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THE DAVID W. TAYLOR MODEL BASIN

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SS INDEPENDENCE

STANDARDIZATION TRIAL ANALYSIS

AND

COMPARISON WITH MODEL TEST RESULTS

By

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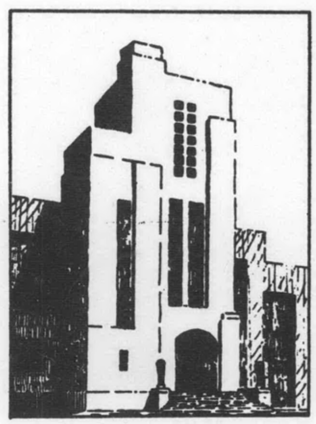

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SS INDEPENDENCE
During Standardization Trials

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INTRODUCTION

As a part of the David Taylor Model Basin's efforts to obtain as much reliable full scale trial data as practicable for the purpose of improving the accuracy of model test predictions, the Maritime Administration was requested to permit the Taylor Model Basin to observe the trials of the SS INDEPENDENCE (1)*. The INDEPENDENCE (U. S. Maritime Administration hull number 2912) was the first of two 30,000-ton, twin-screw, high-speed passenger-cargo vessels constructed for the American Export Lines, Inc., by the Quincy Yard of the Bethlehem Steel Company. The trials were conducted by the Central Technical Department of the Shipbuilding Division, Bethlehem Steel Company on 7 December 1950 at Rockland, Maine.

A model of the INDEPENDENCE, 20.00 feet in length, TMB model No. 3139-1, was tested self-propelled in the deep water basin of the Taylor Model Basin at a draft corresponding as nearly as practicable to that of the ship on trial.

The ship trial data were furnished to the Taylor Model Basin by the Maritime Administration. These data have been analyzed and reduced to standard model basin conditions for comparison with the performance predicted for the ship from self-propulsion test number 45 of Model 3139-1.

APPARATUS AND METHODS FOR OBSERVING TRIAL DATA

In accordance with the present practice of conducting standardization trials, measurements were made of revolutions per minute, shaft horsepower, and speed while traversing the measured mile.

The interval required by the vessel to traverse the measured mile during each run was timed by three observers on the bridge, each equipped with a stop watch. The average of the three stop watch times was used in calculating the average speed over the measured mile. The revolutions per mile of each propeller shaft were indicated by a Smith-Cummings counter operated by an observer on the bridge. The revolutions per mile were divided by the elapsed time of this observer to obtain the revolutions per minute (RPM) for each shaft. These two results were averaged for the average RPM for each run. The torque in each propeller shaft was measured by a Siemens Electric Ford-type

*Figures in parentheses refer to references listed at the end of this report.

torsionmeter. Shaft horsepower (SHP) was computed from the shaft torque and RPM for each shaft and totalled for the ship. Relativ wind data were recorded for the individual runs (commencing with run 8N) with a propeller type anemometer electrically connected t a velocity and direction indicator in the computing room (purser' office). The anemometer was located at the top of the foremast.

SHIP TRIAL AND MODEL TEST CONDITIONS

The underwater hull plates were either pickled or sand blasted prior to painting. The final painting before trials consisted of one coat of Maritime Administration Anti-Corrosive 52-MC-401 and one coat of Maritime Administration Anti-Fouling 52-MC-403 paint. The vessel was water borne three days before the standardization trials. The shell plating has flush welded butts and lapped riveted seams. An examination of the underwater body of the sistership CONSTITUTION by a Model Basin representative indicated that the "structural roughness" of these ship is about average for merchant ship construction. The butt weld beads project about 3/8 of an inch above the surface. There are approximately 10 discharge openings (between 6 and 10 inches in diameter) on each side of the ship. The discharge pipes project beyond the hull not more than an inch. Condenser scoop and most sea chest openings are very fair, with doubler plates installed inboard of the shell plating. The paint film on the CONSTITUTION was thinner and smoother than that exhibited by standard Navy hot plastic. It is felt that the paint had a tendency to smooth out small surface irregularities in the hull plating. In a few places throughout the ship there were slight sags caused by application of an excessive amount of fluid paint at these locations. There was no opportunity for a Model Basin representative to examine the INDEPENDENCE in drydock; however, it is believed that all of the foregoing remarks apply equally well to that ship

The ship was steered over the standardization course by hand control. Rudder angles used during the runs averaged about 5 degrees and occasionally they reached 8 degrees. A straight approach of three miles was made for all runs.

