.

During the passage from New York to Rockland, the stern tube bearings ran hot and noisy. Whether the trouble was in the forward bearing, due to lack of proper water circulation (steam and hot water were drawn from the shaft tube) or whether it was evidence of the shaft working itself down into its bearings in a rather forceful manner, could not be determined at the time. The squeaking noise could be eliminated by changing speed, but it persisted during the trials and could be plainly heard on the poop deck. The stern tube bearings were the cause of some anxiety later, during the passage from Rockland to Rotterdam, but since the completion of the first trip it is understood that the stern tube shaft on this vessel has run cool and normal in all respects.

The weather during the trials was fine and clear, with light breezes from the northern quadrant, shifting to the southern quadrant toward the end of the trials. It is of interest to note that this shift took place suddenly between run No. 10, north and run No. 11, south; had not routine observations of wind velocity and direction been made, it might have been unnoticed.

There was a low but perceptible swell from the open sea on the south, of sufficient magnitude to cause a periodic increase and decrease in the ship speed through the water, as indicated by the pressure log.

The tidal current, as predicted by the U.S. Coast and Geodetic Survey for the Rockland course and as shown by the curve in Fig. 5, was slack at about 6:15 a.m. E.S.T., on the day of the trials, then ran northerly with a maximum velocity of about 0.53 knot at about 9 a.m., slacked at 1 p.m. and ran southerly, reaching a maximum of 0.5 knot at about 3:50 p.m. For comparison with the trial data, it should be noted that the latter times are for daylight saving (60th meridian).

Trial Observations.

In addition to the observations to determine shaft horsepower, revolutions, and speed over the ground, common to all standardization trials, there were recorded rudder angle, instantaneous revolutions, speed and direction of apparent (relative) wind, and ship's speed through the water.

Duplicate observations of elapsed time over the measured mile were made in the usual way by means of stop watches and the Navy chronograph; in addition, elapsed times were marked by a special chronograph whose function was to record simultaneously (1) time, (2) shaft revolutions and (3) relative wind velocity.

Duplicate records of revolutions were made by a Taylor printing counter and by the special (Hamburg) chronograph; the latter recorded individual revolutions of the main shaft, for the purpose of studying variations in revolutions during the running of the mile.

Power was indicated by a Denny-Edgecombe torsionmeter mounted on the main shaft in the shaft tunnel recess just forward of the main shaft stuffing box. There was only one steady bearing on the line shaft between the torsionmeter and the stern tube bearings.

The torsionmeter zero was determined by the procedure known as dragging the shafts, shutting off the power when the ship was traveling at about half speed and allowing the flow of water to turn the propeller. Readings were taken in this manner, both ahead and astern, as long as the shafts revolved. A mean of the readings was taken as the correct zero reading, to be applied to all observed readings. The torsionmeter zeros were also determined before the trials by turning over the shafts by the (hand) jacking gear, and making readings around one complete revolution, both ahead and astern. The speed of rotation when jacking was only about one revolution in ten (10) minutes, so that the friction abaft the torsionmeter was very nearly static. Nevertheless, the zeros obtained in this manner checked remarkably well with those obtained by "coasting."

The section of line shafting carrying the torsionmeter, (the section just forward of the propeller shaft) was not calibrated with the torsionmeter in place.

The exact diameter of the (solid) shaft was used, with an assumed modulus of elasticity in torsion of 12,000,000.

Since the Denny-Edgecombe torsionmeter indicates the torque at one point in the revolution only, for any one observation, readings were taken at twelve (12) different points when the ship was underway at constant revolutions and these readings plotted on a base of observation position angle, from 0 to 360 degrees. The torsionmeter readings during the trials were taken at the angular position which indicated practically the average reading of the twelve.

Duplicate records of the velocity of the apparent (relative) wind were made by a 3-cup and a 4-cup anemometer, each operating solenoid pens on the two chronographs. Wind measurements were made on the measured mile only.

The 3-cup anemometer was mounted so low, with reference to the bridge, and so close to the foremast (see Fig. 3) as to cast some doubt upon the validity of its readings. However, since the 4-cup anemometer mounted on top of the jackstaff gave wind velocities which agreed with it on all runs within one (1) knot, the recorded values of both were considered accurate and their average was used in the trial analysis.

Relative wind direction was indicated by a wind vane mounted on the foremast, as shown in Fig. 3, in conjunction with two flags and smoke from the funnel.

Rudder angles were observed by an observer on the poop deck from an improvised indicator; see Fig. 8. Maximum angles were noted for each rudder movement during the run.

Speed <u>through the water</u> was measured by a pressure speed log (described in subsequent paragraphs) which gave two simultaneous readings of water head and equivalent pressure in the forecastle and a third reading at a distant point in the chart room.

A more complete description of the apparatus and instruments used will be found in Appendix II.

Trial Analysis.

The observed trial data and all accompanying information will be found tabulated on page 7 . The observed data have been corrected down to standard conditions of no wind and no current, by the use of the torque method and the power method.# The computations for this double analysis, in tabular form, are given on page 8 . The observed trial data were analyzed also by Schoenherr's method(2) but as the results differ only slightly from those obtained by the simpler methods, they are omitted.

The values of the coefficient k, representing the ratio of increase in

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#The operations involved in this analysis are given on page 7 ; the methods are described fully in a paper entitled "Trial Analysis Methods,"(1)* by Lt. Comdr. A.S. Pitre, (CC), U.S.N.

*Numbers in parentheses designate references at end of report.

SHEET 1

TRIAL ANALYSIS OF S. S. BLACK FALCON

GENERAL DATA

DATE OF TRIALS,	3 SEPT., 1932
LOCATION OF TRIALS,	ROCKLAND, ME.
DATE OF LAST DOCKING,	10 AUG. 1932
DAYS OUT DOCK,	24 DAYS
LOCATION OF SHIP, N.Y. HARBOR	ENROUTE TO ROCKLAND
LENGTH, FT.	390
BEAM, FT.	54

TRIAL DATA

ITEM	SHIP	MODEL
DISPLACEMENT,	11,112	11,112
DRAFT,	23'3"- 24'5"	23'3"; 24'5"
TRIM,	1'-2"	1'-2"
TEMP. OF WATER,	58°F.	75°F.
SP. G. OF WATER,	1.0244	
APPENDAGES,	RUDDER	RUDDER
MODEL NO.,		3114
TEST NO.,		13

PROPELLER DATA

DIAMETER,	17 FT.
PITCH, DESIGNED,	VARIABLE (12.55 AVE)
PITCH, MEASURED,	
NO. OF BLADES,	4
M. W. R.,	0.227
B. T. F.,	0.05
P.A./D.A.,	0.436
DIR. OF ROTATION,	R.H.
TIPS BELOW SURFACE,	6!92
NO. OF PROPELLERS,	1
MODEL NOS.,	1200

OBSERVED DATA

1 RUN N. & DIR.	2 TIME TO MIDDLE RUN	3 R.P.M. N	4 OBS. SPEED V	5 S.H.P. TOTAL	6 AVE. RUDDER PER RUN	7 MAX. RUDDER PER RUN	8 APPAR. WIND VEL. W_a	8 APPAR. WIND DIR.
1-S	6.78	73.53	10.16	1117	4.0° R	6° R	4.45	F-50-P
2-N	7.42	71.97	9.62	1070	4.3° R	7° R	18.05	F
3-S	8.10	73.38	9.85	1097	3.4° R	5° R	4.30	F-70-P
		72.71	9.81					
4-N	8.71	82.01	11.15	1559	5.2° R	8° R	18.40	F
5-S	9.34	81.36	10.69	1538	3.5° R	7° R	4.75	F-50-P
6-N	9.87	80.82	11.24	1537	3.0° R	5° R	18.35	F-15-S
		81.39	10.94					
7-S	10.54	89.50	11.58	2064	3.5° R	8° R	8.95	F-30-P
8-N	11.11	89.31	12.38	2072	3.3° R	7° R	18.40	F
9-S	11.72	89.75	11.64	2061	4.0° R	6° R	8.60	F-10-P
		89.47	12.00					
10-N	12.22	94.20	13.07	2548	4.4° R	10° R	19.50	F
11-S	12.79	94.29	13.22	2472	3.2° R	5° R	18.35	F-5-P
12-N	13.31	94.48	12.99	2491	3.6° R	5° R	7.85	F-20-S
		94.32	12.63					
13-S	13.85	99.18	13.03	2915	3.2° R	5° R	16.90	F
14-N	14.33	99.86	13.26	3010	3.2° R	5° R	8.85	F
15-S	14.84	98.91	13.35	2960	1.4° R	3° R	18.30	F
		99.45	13.23					
16-N	15.38	107.56	13.56	3790	2.0° R	5° R	9.35	F-20-S
17-S	15.92	107.46	14.66	3800	3.0° R	7° R	19.70	F
18-N	16.38	107.69	13.17	3848	2.4° R	4° R	9.70	F
		107.56	14.01					

