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TRIALS CONDUCTED ON A GERMAN R130-CLASS MINE SWEEPER EQUIPPED WITH VOITH-SCHNEIDER CYCLOIDAL PROPELLERS

BY E.T. KLEMMER AND P.K. JOHNSON

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TRIALS CONDUCTED ON A GERMAN R130-CLASS MINE SWEEPER EQUIPPED WITH VOITH-SCHNEIDER CYCLOIDAL PROPELLERS

by

E.T. Klemmer and P.K. Johnson

ABSTRACT

Trials of a German R130-Class mine sweeper (EMS-1), and especially of its propulsive equipment, were conducted by the David Taylor Model Basin. The results of the trials were compared with those of the German Navy and with model test results of both the German Navy and the Taylor Model Basin.

The EMS-1 maneuvered with ease and versatility. The characteristics of the Voith-Schneider propeller permit much finer control of a vessel than those of the conventional screw propeller and rudder. Thus the Voith-Schneider propeller is ideally suited for installation on vessels requiring unusual operation in restricted waters. Although it was not possible to accurately determine the efficiency of the Voith-Schneider propeller, it appears that at designed loads its efficiency is below that of a typical screw-propeller installation on a similar vessel.

INTRODUCTION

Trials were conducted on a 135 1/2-ft German R130-Class mine sweeper. This vessel was built in Germany by the Abeking and Rasmussen Company for the German Navy as R-148 and was completed early in 1945. At the end of World War II it was taken over by the Army Service Forces Transportation Corps Board, redesignated the EMS-1 (Enemy Mine Sweeper 1), and brought to the United States under its own power. This Board loaned the vessel to the Bureau of Ships for ascertaining the operating characteristics of a Voith-Schneider cycloidal propeller* installed on a German mine sweeper. The results of the trials, which were conducted by the David Taylor Model Basin, are compared with those obtained by the German Navy on similar ships.

To determine the operating characteristics of the EMS-1 and the Voith-Schneider propellers as fully as possible, standardization, towing, dead pulls, turning, crash-ahead, and crash-astern trials were conducted on the Kent Island measured mile in the Chesapeake Bay during the period 25 July

* For theoretical discussion of operation of cycloidal propellers see "Principals of Naval Architecture," Vol. 2, p. 125, by Henry Rossell and Lawrence B. Chapman.

TABLE 1

Characteristics of the Ship, Engines, and Propellers

Dimensions of Vessel	
Type	German R130-Class mine sweeper
Length, overall	135 ft 6 in.
Length between perpendiculars	129 ft 2 in.
Beam, maximum	19 ft 0 in.
Depth, amidships	12 ft 0 in.
Mean draft, light displacement	4 ft 10 1/2 in.
Mean draft, heavy displacement	5 ft 3 in.
Displacement, light	132 tons
Displacement, heavy	147 tons
Designed speed	18.5 knots
Wetted surface, light displacement	2318 sq ft
Wetted surface, heavy displacement	2448 sq ft
Construction	
Hull - Composite, wood planking	
Appendages - Centerline skeg and bow pressure-log supports	
Main Engines	
Type	M.A.N. diesel, W8V 30/38 ou
Number	2
Rated HP	900 each
RPM	700
Engines are coupled to shafts through mechanical clutches.	
Propellers	
Type	Voith-Schneider, size 14
Number	2
RPM	226
Orbit diameter	4.592 ft
Number of blades	7
Blade length	2.852 ft
Blade width at top, maximum	11 21/32 in.
Bevel reduction-gear ratio	3.1 to 1.0
Maximum pitch, pitch setting 10	10.53 ft
Pitch ratio, $P/\pi D$, maximum	0.73
Pitch and steering control	Hydraulic

to 18 September 1946. Supplementary information was obtained from a 20-ft model constructed and tested at the Taylor Model Basin and from German trial reports (1)(2).* Noise measurements were made and are the subject of another Taylor Model Basin Report (3).

The characteristic dimensions of the ship, its propelling machinery, and the Voith-Schneider cycloidal propellers are given in Table 1.

The seven blades of the propellers are of hydrofoil cross section and project vertically down from the face of the rotor, which is flush with the hull of the vessel. The exact shape and composition of these forged stainless-steel blades is the subject of a report by the Transportation Corps Board (4). The motion of the blades is so controlled by a mechanical linkage that lines drawn normal to the centerline of each blade will intersect near a point; see Figure 1. Pitch of the blades and direction of thrust are changed by moving the pitch point. The position of the pitch point is controlled by two hydraulic cylinders with internal control valves which are motivated by the bridge controls, one producing athwartship pitch to steer, the other producing fore and aft pitch to propel ahead or astern or stop. A photograph of the propellers, taken while the ship was in drydock, is shown in Figure 2.

The M. A. N. diesel engines are governor-controlled, making it possible to change propeller pitch or steering setting or both without altering the engine adjustment. Propeller pitch is controlled from the bridge by two vertical levers moving across graduated arcs on the steering-wheel stand. The arcs are evenly graduated from 0 to 10 forward for ahead pitch and from 0 to 10 aft for astern pitch; each division therefore represents approximately 10 per cent of full pitch. An interlocking pin allows simultaneous pitch changes of both propellers by means of one lever.

The bridge steering wheel, which is similar to the steering wheel of an automobile, is located between the pitch levers. The wheel is geared to a pointer with a circular scale which is graduated from 0 to 90 on both sides of the center and is linked to both propellers except for emergencies, when steering control can be shifted to the propeller compartment. The final direction of thrust depends upon both pitch and steering settings, e.g., with a pitch setting of zero a steering setting of 90 on the indicator corresponds to about a 90° thrust angle, whereas at pitch setting 10 a steering setting of 90 corresponds to about a 45° thrust angle. The steering control is also interconnected to the pitch control in such a manner that the ahead component of the pitch is reduced as the steering angle is increased, to prevent overloading of the engines.

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* Numbers in parentheses indicate references at the end of this report.

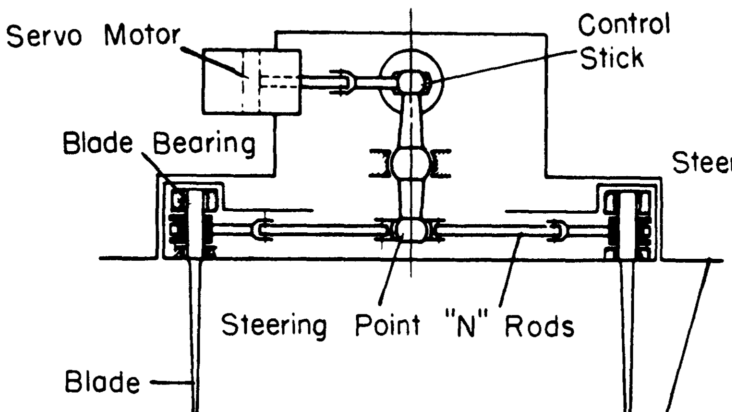


Figure 1a

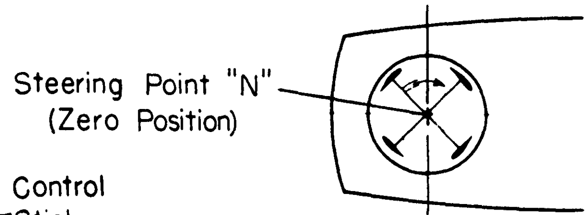


Figure 1c - Position of Steering Point for No Thrust of the VSP

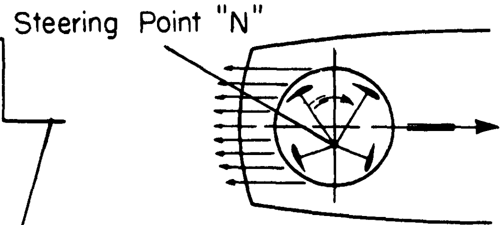


Figure 1d - Thrust Astern for Forward Motion of Ship

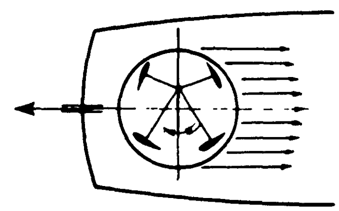
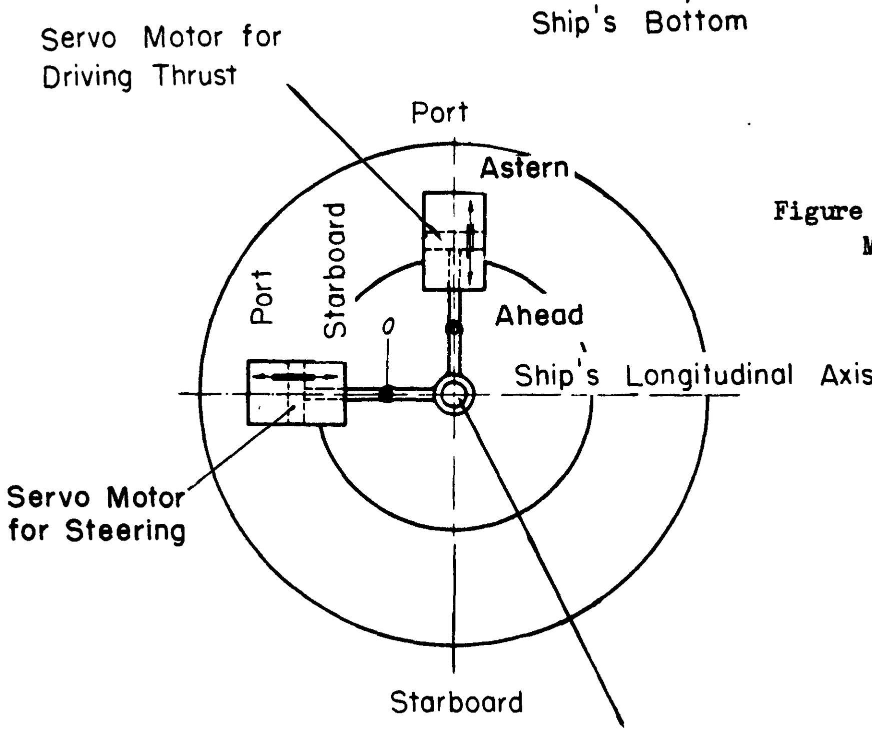


Figure 1e - Thrust Forward for Astern Motion of Ship or Stopping



Steering Point in Zero Position for No Thrust, No Load Condition of the VSP

Figure 1b

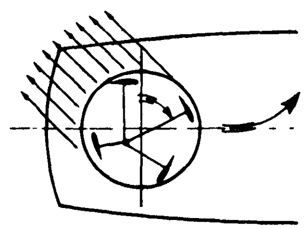


Figure 1f - Forward Turn to Port

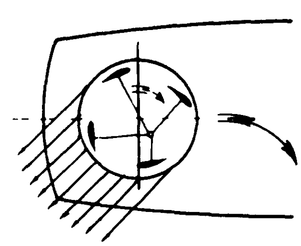


Figure 1g - Forward Turn to Starboard

Figure 1 - Schematic Illustration of the Method of Operation of the Voith-Schneider Propeller

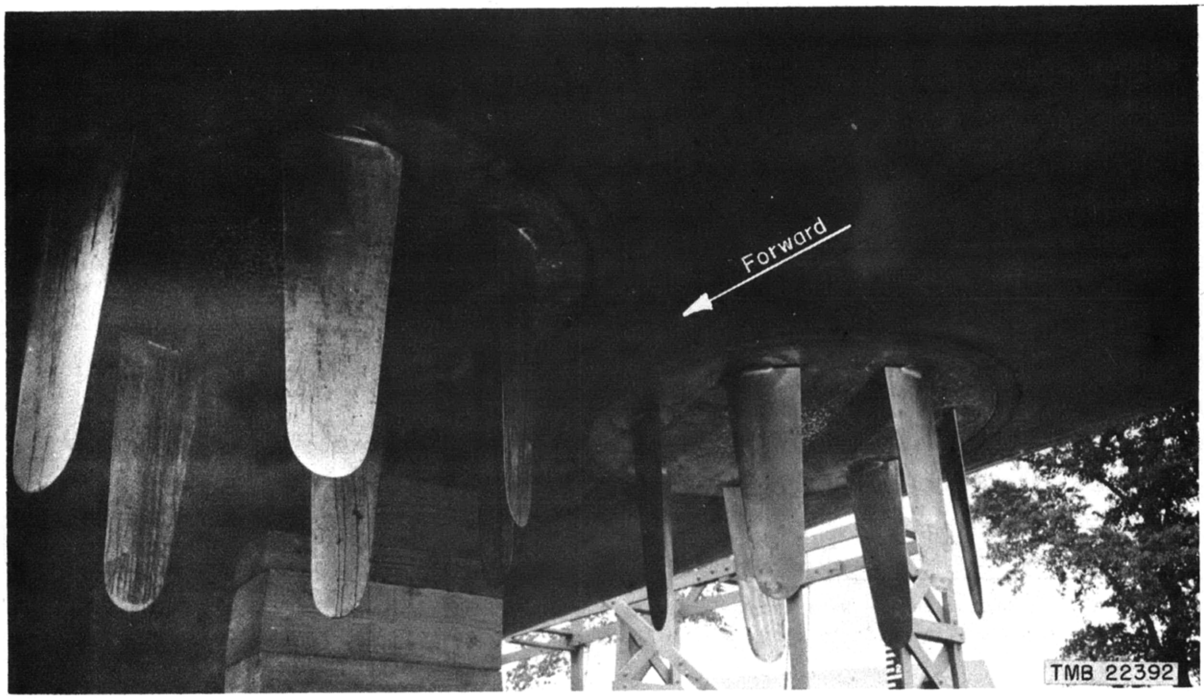


Figure 2 - View Showing Twin Cycloidal Propellers at Zero Pitch

Revolution indicators located in the engine room and pilot house were not accurate; so it was impossible to set engine revolutions per minute (RPM) accurately. There was also some drift in RPM during the runs. Since the engines could not be operated at less than 400 RPM the curves of the higher pitch settings could not be extended to the lower ship speeds.

TRIAL EQUIPMENT

Listed below are the items which were recorded and the recording instruments used during the trials. An LCI was used to obtain towrope loads. Later it was used as an observation vessel from which tactical data was obtained.

Item to Be Recorded	Instrument
Density of water	Hydrometer
Depth of water	Lead line
Distance to anchored LCI during turning trials	35-mm motion-picture camera on LCI and stadimeter on EMS-1.
Propeller Vibration	Cordero hand vibrometer and Frahm vibrating-reed frequency meter.
RPM	One Smith-Cummings counter and one Taylor printer counter on each shaft.

List (Continued)

Item to Be Recorded	Instrument
Sea condition	Visual observation.
Speed through water	Bow pressure log and pitometer log.
Temperature, air and water	Mercurial thermometer.
Time, over trial course and for RPM	Chronograph. Observers' stop-watch check.
Torque	One DTMB 60-cycle a-c modified Ford-Siemens type torsion meter on each shaft.*
Towrope pull	DTMB SR-4 electric strain-gage towing dynamometer.
Wind direction	Wind arrow.
Wind velocity	3-cup anemometer recording on chronograph tape.

* The torsion meters were located between the clutch and the propeller on each shaft. There was one line-shaft bearing between the torsion meter and the propeller.

TRIALS

Trial instruments and special towing pads were installed at the Norfolk Naval Shipyard under the supervision of Taylor Model Basin personnel. The vessel was docked at Norfolk in April 1946, hull offsets were lifted, and Navy bottom paint (15RC) was applied. The undocking date was 6 May 1946. The vessel was again docked 3 to 10 June and the bow pressure log fitted; see Figure 3.

During the trials the EMS-1 was berthed at the Annapolis Yacht Yard. The Yacht Yard supplied the operating crew and maintained the boat for the duration of the trials. Propeller blades were removed and replaced by the Annapolis Yacht Yard on the Severn River Naval Command Marine Railway.

The normal operating displacement of the EMS-1 was 132 tons with about an 11-in. trim by the stern. The heavy displacement, 147 tons, was obtained by filling all fuel-oil and fresh-water tanks and placing lead ballast on the main deck. This decreased the trim from about 11 in. by the stern in the light-displacement condition to 2 in. by the stern in the heavy-displacement condition.

Drafts were taken of the EMS-1 prior to leaving the dock and upon returning each day. Water density was measured once each day. Water temperatures were read twice each day; air temperatures were read during each run. Torsion-meter zero readings were taken before, after, and during each day of trials. The engines were de-clutched and the vessel was dead in the water

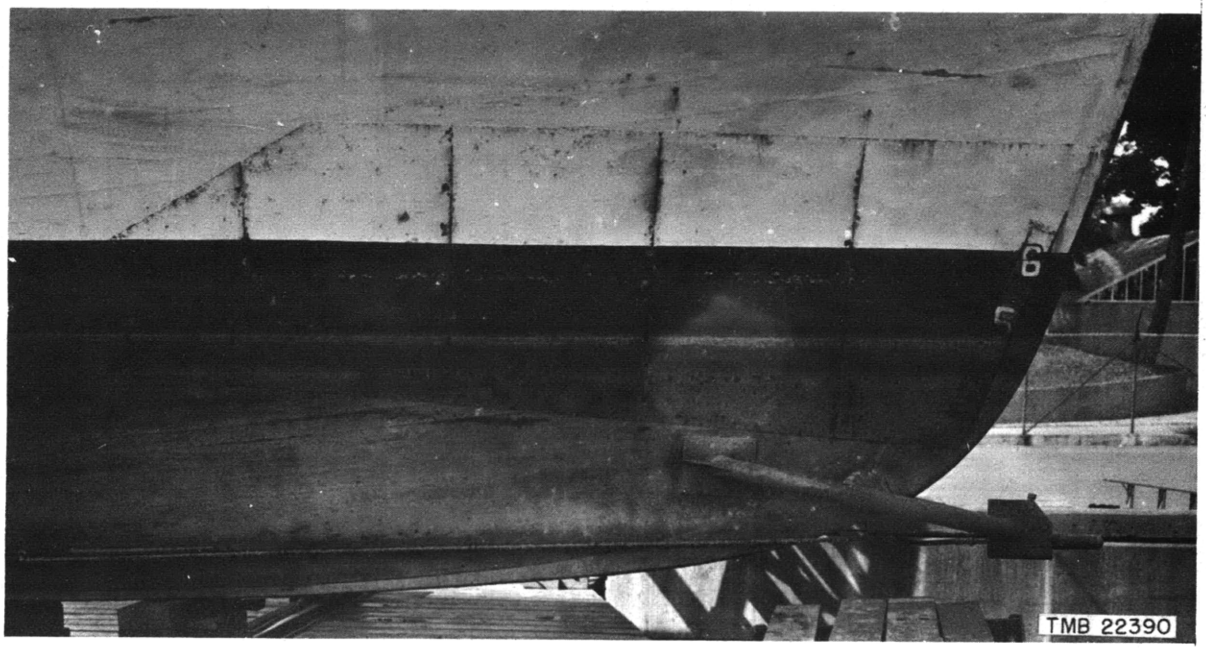


Figure 3 - View of EMS-1 Showing Bow Log

while the torsion-meter zero readings were taken. Since the line-shaft bearings were roller bearings it was assumed that the residual torque was negligible. Zero readings on the torsion meter substantiate this assumption by their consistency.

The ship data are reduced to zero air resistance and zero current by Captain Eggert's power method, which is outlined in Appendix 1. The original trial data are presented as Appendix 2.

Standardization Trials

Standardization trials were conducted with the EMS-1 in four different conditions:

1. Ahead, light displacement.
2. Ahead, heavy displacement.
3. Ahead, light displacement with one propeller removed.
4. Astern, light displacement.

The standardization trials were run over the measured mile off Kent Island. Each set of trials was run at arbitrary propeller-pitch settings of 4, 6, 8, and 10 (full pitch) and at five different values of RPM for each pitch; namely, 400, 500, 575, 650, and maximum RPM. The standard three-run procedure was employed for each pitch setting and RPM.

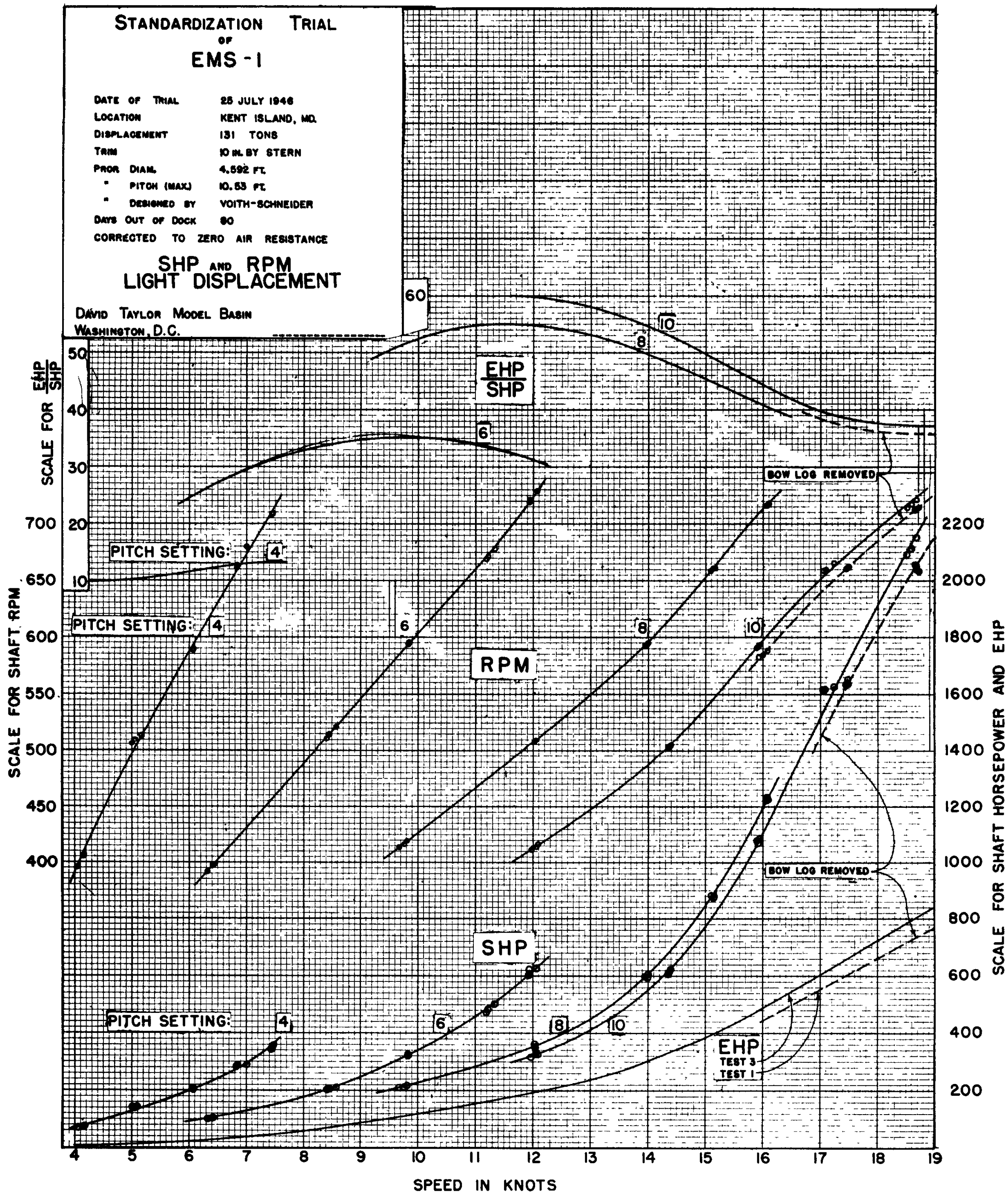


Figure 4 - Standardization Trial at Ahead Light Displacement

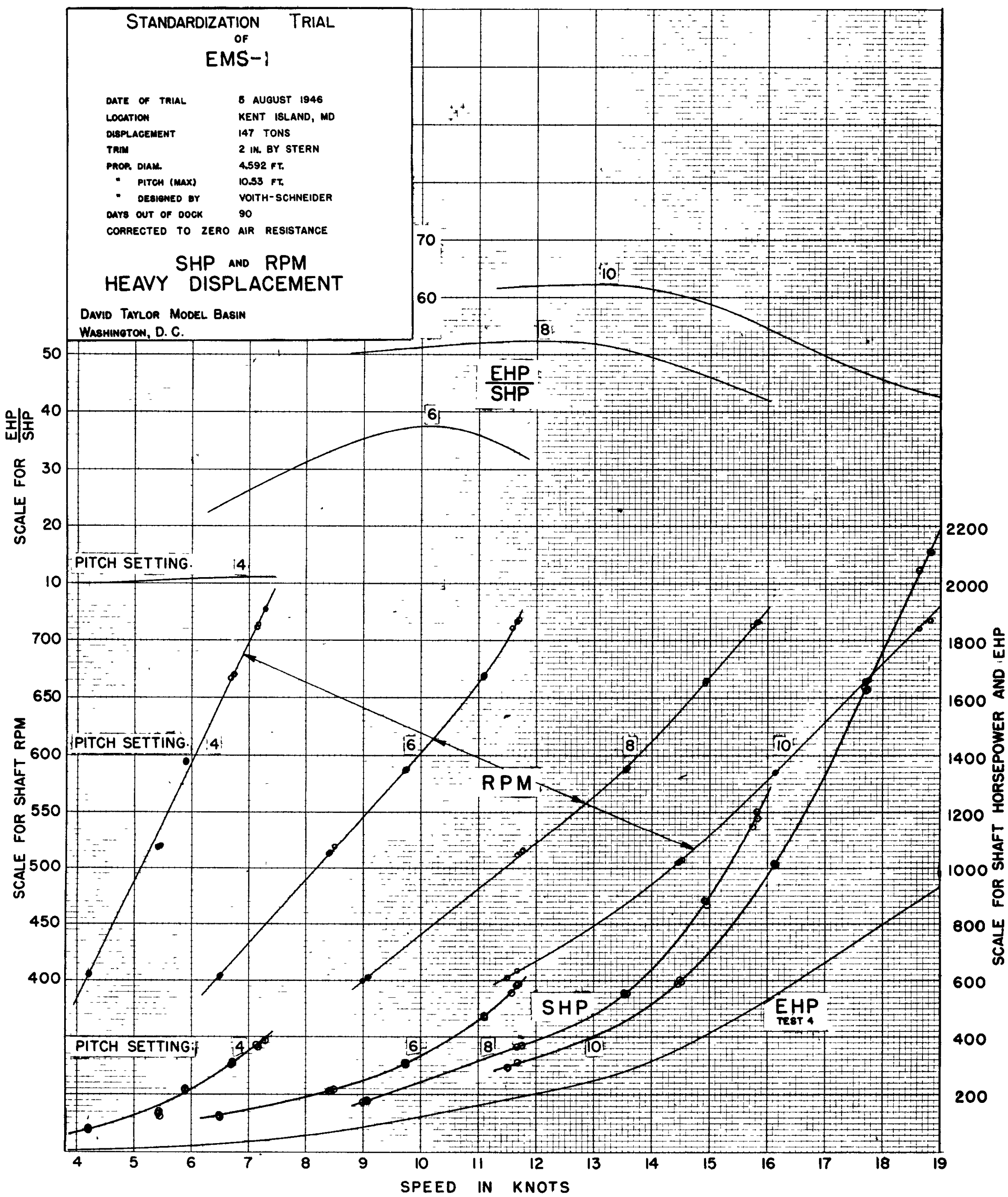


Figure 5 - Standardization Trial at Ahead Heavy Displacement

One observer forward and one aft measured the time over the mile course with stop-watch contact makers which recorded on the chronograph tape. Torsion-meter readings were taken every 30 sec for the duration of the runs. The Taylor shaft-revolution counters were operated by the forward observer's contact maker, the Smith-Cummings shaft-revolution counters by the aft observer's contact maker. Pitometer-log and bow pressure-log readings were taken during all the ahead standardization trials. The bow log, with a mercury U-tube manometer to measure pressure, was calibrated during these runs; see Figure 3.