High winds on the day preceding the trials destroyed the anemometer and the replacement was not in use until run 8N. Air temperature was near freezing and the water temperature about 44° F.

The principal dimensions and characteristics of the ship and model are given in Table 1. Table 1 also gives information on the conditions prevailing during the standardization trials. Figure 1 shows two views of the stern of the model as fitted with propellers for the full scale comparison tests.

No wind resistance tests were made for this ship. In lieu thereof the results of wind resistance tests on a model of the S. S. SANTA ROSA were used to obtain values for specific wind resistance and variation of ahead resistance with direction of relative wind. These tests were fully reported in reference (2).

TABLE 1

Ship and Model Characteristics and Test Conditions

	SS INDEPENDENCE	MODEL 3931-1	
Length on Waterline (LWL)	650.00 ft.	20.00 ft.	
Max. Beam at LWL	89.00 ft.	2.738 ft.	
Linear Ratio	1	32.5	
Appendages	Rudder, Bossings "D", Bilge Keels		
No. of Props	2	2	
		Port	Stbd
Model Prop. Nos.	- -	3121	3120
Prop. Plans *	CTD 1618-E175 Alt.1		
Des. Prop. Dia.	19.50 ft.	7.20 in.	
Des. Prop. Pitch at 0.5 to 1.0 Radius	19.75 ft.	7.292 in.	
No. of Blades	3		
Dir. of Rotation	Outward		
P/D	1.013		
MWR	0.348		
BTF	0.0635		
Projected Area/Disk Area	0.447		

* Ship and model propellers were manufactured from the same plans

TABLE 1 (cont.)

Ship and Model Characteristics and Test Conditions

	SS INDEPENDENCE	Ship Conditions for Model
Trial Course	Rockland, Maine	-
Length of Trial Course	6080 feet	-
Displacement	26,068 tons	26,068 tons
Date of Trial	7 Dec. 1950	5 Apr. 1951
Mean Draft	26.54 ft. #	27.00 ft.
Trim	10 in. by stern	10 in. by stern
Wetted Surface	67,570 sq. ft.	67,570 sq. ft.
Days out of Dock	3	-
Depth of Water	204 ft.	715 ft. (Basin depth 22 ft.)
Temp. of Water	44° F	*
Wind (Beaufort Scale)	4-5	-
Bottom Paint	Commercial A.F.	Enamel on wood
Specific Gravity of Water	1.024 assumed	**

This figure could not be verified while at sea due to rough weather (2).

* Model test predictions have been corrected to standard temperature of 59.0° F.

** Model test predictions have been corrected to a standard sea water specific gravity of 1.028.

DISCUSSION OF TRIAL AND MODEL TEST RESULTS

Three runs were made over the measured mile at each of the speeds tested except for the lowest speed, at which only two runs were made. Elapsed time over the mile, propeller shaft RPM, and propeller shaft torque were recorded by Bethlehem Steel Company personnel (3). These data are given in Appendix 1. Appendix 2 contains the information for calculating SHP from torque and RPM.

Wind data (relative speed and direction) were recorded for runs 8N through 18N, but were not consistent when analyzed vectorially with ship's speed and course. A steady true wind of 20 knots from 055° T was therefore assumed for all runs.

The data from the full scale trials have been reduced to standard model basin conditions of zero wind and current by using Eggert's power method as described by Pitre (4). This method is outlined in some detail in Appendix 3. Curves of SHP, RPM, true slip, apparent slip, and wake fraction for model and ship are presented in Figure 2 for the trial displacement. Appendix 4 contains the corrected data which were used in plotting the ship trial curves. Figure 3 shows the torque and thrust characteristics of the propellers as determined by open water tests in the basin. No cavitation tests were made on the model propellers.

It may be noted from the data in Appendix 1 that the RPM and torque for the two shafts are not the same. Analysis indicates that when corrected to the same SHP, the two shafts still differ in RPM by a nearly constant number of turns amounting to about 1.5 percent. It is possible that this could be due to a mean pitch difference between the two propellers. Such a pitch difference could occur within the propeller manufacturing tolerance which is ± 1 percent.

