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SEA TRIALS ON A VICTORY SHIP, AP3, IN NORMAL MERCHANT SERVICE

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Read in London on March 27, 1953, *Mr. L. Woollard, M.A.* (*Vice-President I.N.A.*) *in the Chair, supported by Mr. R. Cook, M.Sc.,* (*Member of Council I.Mar.E.*)

Summary

During the years 1951 and 1952 an extensive series of trials was undertaken for the Centre Belge de Recherches Navales on a Victory ship AP3 of the Compagnie Maritime Belge. The basic purpose was the determination of the efficiency and economy of the ship and machinery in different conditions of weather and fouling. By collecting reliable and accurate records of fuel and steam consumption and engine output, it was possible to ascertain efficiency of boiler and engine under varying service conditions.

As predominant part of the programme a comparison between service data in smooth water and tank results was to be carried out. During one of the voyages a progressive measured-mile trial was undertaken which gave basic information for the comparison with model experiments. Dr. Allan, Superintendent of the Ship Division N.P.L., was kind enough to run a model and to make the comparison as part of the investigations. Calibration of the pitometer log was achieved, too, on the measured-mile trial.

In different conditions of draught, fouling, and weather, numerous records were collected of power, thrust, revolutions, speed through the water, ship motions, wind, and waves. The service data are analysed and the results given in a series of tables and diagrams.

A similar series of trials will shortly be carried out on a diesel-driven cargo ship.

Introduction

The problem of the comparison between turbine and diesel-driven ships in the merchant service was, in 1948, put before the Centre Belge de Recherches Navales, the Belgian equivalent of the B.S.R.A. At the same time, it was desired to study the correlation between the tank predictions based on model experiments and service performance. Shipbuilders and owners often doubt the absolute value of tank figures which are calculated for the ship on a basis of results obtained from the models. Indeed, the tank applies to these results coefficients of correction, in order to allow for service conditions. But the methods used in working from experimental results with models to real ships vary so much from one tank to another, that even the initiated are on their guard when they desire to interpret results obtained by a tank which is not theirs. Tanks possess for different types of ships coefficients of correction for relating the trial in the tank to trial at sea on a measured mile in dead calm with an approximation which may appear to be sufficient. However, when comparing the basic results of the tank trial and the trial at sea it is found that the actual coefficients of correction often diverge notably from the approximate coefficients.

But it is particularly for passing from conditions in the tank to service conditions that precise data are not available. The increase in roughness due to fouling of the hull, bad weather, and the different movements of the ship in high seas all exercise a considerable influence on the resistance to speed.

Tank trials have taken place to determine the influence of high seas on the resistance to speed, but a correlation between the results and the measurements taken on board ship was difficult to obtain, particularly in view of the irregularity of the waves of the sea.

It is therefore desirable that precise trials should take place on board, not only on a measured mile in the best possible weather but also during the diverse conditions of service. These trials should comprise accurate records of speed through the water, revolutions, power, thrust and, simultaneously, wind and weather, the state of the sea and the ship's movements.

The measurements are extended in such a way as to indicate not only information concerning propulsion, but also on the thermal efficiency of the propulsive installations.

It is current practice in Europe to take the internal-combustion motor as the machine for propulsion when the power required is not greater than 10,000 hp. In America, the steam turbine has preference for power well under the aforementioned limit. There is an economic as much as a scientific interest in comparing these two propulsive machines in ships of the same size.

The Centre Belge de Recherches Navales, in the summer of 1948, instituted a programme of experimental research on the propulsive equipment of two cargo ships of about 10,000 tons

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deadweight, one with a turbine the other with a diesel motor, their speed being from 15 to 17 knots.

The efficiency had to be ascertained at different powers for each part of the installation, i.e. for the turbine ship the individual efficiency of the steam generating group, of the turbine group and of the propulsion, and for the diesel-driven ship efficiency of the motor and of the propulsion. The choice of ships fell on those the models of which had been run in the experimental tank prior to their construction.

The two ships belong to the Compagnie Maritime Belge.

The turbine-driven ship was the s.s. *Tervaete*, a Victory ship, AP3, of which many examples were delivered to European companies after the war.

This programme of research received the approval of the Institute.

PART I

Instrumentation for the Trials

In order to realize this programme it was necessary to compile the list of instruments required for taking the necessary measurements on board the turbine-driven s.s. *Tervaete*. The position of the principal instruments concerning propulsion is indicated in the general arrangement shown in Fig. 1. The general data of the ship and the machinery are given in Appendix IV.

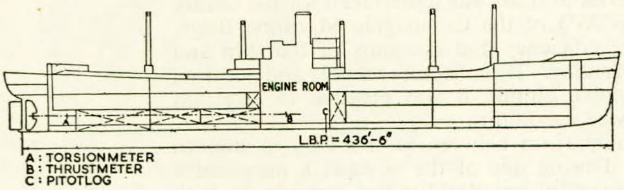

FIG. 1.—INSTRUMENTATION IN S.S. "TERVAETE"

Ship Speed.

The measurement of ship speed through the water is obtained by a Pitot log, fitted in the ship's bottom. The log had to fulfil the following requirements:—

It was necessary to install a rodmeter long enough to go through the boundary layer in order to reach water unaffected by the skin friction of the ship.

In order to explore the distribution of velocity in the boundary layer the rod has to be transferred to any given position up to 3 ft. from the surface of the hull for measurement.

The log was manufactured by the British Pitometer Company. The rodmeter is a hollow bronze rod of oval cross-section, with a pressure orifice facing forward, which measures the combined static and dynamic pressure, and two communicating orifices, one on each side, to take the static pressure only.

These pressures are connected by two pipes to a mercurial differential manometer. In that manner only the dynamic pressure can be read, which is a measure of the speed of the log through the water.

The mercurial differential is completed by a speed transmitter and at a distance by the speed indicator with timing unit.

Thrust Measurement.

As one of the aims of the experiments is the determination of the propulsive efficiency, a thrustmeter had to be installed. The Victory ship has a Kingsbury thrust bearing. In a newly built ship it would have been possible to have the thrust bearing proper in a sliding cage and to have an accurate measurement by balancing the load of the propeller by both ahead and astern pressures. This arrangement would have been highly expensive to build in. An alternative type was adopted which, during berthing at New York, was built in the thrust bearing by the Kingsbury Machine Works.

This simplified apparatus involves accurate measurement of the thrust load imposed on one of the six levelling plates that equalize the distribution of the total load among the six thrust shoes.

However, the equalization is not exact. The error resulting from it, as guaranteed by Kingsbury, should not exceed 1 or 2 per cent. In this single-cell meter, since only that portion of the ahead thrust load carried by one levelling plate is measured, it is necessary to estimate the film reaction on the astern side. That film reaction depends on film thickness. The author takes account of it by correcting the ahead-thrust meter reading roughly by a reduction of 1 per cent. The difference is the net ahead load, i.e. the actual propeller thrust corrected for the axial component of the weight of the shafting, propeller, and pinions. Some slight doubt is still left on the accuracy of the measurement on account of the friction in turbine gears, as the thrust bearing and thrustmeter are located at the forward end of the gear.

Power Measurement.

Accurate measurement of power was of vital importance to this project. As more weight was given in this project to exact knowledge of power delivered to the propeller than to exact knowledge of engine output, it was decided to arrange the meter as near as possible to the propeller. Because of facilities for removing propeller shaft, not the last but the last but one tunnel shaft was fitted with the meter.

Primary requirements were, besides accuracy, applicability to a wide range of power and types of propelling engines. Indeed, in the near future the meter has to be installed in a diesel-driven cargo ship arranged for a further series of trials. Therefore, ease and speed of installation were necessary. Because sea trials over long periods were to be carried out, robustness was another requirement.

In order to meet all these requirements, a Siemens–Ford torsionmeter was installed at the end of the tunnel. The twist of the shaft alters the gap of a small differential transformer mounted on the shaft, and this alteration is measured by electrical means. The twist is directly proportional to the torque and inversely proportional to the rigidity modulus and the fourth power of the diameter. Measurement of the twist leads to determination of the torque.

Propeller Revolutions.

During the first and the second voyages, which were principally intended for determining the engine and boiler efficiency, long duration tests were carried out, mostly under calm weather conditions. It was found most convenient during these voyages to obtain the propeller revolutions from the revolution counter of the shaft. During the third voyage, which occurred under most varying weather conditions and during which the ship met very bad weather, it was found to be more accurate to obtain the propeller revolutions by taking time by stop-watch between zero and one hundred, two or three hundred revolutions of the shaft, these being counted.

Wind.

Wind speed, relative to the ship, was obtained by an anemometer, held by hand on the upper bridge. The anemometer (Short and Mason) was of the propeller type with counter, and care was taken to keep it sufficiently high during three to five minutes in order to measure unobstructed wind.

Wind direction was obtained by estimating. As wind speed was frequently measured, wind direction could be roughly determined by seeking that direction in which wind speed indicated by the propeller-anemometer was at a maximum. Measurement of wind speed was controlled by a cup-anemometer of the National Physical Laboratory.

Waves.

The wave-height was obtained by comparing it with a known height on the ship. The wavelength, too, was a guess, both dimensions being noted after discussion with the ship's officers, whose experience of the state of the sea was of great value. The ship's officers were also helpful in determining wave direction by sighting with their instruments along the crests of the waves. A valuable control could be made by measuring the period of encounter of waves by means of a stop-watch, assuming the usual formula for length and speed of trochoidal waves. Assuming a trochoidal shape of the waves, the maximum wave slopes are calculated from observed lengths and heights. This assumption is only true for gravity controlled waves. Waves which are still under wind control differ in shape from pure trochoidal line. Such was the case for most days in heavy weather on the third voyage, the only one when pitch and roll diagrams were taken. Hence the slope angles of the tables are not quite correct.

Pitching and Rolling.

During the time occupied in collecting the data for each observation it was arranged that pitching and rolling diagrams should be taken by means of a combined roll and pitch recorder which functions by electrically driven gyroscopes. The unit was kindly lent for the last voyage by the National Physical Laboratory, Ship Division, Teddington. No diagrams were taken during the two first voyages.