The bow log gave consistent results in smooth water but owing to the small change of mercury level with speed the errors in the bow-log readings were about 2 per cent at 18 knots and as large as 8 per cent at 3 knots. These errors were further accentuated by slight pitching of the vessel. In order to determine the effect of the bow-log support upon the hull resistance, several light-displacement runs were made with the bow log removed; see Figure 4.

An attempt was made to calibrate the pitometer log but the readings were inconsistent; consequently, it was of no value during the towing and turning trials. The failure of the pitometer log to operate satisfactorily is thought to be due to insufficient submergence of the pump unit, variation in frequency of the electrical power supplied, and possibly the proximity of the rod meter to the propellers.

No bow-log or pitometer-log readings were taken during the astern standardization runs. The steering settings necessary to maintain course were read during the astern standardization.

An observer on the bridge recorded wind direction, sea conditions, and air temperature. The anemometer recorded the relative wind velocity directly on the chronograph tape.

Light-displacement standardization. Curves of EHP, SHP, RPM, and propulsive coefficient (EHP/SHP) are plotted against speed for the light-displacement (131 tons) standardization trials on Figure 4. Each run has been corrected to zero-wind and zero-current conditions. The values of EHP are from the Taylor Model Basin Tests 1 and 3 shown on Figures 31 and 32. It must be remembered that the EHP of the propulsive coefficient is from the model-test results and the SHP from the full-scale trial results.

It is evident from Figure 4 that both maximum speed and propulsive coefficient increase with an increase in pitch. The difference in EHP/SHP values for pitch 8 and pitch 10 is so small, however, that it is probable that 10 is nearly the optimum pitch for free running at light displacement.

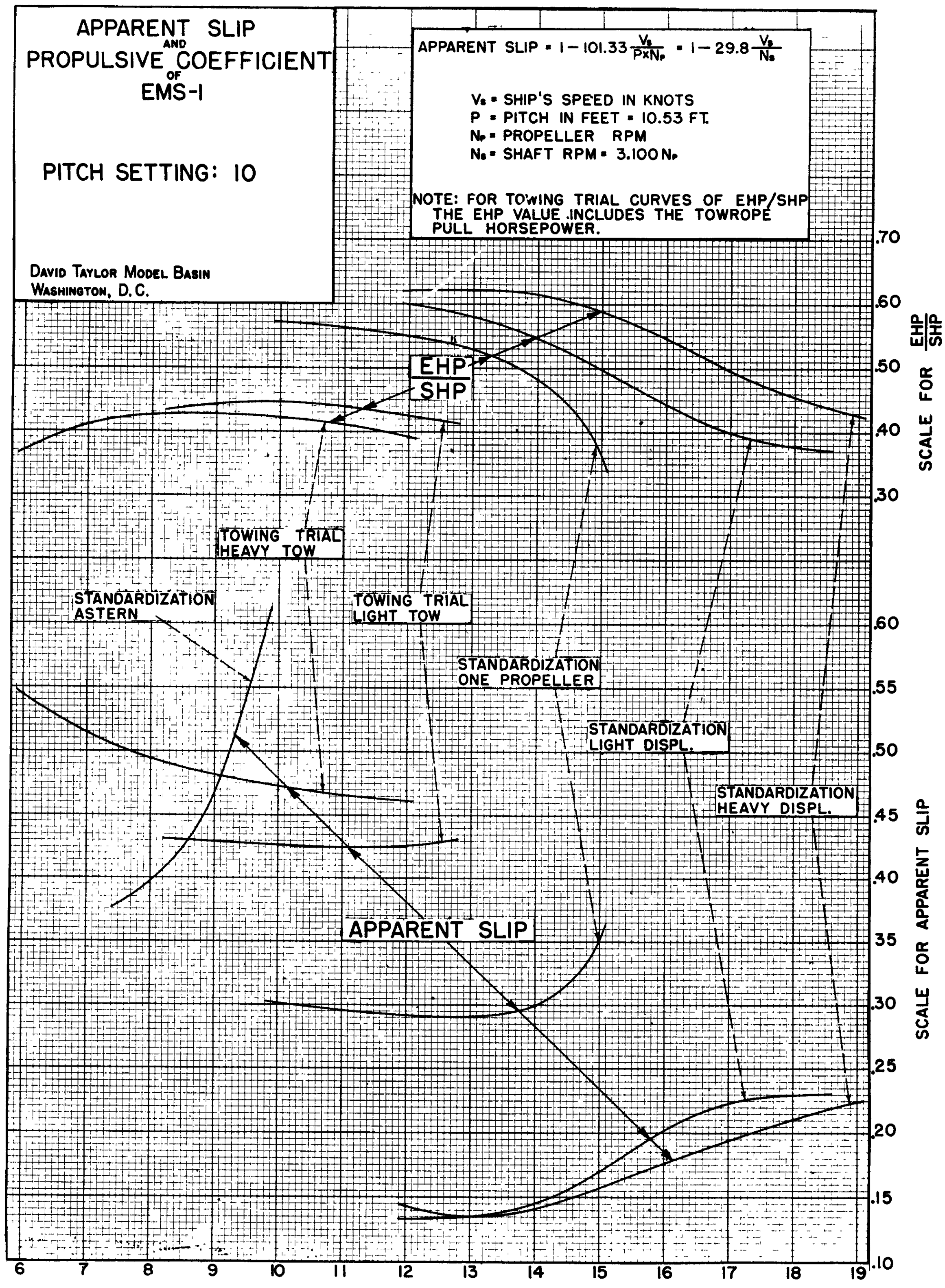


Figure 6 - Apparent Slip and Propulsive Coefficient at Pitch 10

The maximum speed reached by the EMS-1 in the light condition from the bow log was about 18.6 knots at 2120 SHP and 720 RPM at a propulsive coefficient of 37 per cent. The maximum value of EHP/SHP, 60 per cent, was reached with pitch 10 at 12 knots and 320 SHP.

Removing the bow log from the ship lowered the light-displacement SHP by about 5 per cent and the RPM by about 2 per cent. Removing the bow log from the model lowered the EHP values even more and resulted in a slight drop in the propulsive coefficient. The model-test results, however, are probably slightly exaggerated because of scale effect on the bow log. The value of EHP/SHP is, therefore, liable to significant systematic errors due to an incorrect roughness allowance (Gebers "G") applied to the model results. No check on this allowance was possible. The model was not equipped for self-propulsion, so SHP's could not be compared; and since the ship was not towed, EHP's could not be compared. Recent tests have tended to show that the conventional values for roughness allowance which are too low would produce a propulsive coefficient which is also too low.

Heavy-displacement standardization. Curves of EHP, SHP, RPM, and propulsive coefficient are plotted against speed for the heavy-displacement (147 tons) standardization trials on Figure 5. The EHP data are from model Test 4 shown on Figure 32.

As in the light-displacement trials, both maximum speed and propulsive coefficient increase with pitch; however, there is a greater difference in EHP/SHP for pitch 8 and pitch 10 than in the light-displacement trials. From Figure 6 it is evident that the propulsive coefficient for the heavy displacement was considerably higher than for the light displacement. This results from the fact that the SHP was actually lower for the heavy displacement than for the light displacement at corresponding speeds. This paradox is discussed more fully on page 47. The maximum speed for heavy displacement was about 18.7 knots at 2100 SHP and 720 RPM with a propulsive coefficient of 42 per cent. The maximum value of EHP/SHP, 62 per cent, was reached with pitch 10 at 13 knots and 250 SHP.

One-propeller standardization. Figure 7 gives the results of standardization trials run with the blades of the starboard propeller removed. The EHP curve is taken from the model Test 3 shown on Figure 32.

The one-propeller standardization curves are very similar in form to the light- and heavy-displacement standardization trial curves at low speeds. A fairly sudden break occurs in the RPM and EHP/SHP curves for pitch 10 at about 14 knots. Figure 6 shows that the apparent slip is subject to a large positive acceleration between 14 and 15 knots. These breaks seem to indicate the beginning of serious cavitation.

The maximum speed obtained with one propeller was 15 knots at 1060 SHP and 730 RPM with a propulsive coefficient of 36 per cent. The maximum value of EHP/SHP of 58 per cent was reached with pitch 10 at 9.7 knots and 190 SHP.

Astern standardization. Curves of SHP and RPM for the astern standardization trials are given on Figure 8. At full pitch and maximum RPM the propellers absorbed only 1400 SHP. This fact together with the sharp increase in RPM and apparent slip above 8 knots suggests that the propellers were sucking in air or were cavitating badly; see Figures 6 and 8. The maximum speed astern was 9.8 knots at 1400 SHP and 710 RPM.

The EMS-1 crabbed considerably during the astern runs. The position of the bow relative to the wake is shown in Figure 9.

Towing Trials

The towing trials were conducted off the shore of Kent Island using 1-min steady-condition runs. Speed was measured by the bow log. The towing loads were applied by towing an LCI with a 600-ft length of 7/8-in. wire cable. The shafts of the LCI were locked during light-load towing trials and were backed during heavy-load towing trials. Each set of trials was run at propeller pitch settings of 4, 6, 8, and 10 with five different values of RPM for each pitch setting; namely, 400, 500, 575, 650, and maximum RPM. One run was made at each speed and pitch setting for the light-load tow; consecutive runs were made in opposite directions. Two runs at each speed and pitch setting were made for the heavy-load tow condition; the second run was made in the opposite direction from the first.

The two torsion meters were read simultaneously every 15 sec for the duration of the run. The Taylor and Smith-Cummings shaft-revolution counters were operated simultaneously by contact makers in the computing room. Time intervals were obtained from the record on the chronograph tape made by the contact makers. Wind-velocity and bridge-observer data were taken in the same manner as during the standardization trials.

Towrope-pull values were obtained from an SR-4 portable strain indicator, type K, which was connected to an electrical strain-gage dynamometer. This instrument utilizes the null method with manual balancing. Since the towrope pull varied slowly, indicator readings were taken each time a null reading was obtained. The arithmetical average of these readings was used as the towrope pull prevailing throughout the run.

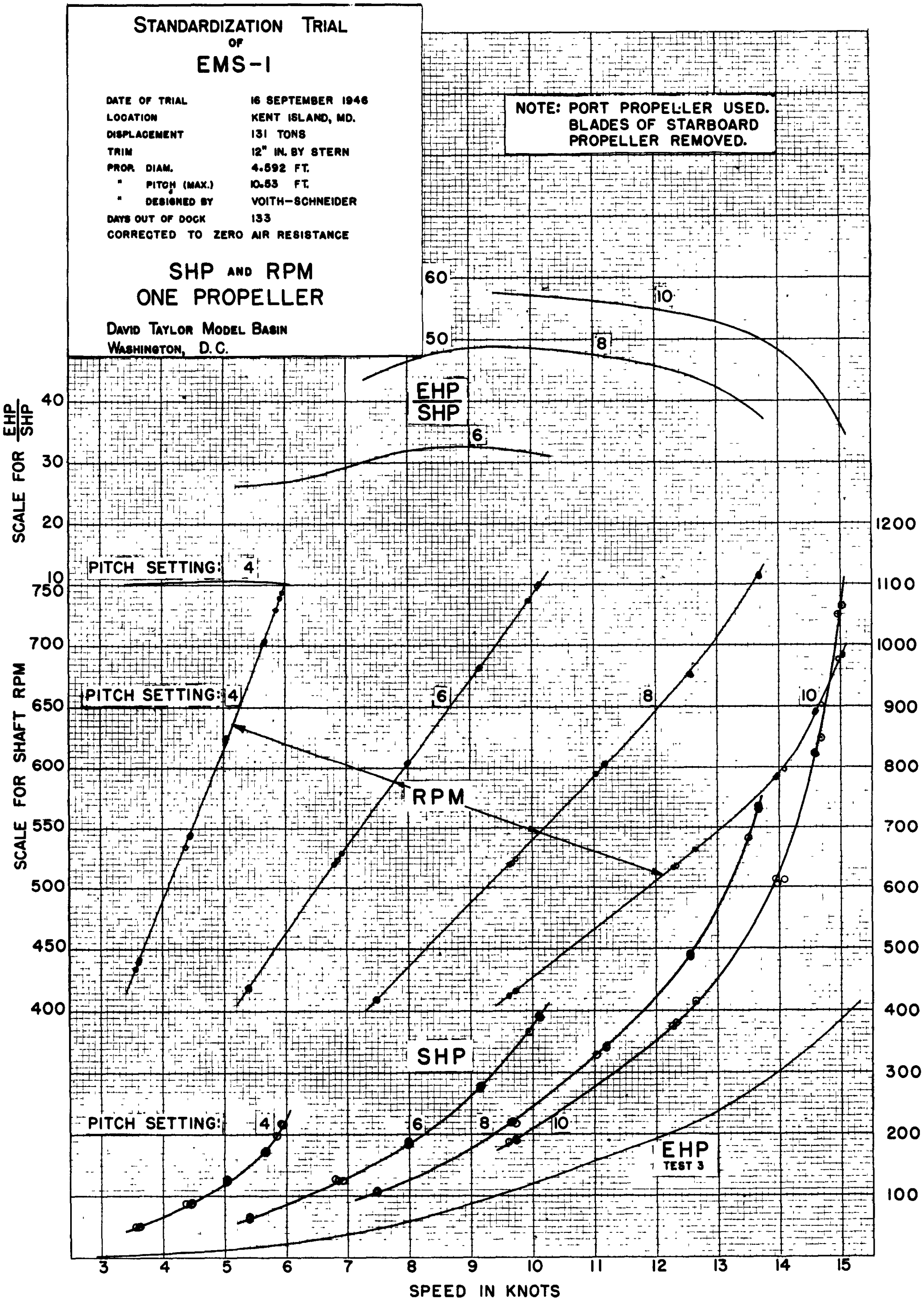


Figure 7 - Standardization Trial Ahead, with One Propeller Operating

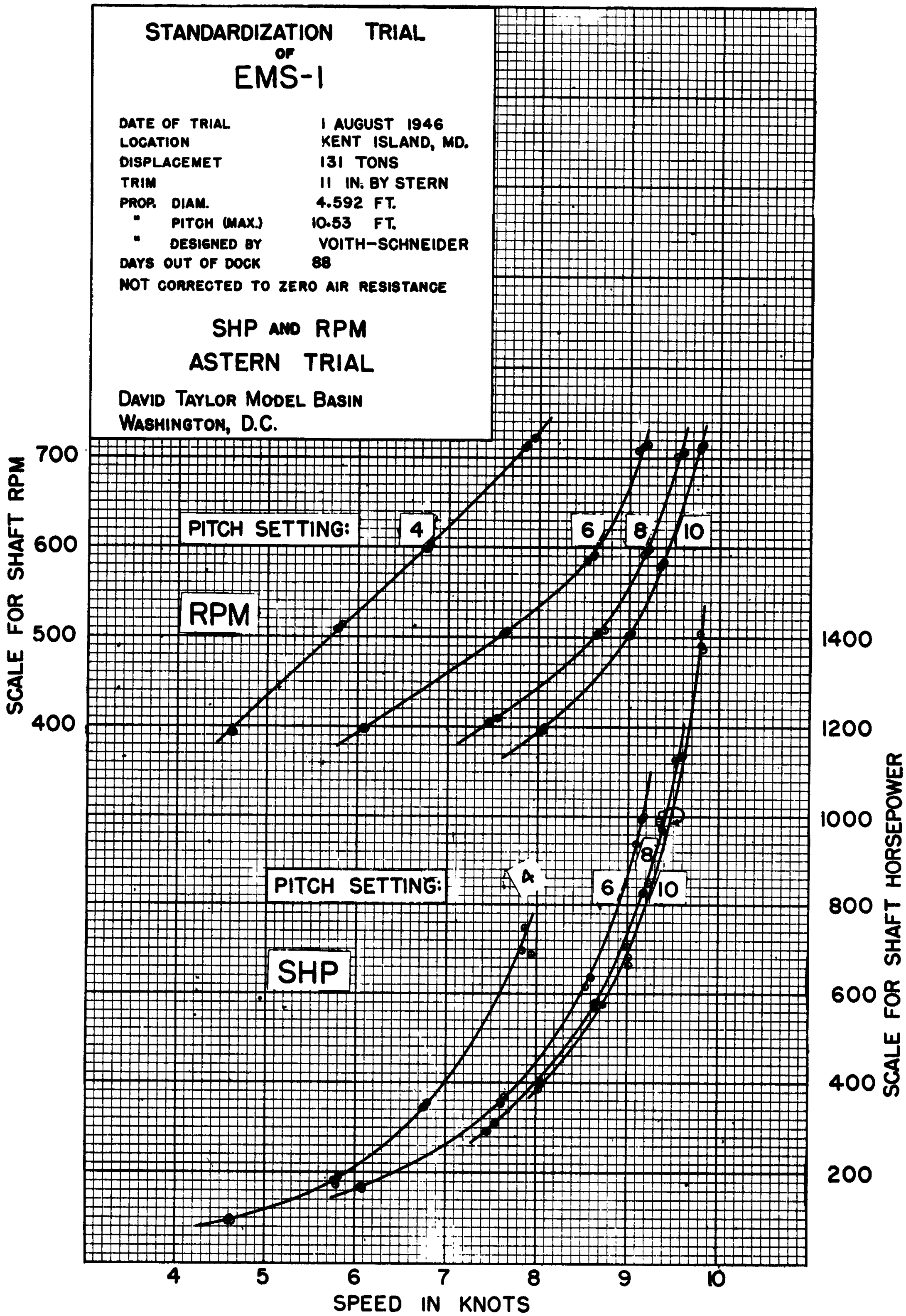


Figure 8 - Standardization Trial Astern

Figure 9 - View Showing Wake during Standardization Trial Astern

Light-load towing trials. Figure 10 is a plot of SHP and RPM versus speed for the light-load towing trials. The wide scatter of the points on these curves is due to the irregular variations in towrope pull, as shown by the points on Figure 12 and the inaccuracy of speed measurements made by the bow log.

The maximum speed obtained was approximately 12.5 knots at 2200 SHP and 650 RPM with a towrope pull of 19,000 lb. Although it was not possible to develop full RPM at full pitch the SHP developed was as large as any encountered during the trials.

Heavy-load towing trials. Figure 11 is a plot of SHP and RPM versus speed for the heavy-load towing trials. The points in this figure are subject to more scatter than those in Figure 10 and for the same reasons. For pitch 8 and pitch 10 during the heavy-load towing trials, the towrope pull at 4 knots was 260 per cent and at 12 knots approximately 109 per cent of the light-load pulls at the same speeds; see Figures 12 and 13. The ineffectiveness of the LCI propellers at 12 knots was undoubtedly due to extensive cavitation.

Figure 13 gives curves of towrope pull versus speed for the three heavy-load conditions of towing: LCI backing one-third, one-half, and full.

Dead-Pull Trials

Dead-pull ahead and astern trials were conducted in both deep and shallow water. The deep-water dead-pull trials were conducted off the Engineering Experiment Station, Annapolis, Md. Figure 14 shows the relation of the ship to the shore. One-min steady-condition trials were made with the pulling cable attached to a dolphin. Trials were made at pitch settings of 2, 4, 6, 8, and 10 with five values of RPM for each pitch; namely, 400, 475, 550, 600, and maximum RPM. Torsion-meter, revolution-counter, trim, and towrope-pull readings were taken in the same manner as during the towing trials.

Shallow-water dead-pull trials, at an 8-ft depth, were conducted off Kent Island with the pulling cable attached to a 3000-lb mushroom anchor. Trials were made at pitch setting 4 only, because the anchor dragged at all higher pitch settings.