The ship trial data shows the SHP for the ship to be essentially that predicted by model test except at the highest speeds. The RPM for the ship are generally lower than for the model which is consistent with the higher wake fraction of the ship. The apparent slip for the ship is slightly smaller than for the model and the true slip is slightly larger.

The SHP for the ship is approximately 3 percent greater than that predicted at the highest trial speed of slightly over 26 knots. The trial spots are few enough to cast some doubt on the certainty of this determination; however, the increased horsepower is a possible indication of incipient cavitation as the propellers are approaching a heavily loaded condition.

In computing the ship data from the model test results, Schoenherr's frictional resistance coefficients were used for both the model and ship with a roughness allowance coefficient added to the ship friction value. The roughness allowance coefficient used was 0.0004 which is the figure adopted by the American Towing Tank Conference in 1947 pending the availability of further reliable full-scale trial data. On the assumption tha the ship propulsive coefficient (P.C.) is the same as that of the model, the roughness allowance coefficient for the INDEPENDENCE on this trial would be 0.0004, the same as that used in the model predictions. This result indicates a relatively smooth hull surface, which is in conformity with the previously expressed opinio resulting from a visual examination of the underwater body.

It should be noted that the roughness referred to above includes not only the paint surface and condition but also the "structural roughness". This roughness is made up of such items as unfairness of the hull, material condition of the hull plates, construction practices, butt and seam welds, laps, or rivets, overboard discharges, condenser scoops, etc. This roughness is always present to some extent, but generally is of smaller magnitude on merchant vessels than on naval ships, since there are fewer sea chests on the former, and doubler plates are usually fitted inside rather than outside as is standard naval practice.

SUMMARY

The standardization trials of the INDEPENDENCE were conducted satisfactorily and the results are in good agreement with model test predictions. Incipient cavitation appears to be indicated above 24 knots.

The roughness allowance coefficient of 0.0004 for ships adopted by the American Towing Tank Conference (ATTC) in 1947 is substantiated by this trial. Two previous trials on commercial tankers, references (5) and (6), yielded results of 0.0003 and 0.0002 respectively. The higher roughness coefficient for the INDEPENDENCE undoubtedly reflects a greater degree of structural roughness than that of the tankers. This is at least partially attributable to the fact that luxury passenger liners of this type have more overboard discharges than tankers. Paint roughness data for commercial type paints is very meager.

REFERENCES

(1) TelCon of 9 October 1950 between Mr. D. S. Brierley, Maritime Administration and Mr. J. B. Hadler, DTMB.

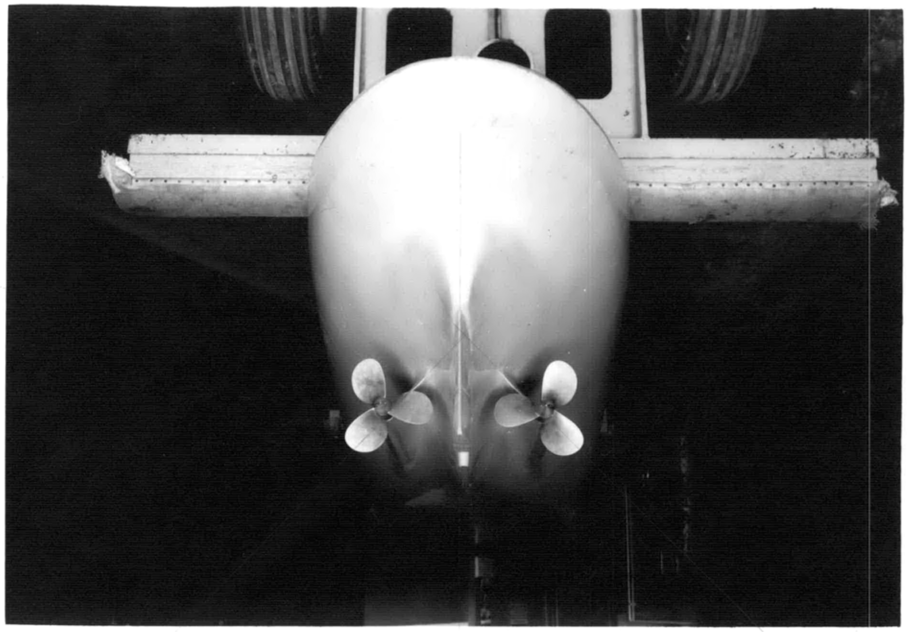
(2) "Test of Model of SS SANTA ROSA to Determine Forces Due to Wind" U.S.E.M.B. Report No. 362.