FORMULAE & COLUMN DESIGNATIONS METHOD I

COL. 9 - THRUST CORRECTED FOR SHAFT DRAG

COL. 10 - $C_T^* = \dfrac{T}{\rho P^2 D^2 n^2} = 0.0773 \dfrac{T}{N^2}$

COL. 11 - $C_Q^* = \dfrac{SHP \times 33000 \times 3600}{\rho N^3 \times 2\pi \times P^3 \times D^2} = 32.21 \dfrac{SHP}{N^3}$

COL. 12 - $S = m\, C_Q - a = 700\, C_Q - 0.477$

COL. 13 - $V_a = \dfrac{PN(1-S)}{101.33} = 0.1239\, N(1-S)$

COL. 14 - WAKE, $\omega = \dfrac{V - V_a}{V}$

COL. 15 - SPEED THRU WATER, $V_1' = \dfrac{V_a}{1-\omega}$

COL. 16 - CURRENT, $C = V - V_1'$

COL. 17 - K, FROM EXPERIMENT DATA

COL. 18 - INCREMENT OF H.P. FROM WIND, ΔSHP

COL. 19 - FROM $\dfrac{dEHP}{dV}$ CURVE

COL. 20 - CORRECTED ΔV = COL. 18 ÷ COL. 19

COL. 21 - CORR. SPEED OVER G'R'D, $V'' = V + \Delta V$

COL. 22 - RPM/KNT, COL. 3 ÷ COL. 21, = N AVE. ÷ V''

COL. 23 - CORR. SP'D THRU WATER, V''' = COL. 3/COL. 22

COL. 24 - CURRENT, $C = V'' - V'''$

COL. 25 - ACT. SP'D THRU WATER, $V_2' = V''' - \Delta V$

COL. 26 - MEAN SP'D THRU WATER, $V' = (V_1' + V_2') \div 2$

COL. 27 - SPEED THRU WATER, BASIS NO WIND

COL. 28 - TORQUE COEFF., BASIS NO WIND

COL. 29 - SHP, BASIS NO WIND

COL. 30 - THRUST COEFF., BASIS NO WIND

COL. 31 - THRUST H.P., BASIS NO WIND

COL. 32 - THRUST DEDUCTION

COL. 33 - EHP, BASIS NO WIND

* N = REV. PER MIN., T = THRUST (LBS.), n = REV./SEC., P = PITCH, D = DIAM. (FT.), ρ = SPECIFIC GRAVITY OF S.W.

OBSERVED DATA

WITH MEASURED SHAFT HORSEPOWER REDUCED 2 PER CENT FOR SHAFT FRICTION

1 RUN N. & DIR.	2 TIME TO MIDDLE RUN	3 R.P.M. N	4 OBS. SPEED V	5 S.H.P. TOTAL	6 AVE. RUDDER PER RUN	7 MAX. RUDDER PER RUN	8 APPAR. WIND VEL. W_a	8 APPAR. WIND DIR.
1-S	6.78	73.53	10.16	1094	4.0° R	6° R	4.45	F-50-P
2-N	7.42	71.97	9.62	1048	4.3° R	7° R	18.05	F
3-S	8.10	73.38	9.85	1075	3.4° R	5° R	4.30	F-70-P
		72.71	9.81					
4-N	8.71	82.01	11.15	1527	5.2° R	8° R	18.40	F
5-S	9.34	81.36	10.69	1507	3.5° R	7° R	4.75	F-50-P
6-N	9.87	80.82	11.24	1506	3.0° R	5° R	18.35	F-15-S
		81.39	10.94					
7-S	10.54	89.50	11.58	2022	3.5° R	8° R	8.95	F-30-P
8-N	11.11	89.31	12.38	2031	3.3° R	7° R	18.40	F
9-S	11.72	89.75	11.64	2020	4.0° R	6° R	8.60	F-10-P
		89.47	12.00					
10-N	12.22	94.20	13.07	2495	4.4° R	10° R	19.50	F
11-S	12.79	94.29	13.22	2421	3.2° R	5° R	18.35	F-5-P
12-N	13.31	94.48	12.99	2440	3.6° R	5° R	7.85	F-20-S
		94.32	12.63					
13-S	13.85	99.18	13.03	2855	3.2° R	5° R	16.90	F
14-N	14.33	99.86	13.26	2948	3.2° R	5° R	8.85	F
15-S	14.84	98.91	13.35	2900	1.4° R	3° R	18.30	F
		99.45	13.23					
16-N	15.38	107.56	13.56	3711	2.0° R	5° R	9.35	F-20-S
17-S	15.92	107.46	14.66	3721	3.0° R	7° R	19.70	F
18-N	16.38	107.69	13.17	3768	2.4° R	4° R	9.70	F
		107.56	14.01					

REDUCTION OF TRIAL DATA ——— S.S. BLACK FALCON

SHEET 2

METHOD I

				TORQUE METHOD					POWER METHOD										CORRECTED RESULTS						
1	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33
	CORR. THRUST	C_T	C_Q	S	V_a	ω	V_1'	C	K	ΔSHP	$\frac{\Delta SHP}{\Delta V}$	ΔV	V''	[illegible]	V'''	C	V_2'	V'	V_o	C_{Q_o}	SHP_o	C_{T_o}	THP_o	t	EHP_o
1-S			.0905	.157	7.68	.229	9.96	.20-S	.90	3.50	225	.155	10.32		10.12	.20-S	9.96	9.96	10.12		1108				
2-N			.0926	.172	7.38	.229	9.58	.04-N	1.00	61.60	212	.291	9.91		9.91	0	9.62	9.60	9.89		1048				
3-S			.0895	.150	7.73	.229	10.02	.17-N	.37	1.35	211	.064	9.91		10.10	.19-N	10.04	10.03	10.09		1104				
					7.56								10.01	7.26						.0898					
4-N			.0912	.162	8.53	.233	11.12	.03-N	1.00	74.18	318	.233	11.38		11.16	.22-N	10.93	11.03	11.26		1559				
5-S			.0920	.167	8.40	.233	10.95	.26-N	.90	4.36	295	.014	10.70		11.06	.36-N	11.05	11.00	11.01		1526				
6-N			.0938	.180	8.22	.233	10.71	.47-N	1.02	72.40	277	.261	11.50		11.00	.50-N	10.74	10.73	10.99		1495				
					8.39								11.07	7.345						.0912					
7-S			.0928	.173	9.18	.238	12.05	.53-N	1.09	20.70	410	.050	11.63		12.13	.50-N	12.08	12.07	12.12		2038				
8-N			.0938	.180	9.08	.238	11.91	.47-N	1.00	79.40	400	.199	12.58		12.10	.48-N	11.90	11.91	12.11		2024				
9-S			.0919	.167	9.27	.238	12.16	.52-N	1.00	17.72	425	.041	11.68		12.18	.48-N	12.12	12.14	12.18		2056				
					9.15								12.12	7.38						.0916					
10-N			.0982	.211	9.22	.254	12.36	.29-N	1.00	92.50	465	.199	13.27		12.76	.51-N	12.56	12.46	12.66		2460				
11-S			.0950	.189	9.48	.254	12.71	.49-N	1.00	84.20	525	.160	12.38		12.77	.39-N	12.51	12.61	12.76		2468				
12-N			.0952	.190	9.49	.254	12.72	.27-N	1.00	15.86	416	.038	13.09		12.80	.23-N	12.76	12.74	12.78		2470				
					9.42								12.77	7.38						.0944					
13-S			.0964	.199	9.85	.259	13.30	.27-N	1.00	75.00	645	.116	13.15		13.24	.09-N	13.12	13.21	13.33		2895				
14-N			.0972	.204	9.86	.259	13.31	.05-S	1.00	20.50	636	.032	13.29		13.33	.04-N	13.30	13.31	13.34		2965				
15-S			.0986	.214	9.64	.259	13.01	.34-S	1.00	85.80	576	.149	13.50		13.21	.29-S	13.06	13.04	13.19		2880				
					9.80								13.31	7.49						.0957					
16-N			.0981	.210	10.55	.252	14.10	.54-S	1.03	25.00	830	.030	13.59		14.08	.49-S	14.05	14.03	14.11		3760				
17-S			.0989	.216	10.46	.252	13.99	.67-S	1.00	106.80	850	.127	14.79		14.05	.74-S	13.92	13.96	14.09		3740				
18-N			.0994	.219	10.43	.252	13.94	.77-S	1.00	25.80	810	.032	13.20		14.10	.90-S	14.07	14.01	14.04		3770				
					10.48								14.09	7.64						.0973					