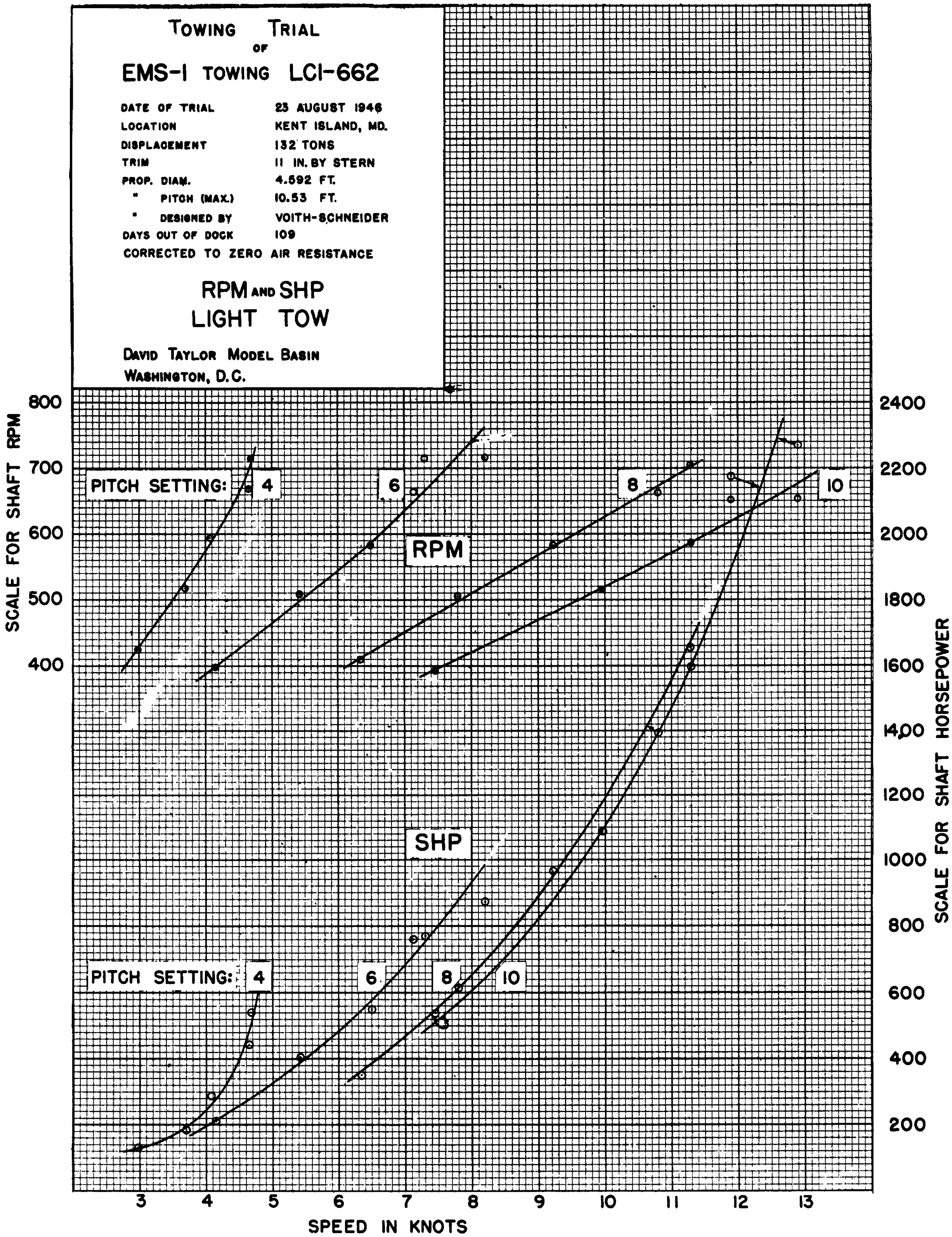


Figure 10 - Towing Trial with Light Tow Load

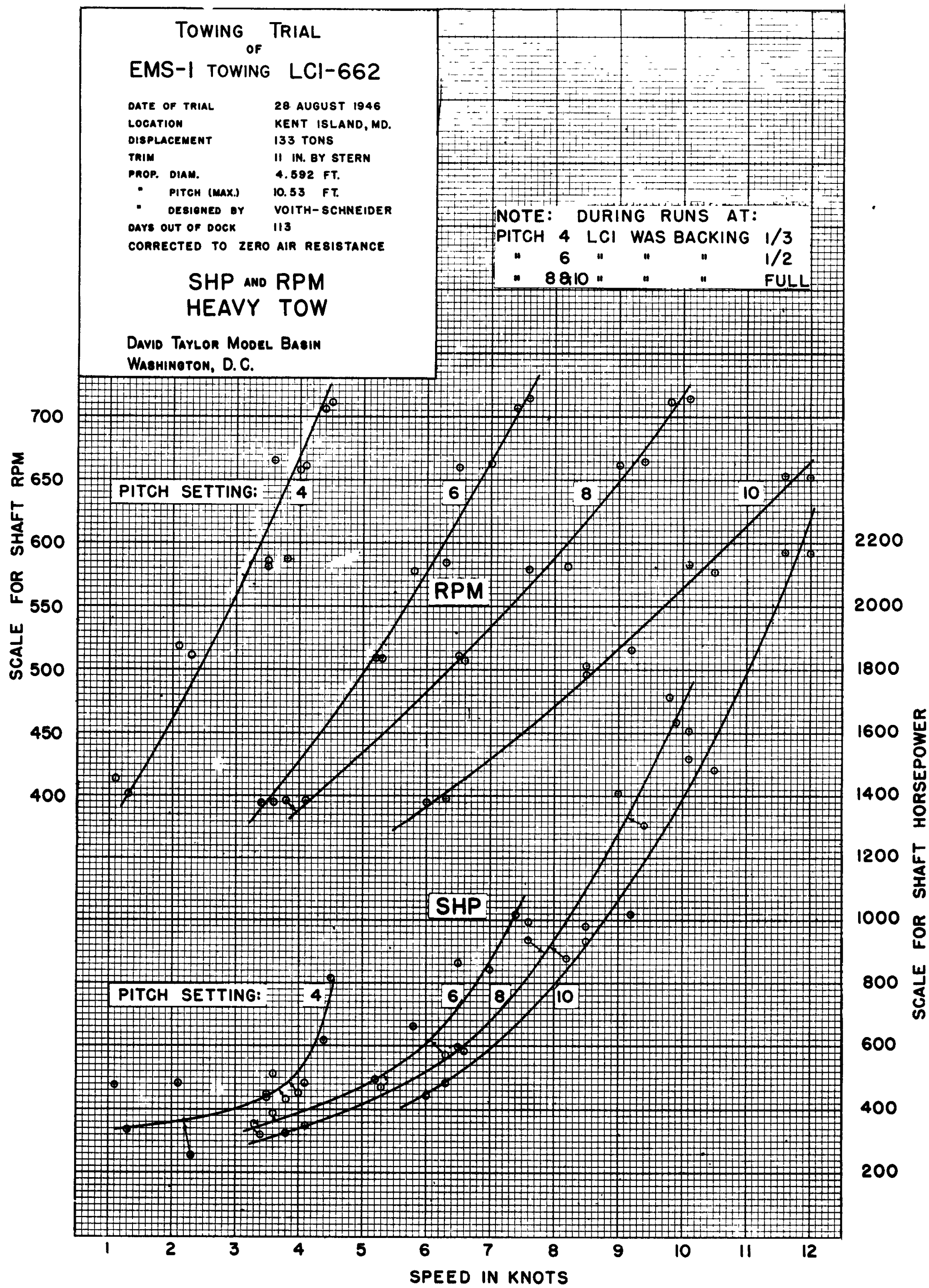


Figure 11 - Towing Trial with Heavy Tow Load

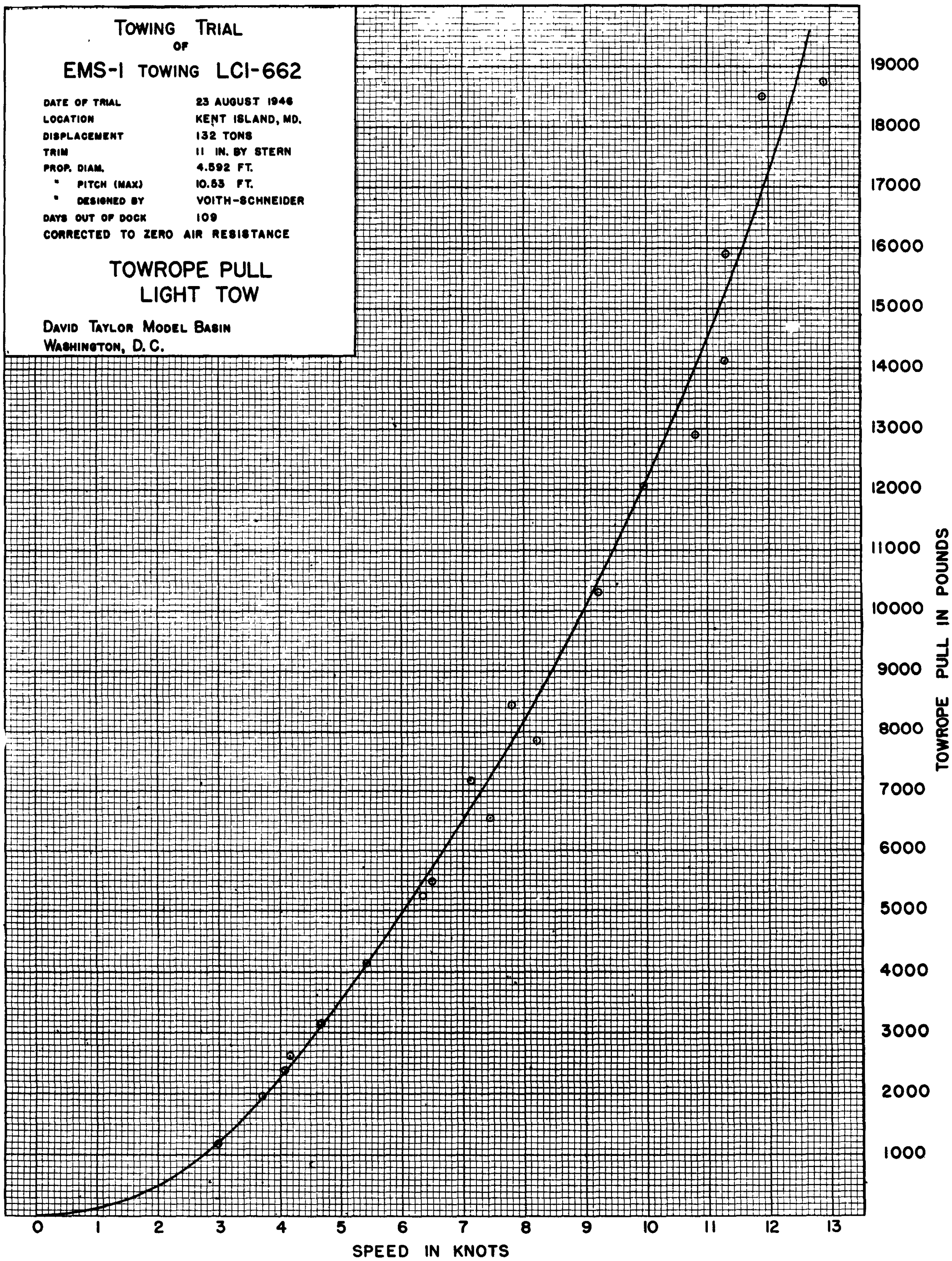


Figure 12 - Towrope Pull at Light Tow Load

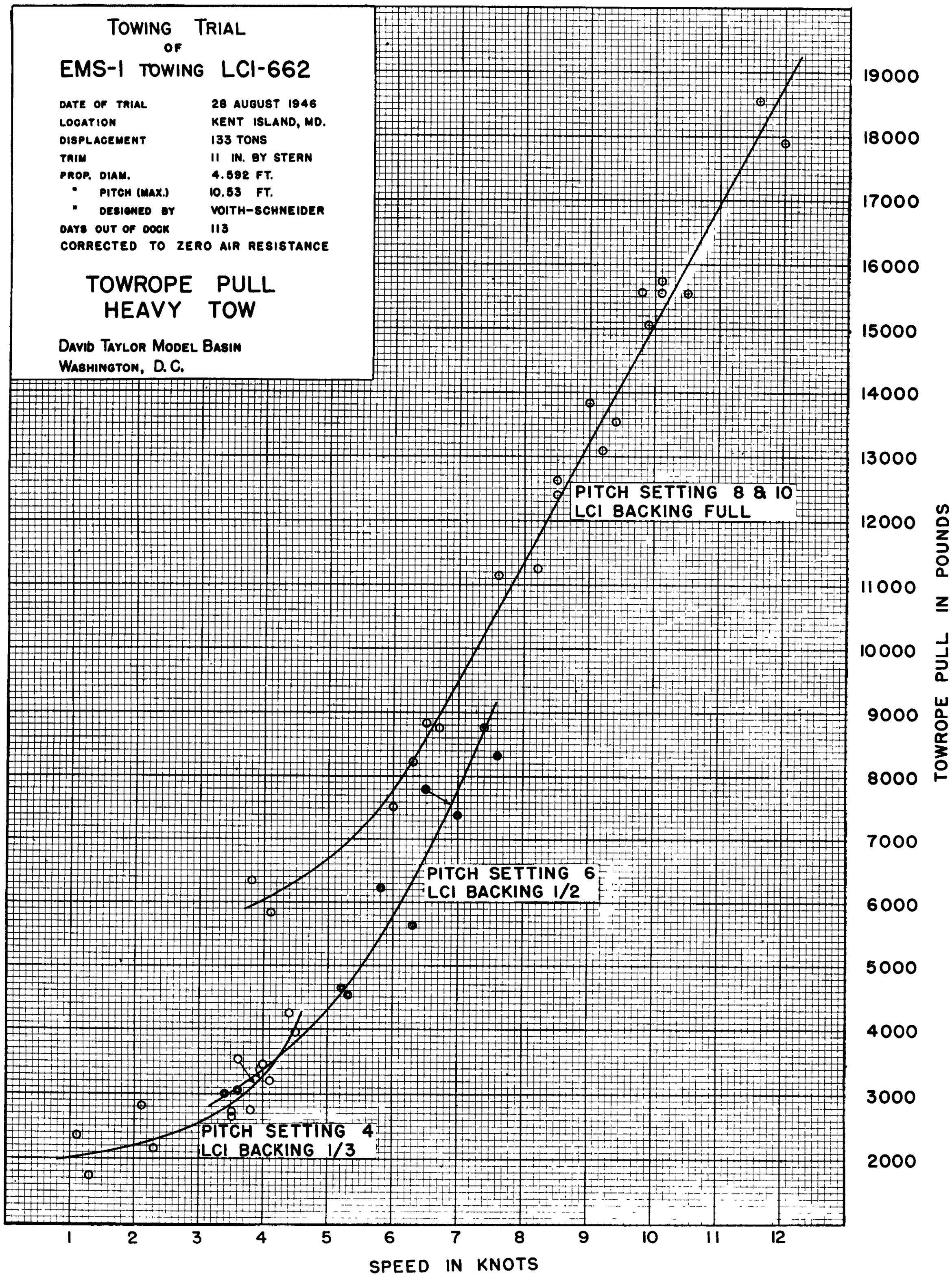


Figure 13 - Towrope Pull at Heavy Tow Load

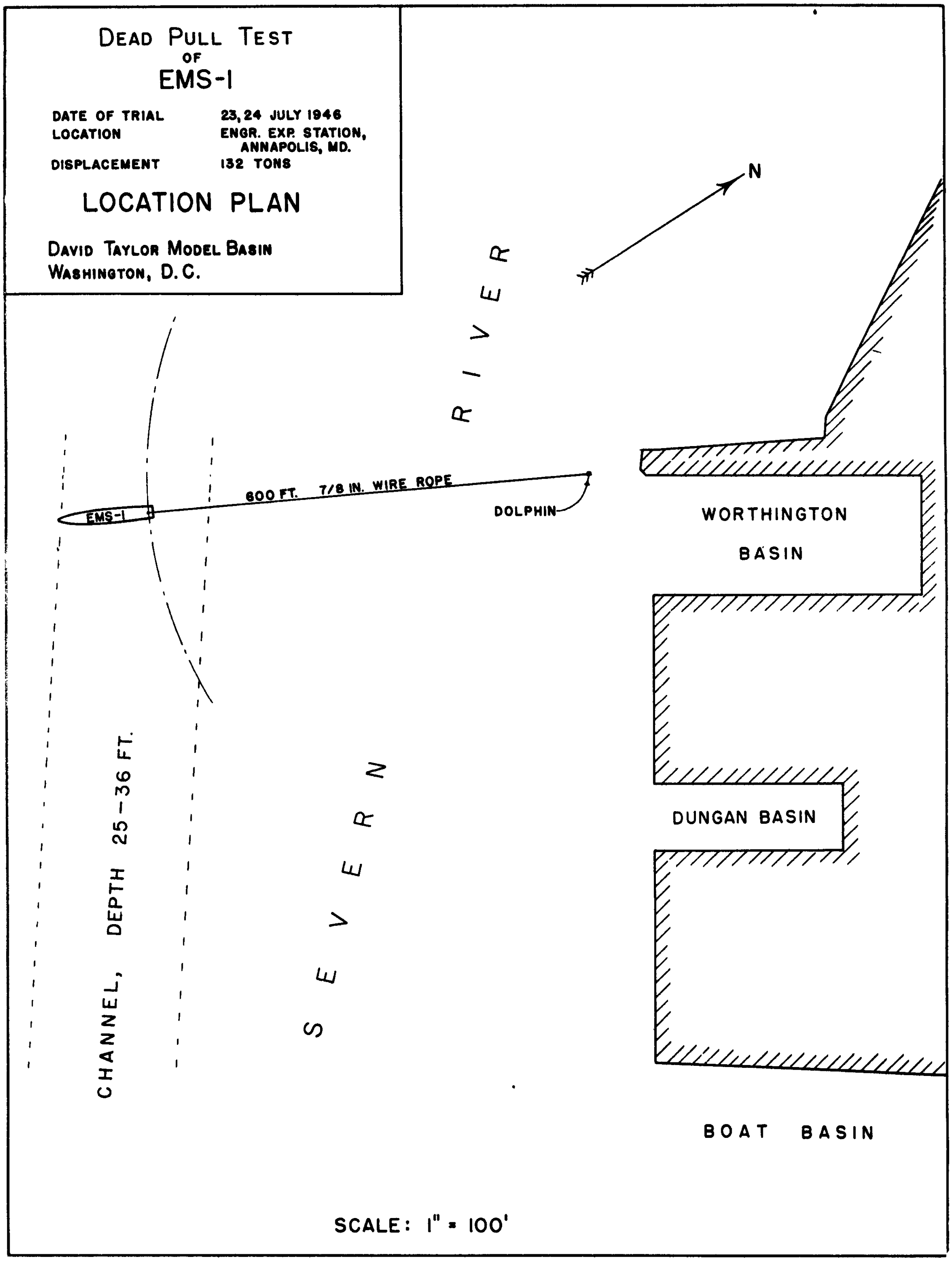


Figure 14 - Dead-Pull Location Plan

Dead pull ahead. Figures 15 and 16 give values of SHP and pull versus RPM for the dead pull ahead trials. The maximum pull of 29,000 lb was achieved with pitch 8 at 2240 SHP and 675 RPM. At full pitch, only 1870 SHP and 555 RPM could be developed, but the resulting pull was 28,800 lb. It would appear, then, that pitch 10 is approximately optimum pitch for dead pull ahead.

The shallow-water curve on Figure 16 compared with the deep-water curve at pitch setting 4 shows a definite loss in pull although the SHP is nearly the same; see Figure 15.

Dead pull astern. Figures 17 and 18 give values of SHP and pull versus RPM for the dead pull astern trials. The SHP curves are similar to those for the dead pull ahead trials. The pull exerted, however, was lower, reaching a maximum of 24,600 lb at pitch 8, with 630 RPM and 2030 SHP.

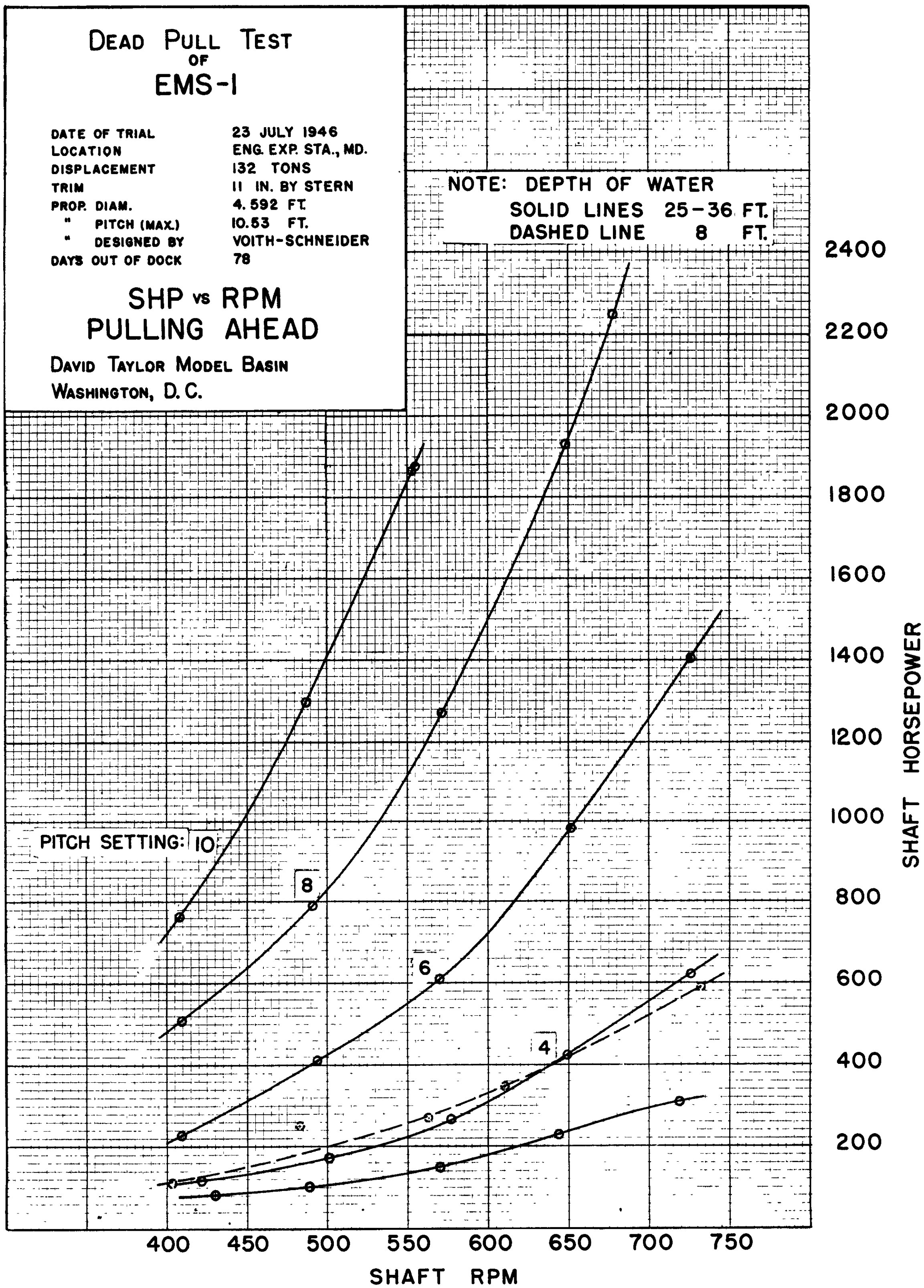


Figure 15 - Dead-Pull Trial Ahead Showing SHP

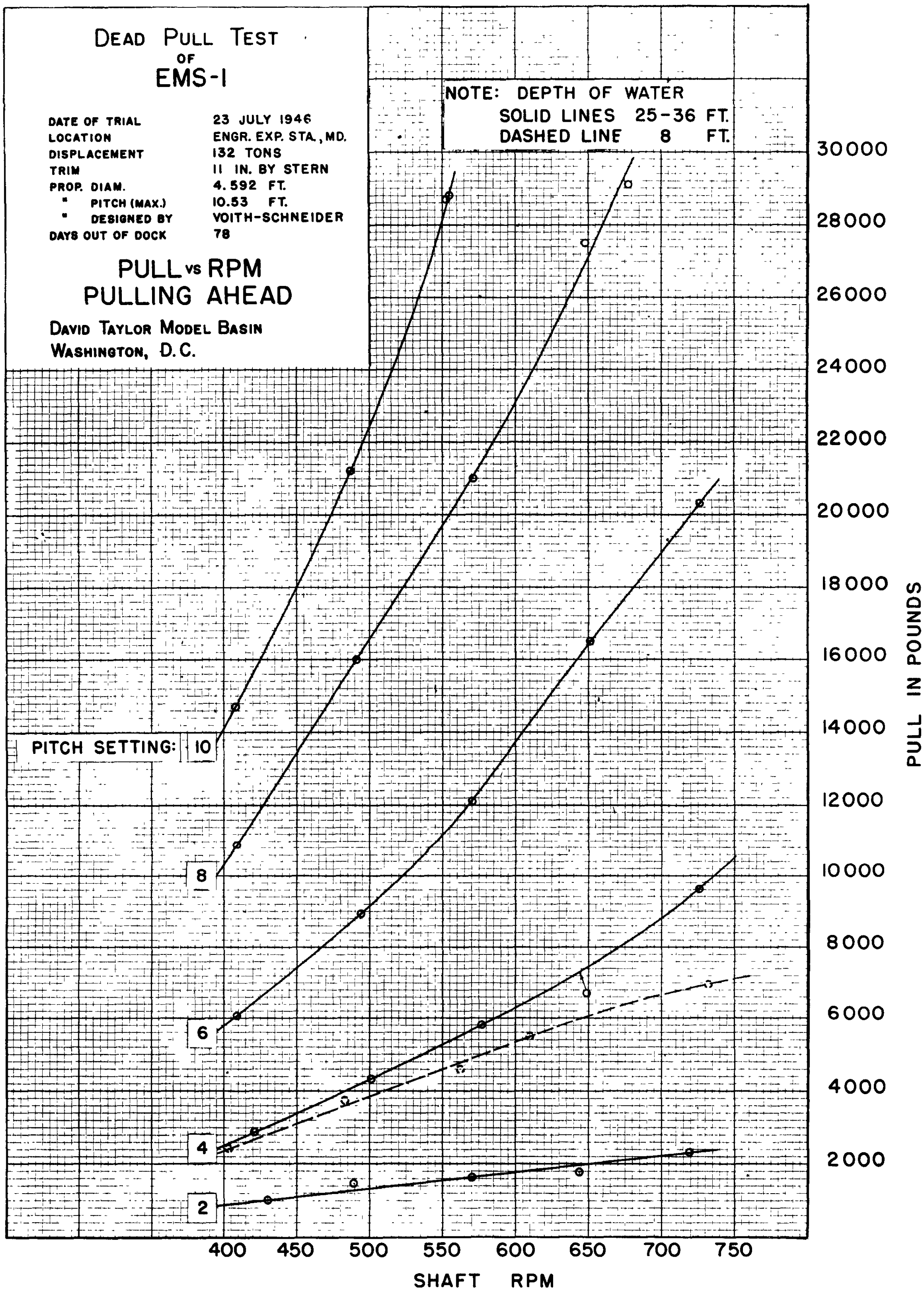


Figure 16 - Dead-Pull Trial Ahead Showing Towrope Pull

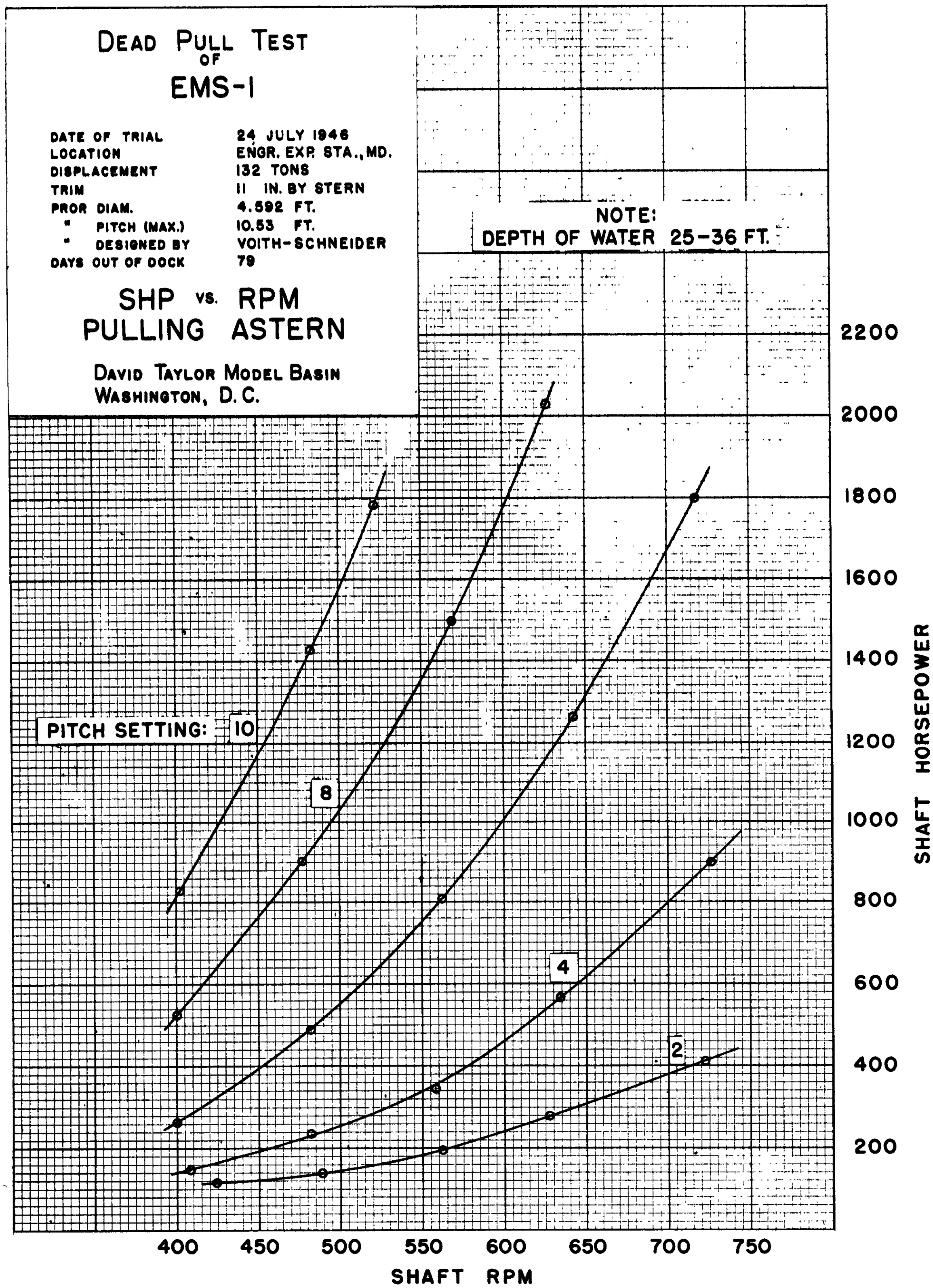


Figure 17 - Dead-Pull Trial Astern Showing SHP

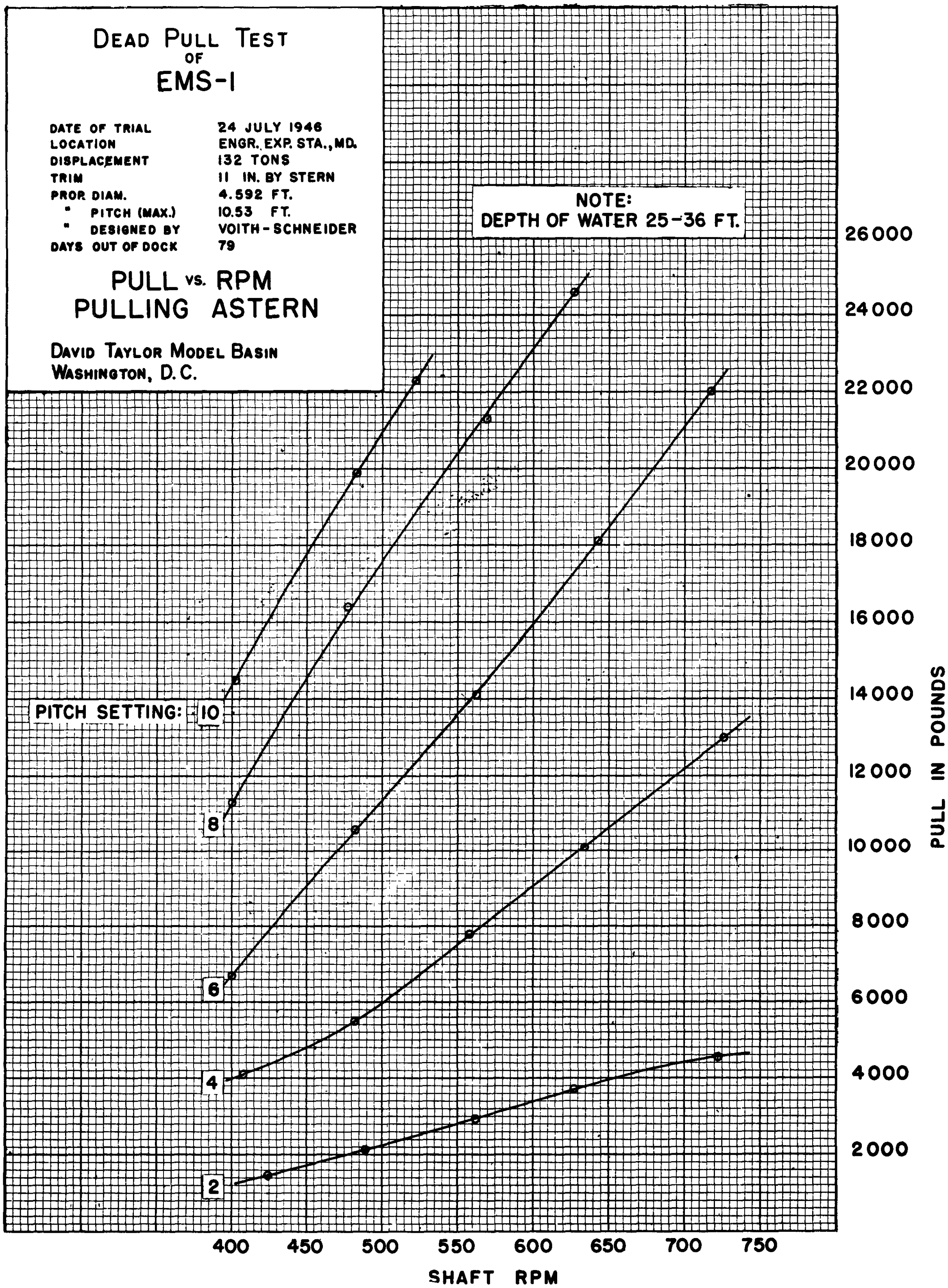


Figure 18 - Dead-Pull Trial Astern Showing Towrope Pull

Turning Trials

Turning trials were conducted off Kent Island at light displacement only. The approach speeds of these trials were 0, 10, 15, and 18 knots, with steering indicator positions of 30, 60, and 90 for each approach speed. The pitch-setting levers were interlocked and remained at the ahead setting during the turns.