(3) "Report of Official Trials, SS INDEPENDENCE, Rockland, Maine, December 6-7, 1950" by Bethlehem Steel Company, Quincy, Mass.

(4) "Trial Analysis Methods", by A. S. Pitre, Trans. Soc. Naval Arch. Marine Engineers, Vol 40, 1932.

(5) "SS PENNSYLVANIA Standardization Trial Analysis and Comparison with Model Test Results", by J. B. Hadler and C. J. Wilson, TMB Report No. 748.

(6) "SS ESSO SUEZ Standardization Trial Analysis and Comparison with Model Test Results", by J. B. Hadler, and C. J. Wilson, TMB Report No. 750.



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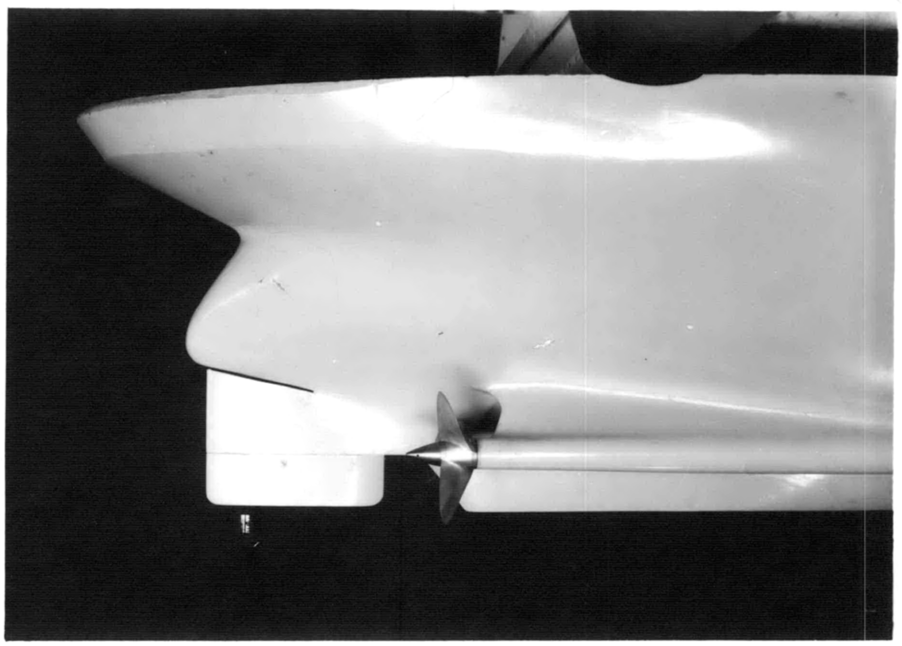

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FIGURE 1 - Stern view and stern profile of Model 3931-1 representing S.S. INDEPENDENCE.