The roll and pitch recorder did not give any trouble during the voyage, although it was not possible to obtain fair roll diagrams.

Course.

The course was read from the gyro-compass.

Rudder Angle.

In order to keep the ship on her course the helm was constantly used by the quartermaster. During the time a series of propulsion data were collected; the extreme angles to port and starboard, through which the rudder was moved, were observed. Weather tables gave for each series of propulsion different data, such as the dry and wet temperature of air, temperature of sea water, barometric pressure, state of the sea, any intermittent occurrences, vibrations, etc. The usual ship's instruments permitted quite satisfactory measurements. By elementary geometry the true wind speed and direction can be calculated from relative wind speed, relative wind direction, and the ship's speed. The data are given in the tables, together with the equivalent Beaufort numbers for wind force. A separate column in the tables gives the wind force in Beaufort numbers as taken from the deck log. Deck officers, each hour, estimated an average wind force; this estimation was usually based upon the state of the sea. It is not without interest to compare the force of the wind as measured by the anemometer with the expressions of opinion of the deck officers. One will remark that there are possible discordances in the tables. Nevertheless, the writer wishes to express his deep appreciation of all the information of a nautical character that he has been able to gather from the master and officers of the s.s. *Tervaete*.

Fuel and Steam Measurement.

The necessary apparatus had to be installed for the correct determination of the efficiency of the power plant. It would have been preferable to determine feed and fuel by weight. The accurateness of measurement would have gained. Place was not available for the installation of the tanks which these operations would have required, so the measurement of the quantities of fuel, water, and steam had to be by means of flowmeters. The advantage of this method resides in the possibility of making proper measurements without being deranged by the ship's motion, which always exists on the high seas to a greater or lesser degree. The arrangement of the piping would have made the installation of separate flowmeters for the two boilers very complicated. As a result, it became necessary to measure the efficiency of the two boilers together. A complication resides in the fact that one is obliged to take the mean temperatures and steam pressures at leaving the boilers as well as the mean of the temperatures of the smoke and of its CO, CO_2 and O_2 content. As loads are not equalized between units, there may be an error. As the differences between the two readings are slight, the errors resulting from the use of these means are considerably reduced. The principal flowmeters are those measuring the feed (A) installed between turbine-driven feed-pump and boilers, the meter measuring superheated steam flow (B) to turbine, and the meter measuring superheated steam flow (C) to turbo-generators. Desuperheated steam flow is calculated by the difference $A - (B + C)$. Bled steam is also measured by a flowmeter. Measurements taken from the flowmeters make it possible to calculate the efficiency of the main turbine and of the group turbo-generators. As it is an interesting feature to know exactly the make-up water introduced into the feedwater circuit, a flowmeter gives the indication.

Because of the varying load of the engines the flowmeters are equipped with integrating devices. It would have been impracticable to arrange for the measurement of every quantity and temperature throughout the entire water and steam circuits. The basic purpose was the calculation of the efficiency of the boiler-turbine unit.

Use was made of ships' thermometers and gauges. No extra thermometers or pressure gauges were installed, with the exception of one thermometer at the exit of the economizer of one boiler, because it was worth while knowing the efficiency of this part of the boiler, and one mercury vacuum-gauge in order to have an accurate measurement of the vacuum of the condenser. The flowmeters are head-meters consisting of two units, a primary device that produces a "differential head" or pressure difference and a secondary device for measuring the differential head. Pressure difference is given by a thin-plate, sharp-edged orifice. The measuring device is a manometer with timing unit for integration and gives as well instantaneous flow as quantity.

These flowmeters were manufactured by Eckhardt. The usual ships' fuel oil meter gives the fuel consumption, together with settling tank soundings. It was planned that accurate measurements of the fuel oil consumed could be based on frequent settling tank soundings, as these tanks are correctly calibrated. However, already during the first voyage, even in the calm tropical seas, it was noticed that any small motion of the ship was a cause of disturbance in the settling tank soundings. As a consequence it was not possible to obtain high accuracy in fuel consumption, except on the basis of fuel-oil meter readings and settling-tank soundings. During a berthing of the ship at Antwerp, prior to the voyage Antwerp–New York–Copenhagen, a small calibration tank with a capacity of 20 cubic ft. was placed in the engine-room. The flow of fuel could be diverted from the fuel meter to the tank by the return piping of one of the boilers. It was, therefore, always possible to calibrate the fuel-oil meter when the ship was in port or at anchorage.

During all the sea trials use was made of the Orsat equipment of the ship for analysis of gas. During the voyage Antwerp–New York–Copenhagen records of CO_2 and CO were taken by means of an electric meter (Hartmann and Braun).

PART II

The s.s. "Tervaete" Sea Trials

The installation of the measuring equipment started at Antwerp in 1950. The thrustmeter was installed at New York by Kingsbury, and while the ship was in dry-dock during the spring of 1951 the measuring equipment was completed.

The ship then left for a voyage of three months to India. Outward and homeward the ship called at Genoa, which gave Mr. van Maanen, technical director of Ceberena, the opportunity to sail to Genoa and back to Antwerp, in order to verify that all the measuring instruments were in working order. In the month of August 1951 a company of three engineers, comprising the writer, Mr. van Maanen, aforementioned, and Mr. Labrique, engineer at the S.A. Cockerill at Seraing, left for the Congo, where they joined the ship. The first trial voyage started at Matadi on August 28th and terminated at Baltimore, where the ship arrived on the morning of October 13th. The ship made two long calls, the first from August 29th to September 12th, at Luanda (Angola), the second from September 13th to 21st, at Lobito (Angola). Then, after shipping wood at Boma (Congo) from September 24th to 26th, she left for the U.S.A., calling for fuel at Takoradi (Gold Coast) and at Porto Grande (St. Vincent). The two trips along the coast of Angola in a very calm sea permitted us to carry out a preliminary calibration of the Pitot log, while the long consecutive days of calm weather in crossing the Atlantic in tropical waters was favourable for the examination of the efficiency of turbine and boilers. The ship was practically fully loaded. Bad weather was only experienced at the end of the voyage. Fig. 2 gives weather experienced during the sea trials. After calling at Chester, the ship proceeded to New York to discharge the largest part of her cargo. Unloading had only just begun on Friday, October 19th, when the strike broke out in the port of New York which immobilized the vessel for several weeks. The research team returned to Europe with the M.V. *Houffalize*. The *Tervaete* reached Antwerp at the end of November and was dry-docked on December 4th.

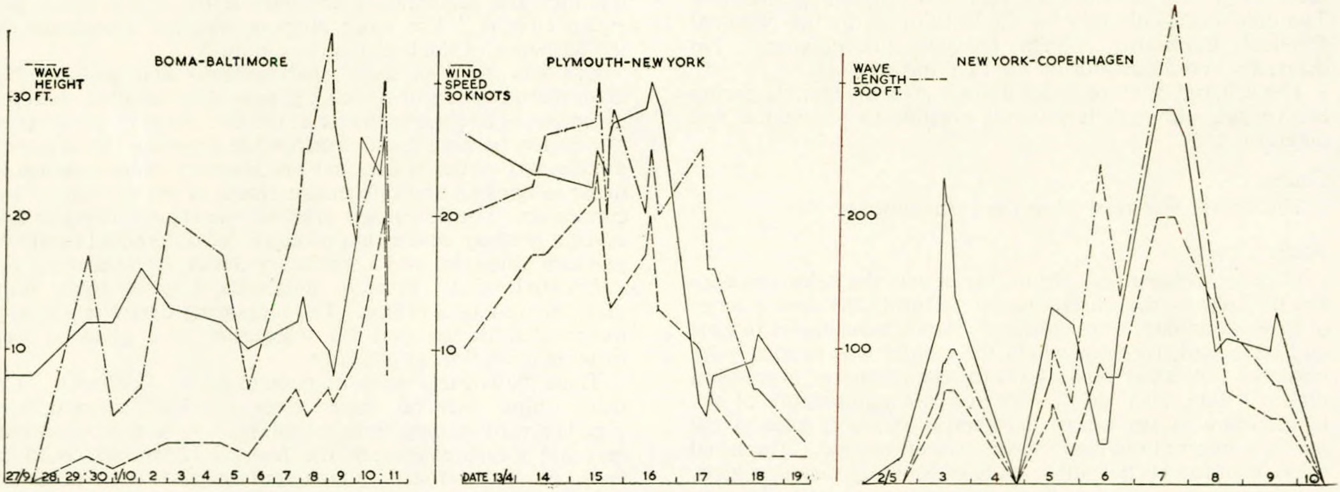

FIG. 2.—WEATHER DIAGRAMS

A second trial of short duration took place between Antwerp and Gibraltar at the end of 1951. The writer and Mr. van Maanen remained on board until Gibraltar was reached. The ship then proceeded to India. The trials were carried out from December 17th to 20th. During these four days the weather was fair and no weather diagram was made for this voyage.

When the vessel returned from her voyage to India, March 1952, it was decided that during the next voyage, which would be from Antwerp to New York, during the passage through the English Channel the ship would run progressive trials over the measured mile of Polperro. These trials would be of more than usual interest because they could be carried out with a draught of near 23 ft. These trials would give a certain basis for others to take place later, at sea. Consequently, the writer, Mr. van Maanen and a finals student, Mr. Ingelbrecht, embarked for the voyage Antwerp–New York and return.

The S.S. *Tervaete* left Antwerp on April 9th. On the 10th the progressive trials on the measured mile of Polperro took place. The following also took part in these trials but left the ship at their conclusion:—

Mr. Van Leeuw, engineer of the Compagnie Maritime Belge; Mr. Eves, of Siemens Bros., who supplied the torsionmeter; Dr. Allan, Superintendent of the Ship Division of the National Physical Laboratory; and Dr. Van Lammeren, Superintendent of the Model Basin of Wageningen. The aforementioned, as well as the two assistants who accompanied them, kindly assisted.

The writer takes this opportunity of putting on record his deep appreciation of the kindness extended to him by the superintendents of the model basins, and of their willingness to co-operate with him.

Unfortunately, the weather was not very calm, and as the ship had made a voyage to India since her last time in drydock, the effect of fouling was noticeable.