Opposed-thrust turns were also made with the steering-indicator position at 90 at approach speeds of 10, 15, and 18 knots. The approach for these turns was made with pitch settings ahead on both propellers. At the signal "execute" the starboard propeller was shifted to full pitch astern and the steering indicator setting applied simultaneously.

The bow pressure log was used to determine the approach speeds. RPM were measured and used to check the bow-log measurement. Times for the several angles of turn were measured by stop-watch observation of a 2 1/2-in. magnetic compass which was somewhat slow in responding to changes in heading. The turning circles were obtained from measurements of masthead heights of the EMS-1 on a 35-mm motion-picture film taken by a camera mounted on the LCI. These values were also checked by stadimeter readings taken on the masthead of the LCI from the EMS-1. The LCI was anchored at the bow and the stern to prevent swinging.

Interlocked-thrust turning. At approach speed of zero knots the vessel pivoted about a point 0.4 its length from bow for all steering-indicator positions. The mechanism of the propeller is such that with zero ahead pitch any steering-indicator position produces a thrust perpendicular to the centerline. The time in seconds to turn through 90°, 180°, and 360° is given on Figure 19. The minimum time to turn through 360° starting dead in the water was 64 sec at 700 RPM with a steering-indicator setting at 90, which is the maximum setting.

When the pitch setting is not zero the propeller-thrust direction is a function of both the pitch setting and the steering setting. This direction is approximately the hypotenuse of a right triangle with legs proportional to the pitch and steering settings.

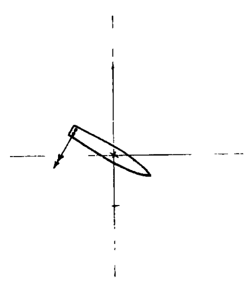
Figures 20, 21, and 22 give diagrams of turning circles and time to turn through 90°, 180°, and 360° for approach speeds of 10, 15, and 18 knots and three steering-indicator positions. The direction of resultant propeller thrust in each case is shown by arrows from the stern of the boat outlined on the turning circles. The minimum time required for the EMS-1 to turn through 360°, considering all conditions tested, was 51 sec obtained with an approach

TURNING TRIAL
OF
EMS-I

DATE OF TRIAL	29 AUGUST 1946
LOCATION	KENT ISLAND, MD.
DISPLACEMENT	133 TONS
TRIM	11 IN. BY STERN
NOT CORRECTED FOR DRIFT	

DAVID TAYLOR MODEL BASIN
WASHINGTON, D.C.

PITCH SETTING: 0, RPM: 700
INTERLOCKED THRUST
APPROACH SPEED 0 KNOTS



	STEERING INDICATOR POSITION	TIME IN SECONDS TO TURN THROUGH: 90°	180°	360°
RUN 1	30	44	87	171
RUN 2	60	27	48	89
RUN 3	90	20	36	64

VESSEL PIVOTS ABOUT .4 × LENGTH FROM BOW

Figure 19 - Turning Trial, with Interlocked Thrust and Approach Speed of 0 Knots

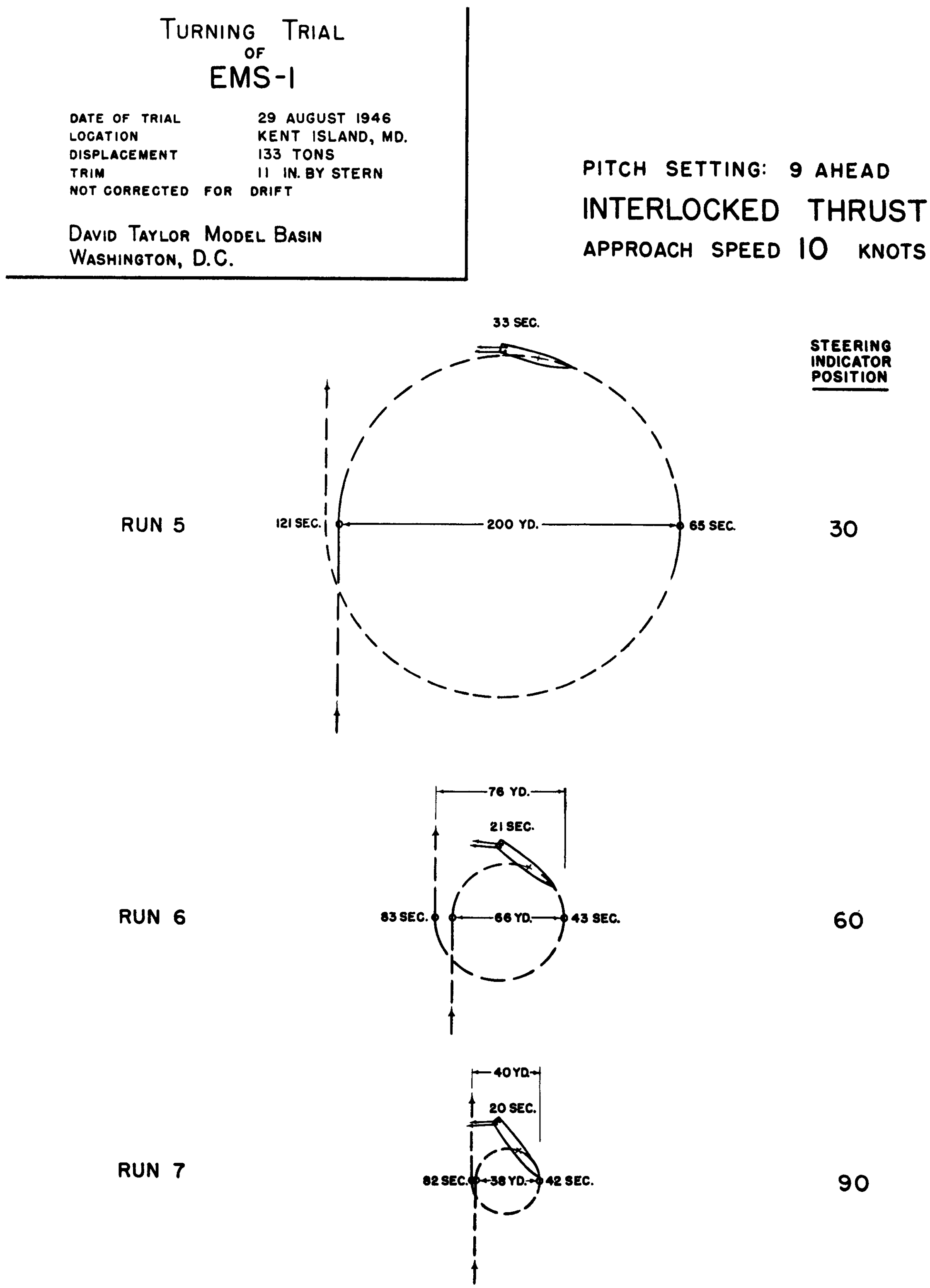


Figure 20 - Turning Trial, with Interlocked Thrust and Approach Speed of 10 Knots

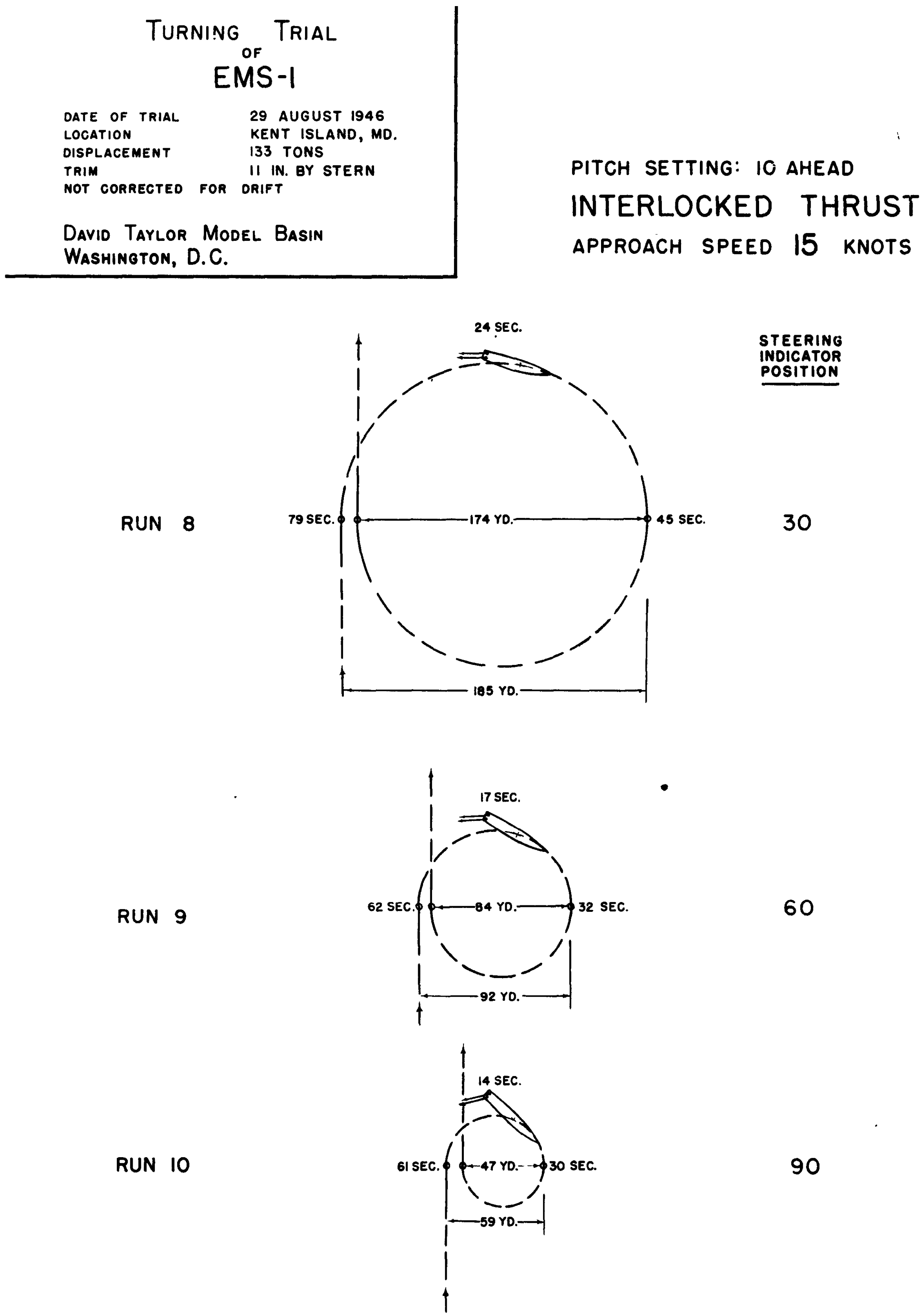


Figure 21 - Turning Trial, with Interlocked Thrust and Approach Speed of 15 Knots

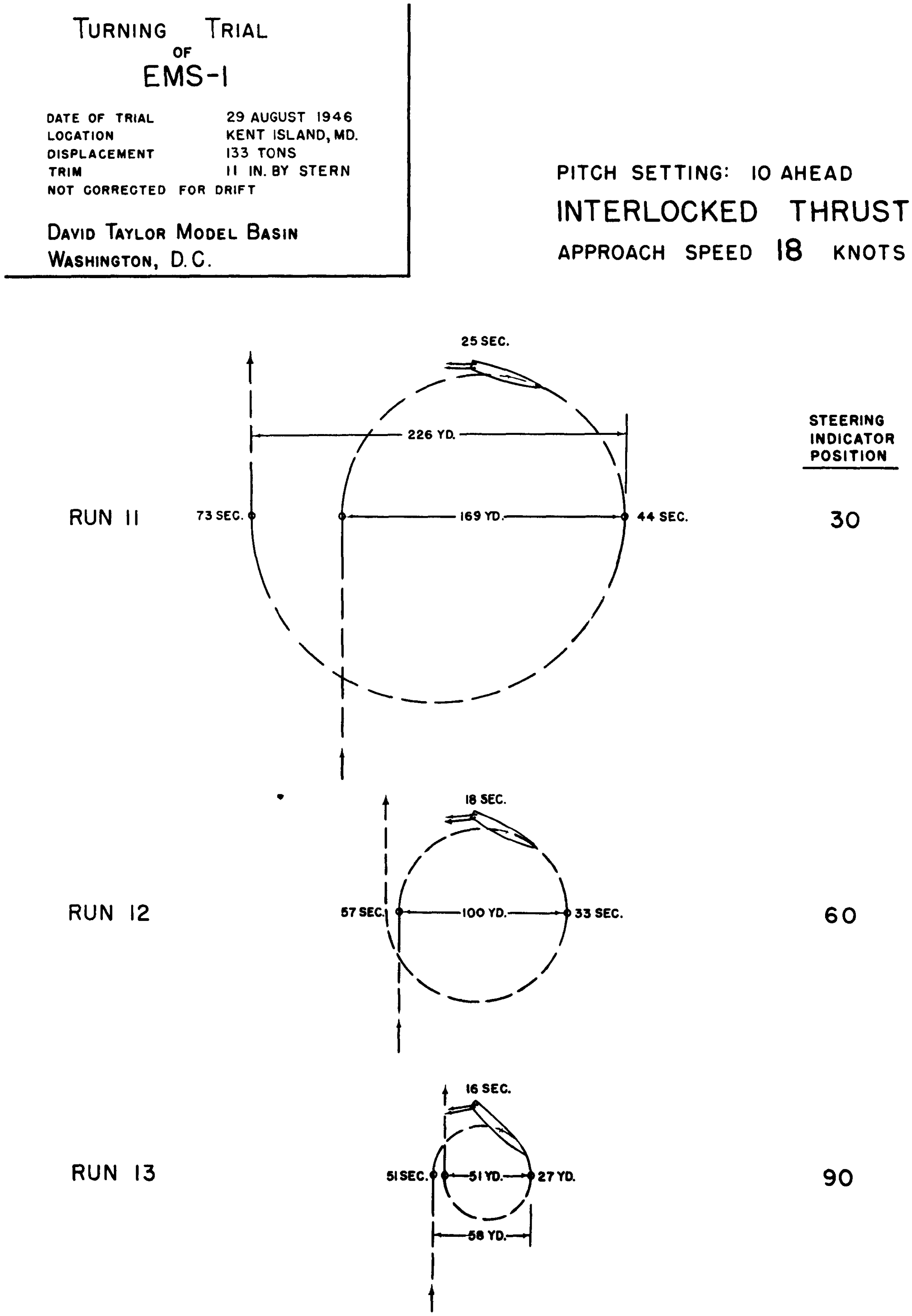


Figure 22 - Turning Trial, with Interlocked Thrust and Approach Speed of 18 Knots

speed of 18 knots and a steering position of 90; see Figure 22. The turning circle produced during this turn at very nearly full speed was 51 yd or slightly more than one boat's length.

Opposed-thrust turning. In understanding the opposed-thrust turns it is important to remember that the pitch settings of the propellers, i.e., the fore and aft thrust components, are opposed. The steering setting of both propellers is controlled by the single steering-control wheel and therefore the transverse components of the propeller thrusts must always be in the same direction. Figure 23 illustrates this point.

The paths taken by the vessel during opposed-thrust turns are shown for several approach speeds in Figure 24. When a state of steady turning was reached the vessel was backing around the turning circle. This behavior is probably due to the fact that the propeller with the ahead pitch setting was operating somewhat in the race of the propeller with the astern pitch setting and was therefore less effective.

The opposed-thrust turning circles varied only from 56 to 59 yd for approach speeds of 10 to 18 knots and a steering-indicator position of 90. The time to turn 360° dropped from 89 sec to 67 sec. Inasmuch as smaller turning circles and faster turns were made with interlocked thrust there seems to be no advantage in using opposed thrust for turns.

Crash Trials

Crash trials, ahead and astern, were conducted off Kent Island at the heavy displacement of 147 tons. The tests were run by changing the propeller-pitch setting from full ahead to full astern, and vice versa, without changing RPM. Times and distances were measured by stop watch and by observing chips in the water. The bow log was used to determine when the designated approach speed ahead had been reached. Astern approach speed was determined by RPM from the astern standardization results. Table 2 gives the results of the crash trials.

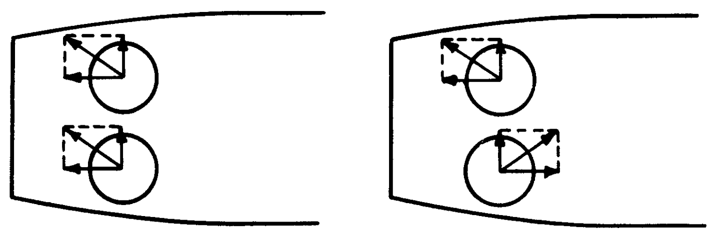


Figure 23 - Force Diagram for Interlocked and Opposed Thrust

Vertical vectors represent propeller thrust due to pitch applied by steering-indicator setting. Horizontal vectors represent propeller thrust due to longitudinal pitch applied by pitch settings. Diagonal vectors represent the direction of the resultant propeller thrust.

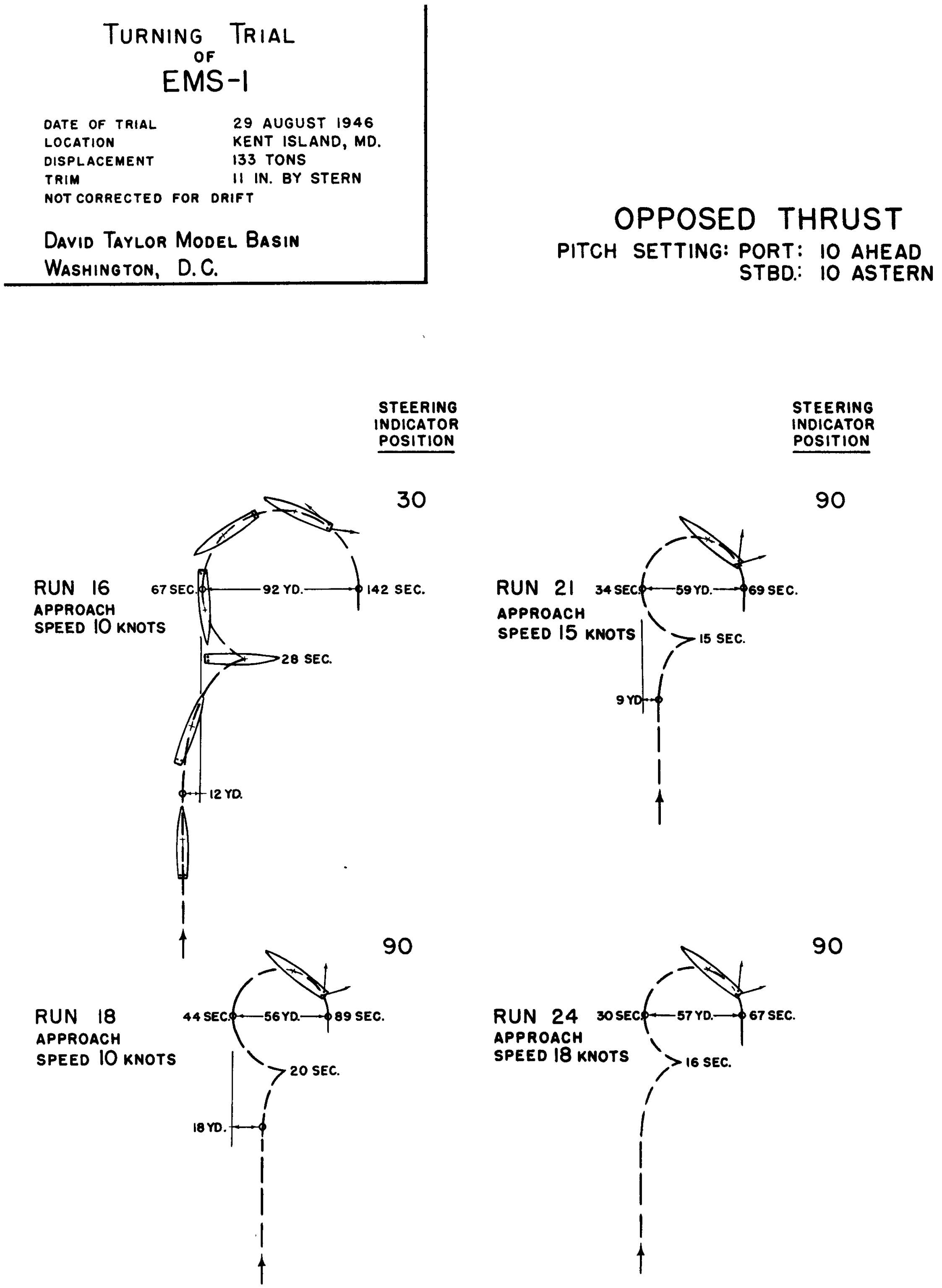


Figure 24 - Turning Trial, with Opposed Thrusts

TABLE 2

Results of Crash Trials

Test	Approach Speed knots	Time to Dead in Water seconds	Reach feet	Time to Full Astern or Full Ahead seconds
Crash back	14.8 ahd	9	130	
	18.0 ahd	9.5	130	25
Crash ahead	9.2 ast	6	30	
	9.8 ast	6	25	30

From Table 2 it is evident that the mine sweeper stopped in almost its own length from 18 knots ahead. The entire time consumed from the "execute" signal to dead in the water was less than 10 sec.

No-Load Tests

Propeller no-load SHP readings were taken on the port propeller unit with the blades removed and the vessel tied to the dock in order to determine the mechanical losses in the propeller mechanism. Tests were also made of both propellers with the blades at absolute zero pitch with the vessel dead in the water.

The results of the no-load tests are shown on Figure 25. It should be remembered that these SHP values include all the mechanical losses in the propeller mechanism.

The J.M. Voith Corporation report (1) gives German estimates of mechanical losses in the propellers ranging from 28 to 65 SHP for a speed range of 10 to 22 knots. Considerably greater mechanical losses are indicated by the EMS-1 propeller on Figure 25. The results are not directly comparable since the German tests were run in air. The EMS-1 propellers were opened and examined by Dr. Hans F. Mueller* after the trials; he stated that there were no signs of abnormal wear or maladjustment.

Propeller-Vibration Measurements

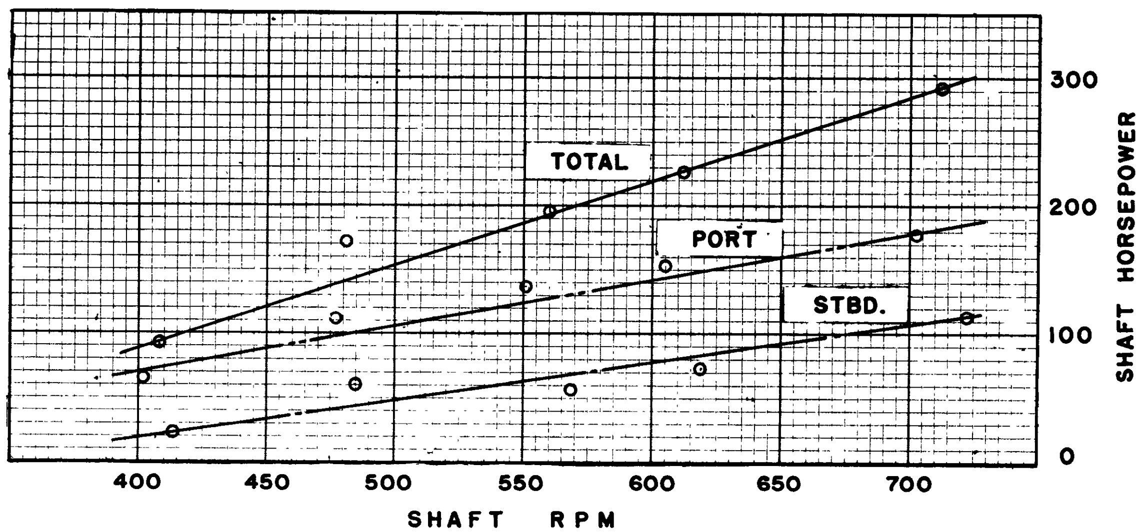
Vibration measurements were made of the Voith-Schneider propeller housings during the trials when the two propellers were operating at several different speeds and pitch settings. During each run the two propellers were rotating at the same speed and operating at the same pitch setting.