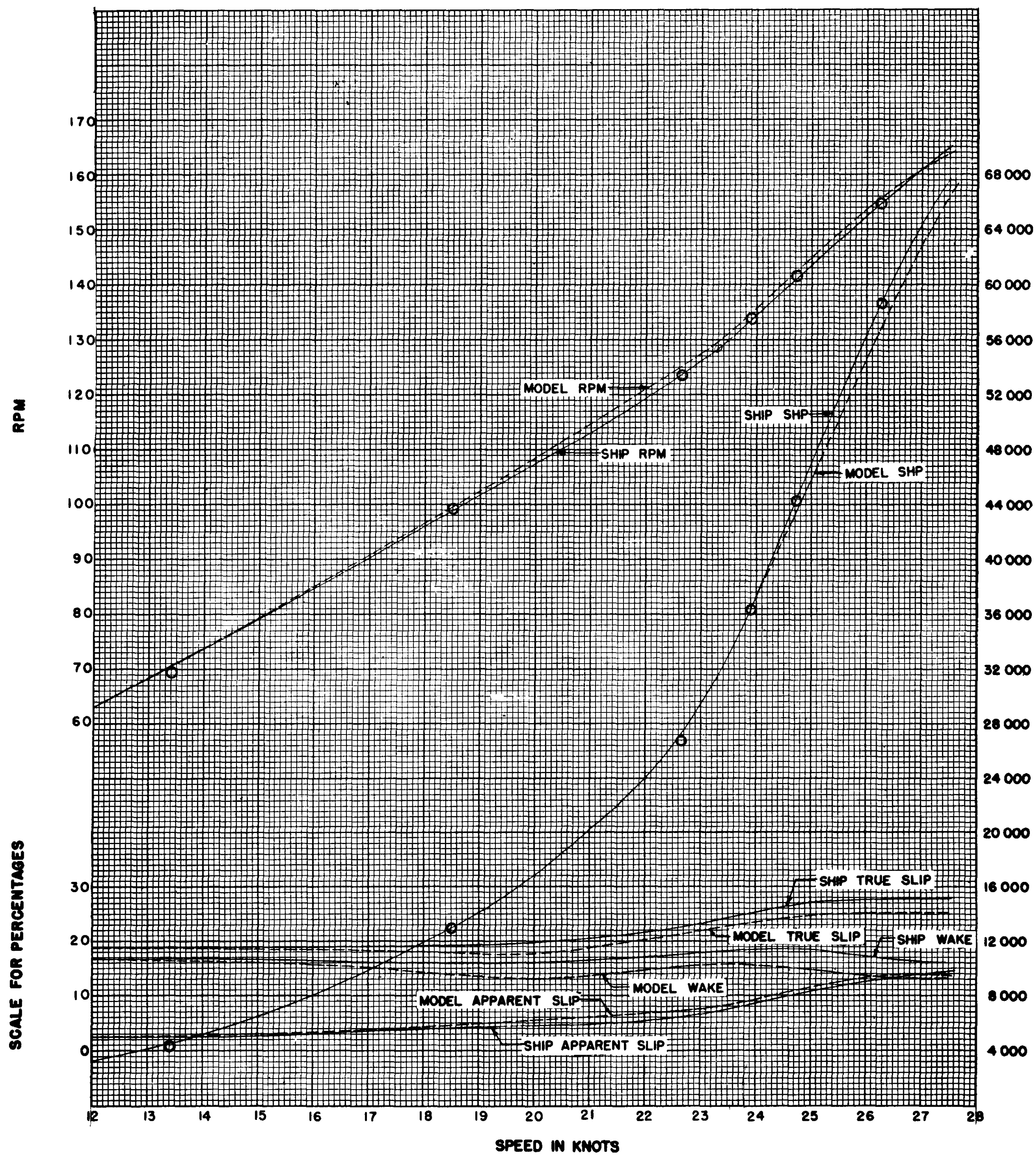

FIGURE 2 - Trial Results for S.S. INDEPENDENCE on 7 December 1950 at a Displacement of 26,068 Tons, Compared with Self-Propulsion Model Test No. 45.