However, the writer insists that the particular aim of these trials was to ascertain the efficiency of ships of this type under ordinary service conditions. Seen from this angle, the progressive measured-mile trials of this ship under conditions which are not ideal could certainly procure useful information. After our collaborators, who had come solely for the Polperro trials, had disembarked at Plymouth, the ship continued her course to New York, where she arrived on April 20th. The return voyage, with a call at Copenhagen, began on May 1st, with a draught of 20 ft. The ship arrived on May 11th. A small part of the cargo was unloaded and on May 12th the ship set course for Antwerp, where she arrived on May 14th. The trials of the third voyage are of particular interest from the point of view of propulsion. Outward and homeward there were weather conditions with a wind force varying in the Beaufort scale from 0–1 to 7–8, and seas varying from calm to very rough.

Exceptionally, it happened that the swell was perfectly regular. It was the case along the Portuguese coast during the second voyage, when weather was fair. However, during the third voyage, when more special attention was paid to the effect of weather on ship propulsion, ship motions were recorded. Waves were most irregular and the swell frequently consisted of groups of waves of different height, a group of three or four of exceptional height periodically appearing. No statement of exceptional heights is made in the tables. Data given are mean values. Different formulae give length and height of waves corresponding to a known force of wind. All the formulae are based on the assumption that wind had blown for a long period, say eight hours, in which the waves have developed a regular shape. This circumstance was exceptional and, as seen on weather diagrams, no regular relation can be discovered between wind force and the dimensions of the waves. The writer found an appreciated guide in this matter in Kent's work.(1)

PART III

Accuracy of Measurements

A large part of the work was the calibration of the instruments. Calibration of the Pitot log, which was carried out during the third voyage, was achieved by using the results of the progressive measured-mile trials. As variation of the calibration factor k, defined by formula, actual speed $=$ $k \times$ Pitot-log speed, was not more than one-half of 1 per cent from a mean value 1·015 for different speed values; this mean value was retained in speed calculations for further sea trials. However, although the Pitot log was given the most forward position in the engine-room, 210 ft. from the forward perpendicular, the thickness of the boundary layer at that position was somewhat more than 3 ft., which is the length of the rodmeter under the bottom. This was apparent from the velocity distribution curves A in the friction belt which were taken some days later; the upper part of these curves has not a fair vertical tangent (Fig. 3). As velocity distribution in the boundary layer is dependent on the state of fouling of the hull, the calibration constant 1·015 was only used for the third voyage.

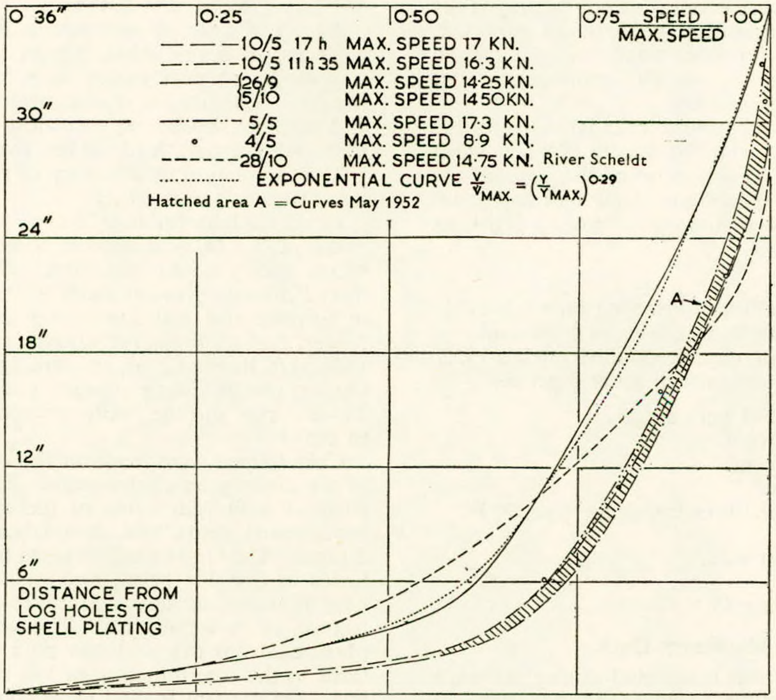

FIG. 3.—VELOCITY DISTRIBUTION IN BOUNDARY LAYER

During the first voyage a preliminary calibration was carried out along the coast of Angola. The ship left Luanda for Lobito on September 12th and returned by the same route on September 21st. Draught was nearly the same. The sea was calm both days, current was slight and although not measured was believed to be practically unchanged. The ship passed several lighthouses of known geographical co-ordinates. Hence the speed over ground was known in both directions, and on the basis of a presumed unchanged current, the Pitot log could be calibrated. The constant was found to be $k = 0{\cdot}992$. Although not determined in as good conditions as for the measured mile trials, this coefficient was taken for calculations of the first and second voyage. One reason was an adjustment of the log mechanism, between the second and third voyage. Furthermore, the degree of fouling was not the same, which certainly had an influence on k value.

The only calibration by dead weights which could be made on the thrustmeter was that of the gauge, which was done with precision between voyages. Measurement of levelling plates that equalize the total load among the six thrust shoes was done by Kingsbury as the thrustmeter was being built in. The writer did not have an opportunity to renew this measurement later on. As the accurateness of torque measurements obtained by means of a torsionmeter depends upon the correctness of zero-torque setting, this reading was made before and after each voyage, and it was also made with special attention before and after the measured-mile trials.

Zero-torque setting was checked by turning the shaft by means of the turning engine. At least five readings were made in each direction. It was stated that as the ship was berthed, even a small current gives a false zero setting. After each voyage the relationship of shaft and indicator transformers was also checked. The variation of this relation never exceeded 1 per cent. It was of primary importance to know the relationship, because the torsionmeter constant was found by calculation and not by calibration. As it was found to be most inconvenient and expensive to determine the constant by calibration, the modulus of rigidity of the shaft material had to be assumed. Cook(2) gives for solid shafts over 16 in. diameter, tested 1945–51, a mean value of 11,900,000 lb. per sq. in. Coffin(3) states that the calibration modulus for more than 50 shafts showed a variation of approximately 2 per cent from 11,600,000. It is understood that these 50 shafts were mostly naval shafts and that some of them were solid for Victory ships.

Coffin's paper was written in the U.S.A. just at the time Victory ships were under construction. Furthermore, a value of 11,700,000 appears to be the highest which is possible for the modulus, having regard to the steam data obtained. These are the reasons which lead the writer to assume a value of G 11,700,000. With this value, reasonable values are obtained for turbine efficiency.

Calibration of the integrating anemometer (Short and Mason) which gives a mean value of the wind speed was done in the aerodynamic tunnel at Rhode St. Genese in comparison with a Pitot tube.

The roll and pitch recorder was calibrated on the ship in Plymouth before she crossed the Atlantic westward, at Staten Island on arrival in New York, before crossing the Atlantic eastward, and on arrival in Copenhagen. All these calibrations showed little variation.

As it was important to know the correct values of steam conditions in order to determine the efficiency of boilers and turbine, pressure gauges and thermometers were calibrated between the voyages in the laboratories of the University of Ghent, the pressure gauges by dead-weight apparatus, and the thermometers by comparing them with standard instruments. An accurate measurement was made of the sharp-edged orifice of the primary device of the flowmeters before trials started and when they came to an end. After trials the diameter was just the same as before. The manometers for measurement of the pressure difference were also calibrated.

Though analyses of flue gases leaving steam-generating unit were made by an electric instrument, correct values were given by Orsat analysis.

Many samples of fuel oil were taken from the settling tanks as frequent changes in composition were to be expected. Eight samples were analysed for determination of the specific gravity, viscosity, percentage of carbon, hydrogen, water, impurities insoluble in benzol and ash.

The displacement of the ship was calculated from the recorded draught fore and aft and the density of water when leaving and entering port. At any time of the voyage, the displacement was calculated on a basis of the fuel and water consumption. The precision of the measurements is within the following limits of error:—

Speed through water:
- (*a*) By approximate calibration of Pitot log for trials 1951: smooth water 2 per cent; rough water 5 per cent.
- (*b*) By correct calibration on measured mile for trials 1952: smooth water 1 per cent; rough water 4 per cent.

Revolutions: smooth water 0·5 per cent.
Torque: smooth water 3 per cent.
Thrust: smooth water 6 per cent.
Pressure gauges: 0·5 per cent.
Thermometers: mercury, 1° F.; pressure-gauge type, 2° F.
Flowmeters: 2 per cent.
Heat value of fuel oil: 0·5 per cent.

PART IV

Analysis of Machinery Data

Boiler and turbine testing was conducted during sea trials on all three voyages. The aim was to establish the economy of operation of the machinery of this turbine-driven vessel, without automatic combustion control, in usual service, at different powers, and different displacements. It is emphasized that the figures obtained are efficiencies under normal operating conditions, not an ideal performance. The prominent data are given in Tables I to V, Table I for general data of power, fuel and steam consumption, and steam conditions; Table II for boiler data; Table III for fuel analysis; Table IV for turbine data; and Table V for auxiliaries data. Fuel rates are corrected for a high heat value of fuel of 18,500 B.Th.U. per lb. As powers of widely different values were obtained during the voyage Congo–America when the ship had, during a long period, continuous fine weather, the data of this voyage were taken in order to calculate the efficiency of the steam generating units. The duration of boiler tests was normally six hours. Readings of gauges, thermometers, vacuum-meter, flowmeters, revolution counter, tachometer, torsionmeter and Orsat apparatus were made every half-hour during the trials. The efficiency was calculated for the boilers taken together. Table I gives mean values of steam conditions, superheated steam conditions being taken at the outlet of the superheater. For each day, the mean value was calculated from the mean values over six hours of temperature and pressure of steam of starboard boiler and port boiler separately. Mean values differ but slightly for starboard and port boilers. The largest difference was 6 lb. per sq. in. and 16° F. and they did not occur on the same day. Due to a disparity in both boiler loads these differences have an influence on the steam conditions at the throttle valve, but not large enough to produce a noticeable discrepancy in the value of the energy of the total steam. It has been verified for each day that the steam conditions at throttle, which were also read, differ but slightly from the mean values as calculated above.