REDUCTION OF TRIAL DATA

BASED UPON 2 PER CENT DEDUCTION FROM SHAFT HORSEPOWER FOR SHAFT FRICTION

1	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33
1-S			.0888	.145	7.80	.218	9.98	.18-S	.90	3.50	225	.155	10.32		10.12	.20-S	9.96	9.97	10.13		1086				
2-N			.0906	.157	7.55	.218	9.42	.20-S	1.00	61.60	212	.291	9.91		9.91	0	9.62	9.52	9.81		1021				
3-S			.0875	.137	7.76	.218	10.02	.17-N	.37	1.35	211	.064	9.91		10.10	.19-N	10.04	10.03	10.09		1095				
					7.67								10.01	7.26						.08815					
4-N			.0893	.147	8.68	.221	11.15	0	1.00	74.16	318	.233	11.38		11.16	.22-N	10.93	11.04	11.27		1531				
5-S			.0902	.155	8.53	.221	10.95	.26-N	.90	4.36	295	.014	10.70		11.06	.36-N	11.05	11.00	11.01		1497				
6-N			.0920	.170	8.32	.221	10.68	.44-N	1.02	72.40	277	.261	11.50		11.00	.50-N	10.74	10.71	10.97		1466				
					8.52								11.07	7.345						.08955					
7-S			.0909	.160	9.32	.227	12.06	.46-N	1.09	20.70	410	.050	11.63		12.13	.50-N	12.08	12.07	12.12		2000				
8-N			.0918	.169	9.20	.227	11.90	.48-N	1.00	79.40	400	.199	12.58		12.10	.48-N	11.90	11.90	12.10		1990				
9-S			.0901	.155	9.40	.227	12.15	.51-N	1.00	17.72	425	.041	11.68		12.16	.48-N	12.12	12.14	12.18		2015				
					9.28								12.12	7.38						.0899					
10-N			.0962	.197	9.38	.241	12.36	.71-N	1.00	92.50	465	.199	13.27		12.76	.51-N	12.56	12.46	12.66		2381				
11-S			.0931	.175	9.65	.241	12.71	.49-N	1.00	84.20	525	.160	12.38		12.77	.39-N	12.51	12.61	12.76		2390				
12-N			.0933	.177	9.64	.241	12.70	.29-N	1.00	15.86	416	.038	13.09		12.80	.23-N	12.76	12.73	12.77		2401				
					9.58								12.77	7.38						.0918					
13-S			.0944	.185	10.02	.246	13.30	.27-N	1.00	75.00	645	.116	13.15		13.24	.09-N	13.12	13.21	13.33		2855				
14-N			.0955	.192	10.02	.246	13.30	.04-S	1.00	20.50	636	.032	13.29		13.33	.04-N	13.30	13.30	13.33		2918				
15-S			.0967	.201	9.80	.246	13.00	.35-S	1.00	85.80	576	.149	13.50		13.21	.29-S	13.06	13.03	13.18		2833				
					9.97								13.31	7.49						.0945					
16-N			.0960	.196	10.73	.240	14.12	.56-S	1.03	25.00	830	.030	13.59		14.08	.49-S	14.05	14.09	14.12		3689				
17-S			.0968	.208	10.82	.240	13.97	.69-S	1.00	106.80	850	.127	14.79		14.05	.74-S	13.92	13.95	14.08		3663				
18-N			.0973	.205	10.61	.240	13.96	.79-S	1.00	25.80	810	.032	13.20		14.10	.90-S	14.07	14.02	14.05		3710				
					10.65								14.09	7.64						.0953					

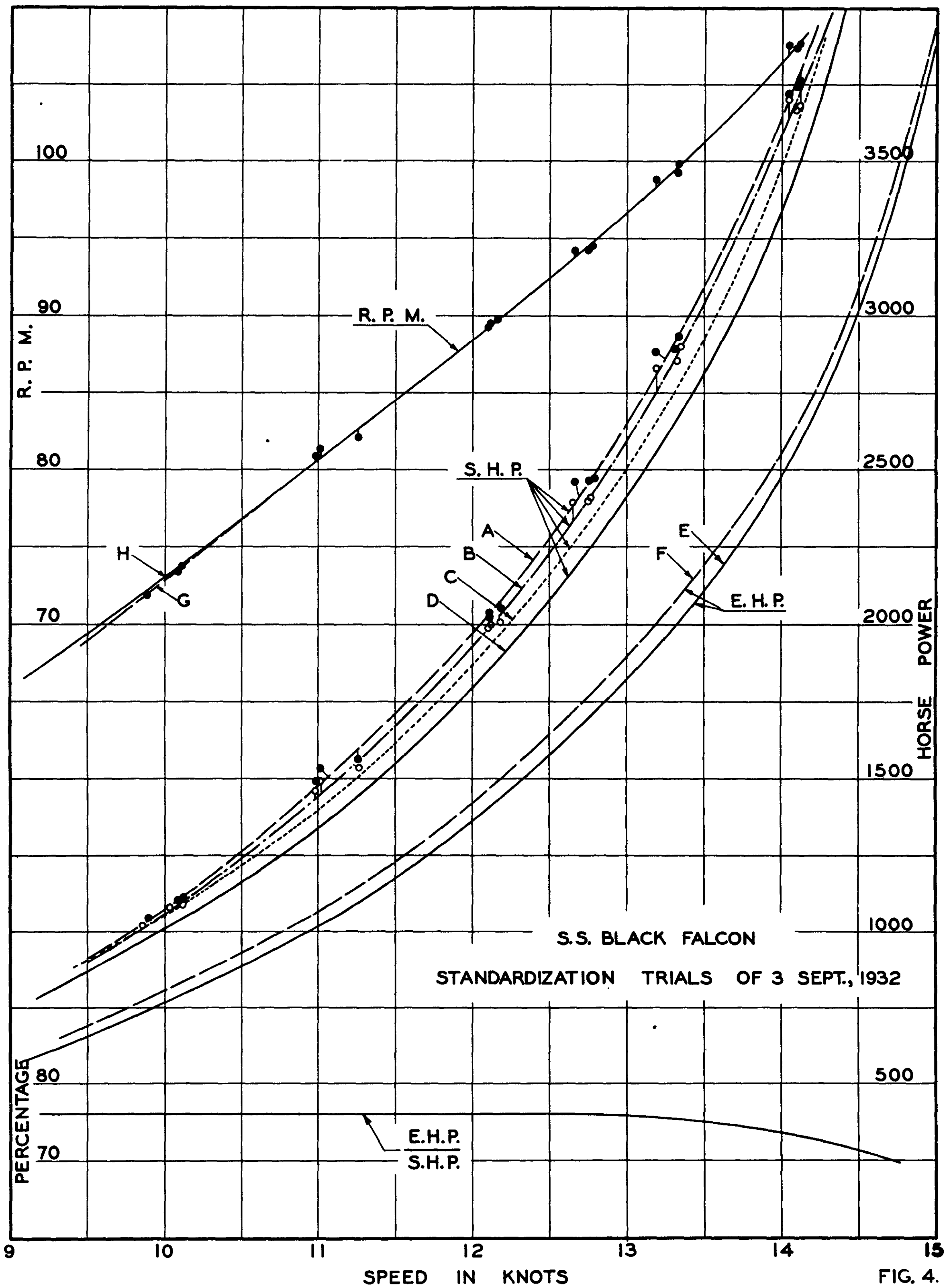
fore and aft resistance for any specified angle of relative wind to the fore and aft wind resistance with a relative angle of zero (wind dead ahead), are taken from experimental data on a model of the S.S. CLAIRTON, as given by the curve in Fig. 1 of Lt. Comdr. Pitre's 1932 paper(1). For the computation of wind resistance of the BLACK FALCON, the specific resistance was assumed to be 0.004 and the effective cross-sectional area equivalent to Beam x ½ Beam, or 1458 sq. ft.

Fig. 4 gives, in conventional form, a comparison between the corrected SHP from the ship trial data, curve A, and the SHP predicted from model self-propulsion tests, curve D, both plotted on a base of ship speed through the water. The ship revolutions per minute, on the same base, are given by curve G; the revolutions predicted from model tests by curve H.

All of the trial analysis methods previously mentioned give the SHP which would have been delivered at the torsionmeter and the resulting speeds through the water with no current and no wind. To permit comparison with the model predictions, it is necessary that the power lost in shaft bearing and stuffing box friction be deducted from these figures to give the SHP delivered at the propeller.