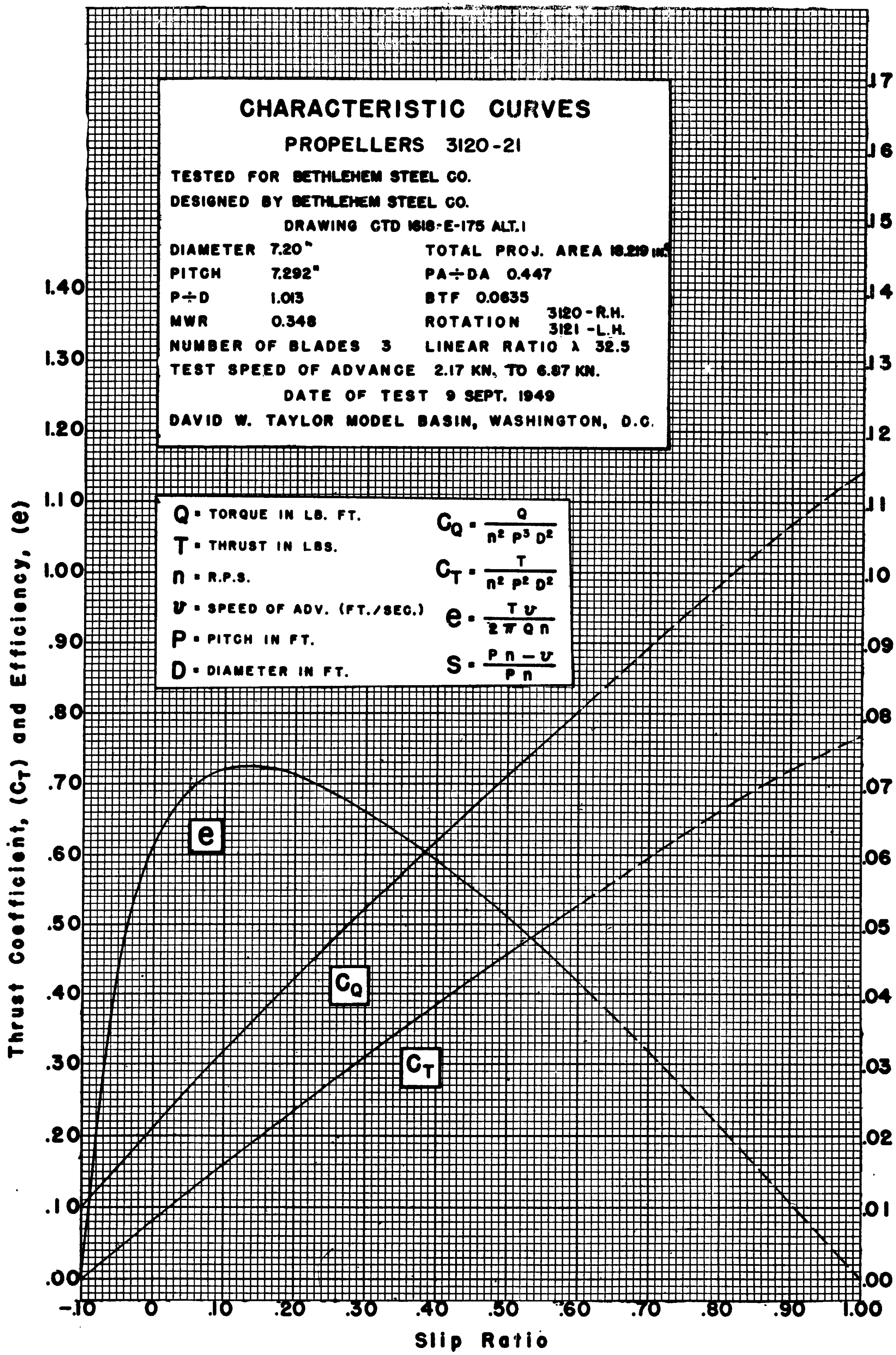

FIGURE 3 - Propeller Characteristic Curves Derived from Tests with Model Propellers No. 3120-21.

APPENDIX 1

Full Scale Trial Data - Observed Values

TABLE 2

SS INDEPENDENCE Standardization Trials - Displacement 26,068 Tons
7 December 1950

Run Number & Direction	Observed Speed (V_O) (Knots)	Observed RPM (N_O) Stbd Shaft	Observed RPM (N_O) Port Shaft	Torsionmeter Readings Stbd	Torsionmeter Readings Port	Relative Wind Speed (Knots)	Relative Wind Dir.
1S	23.97	122.5	125.1	62.2	60.8	Not Measured*	
2N	21.02	122.7	123.7	63.5	61.5	" "	
3S	23.94	122.6	124.7	63.4	62.2	" "	
4N	22.45	133.7	135.2	79.2	76.9	" "	
5S	25.18	133.1	134.6	79.1	76.5	" "	
6N	22.32	133.0	134.3	79.2	77.1	" "	
7S	26.04	140.9	142.4	91.7	88.2	" "	
8N	23.12	140.9	142.2	91.3	88.8	50	035
9S	26.09	140.4	142.3	91.2	89.4	32	327
10N	24.62	153.4	155.8	108.6	108.4	50	020
11S	27.54	153.4	156.3	109.1	109.5	27	330
12N	24.72	153.9	155.9	108.9	108.1	50	020
14N	16.60	97.8	99.4	38.0	37.2	42	030
15S	19.77	98.4	100.6	38.1	36.6	22	305
16N	16.90	98.1	100.1	38.4	37.4	42	030
17S	14.51	70.3	69.5	19.9	15.7	20	293
18N	12.00	69.8	68.2	20.1	16.2	36	035

* Anemometer not in operation prior to run 8N.