* Dr. Hans F. Mueller, formerly of the Berlin Model Basin and the J.M. Voith Corporation, came to this country after the war. He was consulted about the ship and model trials of the EMS-1.

NO-LOAD SHP
FOR
VOITH-SCHNEIDER PROPELLERS OF EMS-I

PROP. SIZE	14		NO. OF BLADES	7	
" ORBIT DIAM.	4.592	FT.	BLADE LENGTH	2.852	FT.
" PITCH (MAX.)	10.53	FT.	BLADE WIDTH AT TOP	0.972	FT.

BLADES ATTACHED PITCH SETTING: 0



BLADES REMOVED SHAFT RPM: 507

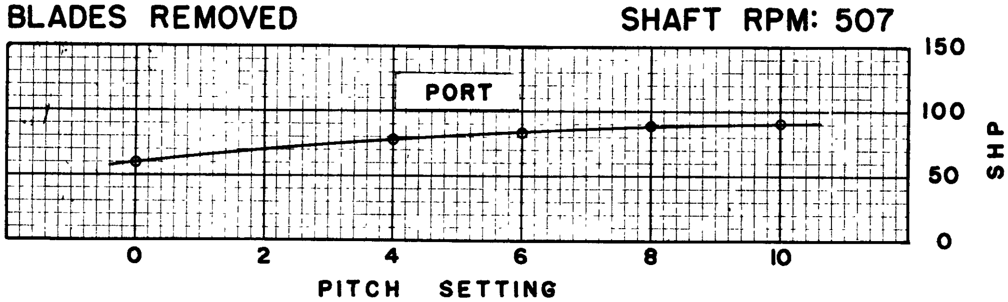


Figure 25 - No-Load Shaft Horsepower

Vibration measurements were made at pitch settings 4, 6, 8, and 10, each at five different RPM; namely, 400, 500, 575, 650, and maximum. Since the bevel-reduction gear reduced the speed of the propellers to approximately one-third the engine speed, the blade frequency is equal to 7 x 1/3 engine RPM.

At each condition measurements were made of the fore, aft, vertical, and transverse motion of the starboard propeller housing and of the transverse and vertical motion of the centerline longitudinal hull stiffener, which is beneath the main deck at about the same frame as the propeller locations. All amplitude readings were obtained by a Cordero hand vibrometer. Frequency of vibrations were determined by means of a set of Frahm's reeds.

The variation in vibration amplitude at the propeller housing is plotted on a basis of engine speed for various propeller-pitch settings, as shown on Figure 26. The maximum double amplitude of 15 mils, in a vertical direction, occurred at full speed at the maximum pitch setting of 10, which was the condition that would be expected to produce the largest vibratory forces. Similar data obtained on the longitudinal hull stiffener are included in the curves of Figure 27, and these curves also show that the amplitude was greatest when the maximum pitch setting was used. Some readings made during astern standardization runs at about 400 and 500 RPM disclosed the maximum double amplitude of 2 mils at the pitch setting of 4.

The frequencies of vibration observed were predominantly in the range from 900 to 1700 cycles per minute, which is the range of blade frequencies encountered on these runs. Some frequencies corresponded closely to the fourth-order frequencies of the engine RPM. Since the engines are 8-cylinder 4-cycle diesels which have a firing frequency corresponding to four times the engine RPM, they are apparently the source of the vibrations of fourth-order frequency.

The maximum observed amplitude of propeller-housing vibration was in a direction parallel to the axis of rotation of the propeller blades. This motion is nearly perpendicular to the keel and was measured near the point where the effect of the reaction forces between the hull and the propeller blades would probably be greatest. The hump appearing at about 600 RPM apparently indicates resonance with some structural mode of vibration. Some of the observers aboard during these trials noticed structural vibration of the hull at about this same speed. Although no measurements were taken during turns, considerable vibration was felt during the sharp high-speed turns.

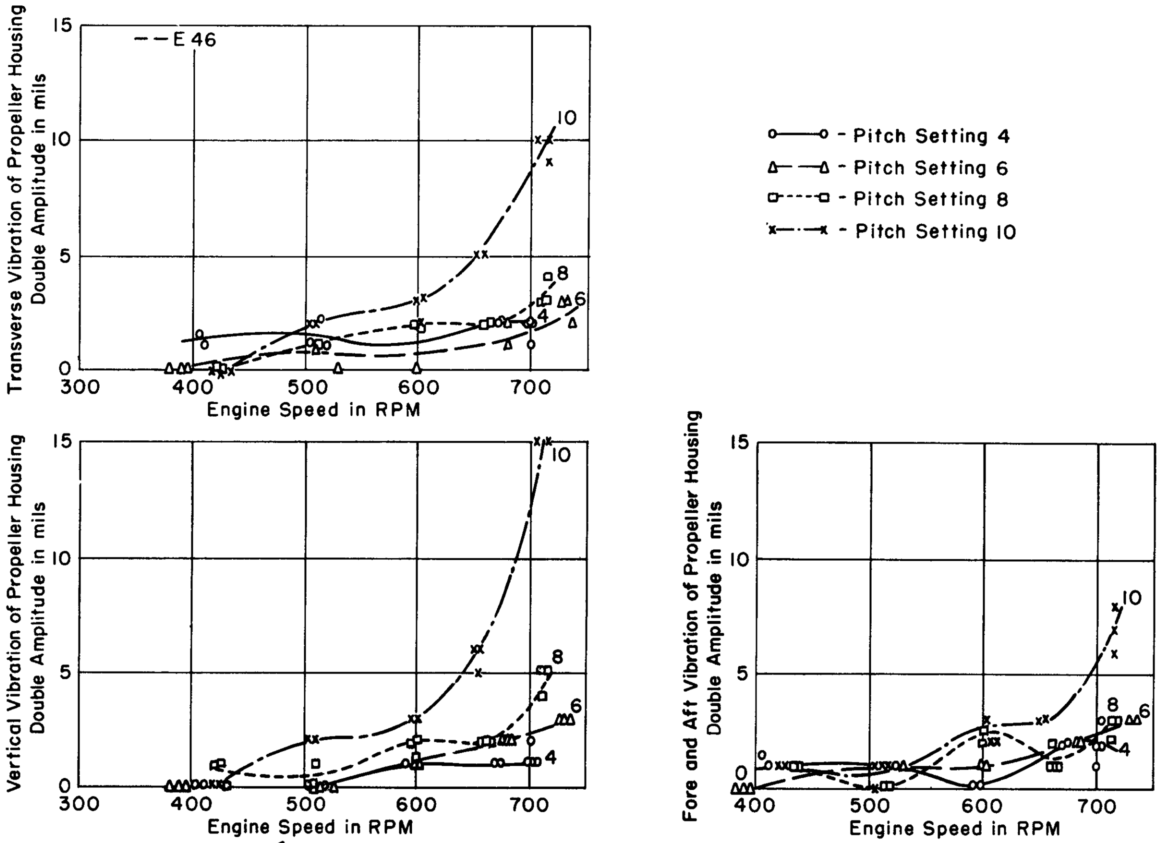


Figure 26 - Vibration Measurements at Propeller Housing

These data were obtained during normal standardization runs of 25-31 July 1946. During that time this ship was equipped with Voith-Schneider propellers having 7 blades.

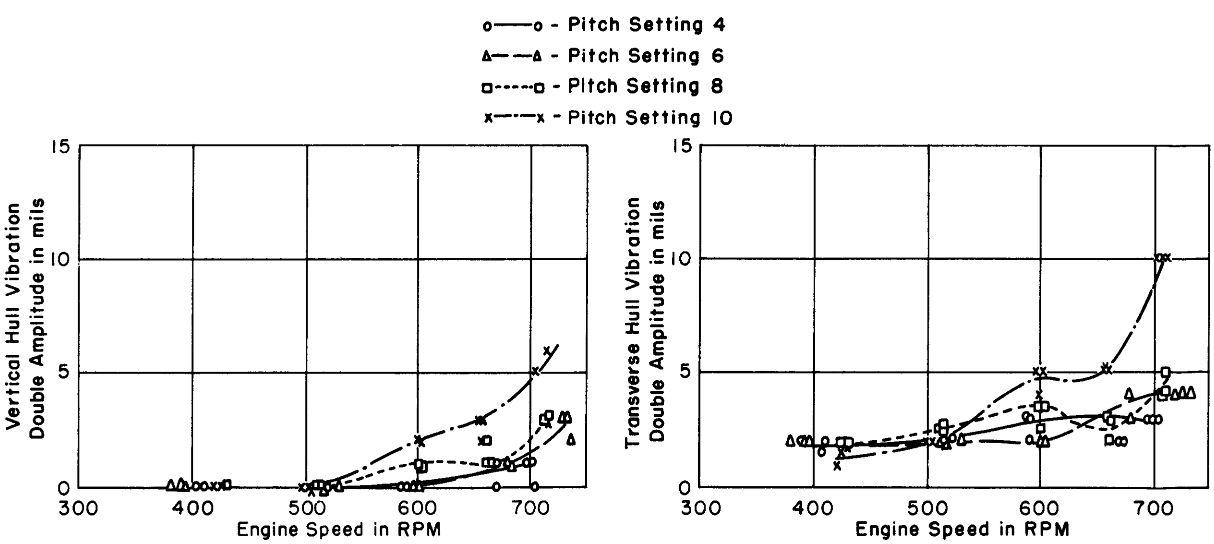


Figure 27 - Vibration Measurements at Main Deck Aft

These data were obtained during the normal standardization runs of 25-31 July 1946. During that time this ship was equipped with Voith-Schneider propellers having 7 blades. These measurements were made on the center longitudinal just beneath the main deck near the propeller locations.

COMPARISONS

References (1) and (2) made available model and full-scale trial results for the R130-Class mine sweepers. Although the German and Taylor Model Basin trials were not conducted under identical conditions, it was possible to correct the German results to Model Basin conditions and to make the several comparisons discussed below.

German Model Results versus United States Model Results

A model of the EMS-1 was built at the Taylor Model Basin to offsets lifted from the vessel by the Norfolk Naval Shipyard. Figures 28, 29, and 30 are photographs of the model. Resistance tests, i.e., EHP, were run at displacements and trims corresponding to the full-scale trial conditions; see Figures 31 and 32. Since no provision was made for self-propulsion tests, thrust deduction and wake fraction could not be determined.

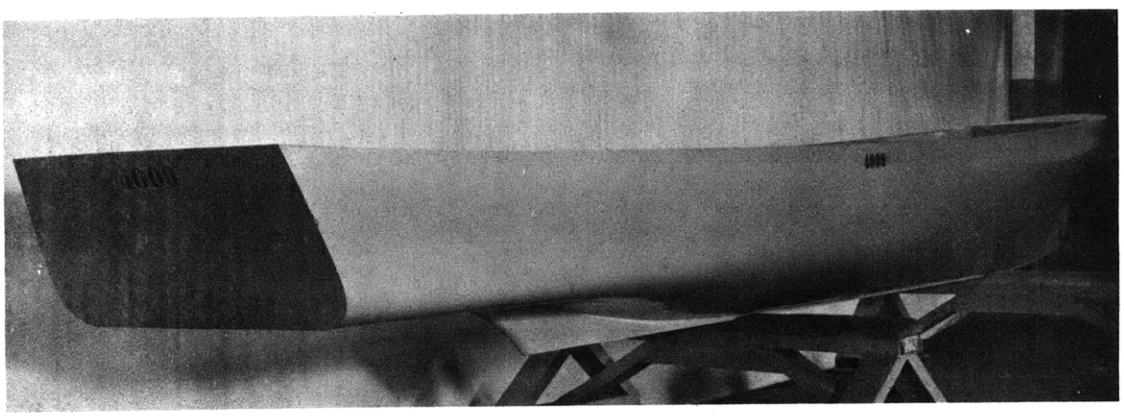


Figure 28 - View Showing Model out of Water

The Hamburg Model Tank conducted resistance and self-propulsion tests on an 18-ft paraffin model of the R130-Class mine sweepers with model Voith-Schneider propellers (2). The propellers used in the self-propulsion tests, however, were different from those installed in the EMS-1. Dr. Hans F. Mueller* stated that minor alterations to ship form were also introduced. Table 3 gives a comparison of the test results from the Hamburg Model Tank with those from the Taylor Model Basin.

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* Oral communication.

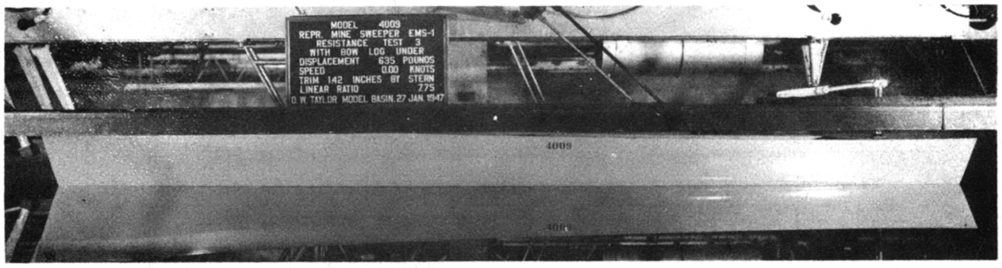


Figure 29a - At Rest

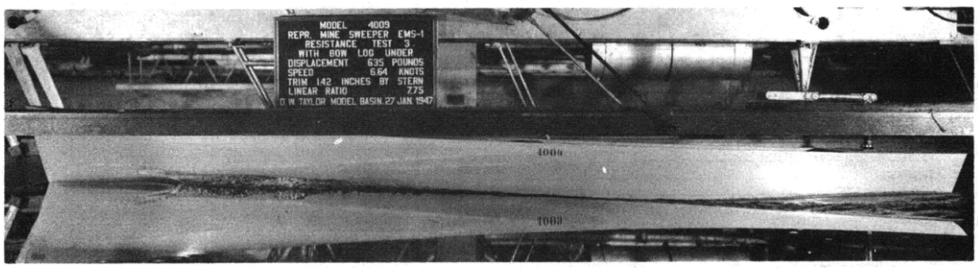


Figure 29b - At 6.64 Knots Equivalent to 18.5 Knots for Vessel

Figure 29 - View Showing Model under Carriage

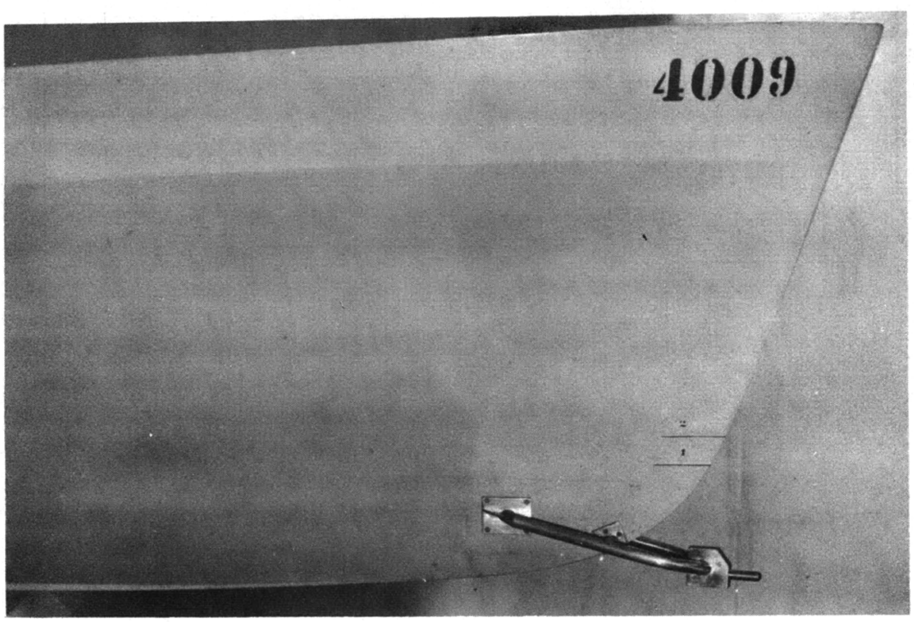


Figure 30 - View of Model Showing Bow Log

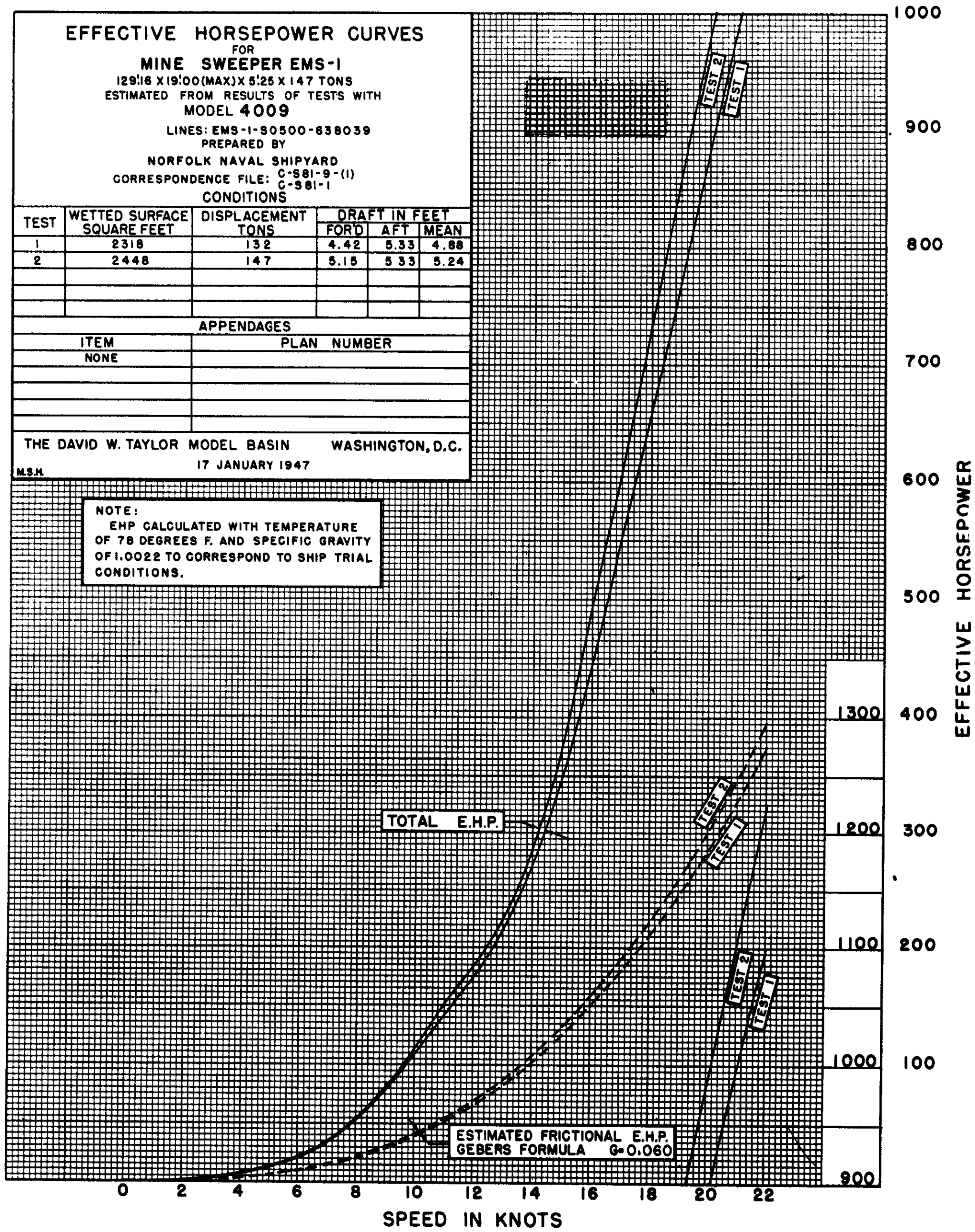


Figure 31 - Model EHP Curves for Tests 1 and 2

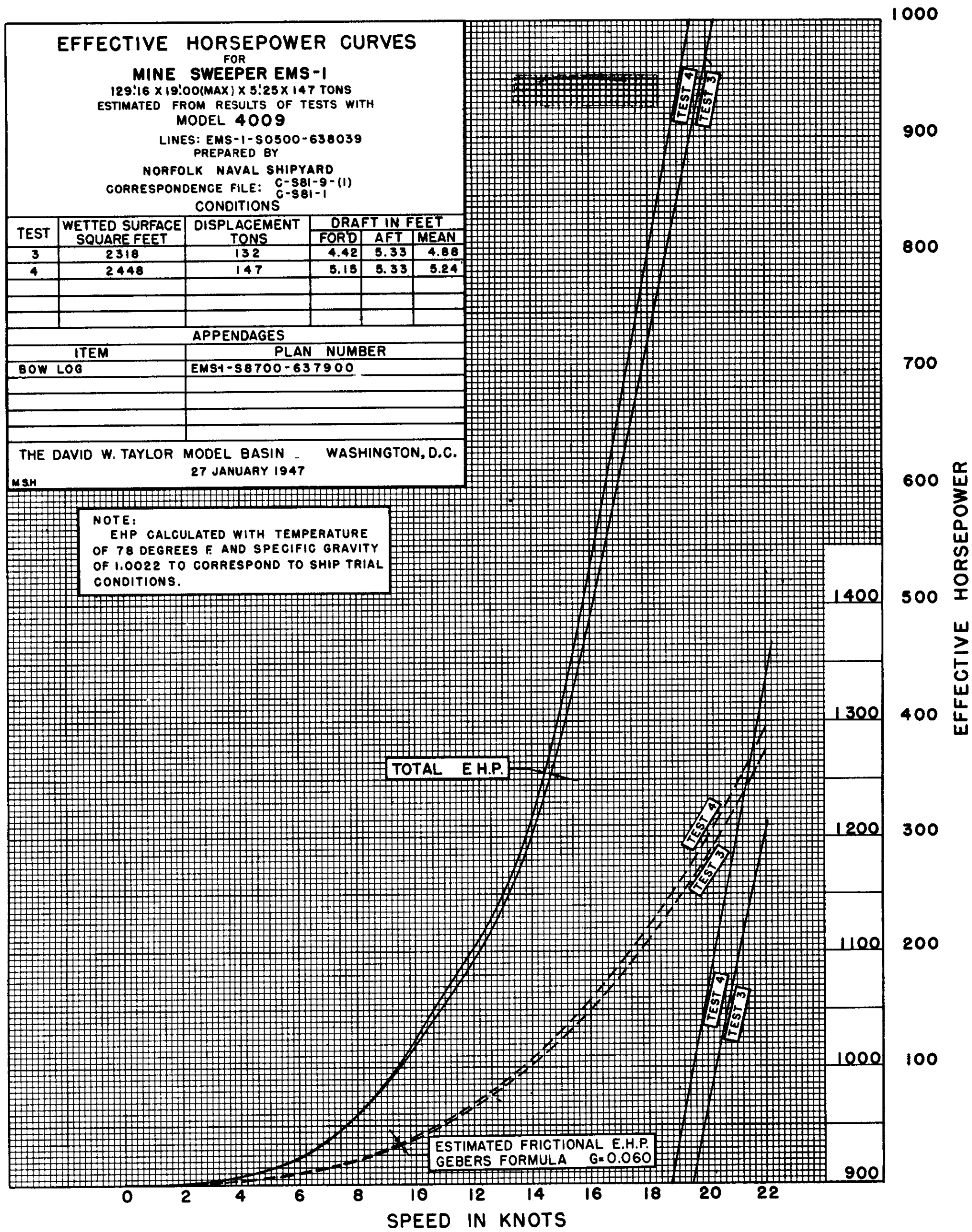


Figure 32 - Model EHP Curves for Tests 3 and 4

TABLE 3

Comparison of Test Results from Hamburg Model Tank and Taylor Model Basin

The figures given in this table are full scale, derived from the model test results.

Items	Light Displacement		Heavy Displacement	
	HSVA* Model	TMB Model	HSVA* Model	TMB Model
Displacement	127.9 tons corr. to 132 tons	132 tons	147 tons	147 tons
Trim	Even keel	0.91 ft by stern	Even keel	0.17 ft by stern
Temperature of water	4.5° C, corr. to 78° F	61.5° F, corr. to 78° F	4.5° C, corr. to 78° F	61.5° F, corr. to 78° F
Method of calc. friction	Froude	Gebers (G = 0.06)	Froude	Gebers (G = 0.06)
Specific gravity	1.000 corrected to 1.0022		1.000 corrected to 1.0022	

Speed knots	Light Displacement			Heavy Displacement		
	EHP(HSVA) Test 15500	EHP(HSVA)** Test 15500 + 4 per cent	EHP(TMB) Test 1	EHP(HSVA) Test 15501	EHP(HSVA** Test 15501 + 4 per cent	EHP(TMB) Test 2
13	162	169	215	192	200	224
14	213	221	273	248	258	286
15	284	295	348	323	336	374
16	377	392	446	430	447	485
17	485	505	555	554	577	607
18	600	624	662	681	708	734
19	714	742	770	812	845	857
20	827	760	883	941	979	980
21	932	969	992	1055	1098	1101
22	1035	1076	1094	1169	1216	1220

* HSVA is the abbreviation for Hamburgische Schiffbau - Versuchsanstalt [Hamburg Model Basin].

** This corrected EHP, obtained by increasing the test EHP by 4 per cent is in accordance with the practice outlined in the J.M. Voith Corporation report (1, p. 3). This increase is based on the assumption that the Froude friction estimates are too low for painted surfaces.

All the Taylor Model Basin predictions of EHP are above the Hamburg Model Tank values even when the latter are increased by 4 per cent for roughness. This difference ranges from 27 per cent at 13 knots to 2 per cent at 22 knots for the light displacement and from 12 per cent to 0.3 per cent for the corresponding speeds for the heavy displacement. The differences between Taylor Model Basin and Hamburg Tank EHP results may be due largely to the fact that the model towed by the Hamburg Tank differed slightly from the actual vessels as built. Another source of discrepancy is the different methods used by the two test basins in calculating frictional resistance.