From friction tests of shafts running in lignum-vitae bearings, underway at the Experimental Model Basin but notyet concluded, it is estimated that from 1/2 to 1 per cent of the shaft horsepower may be absorbed under normal operating conditions by friction in way of the stern tube shaft alone. This includes stuffing box friction as well as shaft bearing friction. It would, therefore, appear logical to assume that under the extreme conditions experienced on this vessel, as much as 2 per cent of the shaft horsepower might be lost between torsionmeter and propeller. Curve B of Fig. 4 was obtained by first subtracting 2 per cent from the observed trial powers and then correcting these powers for standard conditions of no wind and no current. The computations for this curve will be found on page 8 .

The effective horsepower curve E on Fig. 4 was calculated, as is customary at the U.S. Experimental Model Basin, from the observed model resistance curve by the use of Gebers' friction plane formula for the model and Gebers' formula for the ship, with a multiplying factor of 1.14 to allow for increased roughness of the ship surface, still air resistance and the like. This method should give results very nearly correct for a vessel of this size with a clean bottom. The BLACK FALCON had, however, been 24 days out of dock at the time of the trial, and, even under the most favorable conditions, an increase in frictional resistance could be expected. Assuming an average uniform rate of increase of resistance of 0.25 per cent per day out of dock, the increase in frictional resistance alone would have been 6 per cent. Recalculating the effective horsepower of the ship on this basis, curve F on Fig. 4 was obtained. Curve C was then derived from this modified EHP curve by dividing by the values of propulsive coefficient, EHP/SHP, found from the self-propelled tests of the model.



R. P. M.
100
90
80
70
R. P. M.
S. H. P.
A
B
C
D
E
F
E. H. P.
H
G
3500
3000
2500
2000
1500
1000
500
HORSE POWER
S.S. BLACK FALCON
STANDARDIZATION TRIALS OF 3 SEPT., 1932
PERCENTAGE
80
70
E.H.P.
S.H.P.
9
10
11
12
13
14
15
SPEED IN KNOTS

FIG. 4.

The percentage differences between observed shaft horsepower for the ship and predicted values for the model, with and without the power loss corrections for shaft friction and foul bottom, are set forth in Table 1 following. The corrected ship SHP values are higher in each case than the values predicted from the model tests.

It may be of interest to note that the model has been tested self-propelled on three different occasions, under conditions corresponding to those obtaining on the trials, with substantially the same results.

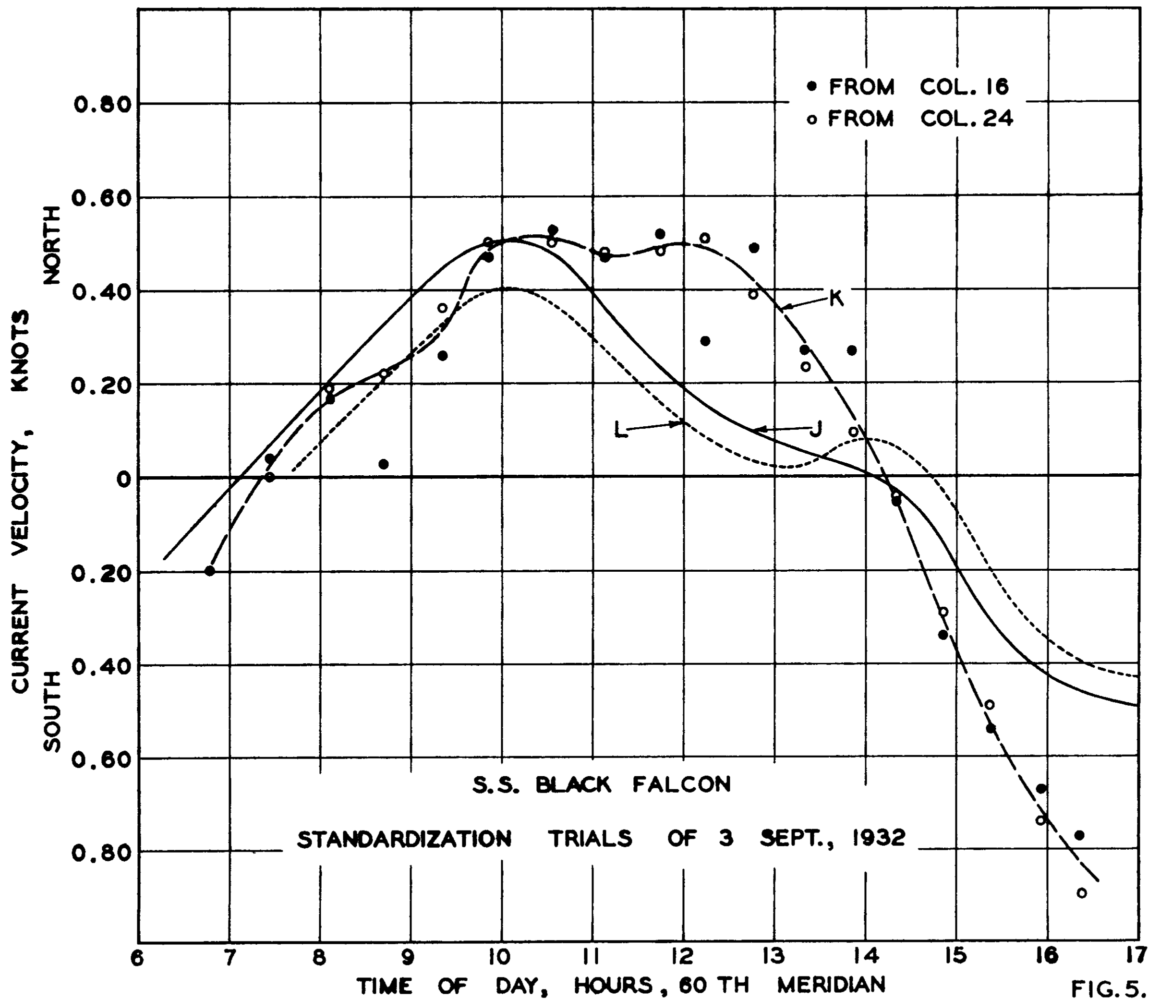
TABLE 1

Ship Speed in Knots	Shaft Horsepower Percentage difference between pairs of curves	
	Curves A and D	Curves B and C
10	6.22	0
11	10.31	3.22
12	9.75	3.21
13	9.96	3.59
14	9.16	2.86

There is another aspect of this analysis to be considered, namely, the relative characteristics of ship and model propellers. During the model experiments, both thrust and torque were measured for the purpose of deriving the characteristic curves shown in Fig. 6. During the full-scale test, torque alone was measured. This made necessary the assumption that model propeller and full-scale propeller were geometrically and hydrodynamically similar; in other words, that the same relation obtained between thrust and torque in the full scale propeller as in the model propeller. Recent experiments with full-scale tests where thrust and torque have been measured indicate that this assumption may not be valid. If thrust measurements had been obtained on the BLACK FALCON it would have been possible not only to compare the performance of the model and full-scale propellers but to form a more accurate estimate of the frictional resistance of the vessel. The results of an analysis based on these data would unquestionably have indicated the source of the discrepancies encountered in ship and model powers.

Fig. 5 gives the tidal current, curve J, as predicted by the U.S. Coast and Geodetic Survey and the total current, curve K, as derived from the corrected trial results and as set forth in columns 16 and 24 on page 8 .

The resultant of the tidal current and the current in the water set up by the true wind is shown by curve L. The irregular differences between curves K and L may be due to river or local currents, variations in actual tidal current from the predicted values, small errors in the observed data (resulting in appreciable errors in the evaluated currents), and/or variations in the rate of change



• FROM COL. 16
○ FROM COL. 24
0.80
0.60
0.40
0.20
0
0.20
0.40
0.60
0.80
NORTH
SOUTH
CURRENT VELOCITY, KNOTS
K
L
J
S.S. BLACK FALCON
STANDARDIZATION TRIALS OF 3 SEPT., 1932
6
7
8
9
10
11
12
13
14
15
16
17
TIME OF DAY, HOURS, 60 TH MERIDIAN

FIG. 5.

of total current between runs.

Comparison of Calculated Speed Through the Water and Pressure Speed Log Readings.

Table 2 gives a comparison between the ship speeds through the water calculated from the trial analysis and those observed by means of the pressure speed log (standpipe float readings). On all except four runs of seventeen, on which observations were obtained, the differences are less than one per cent; the mean difference is about three-fourths of one per cent and the arithmetic sum of the differences is practically zero. It should be noted, furthermore, that the calculated speeds upon which this comparison is based are averages of two sets of ship speeds derived by different methods and are not, of themselves, free from possible error.