As an example, for the trial of September 27th, 1951, when the mean pressures of, respectively, starboard and port boilers differed 6 lb. per sq. in., pressures and temperatures were, respectively, for the starboard boiler 437 lb. per sq. in. and 710° F., and for the port boiler 443 lb. per sq. in. and 702° F.

Assumed pressures and temperatures for both the steam generating units are the means of them, viz. 440 lb. per sq. in. and 706° F.

At the throttle valve, pressures and temperatures were 434 lb. per sq. in. and 704° F.

As these falls in pressure and temperature cannot be neglected, it seems more correct to take a mean value for starboard and port rather than take the conditions at the throttle. Calculation of the mean heat loss between boilers and turbines, boilers at superheater outlet, turbines at inlet high-pressure unit, leads to less than 1 per cent.

The calculation of efficiency of generating units was based upon the analyses for fuel oils.

Orsat analysis for both boilers showed low CO_2, high O_2 and no CO. N_2 was assumed to be the balance. Smoke was white, excess of air was large. For full power 8,000 shp forced draught was normally 3·4 in. water, with 2 in. water in furnace and −0·2 in. water in uptake. For the same power, fuel oil pressures varied during the first voyage from 130 to 160 lb. per sq. in. and temperatures from 185 to 195° F. During the following voyages pressures varied from 220 to 245 lb. per sq. in., with temperatures varying from 200 to 205° F.

Calculations were made in the usual way of the efficiency of the steam generating system. Efficiency is calculated on a basis of high heat value of fuel oil and heat absorbed by superheated steam and desuperheated steam in outlet conditions. The Orsat analysis leads to the determination of the losses in dry flue gases, and water per cent in fuel, to the determination of loss due to the evaporating and superheating of this moisture. The water vapour in the air is obtained from dry and wet bulb thermometers. Table VI leads to the determination of loss due to moisture in the air; hydrogen content in fuel leads to determination of loss due to water from combustion of the hydrogen. Subtracting from the heat input in the fuel, the sum of the heat absorbed by the steam and the calculated losses, leads to losses due to radiation and unburnt hydrocarbons, known as unaccounted for loss.

In R. and U. losses data are further included all errors of measurements.

It may be interesting to know the superheater and economizer efficiencies. Before starting for the third voyage a thermometer was installed at the outlet of the economizer of the starboard boiler. Assuming the temperature to be the same for both economizers, a calculation could be made of their efficiency. Such a calculation was made, in full power condition, on April 18th.

Feedwater entering the economizer had a temperature of 235° F., leaving the economizer a temperature of 290° F.

TABLE I

GENERAL DATA

Date	Nozzles	Duration of test hours	*rpm*	shp	Fuel cons., lb. per hr.	Corrected fuel rate, lb. per shp per hr.	Steam conditions boilers superheated steam		Steam conditions boilers desuperheated steam		Steam cons., lb. per hr.	Steam rate total, lb. per shp per hr.	Superheated steam cons., lb. per hr.	Desuperheated steam cons., lb. per hr.
		h m.					lb. per sq. in.	° F.	lb. per sq. in.	° F.				
27/9	18	6 0	77·1	7,526	5,150	0·680	454	706	427	487	68,170	9·05	59,310	8,860
28/9	18	6 0	77·2	7,516	5,153	0·681	457	712	428	487	68,660	9·13	59,620	9,040
30/9	18	6 0	76·9	7,466	5,005	0·684	456	714	425	487	68,270	9·15	59,370	8,900
1/10	15	6 0	72·9	6,205	4,366	0·718	457	711	431	485	60,580	9·76	50,890	9,690
2/10	15	6 0	72·2	6,103	4,413	0·739	456	704	428	486	60,640	9·94	51,760	8,880
3/10	13	6 0	68·4	5,315	4,048	0·777	451	687	427	482	57,830	10·02	44,830	13,000
5/10	18	6 0	76·0	7,387	5,102*	0·691*	459	715	428	487	65,980	8·93	57,970	8,010
6/10	18	12 0	75·8	7,317	4,957*	0·679*	458	718	430	487	67,740	9·26	57,640	10,100
8/10	18	6 0	74·6	7,193	4,807	0·669	457	721	425	487	64,430	8·96	56,350	8,080
9/10	18	6 0	75·7	7,208	4,820	0·669	458	731	427	487	64,390	8·93	56,350	8,040
10/10	18	6 0	75·3	7,167	4,788	0·669	461	725	432	487	64,200	8·96	56,170	8,030
11/10	13r†	6 0	50·5	2,143	2,388	1·116	455	678	430	480	33,870	15·80	24,530	9,340
11/10	21	6 0	78·8	8,176	5,490	0·672	459	730	427	487	70,150	8·58	64,910	5,240
21/9	13	8 45	70·5	5,480	4,167	0·755	455	680	427	487	57,870	10·06	46,285	11,585
22/9	13	7 45	70·7	5,586	4,080	0·726	454	683	427	487	58,400	10·05	46,220	12,180

* Fuel rate on 5/10 for a 3-hour and on 6/10 for a 6-hour interval only. † 13r=13 nozzles reduced. Steam pressure figures are absolute pressure figures.

TABLE II

BOILER DATA

Date	Feed temp. ° F.	Temp. of air entering boiler, ° F.	CO_2		O_2		Fuel cons. lb. per sq. ft. per hr. heat surface	Fuel cons., lb. per cu. ft. per hr. furnace volume	Uptake gas temp., ° F.		Efficiency per cent	Losses in per cent				
			Port	Starboard	Port	Starboard			Port	Starboard		L.d.g.	L.m.f.	L.m.a.	L.w.h.	R and U
27/9	237	100	10·9	11·2	—	—	0·450	4·26	403	403	81·90	—	0·02	—	6·30	—
28/9	237	100	11·6	11·1	5·8	6·2	0·450	4·26	405	401	82·62	7·30	0·02	0·27	6·30	3·49
30/9	237	100	11·8	11·5	5·4	5·6	0·437	4·14	392	405	82·46	6·78	0·01	0·24	6·12	4·39
1/10	237	100	10·5	11·5	6·5	5·5	0·382	3·61	385	385	83·42	6·57	0·01	0·23	6·10	3·67
2/10	237	100	10·8	11·5	6·4	5·6	0·386	3·65	387	399	82·60	6·69	0·01	0·25	6·10	4·35
3/10	237	102	11·3	11·3	5·7	5·8	0·354	3·35	379	383	84·55	6·53	0·01	0·28	6·07	2·56
8/10	238	100	10·9	10·9	6·1	6·1	0·420	3·97	396	396	82·84	7·30	0·01	0·25	6·24	3·36
9/10	237	100	11·1	11·0	5·9	6·0	0·421	3·98	397	397	82·65	7·29	0·01	0·31	6·25	3·49
10/10	237	100	11·2	11·0	5·8	6·0	0·418	3·96	396	399	82·90	7·25	0·01	0·26	6·25	3·33
11/10	237	100	8·0	8·0	8·5	8·5	0·209	1·97	370	352	84·76	8·69	0·01	0·35	6·16	0·03
11/10	239	99	11·6	11·7	5·4	5·3	0·480	4·54	408	415	79·74	7·30	0·01	0·23	6·29	6·43

TABLE III

Fuel Data

Date	Specific gravity at 60° F.	Viscosity, seconds Redwood at 100° F.	Heat value high, B.Th.U. per lb.	Per cent C	Per cent H	Per cent Water	Per cent impurities insoluble in benzol	Per cent ash
27 and 28/9	0·971	3,400	18,396	85·37	10·99	0·35	0·08	0·05
30/9 till 3/10	0·953	1,320	18,900	85·20	11·00	Less than 0·10	0·08	0·13
8/10 till 11/10	0·971	3,400	18,540	85·35	11·02	0·10	0·34	0·065
10 till 14/4	0·926*	3,100	18,520	84·40	11·30	0·52	—	—
15 till 17/4	0·933*	3,100	18,575	84·40	11·30	0·52	—	—
18 and 19/4	0·933*	3,100	18,650	84·40	11·30	0·52	—	—
2 till 7/5	0·927*	1,448	18,425	84·30	11·40	0·60	—	—
8 till 10/5	0·927*	1,448	18,660	84·30	11·40	0·67	—	—

* Unlike the preceding ones, the specific gravity of the fuel oils used from 10/4 until 10/5 is determined at 200° F.

TABLE IVa

Turbine Data

Date	Steam conditions				Steam cons. turbine. lb. per hr.	Steam rate turbine, lb. per shp per hr.	Bled steam, lb. per hr.	Heat from steam in turbine, B.Th.U. per hr.	Heat rate, B.Th.U. per hr. per shp	Combined efficiency, per cent	Sea water temperature, ° F.	Absol. cond. pressure, lb. per sq. in.
	Inlet h.p.		Inlet l.p.									
	lb. per sq. in.	° F.	lb. per sq. in.	° F.								
27/9	438	703	38·6	325	56,780	7·54	4,203	25,230,541	3,351	75·9	78	0·79
28/9	438	709	38·4	302	57,090	7·59	4,262	25,340,000	3,371	75·5	80	0·84
30/9	437	710	37·4	304	56,930	7·53	4,558	25,328,000	3,393	75·0	78	0·77
1/10	442	707	32·6	298	48,380	7·80	2,392	21,962,500	3,538	71·9	82	0·78
2/10	443	701	32·7	295	49,020	8·03	2,379	22,216,000	3,642	69·9	83	0·76
3/10	441	686	28·8	291	42,050	7·91	No	19,381,000	3,644	69·8	84	0·73
5/10	439	714	37·8	306	55,235	7·47	4,223	24,320,500	3,359	75·7	80	0·75
6/10	440	715	37·4	306	54,930	7·51	3,987	24,714,000	3,378	75·3	82	0·77
8/10	438	720	37·0	306	53,690	7·46	3,877	24,238,000	3,370	75·5	82	0·78
9/10	439	719	36·6	306	53,650	7·44	3,925	24,402,000	3,384	75·2	80	0·71
10/10	444	722	37·0	306	53,820	7·51	4,035	24,873,000	3,469	73·3	79	0·65
11/10	235	674	14·8	302	22,030	10·28	No	9,728,700	4,538	56·1	80	0·58
11/10	432	728	41·3	324	62,200	7·61	5,089	28,084,000	3,434	74·1	78	0·75
21/9	445	681	30·0	293	43,570	7·95	No	20,781,000	3,791	67·1	72	0·53
22/9	443	682	30·0	293	43,395	7·77	No	20,751,000	3,714	68·5	73	0·52

Steam pressure figures are absolute pressure figures.