APPENDIX 2

METHOD OF REDUCTION OF SHAFT TORQUE DATA TO SHAFT HORSEPOWER

1. The shaft torque data were obtained by Siemens Electric Ford-type torsionmeters. This type of torsionmeter contains two husk transformers placed 180° apart to remove any error due to bending moments in the shaft. These transformers, which are connecte in series, indicate the shaft twist on a single transformer in tl indicator. The null balance system is used in these torsionmete: The section moduli of the shafts were obtained by shop calibrati at the same time the torsionmeter meter constants were determine

2. The torsionmeter zeroes were obtained by the so-called "drag shaft" method on the day of the trials. An average of zero readings before and after trials was used. These values agreed closely with previously taken drag shaft zeroes and with those taken the turning gear or jack shaft method.

3. The following information was obtained from reference (2) an Bethlehem Steel Company's report of torsionmeter shafting calibration:

Shafts (solid)	Port	Stbd
Indicator No.	8312	8312
Husk No.	8312	8313
L (Distance between Clamping planes)	42.05 in.	42.05 in.
B (Transformer core radius)	17.00 in.	17.00 in.
Diameter	22.743 in.	22.755 in.
G (Modulus of rigidity)	11,970,000 lbs/sq.in.	12,089,700 lbs/sq.in.
Transformer Ratio	1.010	1.007
Zero reading * (average)	-3.0	+3.0

4. The formula for reducing indicator readings to shaft horespower is:

$$M_t = \frac{G \times J_p \times a}{L}$$

where M_t = Torque in inch pounds per drum division,
G = Modulus of rigidity in pounds per square inch,

* Corrected torsionmeter reading* (ahead) = Actual reading - Zero reading (average).

J_p = Polar moment of inertia = $\frac{\pi D^4}{32}$ inches^4,

L = Distance between clamping planes in inches,

a = Angle of twist in radians per drum

$$\text{division} = \frac{.00025}{B}$$

[One revolution of drum = 200 divisions = $\frac{1}{20}$ inch (20 threads per inch)].

therefore $M_t = \frac{G \times .00025\, \pi D^4}{L \times B \times 32}$ in-lbs per drum division.

SHP = C x N x CTR

where SHP = shaft horsepower,

N = shaft revolutions per minute,

CTR = corrected torsionmeter reading,

C = horsepower constant

$= \frac{M_t}{63,025}$ x gage factor,

where gage factor = reciprocal of transformer ratio.

5. Performing the calculations indicated in paragraph 4 above and using the numerical values listed in paragraph 3, the horsepower constants are as follows:

$$\text{Port Shaft } C = \frac{11,970,000 \times .00025\, \pi (22.743)^4}{63,025 \times 42.05 \times 17.00 \times 32 \times 1.010} = 1.7273$$

$$\text{Stbd Shaft } C = \frac{12,089,700 \times .00025\, \pi (22.755)^4}{63,025 \times 42.05 \times 17.00 \times 32 \times 1.007} = 1.7535$$

APPENDIX 3

METHODS OF TRIAL ANALYSIS TO REDUCE DATA TO STANDARD CONDITIONS

1. The trial data were reduced by Eggert's power method as described by Pitrie in reference (4).

2. The analysis attempts to evaluate the effects of wind and current in order to reduce the data to standard model-basin conditions of zero current and zero air resistance. A description of the analysis as regards speed may be summarized as follows:

a. The relative wind direction and speed were derived vectorially by combining observed ship's course and speed for each run with the assumed true wind - 20 knots from 055° T. The wind direction coefficient, k, for this relative wind was taken from the k-curve derived from model tests of the S. S. SANTA ROSA reference (2), since no wind tests were made for the INDEPENDENCE

b. The horsepower expended in overcoming the wind resistance is calculated from the formula:

$$\Delta EHP = \frac{R_W \, A \, W_a^2 \, V_o \, k}{325.7}$$

where R_W = specific resistance coefficient from a model test (0.0020 from SS SANTA ROSA wind tunnel model test),

A = above-water cross-sectional area of the ship, (6540 sq. ft. based on trial waterline),