TABLE 2

COMPARISON BETWEEN SHIP SPEEDS THROUGH THE WATER
as obtained by trial analysis and by pressure speed log.

Run No. and Direction	Ship Speed Through the Water, Knots: By trial analysis from Col.26	Ship Speed Through the Water, Knots: By Pressure Speed Log	Differences in Knots	Differences in Per Cent
1	9.96	9.80	-0.16	-1.60
2	9.60	9.53	-0.07	-0.73
3	10.03	9.95	-0.08	-0.79
4	11.03			
5	11.00	11.13	+0.13	+1.18
6	10.73	10.82	+0.09	+0.77
7	12.07	12.07	0	0
8	11.91	11.94	+0.03	+0.25
9	12.14	12.14	0	0
10	12.46	12.71	+0.25	+2.10
11	12.61	12.64	+0.03	+0.23
12	12.74	12.75	+0.01	+0.07
13	13.21	13.18	-0.03	-0.23
14	13.31	13.42	+0.11	+0.83
15	13.04	13.14	-0.10	-0.77
16	14.08	14.13	+0.05	+0.35
17	13.96	13.90	-0.06	-0.43
18	14.01	14.11	+0.10	+0.71

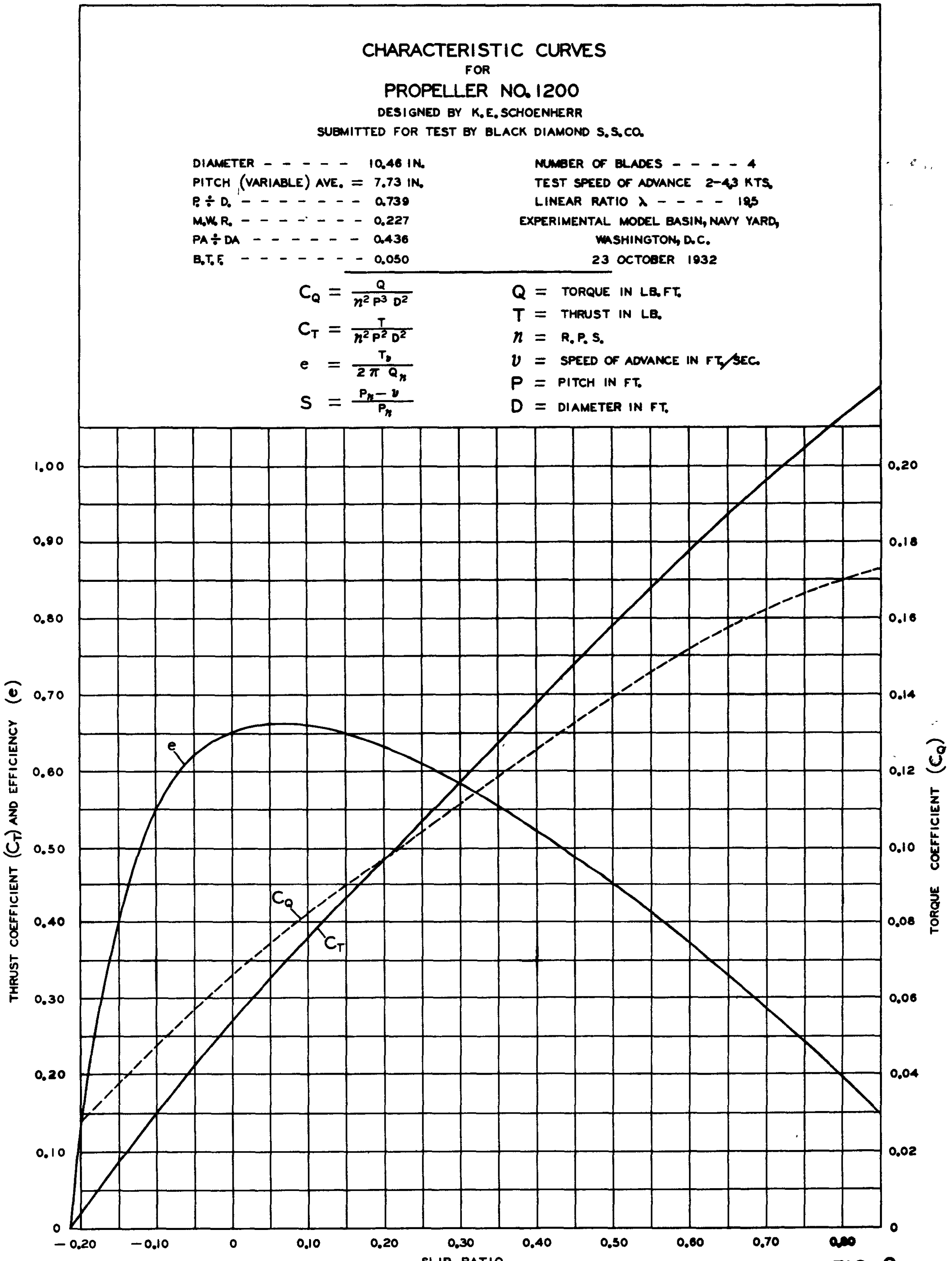

CHARACTERISTIC CURVES
FOR
PROPELLER NO. 1200
DESIGNED BY K. E. SCHOENHERR
SUBMITTED FOR TEST BY BLACK DIAMOND S. S. CO.
DIAMETER - - - - - 10.46 IN.
PITCH (VARIABLE) AVE. = 7.73 IN.
P. ÷ D. - - - - - - - - 0.739
M.W.R. - - - - - - - - 0.227
PA ÷ DA - - - - - - - 0.436
B.T.F. - - - - - - - - 0.050
NUMBER OF BLADES - - - - 4
TEST SPEED OF ADVANCE 2-4.3 KTS.
LINEAR RATIO λ - - - - - 19.5
EXPERIMENTAL MODEL BASIN, NAVY YARD,
WASHINGTON, D.C.
23 OCTOBER 1932
$C_Q = \frac{Q}{n^2 P^3 D^2}$
$C_T = \frac{T}{n^2 P^2 D^2}$
$e = \frac{T_v}{2\pi Q_n}$
$S = \frac{P_n - v}{P_n}$
Q = TORQUE IN LB. FT.
T = THRUST IN LB.
n = R. P. S.
v = SPEED OF ADVANCE IN FT./SEC.
P = PITCH IN FT.
D = DIAMETER IN FT.
e
C_Q
C_T
THRUST COEFFICIENT (C_T) AND EFFICIENCY (e)
TORQUE COEFFICIENT (C_Q)
SLIP RATIO
0
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80
0.90
1.00
0.02
0.04
0.06
0.08
0.10
0.12
0.14
0.16
0.18
0.20
-0.20
-0.10
0
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80

FIG. 9

Discussion of Results.

The steering during the trials was not particularly good, although undoubtedly better than the average of a day's run for a vessel of this type. The retardation due to changes in course and the excess power occasioned by the rudder angles used are indefinite but would probably not exceed one per cent either in speed or power.

In the course of analyses previously made by these methods, it has been considered that the derived values of resultant current over the trial course, plotted on a base of time, offered an excellent indication of the consistency and accuracy of the derived data, especially when compared with the curves of lunar tidal current corrected for minor currents caused by the wind. In the case of the BLACK FALCON trials, this comparison is not particularly satisfying, as the resultant current curve is poorly defined by the spots and it differs in shape from the predicted curve. This lack of agreement has, however, been noted on previous trials which were, like the trials in question, well supervised and carefully conducted; it must, for the present, be ascribed to causes remaining unknown.

The fact that standardization trials were never run on a vessel of this class before conversion prevents a determination of the improvement in propulsive characteristics of the vessel due to the changes in the stern, in the rudder and in the propeller, or of comparing this improvement with that predicted from model self-propulsion tests.

The shaft horsepowers as measured on trial are in excess of those predicted from tests of the model representing the ship in trial condition. However, the allowances estimated for increase in resistance due to fouling and for reduction in power due to shaft friction are reasonable and the final agreement, with excess ship power varying from two to four per cent, is considered satisfactory.

APPENDIX I.