German Trial Results versus United States Trial Results

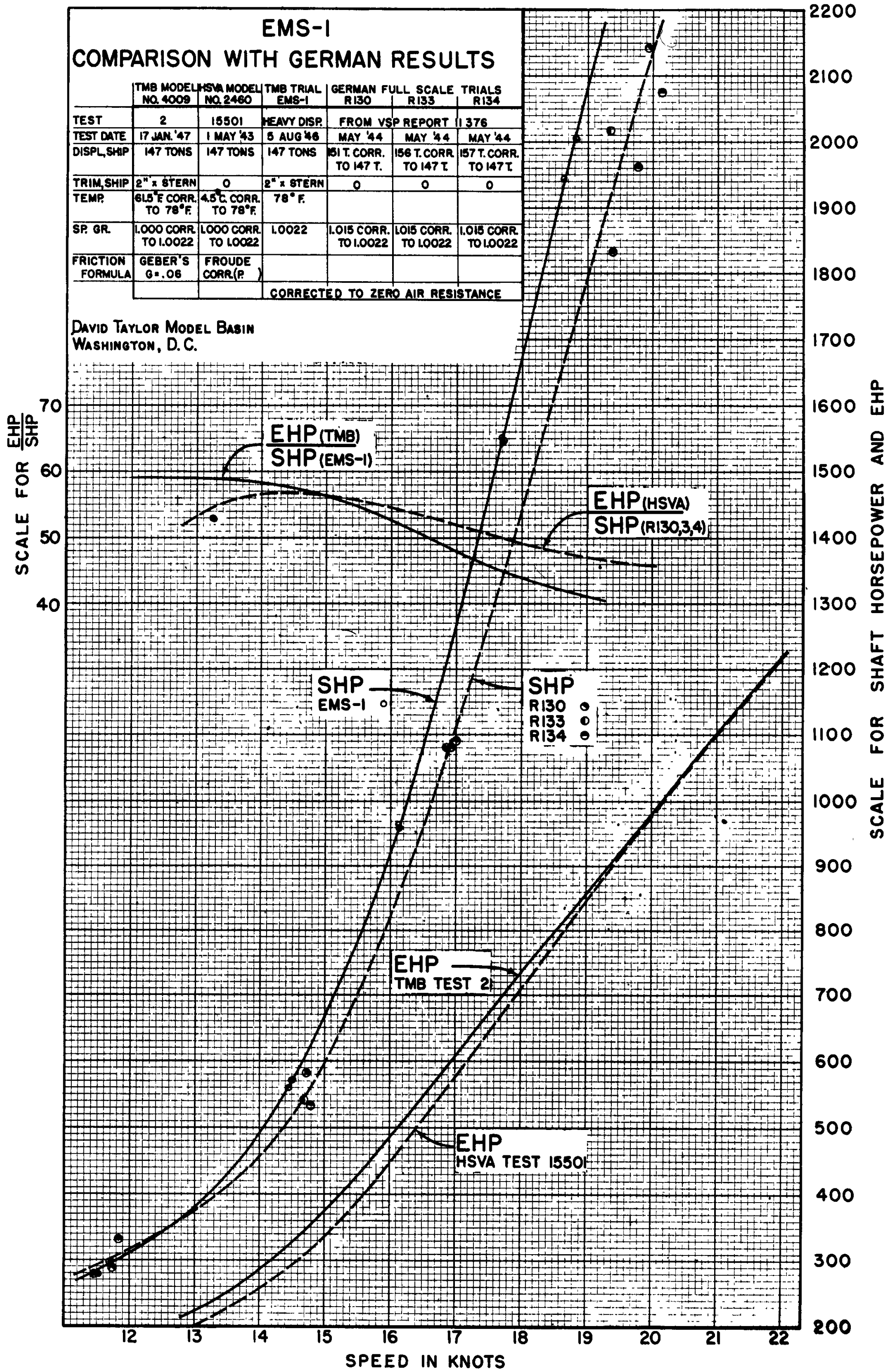
The J.M. Voith Corporation report (1) gives SHP results of the German Navy full-scale trials of the R130-Class mine sweeper, of which EMS-1 is a member. The results, corrected to the EMS-1 heavy displacement and still-air condition are plotted on Figure 33. The EMS-1 SHP values on Figure 33 are for the standardization, heavy displacement, trial results reduced by 5 per cent to correct for the drag of the bow log. This correction is derived from the SHP effect of the bow log indicated on Figure 4. The EHP curves on Figure 33 are from the last two columns of Table 3.

The Hamburg Model Tank and Taylor Model Basin full-scale trial SHP curves are in good agreement at low speeds but the TMB curves are somewhat higher in the upper part of the speed range. The EHP curves converge at higher speeds and again the TMB curve is higher than the Hamburg Model Tank curve over most of the speed range. These differences produce widely different propulsive coefficient curves, also shown on Figure 33.

The discrepancies between the results of the full-scale trials on the EMS-1 and those made by Germany on the R130, R133, and R134 cannot be fully accounted for. Among the probable causes are differences in hull forms, hull roughness, trim, and propellers and errors in the EMS-1 bow-log corrections. See Figure 33.

DISCUSSION

The EMS-1 handled very easily and maneuvered with speed and versatility. She could turn circles about her own foremast, crab through the water at almost any desired angle, and come to a stop from 18 knots ahead in her own length. In coming alongside the dock it was possible to approach with the ship centerline parallel to the dock. Similarly the EMS-1 could pull away from the dock in one motion by backing with appropriate steering settings.



	TMB MODEL NO. 4009	HSVA MODEL NO. 2460	TMB TRIAL EMS-I	GERMAN FULL SCALE TRIALS R130	R133	R134
TEST	2	15501	HEAVY DISP.	FROM VSP REPORT 11 376		
TEST DATE	17 JAN. '47	1 MAY '43	5 AUG '46	MAY '44	MAY '44	MAY '44
DISPL, SHIP	147 TONS	147 TONS	147 TONS	161 T. CORR. TO 147 T.	156 T. CORR. TO 147 T.	157 T. CORR. TO 147 T.
TRIM, SHIP	2" x STERN	0	2" x STERN	0	0	0
TEMP.	61.5°F CORR. TO 78°F.	4.5°C. CORR. TO 78°F.	78° F.			
SP. GR.	1.000 CORR. TO 1.0022	1.000 CORR. TO 1.0022	1.0022	1.015 CORR. TO 1.0022	1.015 CORR. TO 1.0022	1.015 CORR. TO 1.0022
FRICTION FORMULA	GEBER'S G=.06	FROUDE CORR.(P)				
			CORRECTED TO ZERO AIR RESISTANCE			

Figure 33 - Comparison of German and United States Trial Results at Heavy Displacement

During astern standardization, a straight course astern could be maintained only with large steering angles. This condition was unexpected and may be attributed to the flat surface of the transom stern causing an unstable flow of water about the stern and inducing a turning couple.

It is impossible from these trials to determine the characteristics of the Voith-Schneider propeller independent of the hull. The values of EHP/SHP shown on Figures 4, 5, 6, and 7 are considerably less than for screw propellers. This is especially true of the EMS-1 because of its low EHP which is due to the lack of hull appendages and possibly low roughness allowance, as discussed on page 12. Another factor tending to lower the propulsive coefficient is the inclusion of reduction-gear and thrust-bearing losses in the SHP. Although it seems logical to charge these losses to the propeller, it should be remembered that the Voith-Schneider mechanism eliminates the need for a reversing gear on the main engines and for a steering engine with its power consumption. The Voith-Schneider propeller report (1, p. 13) compares the full-scale trial results of the R130-Class mine sweeper equipped with cycloidal propellers (EMS-1 is in this class) with those of the R35 Class equipped with screw propellers. The cycloidal propeller class had a 0.11-knot lower maximum speed for the same SHP and displacement and 0.87-knot lower maximum speed for equal SHP and dead-weight carrying capacity. The stern lines of the Voith-Schneider vessels were improved in order to obtain better performance characteristics. Whether this change in hull lines would not also have improved the performance of the screw propeller is not clear.

In any case the theoretical bases for comparison of screw and cycloidal propellers will have to be controlled much more completely before relative efficiencies can be determined.

The results of standardization, towing, and dead-pull trials at the light displacement and at pitch settings 8 and 10 have been combined into composite curves of contours of SHP and RPM plotted against speed and towrope pull on Figures 34 and 35. It is possible to enter these curves with any two of these four variables and to determine the other two. It must be remembered, however, that the curves are for the EMS-1 only and are not generally applicable to the Voith-Schneider propeller.

Figures 4, 5, and 6 indicate that the SHP and RPM were lower and the propulsive coefficients higher for the heavy displacement than for the light displacement for speeds above 13 knots at pitch setting 10. At 13 knots the RPM and SHP are almost equal for the light-displacement and heavy-displacement standardization trials. At 17 knots the SHP for the light displacement is 14 per cent greater than for the heavy displacement, and the RPM is 3.5 per cent greater. At 18.5 knots the SHP for the light displacement is

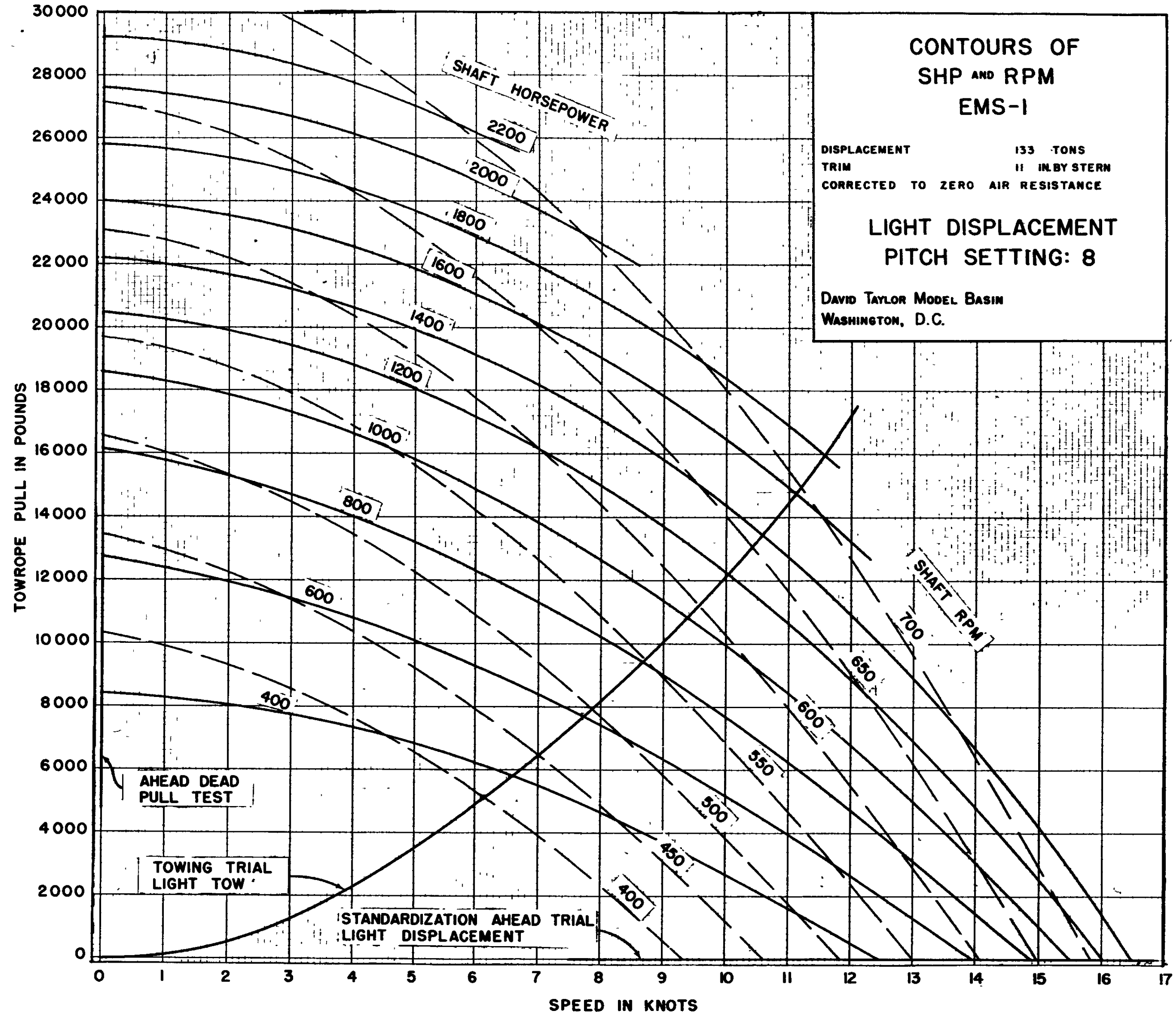


Figure 34 - Contours of SHP and RPM at Light Displacement and Pitch Setting 8

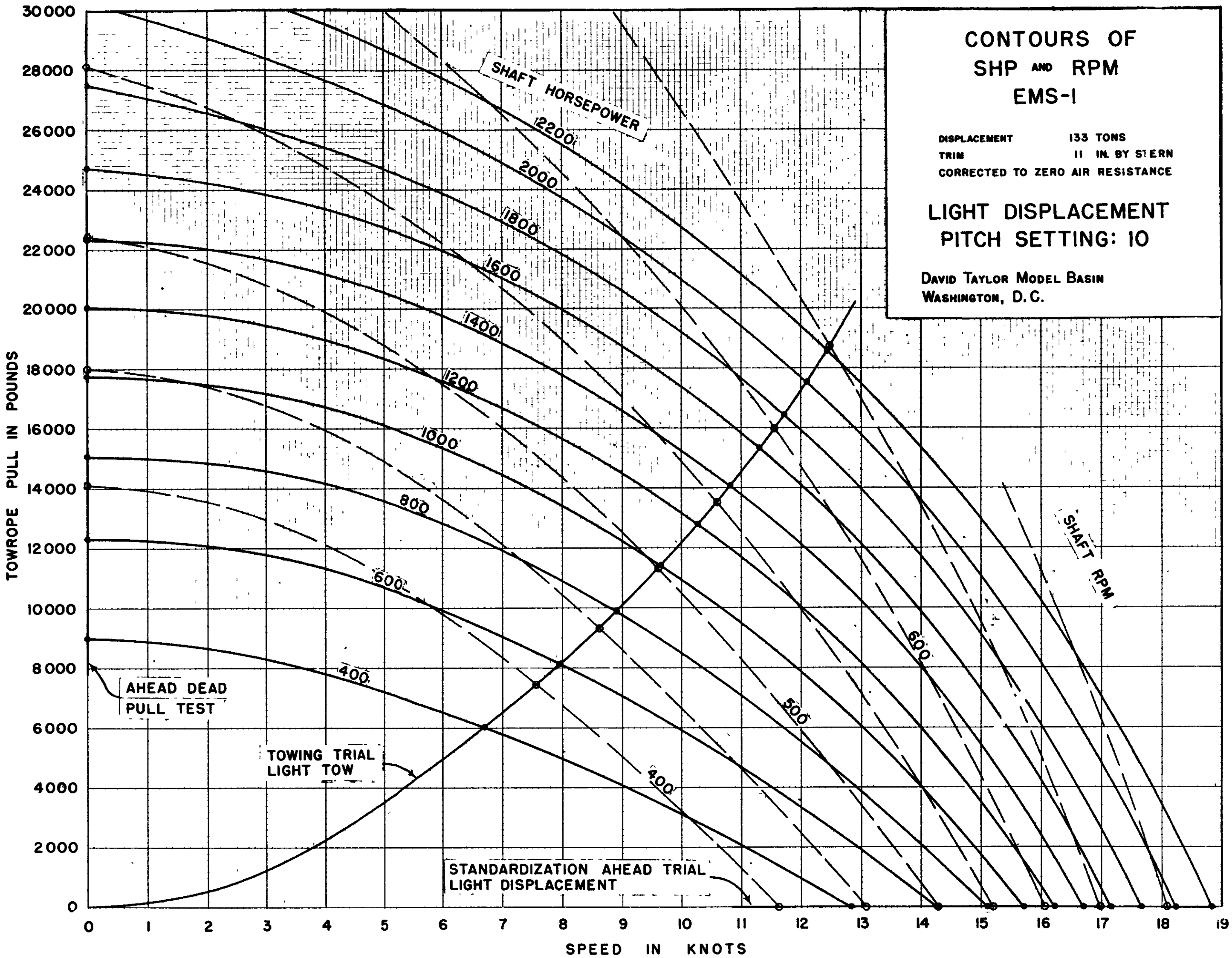


Figure 35 - Contours of SHP and RPM at Light Displacement and Pitch Setting 10

only 6 per cent greater than for the heavy displacement, and the RPM is 1.7 per cent greater. There are two possible causes for increased SHP and RPM: Increased hull resistance and decreased propeller efficiency. The model tests indicate a decrease rather than an increase in hull resistance for the light displacement compared with the heavy displacement. It would hardly be possible for this condition to be revered in the full-scale vessel.

Why the propeller efficiency should be lowered is not clear. The submergence of the stern and the propellers was almost identical for both displacements while the ship was dead in the water; however, no trim measurements were taken during the trial. In view of the fact that at 13 knots SHP and RPM were equal for both conditions it is unlikely that there could have been any mechanical fault in the propeller, such as an incorrect pitch. The question is even more difficult when it is considered that at pitch setting 8 the results of the runs were consistent with the model test results.

It can only be concluded then that some unusual condition - trim, flow, cavitation, and/or drawing in air - existed during the full-pitch runs at light displacement.

CONCLUSIONS

Although it was not possible to determine the exact characteristics of the Voith-Schneider cycloidal propeller from tests on a single installation, several general conclusions may safely be drawn.

1. The Voith-Schneider propeller offers much greater maneuverability than is possible with a screw propeller and rudder.

2. The propulsive-coefficient curves indicate that the efficiency of the Voith-Schneider propeller falls off as the load increases until at full designed speed the efficiency of the propeller is almost certainly below that of a typical screw-propeller installation on the same vessel.

3. The Voith-Schneider propeller installation is much heavier than a screw-propeller installation. Reference (4) gives this increase in weight as 11.1 tons for 150-ton mine sweepers.

4. For the EMS-1 the maximum pitch ratio ($P/\pi D$) of 0.73 was slightly below the pitch ratio required for maximum free-running efficiency.

5. Mechanical losses in the Voith-Schneider propeller mechanism are comparatively large, approximately 10 per cent of load according to these tests. Tests by the German manufacturer indicate about 4 per cent in air. The Voith-Schneider propellers appear to be mechanically excellent. They were trouble-free throughout the extensive series of trials covered in this report.

The Voith-Schneider cycloidal propeller has proved during these trials to be a practical and dependable method of ship propulsion which should be seriously considered whenever the increased maneuverability and ease of handling justifies the added weight, expense, and probable lower efficiency. The efficiency will be a product of the entire design and any loss compared to a screw propeller installation is likely to be insignificant except under conditions of maximum loading.

APPENDIX 1

REDUCTION OF SHIP DATA TO ZERO AIR RESISTANCE AND ZERO CURRENT

The trial data were reduced by Eggert's power method, which has been described in detail in Reference (6).

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

1. The wind-direction coefficient, K, for the observed apparent wind direction is found from a wind-resistance model test.

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

$$\Delta \, \mathrm{EHP} = \frac{R_w \, A \, W_a^2 \, V K}{326}$$

where R_w is the specific resistance coefficient from the model tests,

A is the above-water cross-sectional area of the ship,

W_a is the relative wind velocity,

V is the speed through the water,

K is the 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, and

1/326 is a factor to reduce resistance in pounds multiplied by speed in knots to EHP.

3. A curve of slope of EHP against speed is plotted. The increase in EHP per knot change in speed, Δ EHP/ΔV, is read from this curve.

4. The Δ EHP from Step 2 is divided by the EHP per knot from Step 3, which gives the increment of speed ΔV due to wind effect.

5. These increments of speed are added for ahead wind and subtracted for astern wind from the observed speeds to find the corrected speeds V_0' over the ground with no air resistance.

6. The speeds V_0', Step 5, 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 methods of trial analysis that if the current varies uniformly, the weighted average, i.e., the middle run taken twice, 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 usually varies somewhat over a three-run group, the average RPM for the group is divided by the weighted average V_0' to find the average RPM per knot.

7. The RPM for each run is in turn divided by the RPM per knot, Step 6, to find the speed, V'', through the water with no air resistance and no current.

8. The difference between V_0', Step 5, and V'', Step 7, is the current velocity C. The direction of the current may be determined by inspection from the direction of the run and the relative magnitudes of the speed over the ground and through the water.

9. The actual speed V' through the water is the corrected speed V'' through the water minus the speed correction ΔV due to the wind.

These nine steps outline the procedure used for the three ahead standardization trials of the EMS-1. The reduction of ship data to zero wind and zero current for the towing trials necessitated the four additional steps below.

10. In determining the horsepower expended in overcoming the wind resistance in Step 2, the value for A must include the area of both the towing vessel and the towed vessel. The specific resistance factor R_w and the wind-direction coefficient K are average values for the EMS-1 and the LCI. If these constants were known more accurately for both vessels ΔEHP, the horsepower required to overcome wind resistance, would have been calculated independently for each vessel.

11. For towing trials the EHP curve used in Step 3 must be a curve representing the sum of the EHP of the towing vessel and the towed vessel.

In addition to the speed corrections given above for wind and current the towrope pull in a towing trial must be corrected for wind force on the towed vessel and for the change in resistance of the towed vessel due to the speed correction made for wind. These corrections are accomplished in two additional steps.

12. The wind force acting on the towed vessel in the direction of tow is found from the formula

$$\Delta T_0 = R_w A W_a^2 K$$

where R_w is the specific-resistance coefficient of the towed vessel,
A is the above-water cross-sectional area of the towed vessel,
W_a is the relative wind velocity, and
K is the wind-direction coefficient for the towed vessel.

This force is subtracted from towrope pull for ahead winds and added for astern winds.

13. The towrope-pull correction for change in resistance of the towed vessel due to speed corrections made for wind is found from the formula

$$\Delta T = \Delta V \frac{\Delta T}{\Delta V}$$

where ΔV is the increment of speed due to wind effect, found in Step 4,
$\frac{\Delta T}{\Delta V}$ is the slope of a faired curve of resistance in pounds derived from EHP plotted against speed if available or, as in this report, from a preliminary plot of towrope pull against speed, and
ΔT is the correction in pounds to be added to the towrope pull for positive values of ΔV.

The values for specific-resistance coefficient, R_w, and wind-direction coefficient, K, were derived by examination of the results of several model tests since no tests on models of the trial vessels were available.

No wind correction was made for the astern trials since no EHP data were available for astern running.

APPENDIX 2 - ANALYSES OF TRIAL DATA

TABLE 4

Analysis of Trial Data for Light Displacement

Run Number and Direction	Time at Start of Run	Pitch Setting	Average RPM N	Observed Speed V_0 knots	SHP	Relative Wind Velocity W_a	Relative Wind Direction *	Wind Direction Coefficient K	Power Correction Due to Wind ΔP HP	Slope of EHP Curve $\Delta P/\Delta V$ HP/kt	Speed Correction Due to Wind ΔV knots	Corrected Speed over Ground V'_0 knots	Average Revolutions per knot	Corrected Speed through Water V'' knots	Current C knots	Actual Speed through Water V' knots	EHP	EHP/SHP
1 S	1500 7/25	4	395.6	3.77	71	3.5	A 30 S			10		3.77		4.05	- .28 N	4.05	7	.099
2 N	1515		407.0	4.09	76	16.0	F 05 S	1.04	+2.0	10	+.20	4.29		4.17	+ .12 N	3.97	8	.105
3 S	1540		406.0	4.22	76	5.5	A 10 P			10		4.22		4.16	- .06 N	4.16	8	.105
			403.9	4.04	75							4.14	97.6	4.14		4.04		
4 S	0920 7/26	4	509.6	6.30	140	13.0	A 20 P	1.00	-2.0	12	-.17	6.13		5.04	+1.09 S	5.21	14	.100
5 N	0940		505.6	3.69	142	22.5	F 0	1.00	+3.5	10	+.35	4.04		5.00	- .96 S	4.65	13	.092
6 S	1000		513.2	5.97	143	9.0	A 10 P	1.00	- .9	12	-.08	5.89		5.08	+ .81 S	5.16	14	.098
			508.5	4.91	142							5.03	101.1	5.03		4.92		
7 N	1015	4	588.2	5.11	208	23.5	F 05 S	1.04	+5.5	12	+.42	5.53		6.07	- .54 S	5.65	24	.115
8 S	1030		588.4	6.50	204	4.0	A 20 P			14		6.50		6.07	+ .43 S	6.07	24	.118
9 N	1100		588.5	5.41	206	20.0	F 05 P	1.04	+4.2	12	+.35	5.76		6.07	- .31 S	5.72	24	.116
			588.4	5.88	205							6.07	96.9	6.07		5.88		
10 S	1120	4	679.4	7.01	292	4.5	A 30 S			16		7.01		7.00	+ .01 S	7.00	38	.130
11 N	1135		663.2	6.49	288	20.0	F 0	1.00	+4.9	14	+.35	6.84		6.83	+ .01 N	6.48	35	.122
12 S	1150		662.6	6.78	283	4.0	A 20 S			15		6.78		6.82	- .04 N	6.82	35	.124
			667.1	6.69	288							6.87	97.1	6.87		6.69		
13 N	1225	4	709.2	7.56	357	20.0	F 05 S	1.04	+5.9	22	+.27	7.83		7.46	+ .37 N	7.19	47	.132
14 S	1315		708.8	6.94	350	3.5	A 0			16		6.94		7.45	- .51 N	7.45	47	.134
15 N	1330		707.5	7.76	343	21.3	F 10 S	1.07	+7.1	22	+.32	8.08		7.44	+ .64 N	7.12	47	.137
			708.6	7.30	350							7.45	95.1	7.45		7.30		
16 S	1345	6	392.0	5.76	101	4.0	A 40 P			12		5.76		6.32	- .56 N	6.32	27	.267
17 N	1405		397.4	6.84	106	18.5	F 10 S	1.07	+4.0	15	+.27	7.11		6.41	+ .70 N	6.14	28	.264
18 S	1425		397.8	5.58	107	3.5	A 30 P			12		5.58		6.42	- .84 N	6.42	28	.262
			396.2	6.26	105							6.39	62.0	6.39		6.26		
19 N	1440	6	511.4	9.00	206	21.3	F 10 S	1.07	+8.2	32	+.26	9.26		8.41	+ .85 N	8.15	70	.340
20 S	1455		521.5	7.74	212	3.5	A 50 P			22		7.74		8.58	- .84 N	8.58	73	.344
21 N	1510		514.5	8.98	208	22.5	F 10 S	1.07	+9.1	32	+.28	9.26		8.46	+ .80 N	8.18	71	.341
			517.2	8.36	209							8.50	60.8	8.50		8.37		

*A - from stern and F - from bow.