TABLE V

AUXILIARIES AND TURBO-GENERATOR DATA

Date	Steam cons. turbogener., lb. per hr.	Output, kW.	Generators in service, number	Steam rate, lb. per kWh.	Temperature feed entering d.c., ° F.	Auxiliary pressure		Auxiliary exhaust, 10 norm. lb. per sq. in.	Bled steam after valve		Atmospheric drain tank temperature, ° F.	Make up feed	
						240 norm., lb. per sq. in.	160 norm.		lb. per sq. in.	° F.		Quantity lb. per hr.	Temperature ° F.
27/9	2,531	—	1	—	112	253	169	9·9	15·0	257	214	1,191	125
28/9	2,536	108	1	23·48	112	252	164	10·0	14·9	261	212	1,290	116
30/9	2,439	107	1	22·86	112	252	166	10·0	15·3	260	212	1,279	78
1/10	2,514	109	1	23·02	112	250	164	9·5	11·1	253	212	915	82
2/10	2,740	126	1	21·74	113	251	167	9·2	11·1	249	212	1,345	84
3/10	2,785	133	1	20·94	112	251	173	9·2	No	No	212	1,147	84
5/10	2,734	133	1	20·56	112	255	158	9·6	14·4	265	212	1,665	80
6/10	2,718	130	1	20·91	112	257	166	9·8	14·3	267	205	1,627	135
8/10	2,655	126	1	21·07	112	259	164	10·2	14·4	268	172	1,136	135
9/10	2,701	131	1	20·62	112	258	164	10·3	14·4	267	197	1,069	135
10/10	2,351	102	1	23·04	112	256	167	10·3	14·3	270	212	1,147	135
11/10	2,498	103	1	24·26	112	254	168	9·0	No	No	212	1,692	135
11/10	2,702	127	1	21·28	112	255	171	11·3	16·9	279	212	2,095	150
21/9	2,714	—	2	—	112	251	169	9·4	9·6	220	202	1,014	72
22/9	2,824	—	2	—	112	251	168	9·1	9·8	220	202	1,442	72
14/4	2,159	120	1	18·00	112	243	172	9·5	10·9	260	210	—	—
16/4	2,233	116	1	19·25	112	246	172	10·5	13·9	268	196	—	—
17/4	2,406	114	2	21·10	112	247	172	10·2	12·6	268	183	—	—
18/4	2,344	122	2	19·21	112	247	172	11·0	15·4	270	199	—	—
19/4	2,199	114	2	19·29	112	246	172	9·2	11·0	253	209	—	—
2/5	2,586	127	2	20·37	112	251	174	10·0	13·5	235	198	—	—
4/5	—	—	2	—	112	—	—	—	—	—	209	—	—
5/5	2,262	110	2	20·57	112	251	173	9·1	13·4	237	210	—	—
5/5	2,191	112	2	19·56	112	251	173	12·1	18·1	268	212	—	—
6/5	2,219	125	2	17·75	110	251	173	10·7	17·5	265	210	—	—
7/5	2,118	108	1	19·61	112	251	170	10·4	13·1	218	212	—	—
7/5	2,397	134	1	17·89	112	249	174	8·4	11·2	217	214	—	—
8/5	2,149	144	1	14·93	112	248	175	12·8	16·9	266	213	—	—
9/5	2,399	158	1	15·18	112	249	174	11·0	15·4	265	213	—	—
10/5	2,351	142	1	16·55	112	249	174	10·0	14·8	271	213	—	—
13/5	2,470	136	2	18·16	112	249	173	11·4	18·1	262	206	—	—

TABLE IX

Propulsion Data Voyages Boma–Baltimore and Antwerp–Gibraltar

Observation number	Speed, knots	*rpm*	Apparent slip	dhp	Thrust, 100 lb.*	ehp	$\frac{\text{ehp}}{\text{dhp}}$	Decrease of propulsive efficiency, per cent	$\frac{\text{dhp}}{\Delta}$	Correc. dhp (temp. corr.)	C_s	Increase of C_s due to weather cond., per cent	Displacement Δ tons†	Loss of speed, per cent
1	15·80	70·5	0·0086	5,319	1,122	4,347	0·818	0	0·387	5,436	1·024	0	13,750	0
2	15·85	70·7	0·0072	5,401	1,136	4,417	0·818	0	0·393	5,522	1·032	0	13,750	0
3	16·65	77·1	0·0437	7,306	1,398	5,708	0·781	3·33	0·514	7,528	1·188	6·2	14,200	1·4
4	16·58	77·2	0·0489	7,295	1,378	5,604	0·768	5·05	0·516	7,534	1·206	8·4	14,150	1·8
5	16·41	76·9	0·0560	7,254	1,399	5,630	0·776	4·18	0·507	7,470	1·225	11·8	14,300	2·6
6	15·85	72·9	0·0380	6,022	1,247	4,845	0·805	1·00	0·423	6,239	1·139	8·1	14,250	2·0
7	15·34	71·9	0·0617	5,902	1,248	4,700	0·797	2·15	0·419	6,133	1·243	18·2	14,100	5·0
8	14·47	68·4	0·0639	5,159	1,145	4,126	0·788	3·72	0·367	5,366	1·300	23·7	14,050	6·8
9	16·10	76·0	0·0622	7,170	1,443	5,696	0·795	1·87	0·494	7,411	1·275	19·6	14,500	4·2
10	16·16	75·8	0·0566	7,099	1,443	5,720	0·806	0·53	0·491	7,361	1·256	17·3	14,450	3·7
11	15·35	74·2	0·0843	6,957	1,439	5,416	0·779	4·27	0·485	7,213	1·441	37·3	14,350	8·2
12	15·75	74·8	0·0680	6,995	1,439	5,557	0·795	2·25	0·487	7,252	1·340	27·6	14,350	5·9
13	15·65	74·6	0·0715	6,976	1,439	5,523	0·792	2·62	0·486	7,231	1·363	29·9	14,350	6·5
14	16·20	75·4	0·0490	6,992	1,428	5,674	0·812	0	0·491	7,227	1·233	14·5	14,250	3·2
15	16·30	75·7	0·0469	6,989	1,428	5,708	0·817	0	0·490	7,225	1·210	11·6	14,250	2·6
16	16·05	74·9	0·0515	6,916	1,427	5,616	0·812	0	0·487	7,135	1·257	18·4	14,200	3·9
17	16·05	75·5	0·0591	6,971	1,427	5,616	0·806	0·65	0·491	7,192	1·267	19·3	14,200	4·1
18	9·51	49·8	0·1547	2,017	672	1,566	0·777	6·64	0·143	2,084	1·772	66·9	14,130	15·1
19	9·80	50·4	0·1397	2,087	672	1,614	0·774	7·10	0·148	2,157	1·674	64·2	14,130	13·7
20	16·45	78·8	0·0762	7,933	1,477	5,957	0·751	7·16	0·561	8,174	1·342	23·2	14,130	4·0
21	15·99	71·7	0·0132	5,808	1,170	4,588	0·790	2·58	0·411	5,748	1·035	—	14,000	—
22	16·23	75·1	0·0440	6,806	1,292	5,143	0·756	6·72	0·486	6,758	1·161	—	14,000	—
23	16·50	77·2	0·0534	7,484	1,386	5,608	0·749	7·37	0·535	7,436	1·217	—	14,000	—
24	15·10	70·1	0·0460	5,555	1,200	4,444	0·800	1·90	0·395	5,548	1·186	—	13,975	—
25	16·80	77·4	0·0388	7,505	1,404	5,785	0·771	4·20	0·540	7,565	1·179	—	13,895	—
26	16·89	77·3	0·0324	7,455	1,405	5,820	0·781	2·77	0·539	7,539	1·161	—	13,825	—

* This is propeller thrust = thrust at thrustblock corrected for the axial component of the weight of the shafting, propeller, gear, and pinions.

† Trim by stern: 5·33 ft. on September 21st–22nd; 1·83 ft. on September 27th–28th; varied from 5·33 ft. on September 30th to 4·58 ft. on October 3rd, from 4·75 ft. on October 5th to 4·33 ft. on October 11th; from 1·33 ft. on December 17th to 2·17 ft. on December 20th.