LIST of WORKING and REFERENCE PLANS

S.S. BLACK FALCON — STANDARDIZATION TRIALS

Federal No.	Washington No.	Title
E4-1064, E4-998		Rockland Trial Course.
L4-76	295	Wiring Diagram for Trial Equipment.
	A-987	Wind Direction Indicator.
E2-1188	317	Location of Anemometer and Wind Direction Indicator.
	A-1108	Pressure Speed Log, Arrg't, and Details on Ship.
	A-1122	Pressure Speed Log, Details.
E6-1012	318	Pressure Speed Log, Installation on vessel.
E6-968 (2 sheets)	239	Propeller, Developed Cylindrical Blade Sections.
E4-1045	246	Propeller Inspection.
E2-1141		Propeller Blade Measurements.
E2-1186		Summary of Propeller Measurements.
E4-1036	346	Propeller Shaft and Details.
E4-1037	345	Stern Tube

APPENDIX II

DESCRIPTION of TRIAL INSTRUMENTS and RECORDING APPARATUS

The Navy type chronograph, used on the standardization trials of naval vessels to measure and record elapsed times of three separate observers, was supplemented by a chronograph supplied as part of the resistance speed log apparatus developed by the Hamburg Model Tank (3)(4). It is not customary to duplicate the elaspsed time recording apparatus in this manner, as separate observations of elapsed time are made by the stop watches carried in and operated by the contact makers of the Navy chronograph. However, in view of the importance of carrying the trials through successfully on schedule time and of the fact that the Hamburg chronograph would record individual revolutions on a basis of time, the duplication was considered justified.

The Taylor printing counter was mounted in the shaft tunnel and driven by a worm and worm wheel from the main shaft in the usual manner. The Hamburg chronograph solenoid marking shaft revolutions was actuated by a roller and contact device running on a cam on the shaft ring gear provided for driving the Taylor counter.

The Denny-Edgecombe torsionmeter used on this trial is a late development of previous instruments of the same name, now manufactured by the firm of Kelvin Bottomley and Baird, Ltd., of Glasgow, Scotland. Its diagrammatic arrangement is shown in Figs. 7 and 7A, which will be found self-explanatory.

The 3-cup anemometer is of the type used extensively by the U.S. Navy, the U.S. Weather Bureau and others, manufactured by Julien P. Friez and Sons, Baltimore. It records on the chronograph in units of 1/60 nautical mile of linear wind. This anemometer was mounted on a cross-arm temporarily mounted on the foremast as shown in Fig. 3. The 4-cup anemometer is the instrument furnished by the Hamburg Model Tank with its standard trial equipment. It records in units of 50 meters of linear wind.

The direction of the relative wind was indicated by a wind direction indicator of a simple vane type, having a dial and pointer to be read from below. For the trials, the indicator was mounted on a temporary cross-arm on the foremast at a height about level with the top of the navigating bridge; see Fig. 3. The indicator was too close to the mast for accurate readings, hence for the trials, as previously described, an average was taken of the indicator readings, the direction of two flags and of smoke from the funnel.

There was no rudder angle indicator mounted on the bridge, hence an improvised affair was rigged up from the tiller (see Fig. 8) and read by the after observer on the poop deck. Its readings, while not accurate, are considered sufficient for the purpose of the present analysis.

The pressure speed log was designed by the staff of the U.S. Experimental

Model Basin and installed by the shipbuilder at the owner's expense. The diagrammatic arrangement is shown in Fig. 9. It consists essentially of a hemispherical head about 6 in. diameter, known as the impact tube, welded securely to the stem bar at about the 15 ft. water line, well below the trial water line. In the center of this head, pointing directly forward, is a single orifice about 1/4 in. diameter, connected by a small pipe to the bottom of a shallow expansion tank fitted inside the fore peak tank. A water level is maintained in this tank by a hand air pump; a float gage is provided to indicate this level in the forecastle when, as was the case on this vessel, the fore peak is full of water. The air space in the top of the expansion tank is connected to a precision dial pressure gage; this gage may be located at any convenient point in the vessel, provided the air pipe is kept clear of water.

The pressure speed log operates upon the principle that if a blunt nose approximately perpendicular to the flow of water be fitted in the bow of a vessel, there will be an area in the center of this nose, called the stagnation point, where the water will be at rest with respect to the ship; in other words, where the velocity head in the water, due to the movement of the ship through it, will be entirely converted into pressure head. If an orifice be made in this stagnation area, the pressure head may be measured and the water velocity determined.

The bow of the vessel is selected for the location of the pressure log orifice because the water at this point suffers the minimum disturbance from wave motion, frictional effects, streamline motion, etc. The methods of measuring the net head due to motion of the vessel through the water are explained briefly in the notes accompanying the elementary diagram, Fig. 9.

The simpler and more direct method of measuring the net head by standpipe is employed on moderate speed vessels where, as on the BLACK FALCON, the net head at full speed is of the order of 120 in. It is customary to indicate and to measure the net head by both methods, each serving as a standby and as a check upon the other.

A float in the standpipe is attached to a thread leading over a grooved drum at the top of the pipe; a counterweight on a thread on the outside of the standpipe keeps the float thread taut and causes the drum to turn with vertical motion of the float. The water level may be read directly from the counterweight and adjacent scale. The drum shaft is connected by an electro-magnetic distant reading device so that the position of the float, and hence the net head, may be read in the chart room as well as in the forecastle.

The values of net head for the anticipated range of ship speeds are determined by running the model self-propelled at corresponding speeds, with an impact tube and orifice mounted in its bow and a glass manometer tube inside the model at the fore and aft position of the expansion tank. Calibration in this manner on the model makes allowance automatically for the change in trim of the