W_a = relative wind velocity,

V_o = speed through the water (second mean of the observed speeds for a three-run group),

k = wind direction coefficient representing the ratio of increase in axial resistance for any angle of attack, based on the axial resistance for zero angle of attack,

$\frac{1}{325.7}$ = factor to reduce resistance (pounds) multiplied by speed (knots) to EHP.

c. A curve of slope of EHP against speed is plotted. The increase in EHP per knot change in speed, $\frac{\Delta EHP}{\Delta V}$, is read from this curve at the group average speeds.

d. The Δ EHP from Step b is divided by the EHP per knot from Step c, which gives the increment of speed ΔV due to the wind effect.

e. The increments of speed are added (subtracted if k is negative) to the observed speeds to give V_G, the speed over the ground with no air resistance.

f. The speeds V_G, Step e, corrected for wind effect, are still influenced by the current existing over the trial course during the runs. It has been shown in more detailed papers on trial analysis that if the current varies uniformly, the second mean (weighted average) of the observed speeds in a three-run group at constant RPM is a close approximation to the true speed through the water. Since the RPM varies somewhat over a three-run group, the average RPM for the group is divided by the weighted average V_G to find the average RPM per knot.

g. The RPM for each run is in turn divided by the RPM per knot, Step f, to find the corrected speed through the water V_W.

h. The actual speed through the water, V_{AW}, is the corrected speed through the water, V_W, minus the speed correction ΔV du to the wind.

3. Values of torque coefficient, true slip, apparent slip and wake fraction are determined in the following manner:

a. The observed torque coefficient, C_{Qo}, is calculated from the formula

$$C_{Qo} = \frac{33000 \times 3600 \; SHP_o}{2 \pi \rho P^3 D^2 N_o^3 \; \delta}$$

where 33000 = factor to convert SHP to pound feet per second,
3600 = factor to convert RPM to RPS,
δ = ratio of density of the water in which the ship trials were conducted to the density of the water in which the model propeller openwater test was run,
P = pitch of the propeller in feet,
D = diameter of the propeller in feet,
N_o = RPM of the propeller.

b. Enter the open-water characteristics curves for the model propeller and determine the true slip ratio s_o for the values of C_{Qo}, Step a.

c. The speed of advance for the propeller, V_a, is expressed by the formula

$$V_a = \frac{(1-S_o) \; PN_o}{101.33}$$

where S_o is the observed true slip from Step b.
P and N_o are as defined in Step a.
101.33 is a constant to convert feet per minute to knots

d. The wake fraction w is determined from the formula

$$w = \frac{V_w - V_a}{V_w}$$

where V_w is the corrected speed through water

V_a is the speed of advance

e. The apparent slip $s_a = 1 - \frac{101.33\ V_w}{P\ N_o}$

where

P, N_o, 101.33 are the same as in Step 3c, above.

APPENDIX 4

Full-Scale Trial Data - Corrected to Zero Wind and Zero Current Condition

TABLE 4

Standardization Data from Trials of SS INDEPENDENCE at 26,068 Tons Displacement
December 7, 1950 at Rockland, Maine

Run Number and Direction	Corrected Speed Through Water (V_W)	Observed RPM (N_O)	Observed SHP (SHP_O)	Observed True Slip (s_t)	Wake Fraction (w)	Apparent Slip (s_a)
1S	22.72	123.8	26500			
2N	22.60	123.2	26800			
3S	22.70	123.7	27030			
	22.66	123.5	26780	.225	.177	.058
4N	24.00	134.4	36520			
5S	23.89	133.8	36240			
6N	23.88	133.7	36350			
	23.91	133.9	36340	.254	.186	.084
7S	24.73	141.6	44340			
8N	24.73	141.6	44360			
9S	24.69	141.4	44420			
	24.73	141.6	44370	.270	.185	.104
10N	26.23	154.6	58390			
11S	26.27	154.8	58920			
12N	26.28	154.9	58500			
	26.27	154.8	58680	.277	.170	.130
14N	18.40	98.6	12900			
15S	18.57	99.5	12930			
16N	18.49	99.1	13070			
	18.51	99.2	12960	.194	.158	.042
17S	13.50	69.9	4330			
18N	13.32	69.0	4360			
	13.41	69.4	4345	.188	.181	.009