TABLE 4 (continued)

Run Number and Direction	Time at Start of Run	Pitch Setting	Average RPM N	Observed Speed V_0 knots	SHP	Relative Wind Velocity W_a	Relative Wind Direction *	Wind Direction Coefficient K	Power Correction Due to Wind ΔP HP	Slope of EHP Curve $\Delta P/\Delta V$ HP/kt	Speed Correction Due to Wind ΔV knots	Corrected Speed over Ground V_0' knots	Average Revolutions per knot	Corrected Speed through Water V'' knots	Current C knots	Actual Speed through Water V' knots	EHP	EHP/SHP
22 N	1056 7/30	6	594.0	8.74	326	3.5	F 70 S	.86		30		8.74		9.83	-1.09 S	9.83	113	.347
23 S	1110		594.0	10.75	327	18.3	F 0	1.00	+6.8	42	+.16	10.91		9.83	+1.08 S	9.67	113	.346
24 N	1124		594.0	8.74	322	2.0	F 80 S	.61		30		8.74		9.83	-1.09 S	9.83	113	.351
			594.0	9.75	325							9.83	60.4	9.83		9.75		
25 S	1137 7/30	6	671.1	12.18	484	23.4	F 0	1.00	+12.5	50	+.25	12.43		11.21	+1.22 S	10.96	163	.337
26 N	1147		669.9	10.08	473	2.0	F 75 S	.77		40		10.08		11.19	-1.11 S	11.19	161	.340
27 S	1159		677.8	12.18	500	23.5	F 0	1.00	+12.6	50	+.25	12.43		11.33	+1.10 S	11.08	168	.336
			672.2	11.13	483							11.23	59.9	11.23		11.11		
28 N	1209	6	728.0	11.20	628	3.0	F 70 S	.86		48		11.20		12.07	- .87 S	12.07	195	.310
29 S	1219		720.2	12.57	625	24.5	F 0	1.00	+14.2	56	+.25	12.82		11.94	+ .88 S	11.69	190	.304
30 N	1227		718.6	11.06	603	2.0	F 60 S	1.09		46		11.06		11.92	- .86 S	11.92	190	.315
			721.8	11.85	620							11.98	60.3	11.98		11.84		
31 N	1236 7/29	8	413.0	8.47	211	4.0	F 20 S	1.34	+0.3	30	+.01	8.48		9.67	-1.19 S	9.66	107	.507
32 S	1250		419.0	10.83	219	16.4	F 05 P	1.04	+5.7	42	+.14	10.97		9.81	+1.16 S	9.67	113	.516
33 N	1301		416.9	8.65	212	3.0	F 20 S	1.34		30		8.65		9.76	-1.11 S	9.76	110	.519
			417.0	9.70	215							9.77	42.7	9.77		9.69		
34 S	1325 7/30	8	508.4	12.54	363	24.1	F 0	1.00	+13.7	56	+.24	12.78		12.02	+ .76 S	11.78	194	.536
35 N	1335		509.1	11.26	350	3.5	F 50 S	1.18		48		11.26		12.04	- .78 S	12.04	194	.554
36 S	1345		509.3	12.61	356	24.1	F 0	1.00	+13.8	56	+.25	12.86		12.04	+ .82 S	11.79	194	.545
			509.0	11.92	355							12.04	42.3	12.04		11.91		
37 N	1355	8	592.0	13.25	598	4.0	F 60 S	1.09	+.4	62	+.01	13.26		13.95	- .69 S	13.94	298	.498
38 S	1403		594.0	14.48	608	26.0	F 0	1.00	+18.5	90	+.21	14.69		14.00	+ .69 S	13.79	302	.497
39 N	1413		593.2	13.27	595	3.5	F 25 S	1.36		62		13.27		13.98	- .71 S	13.98	299	.502
			593.3	13.87	602							13.98	42.4	13.98		13.87		
40 S	1421	8	660.4	15.58	876	27.7	F 0	1.00	+22.4	118	+.19	15.77		15.14	+ .63 S	14.95	398	.454
41 N	1430		660.8	14.53	877	4.0	F 20 S	1.34	+0.6	92	+.01	14.54		15.15	- .61 S	15.14	398	.454
42 S	1439		658.6	15.47	881	27.2	F 0	1.00	+20.4	108	+.19	15.66		15.10	+ .56 S	14.91	395	.445
			660.2	15.03	878							15.13	43.6	15.13		15.03		

TABLE 4 (continued)

Run Number and Direction	Time at Start of Run	Pitch Setting	Average RPM N	Observed Speed V_0 knots	SHP	Relative Wind Velocity W_a	Relative Wind Direction *	Wind Direction Coefficient K	Power Correction Due to Wind ΔP HP	Slope of EHP Curve $\Delta P/\Delta V$ HP/kt	Speed Correction Due to Wind ΔV knots	Corrected Speed over Ground V_0' knots	Average Revolutions per knot	Corrected Speed through Water V'' knots	Current C knots	Actual Speed through Water V' knots	EHP	EHP/SHP
43 N	1447	8	715.5	15.67	1220	5.5	F 30 S	1.39	+ 1.2	118	+.01	15.68		16.07	- .39 S	16.06	495	.406
44 S	1455		715.9	16.20	1231	27.2	F 0	1.00	+22.5	118	+.19	16.39		16.08	+ .31 S	15.89	496	.403
45 N	1503		716.6	15.83	1228	4.5	F 25 S	1.36	+ 0.8	118	+.01	15.84		16.09	- .25 S	16.08	498	.406
			716.0	15.98	1227							16.08	44.5	16.08		15.98		
46 S	1315 7/29	10	411.6	12.80	318	20.0	F 0	1.00	+ 9.6	56	+.17	12.97		11.97	+1.00 S	11.80	191	.601
47 N	1326		415.9	11.19	327	4.0	F 0	1.00	+ .3	46	+.01	11.20		12.09	- .89 S	12.08	196	.599
48 S	1340		414.8	12.66	328	20.5	F 0	1.00	+10.0	56	+.18	12.84		12.06	+ .78 S	11.88	195	.595
			414.6	11.96	325							12.05	34.40	12.05		11.96		
49 N	1031 7/31	10	504.7	13.74	622	13.1	F 10 P	1.07	+ 4.8	70	+.07	13.81		14.39	- .58 S	14.32	330	.530
50 S	1041		503.9	14.93	617	16.4	F 10 S	1.07	+ 8.1	102	+.08	15.01		14.37	+ .64 S	14.29	329	.534
51 N	1049		503.2	13.55	606	14.4	F 0	1.00	+ 5.3	66	+.08	13.63		14.35	- .72 S	14.27	328	.541
			503.9	14.29	615							14.37	35.07	14.37		14.29		
52 S	1058	10	592.4	16.70	1084	16.8	F 10 S	1.07	+ 9.5	118	+.08	16.78		15.93	+ .85 S	15.85	480	.443
53 N	1106		591.6	14.98	1071	16.4	F 0	1.00	+ 7.6	102	+.07	15.05		15.91	- .86 S	15.84	479	.447
54 S	1115		591.4	16.67	1081	17.7	F 10 S	1.07	+10.5	118	+.09	16.76		15.90	+ .86 S	15.81	478	.443
			591.7	15.83	1076							15.91	37.19	15.91		15.83		
55 N	1123	10	665.5	16.13	1626	15.5	F 10 P	1.07	+ 7.8	118	+.07	16.20		17.23	-1.03 S	17.16	635	.391
56 S	1131		658.5	17.93	1615	20.6	F 10 S	1.07	+15.3	118	+.13	18.06		17.05	+1.01 S	16.92	614	.380
57 N	1139		659.6	16.00	1619	15.5	F 0	1.00	+ 7.2	118	+.06	16.06		17.08	-1.02 S	17.02	617	.381
			660.5	17.00	1615							17.10	38.63	17.10		17.00		
58 S	1146	10	720.4	19.57	2152	22.6	F 10 S	1.07	+20.1	118	+.17	19.74		18.68	+1.06 S	18.51	806	.374
59 N	1154		717.1	17.40	2113	18.3	F 0	1.00	+11.0	118	+.09	17.49		18.59	-1.10 S	18.50	795	.376
60 S	1201		713.7	19.47	2093	22.0	F 10 S	1.07	+18.9	118	+.16	19.63		18.50	+1.13 S	18.34	784	.374
			717.0	18.46	2118							18.59	38.57	18.59		18.46		
Re-Runs - 23 September 1946 - Without Bow Log																		
1 S	1358 9/23	10	714.2	17.69	2034	29.6	F 10 S	1.07	+31.1	118	+.26	17.95		18.70	- .75 N	18.44	735	.361
2 N	1405	10	712.0	19.30	2057	9.5	F 30 P	1.39	+ 4.5	118	+.04	19.34		18.64	+ .70 N	18.60	730	.355
3 S	1413		713.6	17.86	2039	29.6	F 10 S	1.07	+31.4	118	+.27	18.13		18.68	- .55 N	18.41	733	.360
4 N	1420		712.8	19.22	2051	9.5	F 30 P	1.39	+ 4.5	118	+.04	19.26		18.66	+ .60 N	18.62	732	.357
			713.2	18.52	2045							18.67	38.20	18.67		18.52		
5 N	1438	10	662.2	18.16	1635	10.3	F 30 P	1.39	+ 5.0	118	+.04	18.20		17.48	+ .72 N	17.44	604	.370
6 S	1444		662.2	16.44	1650	28.3	F 10 S	1.07	+26.4	118	+.22	16.66		17.48	- .82 N	17.26	604	.366
7 N	1455		661.0	18.25	1633	11.2	F 40 P	1.30	+ 5.6	118	+.05	18.30		17.44	+ .86 N	17.39	601	.368
			661.9	17.32	1642							17.46	37.91	17.47		17.34		

TABLE 5

Analysis of Trial Data for Heavy Displacement

Run Number and Direction	Time at Start of Run	Pitch Setting	Average RPM N	Observed Speed V_0 knots	SHP	Relative Wind		Wind Direction Coefficient K	Power Correction Due to Wind ΔP HP	Slope of EHP Curve $\Delta P/\Delta P$ HP/kt	Speed Correction Due to Wind ΔV knots	Corrected Speed over Ground V_0' knots	Average Revolutions per knot	Corrected Speed through Water V'' knots	Current C knots	Actual Speed through Water V' knots	EHP	EHP/SHP
						Velocity W_a	Direction *											
1 N	1344 8/5	4	405.5	4.31	79		A 0			10		4.31		4.20	N .11	4.20	8	.101
2 S	1409		405.2	4.13	81	10.0	F 0	1.00	0.78	10	.08	4.21		4.20	S .01	4.12	8	.099
3 N	1436		405.4	4.06	84		A 15 P			10		4.06		4.20	S .14	4.20	8	.095
			405.3	4.16	81							4.20	96.50	4.20		4.16		
4 S	1457	4	518.0	5.58	136	11.5	F 10 S	1.07	1.48	14	.11	5.69		5.43	S .23	5.32	17	.125
5 N	1513		519.7	5.02	142		F 70 S	.86		12		5.02		5.44	S .58	5.44	17	.120
6 S	1537		520.2	5.75	126	19.5	F 10 S	1.07	4.40	15	.29	6.04		5.45	S .59	5.16	18	.143
			519.4	5.34	136							5.44	95.48	5.44		5.34		
7 N	0928 8/7	4	594.4	4.94	218	16.0	F 30 P	1.39	3.30	12	.28	5.22		5.89	S .67	5.77	22	.101
8 S	0946		595.2	6.44	217	9.0	A 70 S			20		6.44		5.89	S .55	5.69	22	.101
9 N	1011		594.8	5.10	219	18.4	F 35 P	1.32	4.29	12	.36	5.46		5.89	S .43	5.77	22	.101
			594.9	5.73	218							5.89	101.00	5.89		5.73		
10 S	1024	4	666.8	7.06	302	10.0	F 80 S	0.61	.81	21	.04	7.10		6.69	S .41	6.65	33	.109
11 N	1041		669.6	5.94	306	19.5	F 30 P	1.39	5.91	15	.39	6.33		6.72	S .39	6.33	34	.111
12 S	1056		669.8	7.09	313	8.5	F 90 S	.35	.35	21	.02	7.11		6.72	S .39	6.70	34	.109
			669.7	6.51	307							6.72	99.66	6.71		6.50		
13 N	1115	4	712.0	6.45	371	15.5	F 30 P	1.39	4.04	20	.20	6.65		7.14	S .49	6.94	41	.111
14 S	1130		727.3	7.67	385	3.0	F 90 S	0.35	.06	22		7.67		7.29	S .38	7.29	43	.112
15 N	1144		713.6	6.69	363	15.5	F 30 P	1.39	4.20	20	.21	6.90		7.16	S .26	6.95	41	.113
			720.0	7.12	376							7.22	99.72	7.22		7.12		
16 S	1251	6	404.6	6.73	127	7.7	A 70 S			20		6.73		6.50	S .23	6.50	30	.236
17 N	1311		403.9	5.85	129	20.6	F 30 P	1.39	6.49	15	.43	6.28		6.49	S .21	6.06	29	.225
18 S	1328		404.8	6.71	121	9.5	A 70 S			20		6.71		6.50	S .21	6.50	30	.248
			404.3	6.28	126							6.50	62.20	6.50		6.28		
19 N	1344	6	514.0	7.80	213	21.2	F 25 P	1.36	8.95	22	.41	8.21		8.42	S .21	8.01	71	.333
20 S	1356		513.2	8.67	211	10.4	F 90 S	0.35	.61	29	.02	8.69		8.40	S .29	8.38	70	.332
21 N	1410		518.7	7.73	219	21.2	F 25 P	1.36	8.87	22	.40	8.13		8.49	S .36	8.09	73	.333
			514.8	8.22	214							8.43	61.07	8.43		8.22		

* A - from stern and F - from bow.

TABLE 5 (continued)

Run Number and Direction	Time at Start of Run	Pitch Setting	Average RPM N	Observed Speed V_o knots	SHP	Relative Wind Velocity W_a	Relative Wind Direction •	Wind Direction Coefficient K	Power Correction Due to Wind ΔP HP	Slope of EHP Curve $\Delta P/\Delta V$ HP/kt	Speed Correction Due to Wind ΔV knots	Corrected Speed over Ground V_o' knots	Average Revolutions per knot	Corrected Speed through Water V'' knots	Current C knots	Actual Speed through Water V' knots	EHP	EHP/SHP
22 S	1424	6	586.6	10.16	310	8.6	F 90 S	0.35	.50	39	.01	10.17		9.73	S .44	9.72	114	.368
23 N	1435		587.1	8.84	306	24.0	F 20 P	1.34	12.80	30	.43	9.27		9.74	S .47	9.31	115	.376
24 S	1447		587.3	10.20	310	10.0	F 90 S	0.35	.67	39	.02	10.22		9.74	S .48	9.72	115	.371
			587.0	9.51	308							9.74	60.27	9.74		9.51		
25 N	1459	6	669.1	10.16	473	27.0	F 20 P	1.34	18.64	40	.47	10.63		11.10	S .47	10.63	170	.360
26 S	1509		669.2	11.63	470	10.5	F 90 S	0.35	.85	57	.01	11.64		11.10	S .54	11.09	170	.362
27 N	1519		669.2	10.07	477	26.0	F 30 P	1.39	17.75	40	.44	10.51		11.10	S .59	10.66	170	.356
			669.2	10.87	472							11.10	60.29	11.10		10.87		
28 S	0933 8/8	6	717.0	12.72	584		F 30 S	1.39		69		12.72		11.67	S 1.05	11.67	191	.327
29 N	0943		718.4	10.42	589	21.3	F 0	1.0	8.91	41	.22	10.64		11.70	S 1.06	11.48	192	.326
30 S	0955		711.0	12.61	558		F 0	1.0		62		12.63		11.58	S 1.05	11.58	187	.335
			716.2	11.54	580							11.66	61.42	11.66		11.55		
31 N	1007	8	399.4	7.71	172	16.8	F 0	1.0	4.10	22	.19	7.90		8.99	S 1.09	8.80	88	.511
32 S	1021		402.8	10.12	178		F 50 S	1.18		40		10.12		9.07	S 1.05	9.07	90	.506
33 N	1037		402.5	7.89	180	16.4	F 0	1.0	3.99	22	.18	8.07		9.06	S .99	8.88	90	.500
			401.9	8.96	177							9.05	44.41	9.05		8.96		
34 S	1045	8	512.0	12.58	366	3.5	F 20 S	1.34	.39	63	.01	12.59		11.67	S .92	11.66	191	.522
35 N	1055		516.0	10.78	370	18.2	F 0	1.0	6.71	48	.14	10.92		11.76	S .84	11.62	194	.524
36 S	1106		515.8	12.50	371	6.6	F 0	1.0	1.02	62	.02	12.52		11.76	S .76	11.74	194	.523
			515.0	11.66	369							11.74	43.87	11.74		11.66		
37 N	1115	8	586.9	12.77	552	18.0	F 10 S	1.07	8.31	70	.12	12.89		13.53	S .64	13.41	282	.511
38 S	1125		587.1	14.10	558	10.5	F 0	1.0	2.92	90	.03	14.13		13.53	S .60	13.50	282	.505
39 N	1139		588.6	12.88	554	17.2	F 10 S	1.07	7.66	72	.12	13.00		13.57	S .57	13.45	283	.511
			587.4	13.46	555							13.54	43.38	13.54		13.46		
40 S	1144	8	662.5	15.33	884	12.8	F 0	1.0	4.73	125	.04	15.37		14.91	S .54	14.87	400	.452
41 N	1153		664.6	14.47	868	12.8	F 10 S	1.07	9.22	105	.09	14.56		14.95	S .39	14.86	405	.467
42 S	1202		664.0	15.22	880	15.1	F 0	1.0	6.53	125	.05	15.27		14.94	S .31	14.89	405	.460
			663.9	14.87	875							14.94	44.44	14.94		14.87		

TABLE 5 (continued)

Run Number and Direction	Time at Start of Run	Pitch Setting	Average RPM N	Observed Speed V_0 knots	SHP	Relative Wind Velocity W_a	Relative Wind Direction ϕ	Wind Direction Coefficient K	Power Correction Due to Wind ΔP HP	Slope of EHP Curve $\Delta P/\Delta V$ HP/kt	Speed Correction Due to Wind ΔV knots	Corrected Speed over Ground V_0' knots	Average Revolutions per knot	Corrected Speed through Water V'' knots	Current C knots	Actual Speed through Water V' knots	EHP	EHP/SHP
43 N	1213	8	716.4	15.49	1180	16.4	F 10 S	1.07	8.37	127	.07	15.56		15.83	S .27	15.76	511	.433
44 S	1219		715.6	15.95	1202	16.8	F 10 S	1.07	9.05	130	.07	16.02		15.81	S .21	15.74	509	.423
45 N	1228		713.2	15.56	1150	13.7	F 0	1.0	5.49	127	.04	15.60		15.75	S .15	15.71	499	.434
			715.2	15.74	1184							15.80	45.27	15.80		15.74		
46 S	1324	10	408.3	11.62	312	14.4	F 10 S	1.07	4.85	56	.07	11.69		11.68	S .01	11.61	192	.615
47 N	1339		402.6	11.49	294	10.0	F 10 P	1.07	2.31	53	.04	11.53		11.51	N .02	11.47	185	.629
48 S	1345		402.2	11.36	294	13.5	F 10 S	1.07	4.16	51	.08	11.44		11.50	N .06	11.42	184	.606
			403.9	11.49	298							11.55	34.97	11.55		11.49		
49 N	1355 8/8	10	505.2	14.53	589	12.2	F 0	1.0	4.07	105	.04	14.57		14.45	N .12	14.41	357	.606
50 S	1405		506.6	14.31	601	17.3	F 0	1.0	8.05	100	.08	14.39		14.49	N .10	14.41	360	.599
51 N	1415		507.0	14.57	597	12.8	F 10 S	1.07	4.79	105	.05	14.62		14.51	N .11	14.46	362	.606
			506.4	14.43	597							14.49	34.95	14.48		14.42		
52 S	1426	10	584.9	15.93	1011	17.3	F 0	1.0	8.98	130	.07	16.00		16.14	N .14	16.07	548	.542
53 N	1435		584.7	16.19	1010	15.5	F 0	1.0	7.31	130	.06	16.25		16.13	N .12	16.07	547	.542
54 S	1445		584.4	15.93	1015	18.2	F 0	1.0	9.92	130	.08	16.01		16.12	N .11	16.04	546	.538
			584.7	16.06	1012							16.13	36.25	16.13		16.06		
55 N	1454	10	663.2	17.68	1624	17.2	F 0	1.0	9.82	130	.08	17.76		17.70	N .06	17.62	760	.468
56 S	1504		662.6	17.51	1633	20.5	F 0	1.0	13.82	130	.11	17.62		17.69	N .07	17.58	759	.465
57 N	1512		663.9	17.73	1627	14.6	F 0	1.0	7.11	130	.05	17.78		17.72	N .06	17.67	761	.467
			663.1	17.61	1629							17.70	37.46	17.70		17.61		
58 S	1520	10	710.0	18.57	2046	22.0	F 10 S	1.07	16.90	130	.13	18.70		18.63	S .07	18.50	887	.433
59 N	1530		717.0	18.65	2110	18.2	F 0	1.0	11.31	130	.09	18.74		18.81	S .07	18.72	911	.432
60 S	1538		717.2	18.75	2109	23.4	F 0	1.0	19.30	130	.15	18.90		18.82	S .08	18.67	914	.433
			715.3	18.66	2094							18.77	38.11	18.77		18.65		

TABLE 6

Analysis of Trial Data for One-Propeller Standardization

Run Number and Direction	Time at Start of Run	Pitch Setting	Average RPM N	Observed Speed V_0 knots	SHP	Relative Wind Velocity W_a	Relative Wind Direction *	Wind Direction Coefficient K	Power Correction Due to Wind ΔP HP	Slope of EHP Curve $\Delta P/\Delta V$ HP/kt	Speed Correction Due to Wind ΔV knots	Corrected Speed over Ground V_0' knots	Average Revolutions per knot	Corrected Speed through Water V'' knots	Current C knots	Actual Speed through Water V' knots	EHP	EHP/SHP
1 N	1316	4	440.6	2.37	52	5.5	F 20 P	1.34	.2	3	.07	2.44		3.62	S 1.18	3.55	6	.115
2 S	1349		439.0	4.66	51		F 40 S	1.25		7		4.66		3.61	S 1.05	3.61	6	.118
3 N	1409		433.6	2.55	52	6.0	F 30 P	1.39	.2	3	.07	2.62		3.56	S .94	3.49	6	.115
			438.0	3.56	52							3.60	121.7	3.60		3.56		
4 S	1440	4	533.4	5.08	88		F 50 P	1.18		8		5.08		4.38	S .70	4.38	9	.102
5 N	1457		543.2	3.68	88	10.5	F 20 S	1.34	1.0	5	.20	3.88		4.46	S .58	4.26	10	.114
6 S	1518		544.9	4.94	89		90 P	.35		8		4.94		4.47	S .47	4.47	10	.112
			541.2	4.34	88							4.44	121.9	4.44		4.34		
7 N	0909	4	623.2	5.66	129	5.0	F 10 S	1.07	.3	11	.03	5.69		5.03	N .66	5.00	14	.109
8 S	0925		623.4	4.47	125		F 40 P	1.25		6		4.47		5.03	N .56	5.03	14	.112
9 N	0942		625.0	5.43	125	6.4	F 15 S	1.20	.5	10	.05	5.48		5.04	N .44	4.99	14	.112
			623.8	5.01	126							5.03	124.0	5.03		5.01		
10 S	1000	4	701.2	5.36	173		F 50 P	1.18		10		5.36		5.65	N .29	5.65	19	.110
11 N	1017		702.1	5.74	174	9.4	F 15 S	1.20	1.1	11	.10	5.84		5.66	N .18	5.56	19	.109
12 S	1031		703.0	5.62	172		A 20 P	.86		11		5.62		5.67	N .05	5.67	19	.111
			702.1	5.62	173							5.66	124.0	5.66		5.61		
13 N	1051	4	728.8	5.65	198	9.9	F 10 S	1.07	1.1	11	.10	5.75		5.84	S .09	5.74	21	.106
14 S	1110		738.6	6.10	218		F 50 P	1.18		12		6.10		5.91	S .19	5.91	22	.101
15 N	1123		742.9	5.59	216	7.7	F 10 S	1.07	.7	11	.06	5.65		5.95	S .30	5.89	23	.107
			737.2	5.86	212							5.90	124.9	5.90		5.86		
16 S	1243	6	417.6	6.19	65		F 15 P	1.20		13		6.19		5.40	S .79	5.40	17	.262
17 N	1259		417.8	4.51	63	6.2	F 10 S	1.07	.3	7	.04	4.55		5.40	S .90	5.36	17	.270
18 S	1316		418.2	6.29	65		F 0	1.00		13		6.29		5.40	S .89	5.40	17	.262
			417.8	5.38	64							5.40	77.37	5.40		5.38		
19 N	1331	6	519.1	5.89	127	7.0	F 10 S	1.07	.4	12	.03	5.92		6.80	S .88	6.77	35	.275
20 S	1335		528.0	7.87	126		F 5 P	1.03		23		7.87		6.92	S .95	6.92	37	.293
21 N	1358		522.6	5.76	126	7.3	F 10 S	1.07	.6	12	.05	5.81		6.85	S 1.04	6.80	36	.286
			524.4	6.85	126							6.87	76.33	6.87		6.85		

* A - from stern and F - from bow.