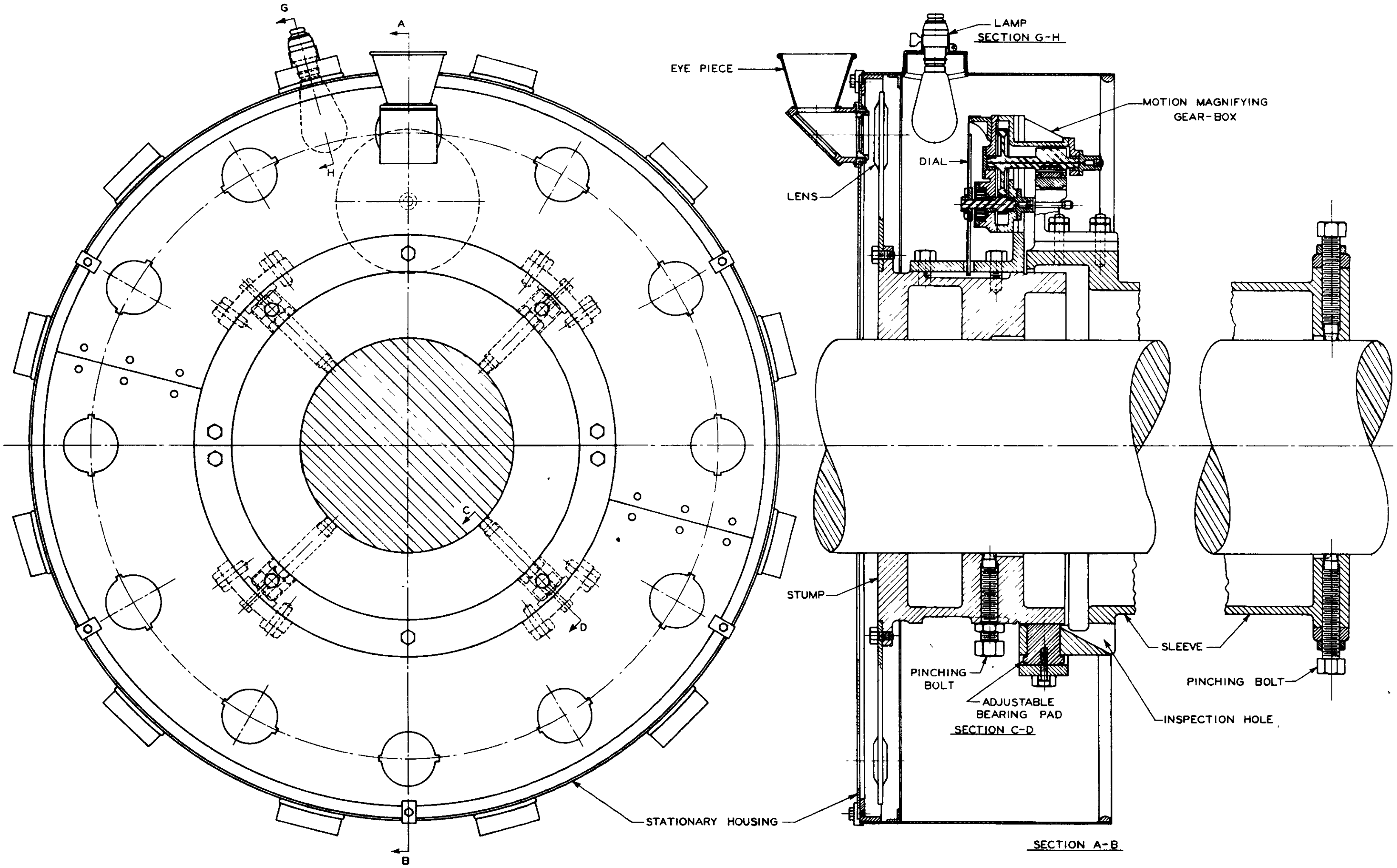


FIG. 7 DENNY-EDGECOMBE TORSIONMETER

GENERAL ARRANGEMENT

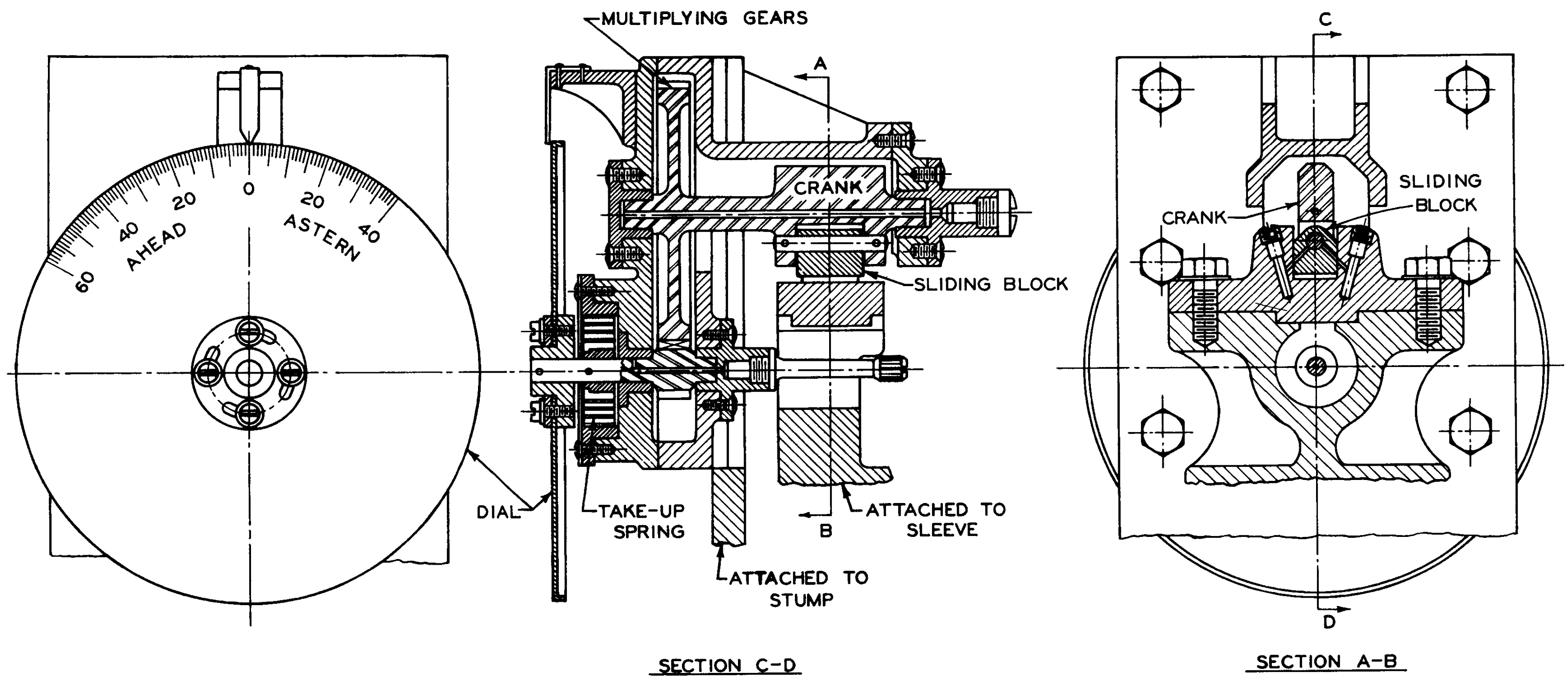


FIG. 7A DENNY-EDGECOMBE TORSIONMETER

DETAILS OF INDICATING AND MULTIPLYING GEAR vessel when underway and for the variations in head and in pressure due to the wave system at the bow.

The net head observed on the model, multiplied by the linear ratio of ship to model, gives the net head for the ship at the corresponding speed. For example, if the model is calibrated at speed v, the observed net velocity head, h, may be represented by $h = v^2/2g$

But $\quad v = V/\lambda^{\frac{1}{2}}$, or $v^2 = V^2/\lambda$

whence $\quad h = V^2/\lambda \times 1/2g$

or $\quad h \times \lambda = H = V^2/2g$

A plot of the predicted ship values of net head, for use in determining the ship speed through the water, is shown in Fig. 10.

S. S. BLACK FALCON

ELEMENTARY DIAGRAM OF PRESSURE SPEED LOG USED ON TRIALS

3 SEPTEMBER 1932

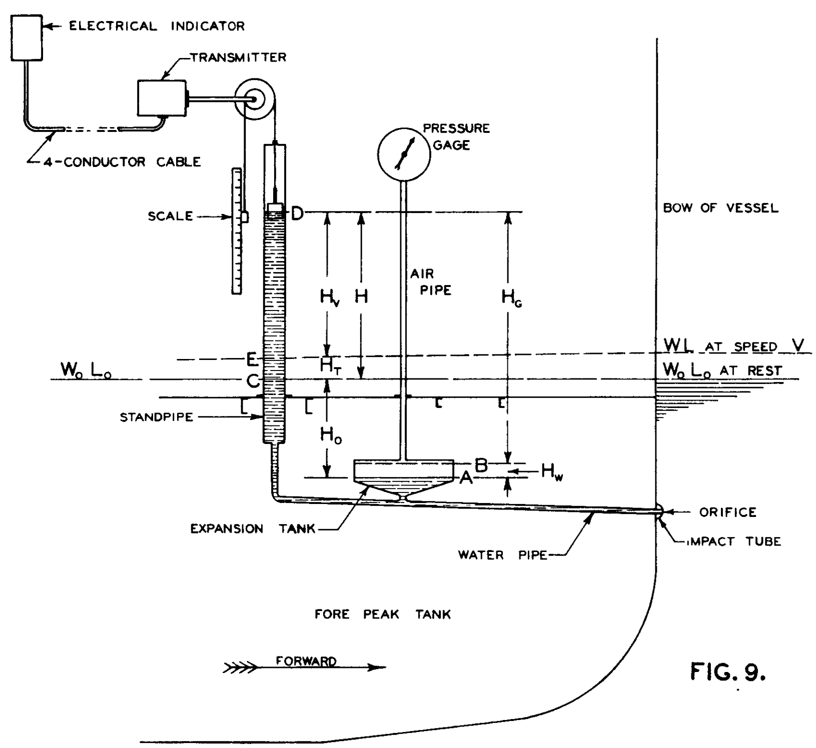


FIG. 9.

Water line W_oL_o at rest rises to WL at ship speed V.

Water level in expansion tank rises from A when vessel is at rest to B when vessel is moving at speed V, due to compression of air in tank, pipe and gage.

Water level in standpipe rises from C when vessel is at rest to D when vessel is moving at speed V.