TABLE X

PROPULSION DATA VOYAGE PLYMOUTH–NEW YORK

Observation number	Speed, knots	*rpm*	Apparent slip	dhp	Thrust, 100 lb.*	ehp	$\frac{\text{ehp}}{\text{dhp}}$	Decrease of propulsive efficiency, per cent	$\frac{\text{dhp}}{\Delta}$	Correc. dhp (temp. corr.)	C_s	Increase of C_s due to weather cond., per cent	Displacement, tons†	Loss of speed, per cent
27	16·88	78·9	0·0535	8,009	1,539	6,372	0·796	2·35	0·654	7,887	1·319	10·3	12,245	2·2
28	16·37	75·0	0·0346	6,855	1,384	5,557	0·811	1·28	0·560	6,746	1·237	7·4	12,245	2·0
29	15·70	71·6	0·0284	5,894	1,282	4,937	0·838	0	0·481	5,803	1·206	7·1	12,245	2·3
30	11·16	49·7	0·0071	1,954	598	1,637	0·838	0	0·160	1,926	1·113	1·2	12,245	0
31	16·10	77·1	0·0757	7,748	1,468	5,797	0·748	9·42	0·643	7,785	1·517	33·6	12,044	6·6
32	13·50	70·0	0·1464	6,138	1,381	4,573	0·745	13·73	0·512	6,148	2·038	74·9	11,989	17·5
33	13·10	69·1	0·1609	5,968	1,376	4,421	0·741	10·63	0·498	5,977	2·168	90·8	11,989	19·4
34	12·30	64·3	0·1533	4,756	1,147	3,460	0·728	12·32	0·399	4,763	2·093	83·3	11,934	18·8
35	11·40	60·8	0·1701	3,883	1,003	2,805	0·722	12·98	0·325	3,889	2·146	93·5	11,934	19·3
36	15·00	73·0	0·0905	6,687	1,369	5,037	0·753	9·15	0·560	6,718	1·628	45·5	11,934	10·6
37	14·60	73·0	0·1147	6,642	1,369	4,902	0·738	10·95	0·561	6,668	1·754	56·7	11,934	12·7
38	15·70	76·5	0·0916	7,707	1,496	5,761	0·748	9·71	0·646	7,745	1·637	45·8	11,934	9·0
39	16·00	76·9	0·0791	7,626	1,491	5,851	0·767	7·11	0·642	7,639	1·531	35·7	11,874	7·0
40	15·30	75·6	0·1042	7,539	1,532	5,749	0·763	8·00	0·635	7,575	1·736	55·0	11,874	10·9
41	13·20	67·6	0·1357	5,573	1,271	4,115	0·738	11·03	0·469	5,598	1·998	75·8	11,874	17·5
42	16·10	77·5	0·0805	7,708	1,532	6,050	0·785	4·96	0·651	7,755	1·527	34·6	11,850	6·8
43	16·50	78·0	0·0637	7,760	1,528	6,184	0·797	2·93	0·655	7,767	1·421	22·7	11,850	4·5
44	16·70	78·0	0·0523	7,760	1,519	6,222	0·802	2·22	0·655	7,893	1·393	18·3	11,850	3·5
45	17·10	78·9	0·0407	7,766	1,496	6,270	0·807	0·45	0·660	7,738	1·278	4·6	11,760	1·0
46	17·10	78·1	0·0309	7,686	1,487	6,232	0·811	0	0·654	7,635	1·261	3·2	11,760	0·8
47	16·00	71·4	0·0081	5,681	1,199	4,705	0·828	0	0·483	5,563	1·126	0	11,700	0

* This is propeller thrust = thrust at thrustblock corrected for the axial component of the weight of the shafting, propeller, gear, and pinions.

† Trim by stern: varied from 0·75 ft. on April 13th to 4·25 ft. on April 19th

TABLE XI

PROPULSION DATA VOYAGE NEW YORK–COPENHAGEN

Observation number	Speed, knots	*rpm*	Apparent slip	dhp	Thrust, 100 lb.*	ehp	$\frac{\text{ehp}}{\text{dhp}}$	Decrease of propulsive efficiency, per cent	$\frac{\text{dhp}}{\Delta}$	Correc. dhp (temp. corr.)	C_s	Increase of C_s due to weather cond., per cent	Displacement, tons†	Loss of speed, per cent
48	16·65	72·7	−0·0133	5,739	1,152	4,704	0·820	0	0·571	5,648	1·122	0	10,050	0
49	17·07	75·8	0·0027	6,583	1,235	5,168	0·785	1·92	0·655	6,467	1·192	2·9	10,050	0·6
50	17·15	75·5	−0·0054	6,562	1,239	5,212	0·794	0·72	0·653	6,446	1·173	0	10,050	0
51	17·20	76·0	−0·0017	6,525	1,242	5,236	0·803	0	0·649	6,420	1·157	0	10,050	0
52	17·15	75·9	−0·0001	6,537	1,239	5,212	0·797	0·37	0·650	6,432	1·169	0	10,050	0
53	16·70	75·2	0·0169	6,543	1,265	5,180	0·792	2·26	0·656	6,386	1·264	12·4	9,975	2·5
54	17·02	76·6	0·0169	6,952	1,291	5,388	0·775	3·45	0·697	6,796	1·271	10·1	9,975	1·8
55	17·20	76·5	0·0052	6,901	1,282	5,408	0·784	1·78	0·692	6,746	1·222	2·5	9,975	0·6
56	17·07	76·7	0·0143	6,942	1,282	5,366	0·773	3·45	0·696	6,764	1·253	8·2	9,975	1·4
57	16·50	76·4	0·0445	6,922	1,282	5,188	0·750	7·71	0·694	6,746	1·384	23·2	9,975	4·7
58	9·40	42·8	0·0279	1,272	439	1,012	0·795	4·17	0·128	1,225	1·366	5·8	9,900	5·1
59	16·30	71·5	−0·0090	5,632	1,165	4,657	0·827	0	0·572	5,515	1·184	7·8	9,850	1·9
60	16·10	71·4	0·0019	5,626	1,170	4,618	0·821	0	0·571	5,528	1·231	13·8	9,850	3·2
61	17·35	78·8	0·0255	7,786	1,442	6,092	0·782	1·22	0·790	7,736	1·377	13·7	9,850	2·0
62	16·50	78·4	0·0688	7,751	1,458	5,898	0·761	6·27	0·793	7,590	1·578	42·1	9,775	6·6
63	15·83	75·9	0·0771	6,656	1,362	5,287	0·794	3·13	0·681	6,517	1·535	42·5	9,775	8·2
64	16·10	75·9	0·0614	6,723	1,346	5,314	0·791	3·12	0·688	6,606	1·448	33·8	9,775	6·9
65	5·40	39·0	0·3871	1,123	418	554	0·493	—	0·115	1,100	6·541	—	9,735	44·2
66	9·10	52·0	0·2254	2,492	715	1,596	0·640	22·85	0·256	2,441	3·034	139·1	9,735	27·7
67	14·60	71·3	0·0942	5,864	1,189	4,257	0·726	12·32	0·602	5,751	1·731	59·6	9,735	13·2
68	16·50	76·0	0·0391	6,835	1,313	5,314	0·777	4·26	0·702	6,736	1·405	26·5	9,730	5·0
69	17·00	79·5	0·0535	7,773	1,456	6,068	0·781	2·77	0·799	7,661	1·461	26·8	9,730	3·9
70	17·05	79·3	0·0483	7,806	1,437	6,008	0·770	3·87	0·807	7,707	1·463	26·4	9,670	3·8
71	17·30	79·3	0·0344	7,785	1,419	6,021	0·773	2·47	0·805	7,685	1·397	15·6	9,670	2·4
72	17·40	79·4	0·0300	7,681	1,419	6,054	0·788	0	0·794	7,583	1·354	11·2	9,670	1·6
73	17·60	79·3	0·0177	7,649	1,408	6,077	0·795	0	0·793	7,514	1·299	3·7	9,650	0·3
74	17·00	78·8	0·0451	7,552	1,408	5,905	0·782	2·55	0·785	7,443	1·406	20·5	9,620	3·7

* This is propeller thrust = thrust at thrustblock corrected for the axial component of the weight of the shafting, propeller, gear, and pinions.

† Trim by stern: varied from 5·5 ft. on May 1st to 4 ft. on May 10th.

Uptake temperatures were 387° F. for starboard and 394° F. for port. Separate efficiences were: for the economizer 4 per cent, for the superheater 11 per cent, taken on the basis of high heat value of fuel oil. Higher temperatures at outlet economizer, hence higher efficiency, were obtained at reduced power conditions. Calculation of superheater efficiency is made on the basis of the full quantity of steam leaving the superheater. The performance of the steam generating system is given by Fig. 4, which shows an efficiency of 83 per cent at normal load.

Table IV contains all data relative to turbine efficiency. The data are given for all the voyages. Steam conditions are at the inlet of the high-pressure turbine, at the inlet of the low-pressure turbine, and at the inlet of the condenser. As there was subcooling in the main condenser during the third voyage, this figure, together with inlet and outlet temperatures of cooling water, are given for this voyage.

In order to obtain the correct combined efficiency and the correct steam rate of the turbine, it is recommended operating non-bleeding and non-induction. However, as bled steam is measured and a performance in usual service should be calculated, the figures aforementioned were calculated under normal conditions. The isentropic drop of the bled steam from inlet low-pressure turbine to condenser pressure is then subtracted from the isentropic drop of the total steam from inlet high-pressure turbine to condenser pressure. The difference is called in Table IV "heat from steam in turbine." Turbine shp divided by this difference leads to the combined efficiency, with gears, of the turbine. This value is sufficiently close to the combined efficiency non-bleeding.

The performance of the turbine is given by Fig. 5, which shows a combined efficiency of 75·5 per cent and a corrected fuel rate, all purposes, of 0·676 lb. per shp per hour at normal power. The superheated steam for the turbo-generators and the desuperheated steam for all the other auxiliaries are together in excess of some 20 per cent on the steam consumption of the turbine at normal load. This is clear from the curves of the steam rate of the turbine and the steam rate, all purposes. It is somewhat difficult to get a consistent curve for bled steam because this figure depends to a considerable degree on the routine of the operators. At normal power, a usual figure is 4,000 lb. per hour. The consumption of lubricating oil for all purposes was, throughout the whole of the first voyage, 2·6 gallons U.S.A. a day. (1 gallon U.S.A. = 3·785 litres.)

The data for the auxiliaries are given in Table V. The figures of generator load are varying from 102 to 158 kW. They are well beneath the 225 kW. given in the design as a normal load for one generator. Steam rate is given in Fig. 6. 17·5 lb. per kW. per hour is the lowest figure for an output of 130 kW. It is seen in Fig. 6 that the steam rate of the turbo-generators depends in a large measure upon maintenance of the group and routine of the operators. A better vacuum obtained during the third voyage undoubtedly led to a lower steam rate, but that alone does not explain the large difference. The influence of a better vacuum due to low sea water temperatures is stated in Fig. 5 where, for 18 open nozzles, a higher output could be obtained in cold water, corresponding with a better steam rate.

PART V

Analysis of Propulsion Data

Propulsion efficiency is determined in a different way from that of engine efficiency. Whereas for the latter means are calculated for usually 6-hour trials, in order to determine propulsion efficiency, readings of torque, thrust, *rpm*, speed, wind force, ship's course, barometric pressure, temperature of air and water, as well as the estimation of wave data, were made on every occasion that a change in weather conditions or *rpm* occurred. Circumstances did not permit of all these readings being taken simultaneously, as would have been desirable for a correct calculation of propulsion efficiency. The time taken by each of the three observers in collecting all the data during each observation was approximately half an hour. It was unlikely that weather and state of the sea would change before that time elapsed.