TABLE 6 (continued)

Run Number and Direction	Time at Start of Run	Pitch Setting	Average RPM N	Observed Speed V_0 knots	SHP	Relative Wind Velocity W_a	Relative Wind Direction •	Wind Direction Coefficient K	Power Correction Due to Wind ΔP HP	Slope of EHP Curve $\Delta P/\Delta V$ HP/kt	Speed Correction Due to Wind ΔV knots	Corrected Speed over Ground V_0' knots	Average Revolutions per knot	Corrected Speed through Water V'' knots	Current C knots	Actual Speed through Water V' knots	EHP	EHP/SHP
22 S	1413	6	603.7	9.00	184	5.0	F 0	1.00	.4	32	.01	9.01		7.98	S 1.03	7.97	59	.320
23 N	1424		604.6	6.93	188	8.0	F 0	1.00	.8	17	.05	6.98		7.99	S 1.01	7.94	59	.314
24 S	1437		604.8	8.97	185	9.0	F 0	1.00	1.5	39	.04	9.01		8.00	S 1.01	7.96	60	.324
			604.4	7.96	186							7.99	75.64	7.99		7.95		
25 N	1448	6	681.0	8.10	274	4.4	F 5 S	1.03	.3	25	.01	8.11		9.15	S 1.04	9.14	90	.328
26 S	1459		682.5	10.08	279	12.4	F 20 P	1.34	3.9	39	.10	10.18		9.17	S 1.01	9.07	91	.326
27 N	1509		681.9	8.18	279	3.5	F 20 S	1.34	.3	27	.01	8.19		9.16	S .97	9.15	90	.323
			682.0	9.11	278							9.16	74.45	9.16		9.11		
28 S	1520	6	750.1	10.89	390	14.5	F 20 P	1.34	5.8	44	.13	11.02		10.12	S .90	9.99	123	.315
29 N	1530		736.9	9.10	367		F 10 S	1.07		32		9.10		9.95	S .85	9.95	117	.319
30 S	1540		748.6	10.76	391	15.1	F 10 P	1.07	5.6	43	.13	10.89		10.10	S .79	9.97	123	.315
			743.1	9.96	379							10.03	74.09	10.03		9.96		
31 N	0846	8	409.2	7.88	108	8.6	F 50 S	1.18	1.3	23	.06	7.94		7.48	N .46	7.42	108	.444
32 S	0858		409.1	6.86	108	7.8	F 30 P	1.39	1.1	17	.06	6.92		7.48	N .56	7.42	108	.444
33 N	0911		408.8	8.11	109	5.2	F 30 S	1.39	.6	25	.02	8.13		7.48	N .65	7.46	109	.440
			409.0	7.43	108							7.48	54.68	7.48		7.43		
34 S	0923	8	523.2	8.98	218	11.2	F 10 P	1.07	2.3	32	.07	9.05		9.73	N .68	9.66	218	.504
35 N	0934		519.4	10.34	220	9.5	F 0	1.00	1.7	41	.04	10.38		9.65	N .73	9.61	220	.487
36 S	0944		520.4	8.89	221	8.2	F 10 P	1.00	1.1	31	.04	8.93		9.67	N .74	9.63	221	.484
			520.8	9.64	220							9.68	53.80	9.68		9.63		
37 N	0956	8	594.0	11.76	329	9.0	F 10 S	1.07	1.9	50	.04	11.80		11.03	N .77	10.99	329	.474
38 S	1012		602.4	10.43	340	10.5	F 10 P	1.07	2.3	42	.05	10.48		11.19	N .71	11.14	340	.473
39 N	1022		602.3	11.78	342	11.6	F 0	1.00	3.0	50	.06	11.84		11.19	N .65	11.13	342	.471
			600.3	11.10	338							11.15	53.84	11.15		11.10		
40 S	1031	8	676.0	11.89	489	10.4	F 20 P	1.34	3.2	50	.06	11.95		12.56	N .61	12.50	489	.442
41 N	1040		675.7	13.01	490	15.5	F 0	1.00	5.8	60	.10	13.11		12.56	N .55	12.46	490	.441
42 S	1048		676.2	12.01	488	8.4	F 20 P	1.34	2.0	50	.04	12.05		12.56	N .51	12.52	488	.443
			675.9	12.48	489							12.56	53.81	12.56		12.48		

TABLE 6 (continued)

Run Number and Direction	Time at Start of Run	Pitch Setting	Average RPM N	Observed Speed V_0 knots	SHP	Relative Wind		Wind Direction Coefficient K	Power Correction Due to Wind ΔP HP	Slope of EHP Curve $\Delta P/\Delta V$ HP/kt	Speed Correction Due to Wind ΔV knots	Corrected Speed over Ground V_0' knots	Average Revolutions per knot	Corrected Speed through Water V'' knots	Current C knots	Actual Speed through Water V' knots	EHP	EHP/SHP
						Velocity W_a	Direction *											
43 N	1058	8	757.2	13.99	735	19.3	F 10 S	1.07	10.4	77	.14	14.13		13.67	N .46	13.53	735	.378
44 S	1105		757.1	13.22	731	8.8	F 20 P	1.34	2.6	63	.04	13.26		13.67	N .41	13.63	731	.380
45 N	1114		756.8	13.88	730	20.6	F 0	1.00	11.0	75	.15	14.03		13.67	N .34	13.52	730	.381
			757.0	13.58	732							13.67	55.38	13.67		13.58		
46 N	1235	10	410.9	9.23	188	11.0	F 30 S	1.39	2.9	33	.09	9.32		9.61	S .29	9.52	188	.564
47 S	1248		415.9	9.93	191	12.5	F 25 P	1.36	4.0	38	.11	10.04		9.73	S .31	9.62	190	.579
48 N	1259		415.8	9.33	191	8.1	F 30 S	1.39	1.6	33	.05	9.38		9.73	S .35	9.68	190	.579
			414.6	9.60	190							9.70	42.74	9.70		9.61		
49 S	1309	10	516.0	12.55	375	16.7	20 P	1.34	8.8	60	.15	12.70		12.28	S .42	12.13	375	.547
50 N	1317		517.4	11.82	380	9.9	20 S	1.34	2.9	50	.06	11.88		12.32	S .44	12.26	380	.542
51 S	1325		531.1	12.96	416	16.4	20 P	1.34	8.8	60	.15	13.11		12.64	S .47	12.49	416	.531
			520.5	12.29	388							12.39	42.01	12.39		12.28		
52 N	1334	10	591.5	13.37	613	12.2	20 S	1.34	5.00	64	.07	13.44		13.94	S .50	13.87	613	.485
53 S	1342		597.5	14.38	611	22.0	20 P	1.34	17.4	85	.20	14.58		14.09	S .49	13.89	611	.504
54 N	1350		592.4	13.46	606		0	1.00		67		13.46		13.97	S .51	13.97	606	.492
			594.7	13.90	610							14.02	42.42	14.02		13.90		
55 S	1357	10	644.8	14.94	824	25.0	10 P	1.07	18.8	67	.28	15.22		14.57	S .65	14.29	824	.419
56 N	1405		645.8	14.02	822	5.5	50 S	1.18	.9	77	.01	14.03		14.59	S .56	14.58	822	.421
57 S	1411		650.4	14.94	849	27.0	10 P	1.07	21.7	100	.22	15.16		14.69	S .53	14.47	849	.419
			646.7	14.48	829							14.61	44.26	14.61		14.48		
58 S	1138	10	692.2	14.69	1064	9.0	30 P	1.39	3.1	94	.03	14.72		15.02	N .30	14.99	1064	.364
59 N	1130		691.8	15.09	1064	21.2	0	1.00	12.7	100	.13	15.22		15.01	N .21	14.88	1064	.363
60 S	1122		689.2	14.80	1050	10.0	10 P	1.07	3.0	97	.03	14.83		14.96	N .13	14.93	1050	.362
			691.2	14.92	1060							15.00	46.08	15.00		14.92		

TABLE 7

Analysis of Data for Astern Standardization at Light Displacement

Run Number and Direction	Time at Start of Run	Pitch Setting	Average RPM N	Observed Speed V_0 knots	SHP	Relative Wind Velocity W_a	Relative Wind Direction *	Steering Indicator Position Setting	Wind Direction Coefficient K	Power Correction Due to Wind ΔP HP	Average Revolutions per knot	Corrected Speed through Water V'' knots
1 N	1318 7/31	4	394.7	3.54	95		A 70 S	15				4.61
2 S	1340		395.6	5.66	97	7.8	A 30 P	15	.80	+ .5		4.61
3 N	1357		394.6	3.59	98		A 80 S	15				4.61
			395.1	4.61	96						85.7	4.61
4 S	1423	4	513.9	6.77	191	9.0	A 20 P	15	.90	+ .9		5.82
5 N	1434		508.7	5.01	183		A 50 S	15				5.77
6 S	1450		510.4	6.35	175	7.7	A 20 S	15	.90	+ .6		5.79
			510.4	5.79	183						88.2	5.79
7 N	0851 8/1	4	601.7	7.12	354	17.5	A 60 P	15	.20	+ .8		6.80
8 S	0909		597.8	6.52	347		F180 S	15				6.76
9 N	0921		598.2	6.93	350	14.4	A.30 P	15	.80	+2.2		6.77
			598.9	6.77	350						88.4	6.77
10 S	0935	4	721.0	7.75	688		F 80 S	15				7.94
11 N	0945		714.8	7.86	748	17.7	A 10 P	15	0			7.87
12 S	0956		711.6	8.03	698		A 80 S	15				7.84
			715.6	7.88	726						90.8	7.88
13 N	1018	6	398.4	5.90	164	15.5	A 30 P		.80	+2.1		6.07
14 S	1031		398.2	6.34	168	6.0	F 80 S	30	-.15			6.07
15 N	1042		399.0	5.71	169	14.8	A 40 P	25	.60	+1.4		6.07
			398.5	6.07	167						65.7	6.07
16 S	1056	6	503.8	7.96	355	10.0	F 80 S	25-30	-.15	- .2		7.61
17 N	1106		506.2	7.17	367	16.8	A 50 P	25-30	.40	+1.5		7.65
18 S	1119		503.5	8.20	356	8.8	A 80 S	25-30	0			7.61
			504.9	7.63	361						66.2	7.63
19 N	1129	6	590.3	7.98	636	16.8	A 30 P	25-30	.80	+3.4		8.61
20 S	1139		584.9	9.24	615		A 30 A	25-30				8.53
21 N	1148		590.0	7.76	639	15.5	A 20 P	25-30	.90	+3.1		8.60
			587.5	8.56	626						68.6	8.57
22 S	1158	6	709.6	9.97	939	6.5	A 40 S	30	.60	+ .5		9.09
23 N	1210		713.7	8.22	993	14.4	A 20 P	30	.90	+2.9		9.15
24 S	1219		715.0	10.14	1000	8.5	A 60 S	30	.20	+1.2		9.17
			713.0	9.14	981						78.0	9.14

* A - from stern and F - from bow.

TABLE 7 (continued)

Run Number and Direction	Time at Start of Run	Pitch Setting	Average RPM N	Observed Speed V_o knots	SHP	Relative Wind Velocity W_a	Relative Wind Direction θ	Steering Indicator Position Setting	Wind Direction Coefficient K	Power Correction Due to Wind ΔP HP	Average Revolutions per knot	Corrected Speed through Water V'' knots
25	1255 8/1	8	404.8	6.48	292	14.4	A 10 P	30	1.00	+2.5		7.47
26	1310		403.9	8.49	293		F 30 S	30				7.45
27	1320		409.4	6.46	310	18.3	A 10 S	30	1.00	+4.0		7.55
			405.5	7.48	297						54.2	7.48
28	1332	8	508.2	9.80	576		F 60 S	35				8.73
29	1341		503.8	7.58	580	17.8	A 0	32	1.00	+4.5		8.65
30	1351		503.2	9.72	570		A 10 P	35				8.64
			504.8	8.67	577						58.2	8.67
31	1401	8	595.4	8.17	829	18.3	A 0	40	1.00	+5.1		9.19
32	1411		593.6	10.14	825		A 10 P	40				9.16
33	1419		597.8	8.26	850	20.0	A 0	40	1.00	+6.2		9.22
			595.1	9.18	832						64.8	9.18
34	1430	8	706.0	10.42	1134		F 40 S	40				9.59
35	1440		700.7	8.75	1127	18.8	A 15 P	40	1.00	+5.8		9.52
36	1450		706.5	10.28	1135		F 30 S	40				9.60
			703.5	9.55	1131						73.6	9.56
37	1459	10	398.7	7.35	398	20.0	A 0	40	1.00	+5.5		8.06
38	1510		397.5	8.73	384		F 10 P	40				8.03
39	1520		398.5	7.40	403	19.3	A 10 S	40	1.00	+5.2		8.05
			398.1	8.05	392						49.5	8.04
40	1532	10	503.4	9.53	682		F 0	45				9.01
41	1541		502.9	8.52	707	20.6	A 0	45	1.00	+6.8		9.00
42	1551		503.9	9.41	663		F 40 S	45				9.01
			503.3	9.00	690						55.9	9.00
43	0826 8/2	10	581.6	9.99	1006	17.8	A 40 P	50	.60	+3.5		9.38
44	0836		581.8	8.72	972	7.0	A 60 S	45	.20	+ .2		9.38
45	0847		579.4	10.03	991	15.0	A 40 P	45	.60	+2.6		9.34
			581.2	9.37	985						62.0	9.37
46	0856	10	711.6	9.13	1383	6.0	A 40 S	45	.60	+ .4		9.80
47	0907		710.8	10.42	1408	16.0	A 40 P	45	.60	+3.0		9.79
48	0916		712.3	9.18	1376	7.5	A 40 S	45	.60	+ .6		9.81
			711.4	9.79	1394						72.6	9.80

TABLE 8

Analysis of Data for Light-Load Towing Trials

Run Number and Direction	Time at Start of Run	Pitch Setting	Average RPM N	Observed Speed V_0'' knots	SHP	Relative Wind Velocity W_a	Relative Wind Direction *	Towrope Pull T	Wind Direction Coefficient K	Power Correction Due to Wind ΔP HP	Slope of EHP Curve $\Delta P/\Delta V$ HP/kt	Speed Correction Due to Wind ΔV knots	Corrected Speed through Water V_0' knots	$\frac{N}{V}$	V^3	$\frac{SHP}{V^3}$	Wind Force on LCI in lb	Towrope Pull Corrected for Corrected Speed	Wind Corrected Towrope Pull T'	Fully Corrected Towrope Pull T''
1 N	0848 8/23	4	423.8	2.50	131	14.2	F 30 P	1300	1.39	+ 5.3	11	.48	2.98	142	26.	4.94	470	+350	830	1180
2 S	0903		518.0	3.70	185		A 50 S	1960					3.70	140	50.	3.75			1960	1960
3 N	0912		594.0	3.90	290	11.3	F 30 P	2490	1.39	+ 5.2	26	.17	4.07	146	67.	4.31	300	200	2190	2390
4 S	0925		669.2	4.65	443		A 70 S	3140					4.65	144	100.	4.41			3140	3140
5 N	0939	4	714.0	4.60	541	8.8	F 05 P	3204	1.00	+ 2.7	38	.08	4.68	152	102.	5.28	130	90	3070	3160
6 S	0953	6	398.0	4.15	212		F 50 S	2620					4.15	96	71.	2.97			2620	2620
7 N	1007		509.0	5.26	404	14.4	F 0	4250	1.00	+ 8.0	48	.16	5.42	94	159	2.54	340	240	3910	4150
8 S	1018		582.0	6.50	552		F 20 S	5490					6.50	89	275.	2.01			5490	5490
9 N	1030	6	662.8	7.00	760	12.5	F 05 S	7260	1.00	+ 8.3	70	.12	7.12	93	361	2.10	260	180	7000	7180
10A S	1041		715.2	8.20	874		F 15 P	7850					8.20	87	551	1.58			7850	7850
10C S	1056		714.5	7.00	772	20.0	F 0	7150	1.00	21.2	70	.30	7.30	98	389	1.98	670	500	6500	7000
11 N	1053 8/23	8	410.0	6.25	351	10.2	F 0	5360	1.00	+ 4.9	58	.09	6.34	65	255	1.56	180	100	5140	5240
12 S	1103	8	504.7	7.80	615		F 05 P	8440					7.80	65	475	1.29			8440	8440
13 N	1115		581.2	9.05	966	15.4	F 0	10400	1.00	+16.2	100	.16	9.21	63	781	1.24	400	300	10000	10300
14 S	1125		662.5	10.08	1394		F 15 P	12900					10.80	61	1260	1.11			12900	12900
15 N	1136		704.5	11.10	1655	18.3	F 10 S	14300	1.07	+30.0	160	.19	11.29	62	1438	1.15	600	430	13700	14130
16 S	1148	10	393.0	7.45	539		F 70 P	6540					7.45	53	414	1.30			6540	6540
17 N	1159		516.0	9.80	1087	15.9	F 05 S	12100	1.00	+18.7	120	.16	9.96	52	989	1.10	420	350	11700	12050
18 S	1211		586.2	11.30	1597		F 10 P	15900					11.30	52	1443	1.11			15900	15900
19 N	1227		652.0	12.70	2269	20.3	F 05 S	18800	1.00	+40.0	200	.20	12.90	51	2145	1.06	700	650	18100	18750
19B S	1100	10	651.0	11.60	2175	24.5	F 0	18500	1.00	+52.7	175	.30	11.90	55	1683	1.29	1000	1000	17500	18500

* A - from stern and F - from bow.

TABLE 9

Analysis of Data for Heavy-Load Towing Trials

Run Number and Direction	Time at Start of Run	Pitch Setting	Average RPM N	Observed Speed V_o'' knots	SHP	Relative Wind Velocity W_a	Relative Wind Direction *	Towrope Pull T	LCI Backing	Wind Direction Coefficient K	Power Correction Due to Wind ΔP HP	Slope of EHP Curve $\Delta P/\Delta V$ HP/kt	Speed Correction Due to Wind ΔV knots	Corrected Speed through Water V_o' knots	Average Revolutions per knot	$\frac{N}{V}$	V^3	$\frac{SHP}{V^3}$	Fully Corrected Towrope Pull T''	Towrope Pull Corrected for Corrected Speed	Wind Corrected Towrope Pull T'	Wind Force on LCI in lb
1 N	1155	4	413.0	1.0	478	9.5	F 10 S	2490	1/3	1.07	+ .7	10	+.1	1.1		375	1	478	2380	50	2330	160
1A S	1345		401.2	1.3	335	10.0	A 50 P	1700		.30	- .3	11		1.3		309	2	168	1750		1750	-50
			407.1	1.15	406									1.2	339.3				2070			
2 N	1150	4	518.0	2.0	482	10.0	F 10 S	2940	1/3	1.07	+1.6	14	+.1	2.1		246	9	54.0	2820	60	2760	180
2A S	1243		511.8	2.3	254		A 30 P	2160				15		2.3		222	12	21.0	2160		2160	
			514.9	2.15	368			2550						2.2	234.0	234	11	33.5	2490		2460	
3 S	1240	4	587.8	3.8	432		A 30 P	2750	1/3			26		3.8		155	55	7.85	2750		2750	
3A N	1259		586.0	3.4	439	10.0	F 10 S	2750		1.07	+2.8	23	+.1	3.5		168	43	10.20	2650	80	2570	180
3B N	1451		581.5	3.4	449	9.5	F 10 P	2810		1.07	+2.5	23	+.1	3.5		166	43	10.40	2730	80	2650	160
			585.8	3.6	438			2760						3.6	160.5	160	49	8.94	2720		2680	
4 N	1255	4	660.8	3.8	483	13.6	F 20 S	3340	1/3	1.34	+7.1	26	+.3	4.1		161	69	7.00	3200	280	2920	420
4A S	1402		665.0	3.6	511		A 50 P	3530				25		3.6		184	47	10.90	3530		3530	
4B N	1455		657.8	3.8	431	11.2	F 20 P	3600		1.34	+4.8	26	+.2	4.0		164	64	6.73	3490	170	3320	280
			662.2	3.7	484			3500						3.8	174.4	174	55	8.80	3440		3330	
5 S	1351	4	705.5	4.4	617		A 50 P	4250	1/3			32		4.4		160	85	7.26	4250		4250	
5A N	1421		711.8	4.4	814	10.7	F 05 S	4060		1.00	+3.8	32	+.1	4.5		158	91	8.95	3970	100	3870	190
			708.6	4.4	716			4160						4.4	159.2	159	88	8.14	4110		4060	
6 N	1413	6	395.0	3.4	389	12.5	F 05 S	3200	1/2	1.00	+4.0	23	+.2	3.6		110	47	8.28	3080	140	2940	260
6A S	1437		394.2	3.4	320	5.0	A 30 S	3000		.70	- .5	23		3.4		116	39	8.21	3000		3000	
			394.6	3.4	354			3100						3.5	112.7	113	43	8.24	3040		2970	
7 S	1434	6	509.0	5.2	496		A 30 S	4640	1/2			45		5.2		98	140	3.55	4640		4640	
7A N	1448		509.0	5.2	470	11.2	F 10 P	4640		1.07	+5.3	45	+.1	5.3		96	149	3.15	4520	110	4410	230
			509.0	5.2	483			4640						5.2	96.9	97	145	3.33	4580		4530	
8 N	1445	6	584.8	6.0	571	16.7	F 25 P	5760	1/2	1.27	+16.1	60	+.3	6.3		93	250	2.28	5660	500	5160	600
8A S	1505		578.2	5.8	661		90 S	6200				55		5.8		100	195	3.39	6200		6200	
			581.5	5.9	616			5980						6.0	96.1	96	222	2.91	5930		5680	
9 S	1500	6	663.2	7.0	842		F 80 S	7400	1/2			90		7.0		95	343	2.45	7400		7400	
9A N	1416		660.0	6.4	863	13.7	F 0	7900		·1.00	+9.1	70	+.1	6.5		102	275	3.14	7800	200	7600	300
			661.6	6.7	853			7650						6.7	98.0	99	308	2.77	7600		7500	

* A - from stern and F - from bow.

TABLE 9 (continued)

Run Number and Direction	Time at Start of Run	Pitch Setting	Average RPM N	Observed Speed V_0'' knots	SHP	Relative Wind Velocity W_a	Relative Wind Direction *	Towrope Pull T	LCI Backing	Wind Direction Coefficient K	Power Correction Due to Wind ΔP HP	Slope of EHP Curve $\Delta P/\Delta V$ HP/kt	Speed Correction Due to Wind ΔV knots	Corrected Speed through Water V_0' knots	Average Revolutions per knot	$\frac{N}{V}$	V^3	$\frac{SHP}{V^3}$	Fully Corrected Towrope Pull T''	Towrope Pull Corrected for Corrected Speed	Wind Corrected Towrope Pull T'	Wind Force on LCI in lb
10 N	1413 8/27	6	706.8	7.3	1019	14.7	F 0	8900	1/2	1.00	+12.0	100	+.1	7.4		96	405	2.51	8740	200	8540	360
10A S	1531		714.5	7.6	994		F 0	8310				110		7.6		94	440	2.24	8310		8310	
			710.6	7.45	1006			8600						7.5	94.7	9.5	420	2.39	8530		8430	
11 S	0835 8/28	8	396.0	3.6	323	14.7	F 50 S	6670	Full	1.18	+ 7.0	35	+.2	3.8		104	55	5.88	6340	100	6240	430
11A N	0849		396.0	4.1	350	6.7	A 85 P	5820		0		37		4.1		97	69	5.07	5820		5820	
			396.0	3.85	336			6240						3.9	100.3	100	62	5.42	6080		6030	
12 N	0845	8	510.5	6.5	599	4.5	A 80 P	8830	Full	0		70		6.5		79	275	2.18	8830		8830	
12A S	0905		507.0	6.4	582	16.0	F 50 S	8960		1.18	+14.6	69	+.2	6.6		77	288	2.02	8750	300	8450	510
			508.8	6.45	590			8900						6.5	77.7	78	280	2.10	8790		8630	
13 S	0901	8	581.8	7.9	879	20.3	F 50 S	11510	Full	1.18	+29.1	100	+.3	8.2		71	550	1.60	11240	550	10690	820
13A N	0919		579.5	7.6	937		F 80 P	11120				94		7.6		76	440	2.13	11120		11120	
			580.6	7.75	908			11310						7.9	73.5	74	490	1.85	11180		10910	
14 N	0915	8	661.0	9.0	1407	6.0	F 80 P	13860	Full	.61	+ 1.5	111		9.0		73	730	1.93	13820		13820	40
14A S	0932		665.0	9.0	1304	22.3	F 35 S	13860		1.30	+44.1	111	+.4	9.4		71	830	1.57	13520	750	12770	1090
			663.0	9.0	1356			13860						9.2	72.1	72	780	1.74	13670		13300	
15 S	0928	8	711.5	9.6	1634	20.3	F 40 S	15370	Full	1.25	+37.5	125	+.3	9.9		72	970	1.68	15050	550	14500	870
15A N	0951		714.0	10.1	1608		A 80 P	15570				134		10.1		71	1020	1.58	15570		15570	
15B N	1041		711.2	9.8	1713		F 75 P	15570				130		9.8		73	940	1.82	15570		15570	
			712.0	9.8	1647			15470						9.9	71.9	72	970	1.70	15320		15040	
16 N	0942	10	395.0	6.0	441	8.0	A 80 P	7520	Full	0		60		6.0		66	216	2.04	7520		7520	
16A S	1002		398.2	6.0	482	18.0	F 40 S	8440		1.25	+18.4	60	+.3	6.3		63	250	1.93	8210	450	7760	680
			396.6	6.0	462			7980						6.1	64.5	6.5	232	1.99	7870		7640	
17 S	0958	10	515.5	8.8	1019	22.3	F 45 S	13340	Full	1.20	+39.8	109	+.4	9.2		56	780	1.31	13090	750	12340	1000
17A N	1018		502.8	8.5	980		F 75 P	12620				102		8.5		59	620	1.58	12620		12620	
17B S	1104		496.0	8.2	933	22.3	F 10 S	12690		1.07	+33.0	100	+.3	8.5		58	620	1.51	12400	600	11800	890
			504.3	8.5	978			12820						8.7	58.0	58	660	1.48	12680		12350	
18 N	1013	10	583.0	10.1	1519		F 75 P	15760	Full			134		10.1		58	1020	1.49	15760		15760	
18A S	1029		577.2	10.1	1481	23.4	F 20 S	16090		1.34	+56.2	134	+.4	10.5		55	1160	1.28	15550	700	14850	1240
			580.1	10.1	1500			15920						10.3	56.3	56	1100	1.36	15660		15300	
19 S	1025	10	652.2	11.6	2167	24.1	F 20 S	18510	Full	1.34	+68.4	170	+.4	12.0		54	1730	1.25	17900	700	17200	1310
19A N	1038		653.0	11.6	2170		F 75 P	18570				170		11.6		56	1560	1.39	18570		18570	
			652.6	11.6	2168			18540						11.8	55.3	55	1640	1.32	18240		17890	

TABLE 10

Analysis of Data for Dead Pull

Run Number	Pitch Setting	Ahead Runs				Astern Runs			
		Shaft RPM	Total SHP	Pull in pounds	Pull in lb/SHP	Shaft RPM	Total SHP	Pull in pounds	Pull in lb/SHP
1A	2	430	81	1010	12.5	424	115	1670	14.5
2	2	489	101	1440	14.3	489	139	2140	15.4
3	2	570	150	1620	10.8	562	195	2940	15.1
4	2	644	228	1790	7.8	627	279	3700	13.3
5	2	719	309	2310	7.5	722	411	4560	11.1
6	4	421	118	2880	24.4	408	148	4100	27.7
7	4	501	172	4330	25.2	482	236	5470	23.2
8	4	577	266	5820	21.9	558	345	7790	28.1
9	4	649	422	6710	15.9	634	568	10100	17.8
10	4	726	621	9610	15.5	726	899	13000	14.5
11	6	409	227	6050	26.7	400	263	6690	25.4
12	6	494	410	8940	21.8	482	490	10600	21.6
13	6	570	609	12100	19.9	562	808	14100	17.4
14	6	651	982	16500	16.8	643	1264	18100	14.3
15	6	726	1406	20300	14.4	717	1799	22000	12.2
16	8	409	506	10900	21.5	400	524	11300	21.6
17	8	491	791	16000	20.2	477	902	16400	18.2
18	8	571	1272	21000	16.5	569	1497	21300	14.2
19	8	648	1930	27500	14.2				
20	8	678	2248	29100	13.0	627	2098	24600	11.7
21	10	408	762	14700	19.3	402	829	14500	17.5
22	10	487	1296	21200	16.4	483	1425	19900	13.4
23	10	553	1865	28700	15.4	522	1783	22300	13.1
24	10	555	1872	28800	15.4				
26	10	619 Stbd. only	1068 Stbd. only	13300	12.2				
27	10	520 Port only	798 Port only	12400	15.5				

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