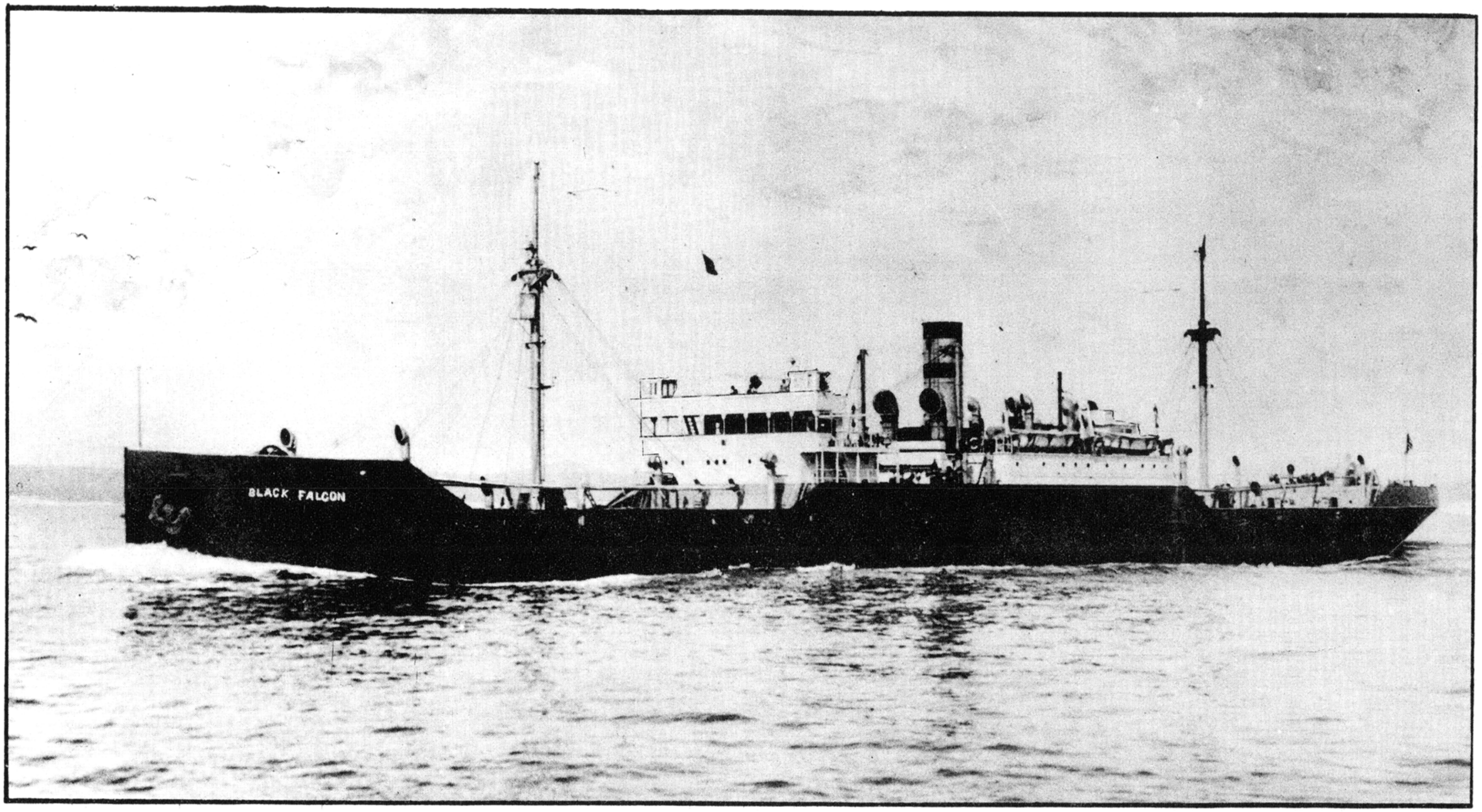


FIG. 1. S.S. BLACK FALCON ON THE TRIAL COURSE AT ROCKLAND.

H_o is the pressure gage reading when vessel is at rest, expressed in inches head of sea water of the given specific gravity.

H_g is the pressure gage reading when vessel is moving at speed V.

H_w is the rise of water level in expansion tank from A to B, indicated by suitable gage glass or float device.

H is the increase in head when the vessel changes from speed 0 to speed V, obtained by test of the ship model with an impact tube, orifice and standpipe reduced to scale. This is called the net head.

$$\text{Then } H = H_g - H_o + H_w$$

From which relation the net head H at any speed can be determined on the vessel. The net head H is also indicated directly by the standpipe and float device, when the water level rises from C to D.

Entering the model calibration,curve, Fig. 10, with the net head H, the ship speed V is at once determined.

References

(1) "Trial Analysis Methods," by Lt. Comdr. A.S. Pitre, (CC), U.S.N., Trans. Soc. Nav. Arch. and Mar. Engrs., vol. 40, 1932.

(2) "On the Analysis of Ship Trial Data," by K.E. Schoenherr, Trans. Soc. Nav. Arch. and Mar. Engrs., vol. 39, 1931.

(3) "Probefahrtsmessungen" (Ship Trial Measurements), by Dr. Ing. G. Kempf and Dipl. Ing. W. Sottorf, Werft Reederei Hafen, 22 June 1928.

(4) "Measurements of the Propulsive and Structural Characteristics of Ships," by Dr. Ing. G. Kempf, Trans. Soc. Nav. Arch. and Mar. Engrs., vol. 40, 1932.

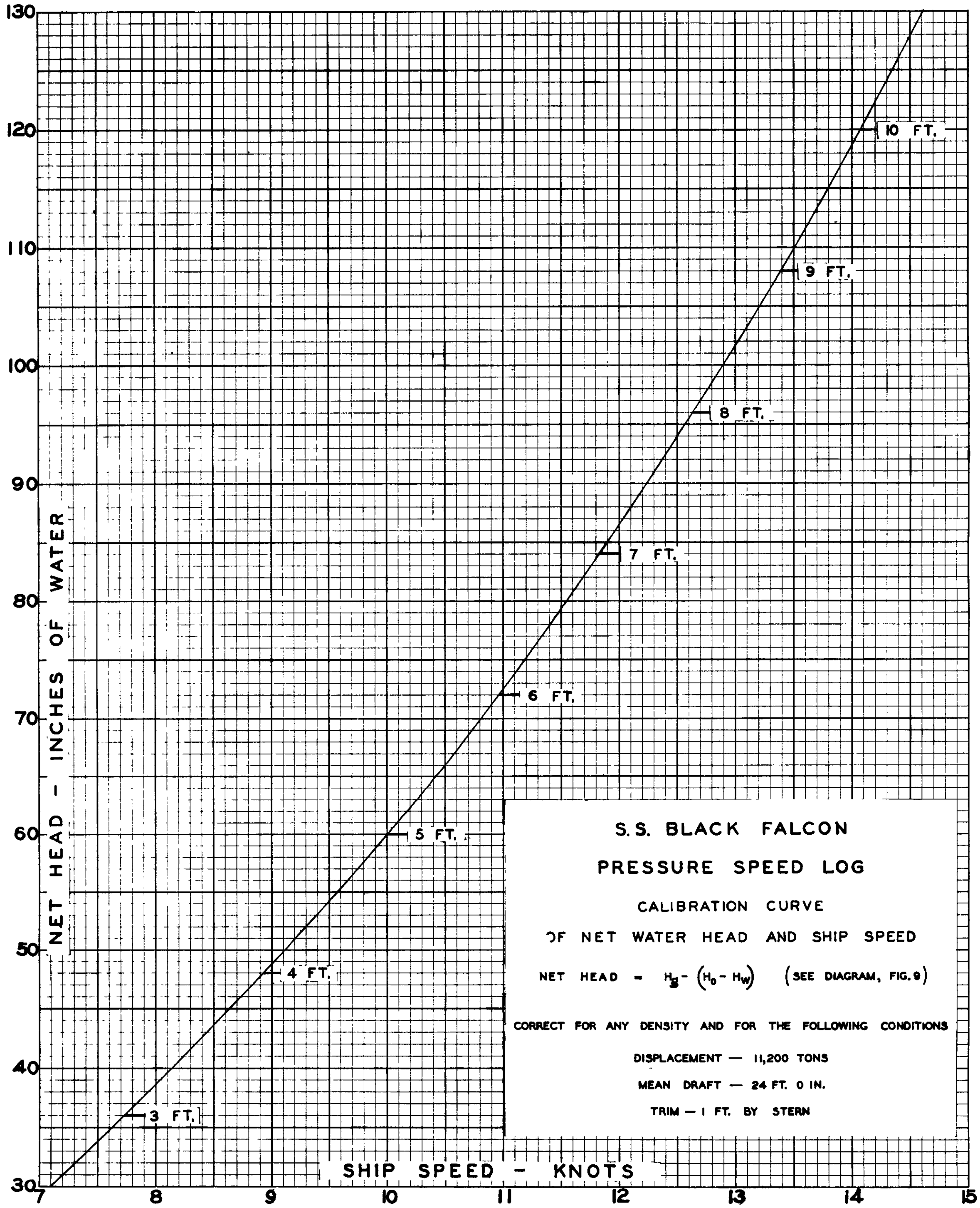

S. S. BLACK FALCON
PRESSURE SPEED LOG
CALIBRATION CURVE
OF NET WATER HEAD AND SHIP SPEED
NET HEAD = $H_S - (H_o - H_W)$ (SEE DIAGRAM, FIG. 9)
CORRECT FOR ANY DENSITY AND FOR THE FOLLOWING CONDITIONS
DISPLACEMENT — 11,200 TONS
MEAN DRAFT — 24 FT. 0 IN.
TRIM — 1 FT. BY STERN
NET HEAD - INCHES OF WATER
SHIP SPEED - KNOTS
3 FT.
4 FT.
5 FT.
6 FT.
7 FT.
8 FT.
9 FT.
10 FT.
130
120
110
100
90
80
70
60
50
40
30
7
8
9
10
11
12
13
14
15

FIG. 10.