Tables VI, VII, and VIII give weather data for the three voyages. Wind force and wave dimensions are plotted in diagrams (Fig. 2), which show variation of weather during the three voyages Boma–Baltimore, Plymouth–New York and New York–Copenhagen. As readings were made only by day, it was assumed that weather did not change exceptionally during the night. No diagram was made for the voyage Antwerp–Gibraltar. The weather remained generally fine.

Owing to squalls it was usually difficult to read the wind force by cup-anemometer. As the wind remained more or less steady between the squalls, an average of that steady wind was read. The anemometer with counter gives an average. The true wind speed was obtained by calculation and compared with the wind force Beaufort as given by the deck log. Generally, the data are close, the tendency of the ship's officers being rather to over-estimate the wind force. Formulae exist which show a relation between dimensions of waves and recorded wind speed. These formulae assume a steady wind of many hours. However, the wind was rarely steady, as well in force as in direction, therefore the length and the height of the waves as given in the tables are often not in agreement with recorded wind force. On account of this it is very difficult to give figures of power increase plotted on wind force. On the other hand, though the state of the sea was often confused, series of waves of well-defined length and height could be frequently observed.

The author did not have an opportunity to measure the propeller pitch, so design pitch was introduced into calculations of slip. The obtained propulsion data are given in Tables IX, X, and XI. As distance records of the Pitot log were not always reliable, frequent measurements of the instantaneous speed had to be made for each observation number, especially in rough water, and a mean value is given in the tables.

The transformer of the torsionmeter, clamped on the shaft at the end of the tunnel, gives a measured shp which, multiplied by the factor 1·015, is the engine output shp, and multiplied by the factor 0·985 is the power delivered to the propeller dhp. These figures of shaft losses are low; however, they are in agreement with the figures adopted at the Tank Conference of Paris, 1935.

Ehp is derived from recorded thrust and speed with introduction of a thrust-deduction coefficient, which according to the form of the hull, is assumed to be 0·20. Hence the actual propulsive efficiency ehp/shp can be calculated for a given observation.

Frictional resistance is a large part of total resistance and is dependent on temperature, so dhp has to be corrected to a uniform sea-water temperature of 59° F. For the first voyage which occurred in tropical waters the correction is substantial. The correction adopted is that of the 1935 Paris Conference.

A diagram of corrected dhp plotted on speed gives for three different displacements of the ship the means to obtain the effect of weather on ship's speed (Figs. 7, 8, 9).

The diagram is basic for all further calculations. A true comparison requires elimination of the effect of change in draught which occurs day by day during each voyage. For each observation the value of

$$C_s = \frac{\text{dhp} \times 427{\cdot}1}{\Delta^{\frac{2}{3}} \times V^3}$$

is worked out from the measured data. From the observations made, on a smooth sea and in fine weather, a basic curve results for each voyage, which gives for a known displacement the dhp values in calm conditions, plotted at speed.

The increase of power due to weather is then worked out in the following manner. For each observation and a known speed the basic curve calm conditions gives a dhp, and a new C_s is then worked out but in calm conditions. That C_s is always lower than the actual C_s for the observation number.

By dividing both C_s values an increase of C_s is obtained, hence our increase in power which gives the effect of weather alone.

Instead of estimating weather influence by an increase of power required, a loss of speed can be calculated. The dhp values of Figs. 7, 8, 9 then have to be corrected for displacement in order to compare them with the dhp values smooth. A rough estimation of the power required for wind forces 4 and 7 of the Beaufort scale is given in Figs. 7, 8, 9, assuming that the wind has blown for at least 8 hours to assure that the state of the sea corresponds to the wind force and that the vessel is running directly into the wind. The relation between fuel consumption per day and speed in calm weather is also given in Figs. 7, 8, 9.

In the same manner, the loss of propulsive efficiency, due to weather effect, is calculated. Figs. 7, 8, 9 give basic curves ehp/dhp in calm sea conditions for the three displacements. For each observation, ehp/dhp is compared with ehp/dhp calm sea at the same speed.

During the trip Lobito–Boma of the first voyage and the voyage Antwerp–Gibraltar, weather was generally fine. The observations during these days were useful in establishing the basic curve in calm weather for a displacement of 13,750 tons, which was nearly the displacement during the voyages Congo–U.S.A. and Antwerp–Gibraltar (Fig. 7). In the range of ship's speeds, 15 to 17 knots, several observations in calm or nearly calm are available, but for low values of speed only the observation numbers 18 and 19 can aid, which were made, unfortunately, in bad weather. Although reference can be made to observation number 30 of the voyage Plymouth–New York and observation number 59 of the voyage New York–Copenhagen, provided corrections are adduced for the draught which was not the same, the lower part of the curve of Fig. 7 is somewhat questionable.

The s.s. *Tervaete* was dry-docked from February 23 to 26, 1951. Her shell plating was covered from bottom to 16-ft. draught with one coat of anti-corrosive and one coat of antifouling, and between waterlines 16 ft. and 24 ft., respectively, light and loaded, with one coat of boot-topping. She left Antwerp for a voyage of three months to India and East Africa, came back to Antwerp on June 22nd, and left for a voyage of four months, Antwerp–U.S.A.–Congo–U.S.A.–Antwerp. Trials were carried out on the voyage westward Congo–U.S.A., and after that long voyage the vessel was dry-docked on December 4th. Although the vessel came back from a voyage to India, she was not really dirty. The aspect of the shell plating was as follows: the shell plating was covered with small barnacles $\frac{1}{24}$ to $\frac{1}{12}$ in. in diameter, $\frac{1}{48}$ to $\frac{1}{24}$ in. high, generally with a density of 10 per cent. There were a few patches 10 sq. ft. with barnacles $\frac{1}{8}$ in. in diameter, $\frac{1}{12}$ in. high and with a density going up to 100 per cent. There were many scales of rust, $\frac{1}{12}$ to $\frac{1}{8}$ in. high; at the bow some scales being thicker, up to $\frac{1}{16}$ in. and coming off. Also, there were numerous indentations half an inch high, exceptionally 1 to 1·5 in. Not much time was available for cleaning and painting the ship's plating and the season was not favourable to a perfect cleaning. The ship was dry about 4 p.m., when darkness fell, and cleaning and painting had to be carried out in less than 24 hours. Cleaning was done by night. The shell plating received one coat of antifouling from the bottom to 16 ft. draught and from 16 ft. draught to 24 ft. draught one coat of boot-topping.

Compared with the values of C_s obtained during the Congo voyage the decrease of C_s for the voyage Antwerp–Gibraltar was not worth mentioning. The ship came back to Antwerp after a three months' voyage to India and East Africa. The vessel left Antwerp again for New York. A series of trials were carried out in April and May 1952. As during this voyage the ship made her measured-mile trials at Polperro on April 10, 1952, the plating between light and loaded waterlines was examined after the trials at New York. The aspect was as follows: small barnacles $\frac{1}{48}$ to $\frac{1}{8}$ in. diameter, $\frac{1}{48}$ in. high, and serpulas 1 in. long, generally with a density of 30 per cent, but 30 to 50 per cent near the stern, and many scales of rust $\frac{1}{12}$ to $\frac{1}{8}$ in. high.

The ship's plating was rather rough, due for a large part to the voyage to India and East Africa. The results of the measured-mile trials are given in Appendix I. These results, per group of four runs, are also given in the propulsion data, the four groups having observation numbers 27, 28, 29, and 30. Weather data for these special trials are also given in Appendix I. The results are most valuable because they give a reliable value of speed and are an opportunity for the calibration of the Pitot log. Though weather was not fine, especially in the morning, they are also useful for the determination of the curves dhp smooth water, plotted at speed. Weather was fine during a couple of days after the Polperro trials on April 18th and 19th. Plotted under the curve of the Polperro results they lead to the dhp curve smooth water. It is stated that Polperro weather effect was an increase of C_s, hence an excess of power of some 10 per cent.

The comparison of C_s smooth for a given speed during different voyages shows the effect of fouling. At a speed of 16 knots and a displacement of 14,000 tons, the vessel, immediately after cleaning and painting, December 1951, had a C_s nearly one. During the voyage Congo–America in 1951, just before docking, for a displacement of 13,750 tons $C_s = 1{,}047$. After the India voyage in the spring of 1952 and during the Plymouth–New York voyage, for a displacement of 11,700 tons, $C_s = 1{,}126$, and during the New York–Copenhagen voyage, with a displacement of 10,050 tons, $C_s = 1{\cdot}082$.

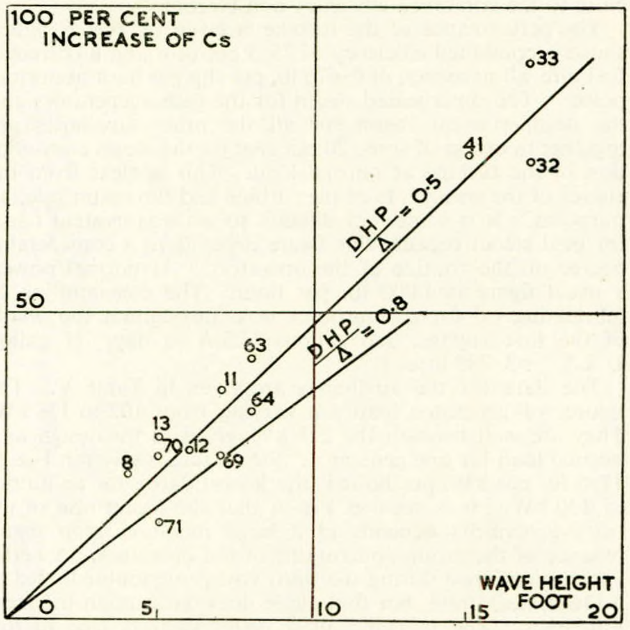

FIG. 10.—RELATION BETWEEN C_s AND WAVE-HEIGHT

The excess of power due to fouling that occurred during the India voyage of 1952 is important. This result is somewhat surprising compared to the small gain obtained by cleaning and painting after the India voyage 1951, followed by a voyage to America and the Congo. Further, the ship was eight years old and that again requires another excess of power as compared with a newly built hull.

The effect of weather is given by a series of diagrams resulting from the propulsion data. Fig. 10 shows the relation between increase of C_s and wave height, Fig. 11 the relation between loss of speed and wave height, Fig. 12 the relation between loss of ship speed and wind speed, assuming that waves are within ten degrees of either bow, and have dimensions corresponding to wind force. Separate curves are drawn for the mean displacement of the voyage New York–Copenhagen, the ratio dhp/Δ for the displacement being rather large compared with other voyage conditions.

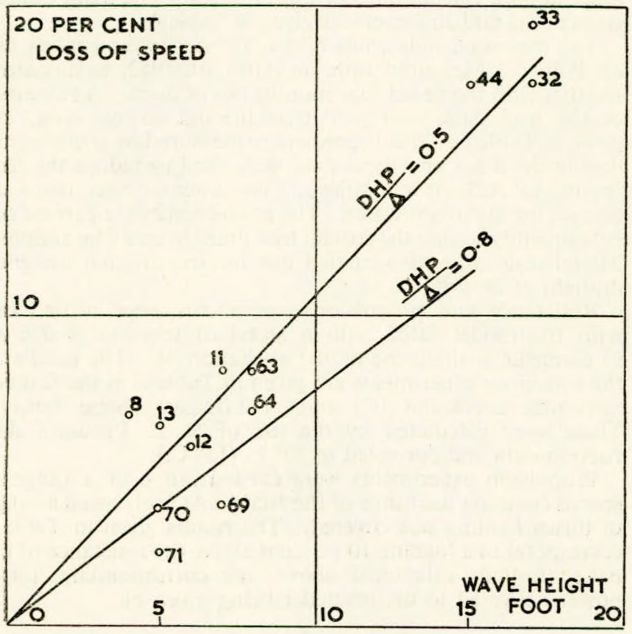

FIG. 11.—RELATION BETWEEN LOSS OF SPEED AND WAVE-HEIGHT

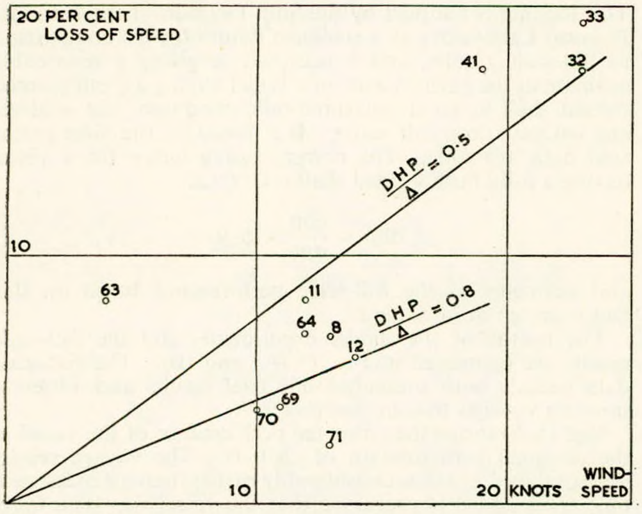

FIG. 12.—RELATION FOR WAVES AHEAD BETWEEN LOSS OF SPEED AND WINDSPEED

The block coefficient was 0·666 for the voyages of 1951, 0·653 for the voyage Plymouth–New York, and 0·642 for the voyage New York–Copenhagen. It was only possible on one voyage, Plymouth–New York and New York–Copenhagen, to record ship motions. Data are given in Table XIII. Neither yawing nor dipping were recorded. The motion consists of two separate periodic oscillations, one in the ship's natural period and one in the period of encounter. The vessel moves in cycles of long period in which the two oscillations alternatively cancel out and augment each other. The maximum amplitude of each cycle is stated in the table, but as the dimensions of waves vary, some cycles give higher amplitudes than others. A maximum maximorum is noted in the table. That cyclic motion is better shown by pitching diagrams than by roll diagrams. Roll amplitude was undoubtedly much larger than shown by the diagrams and given in the table. During heavy rolling of the ship, as recorded by the ship's clinometer, the roll recorder showed rather small amplitudes. Fortunately, unless amplitudes are very large, the effect of rolling on propulsion is not important.

Unlike roll diagrams, pitch diagrams were fair and some of them have been analysed in Appendix II.

The pitch and roll amplitudes, noted in the table, are taken as out to out.

Fig. 13 shows the relation between loss of speed and pitch amplitude; Fig. 14 the relation between loss of speed and period of encounter of waves.

The calculated natural pitching period of the ship was 6·78 sec. on April 14th for the passage westward and 6·69 sec. on May 7th for the passage eastward. When the period of encounter approaches the ship's pitching period, the maximum angles of pitch are always large and loss of speed increases to a considerable extent.

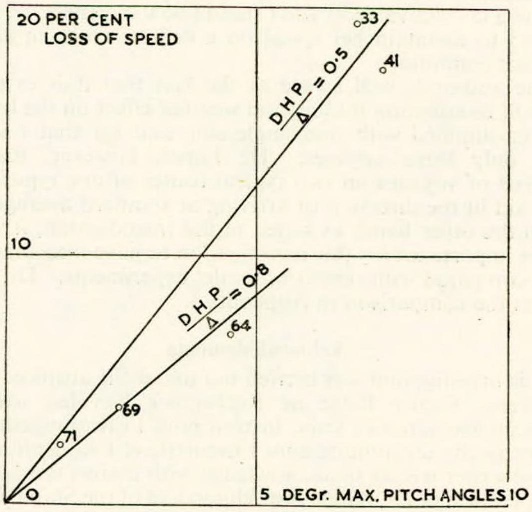

FIG. 13.—RELATION BETWEEN LOSS OF SPEED AND MAXIMUM PITCH ANGLE

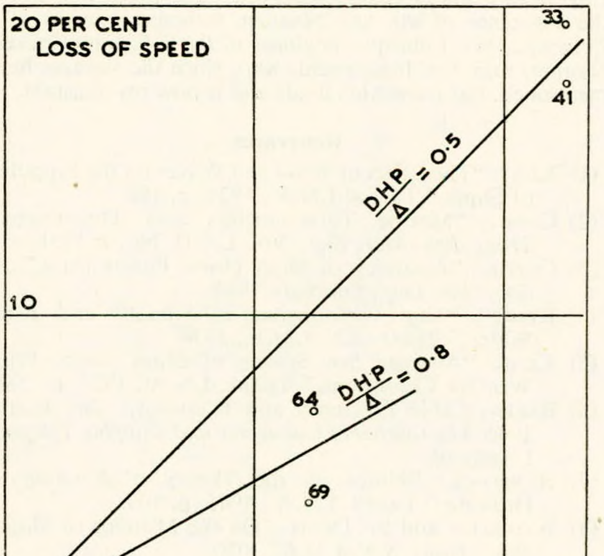

FIG. 14.—RELATION BETWEEN LOSS OF SPEED AND PERIOD OF ENCOUNTER

It is difficult to give a correct value for what is commonly called the margin of power of a ship.

Calculating for the different voyages day by day the increase of C_s due to weather effect, a mean value of the increase of power due to weather is found:—

19 per cent for the voyage St. Vincent–Baltimore (end of September, beginning of October).
32 per cent for the voyage Plymouth–New York (April).
24 per cent for the voyage New York–Copenhagen (May).
28 per cent for the combined voyage Plymouth–New York–Copenhagen.

It will not be far from the truth to assume that the voyage Congo–U.S.A., as well as the voyage Plymouth–New York–Copenhagen, took place in weather conditions which may be considered as average conditions for these routes. As the vessel reduced her speed of 17 knots in waves ahead of 10 ft. in height, in order to save the hull, it is almost hopeless to try to find a correct value of what should be the increase of power needed to maintain her speed on a definite route in varying weather conditions.

The author is well aware of the fact that it is extremely difficult to ascertain fouling and weather effect on the basis of results obtained with one single ship and for that one ship with only three voyages. He hopes, however, that the analysis of voyages on two typical routes of one typical ship may aid in the direction of arriving at standard averages.

On the other hand, as stated in the Introduction, it was of prime importance for this investigation to have measured-mile data compared with results of model experiments. Dr. Allan makes the comparison in Appendix I.

Acknowledgments

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Appendix I

Report on Ship-Model Correlation Experiments made in connection with the Measured Mile Trials of s.s. "Tervaete"

The model hull No. 3297, model screw No. S.6, and the model rudder and stern frame were made in accordance with drawings prepared by the builders of the vessel, the California Shipbuilding Corporation of Los Angeles. The main dimensions of the hull and screw are given in Table A.

The measured mile trials of s.s. *Tervaete* were carried out on Polperro Measured Mile on April 10, 1952, in moderate weather with the vessel four months out of dock. A summary of the trial data, and certain additional voyage data, are given in Table E. Wind speeds were measured by anemometer during the trials and these data were used to reduce the trial results to still air conditions. No attempt was made to correct for disturbed water. The model tests were carried out subsequently so that the correct trial draught could be adopted. Model tests were also carried out for the original designed draught of 28·0 ft.

Resistance and propulsion experiments were carried out with the model fitted with a standard trip-wire 0·036 in. in diameter girthing the model at Station 9½. The results of the resistance experiments are given in Table B in the form of resistance coefficient (C) and of Effective Horse Powers. These were calculated by the use of R. E. Froude's skin friction data and corrected to 59° F. (15° C.).

Propulsion experiments were carried out over a range of speeds covering the range of the trials. At each speed a range of thrust loading was covered. The results given in Table C correspond to a loading 10 per cent above the resistance of the naked hull as calculated above, the corresponding horsepower delivered to the propeller being given by

$$\text{dhp} = \frac{\text{ehp}}{\text{qpc}} \times 1{\cdot}1$$

This loading is adopted by the Ship Division of the National Physical Laboratory as a standard datum for the comparison of full-scale results, and is accepted as giving a reasonable estimate of the performance of a vessel having a clean painted riveted shell in good measured-mile conditions, i.e. still air and smooth, deep salt water. It is based on the most recent trial data available. The corresponding factor for a vessel having a fully flush welded shell is 0·9, i.e.

$$\text{dhp} = \frac{\text{ehp}}{\text{qpc}} \times 0{\cdot}9$$

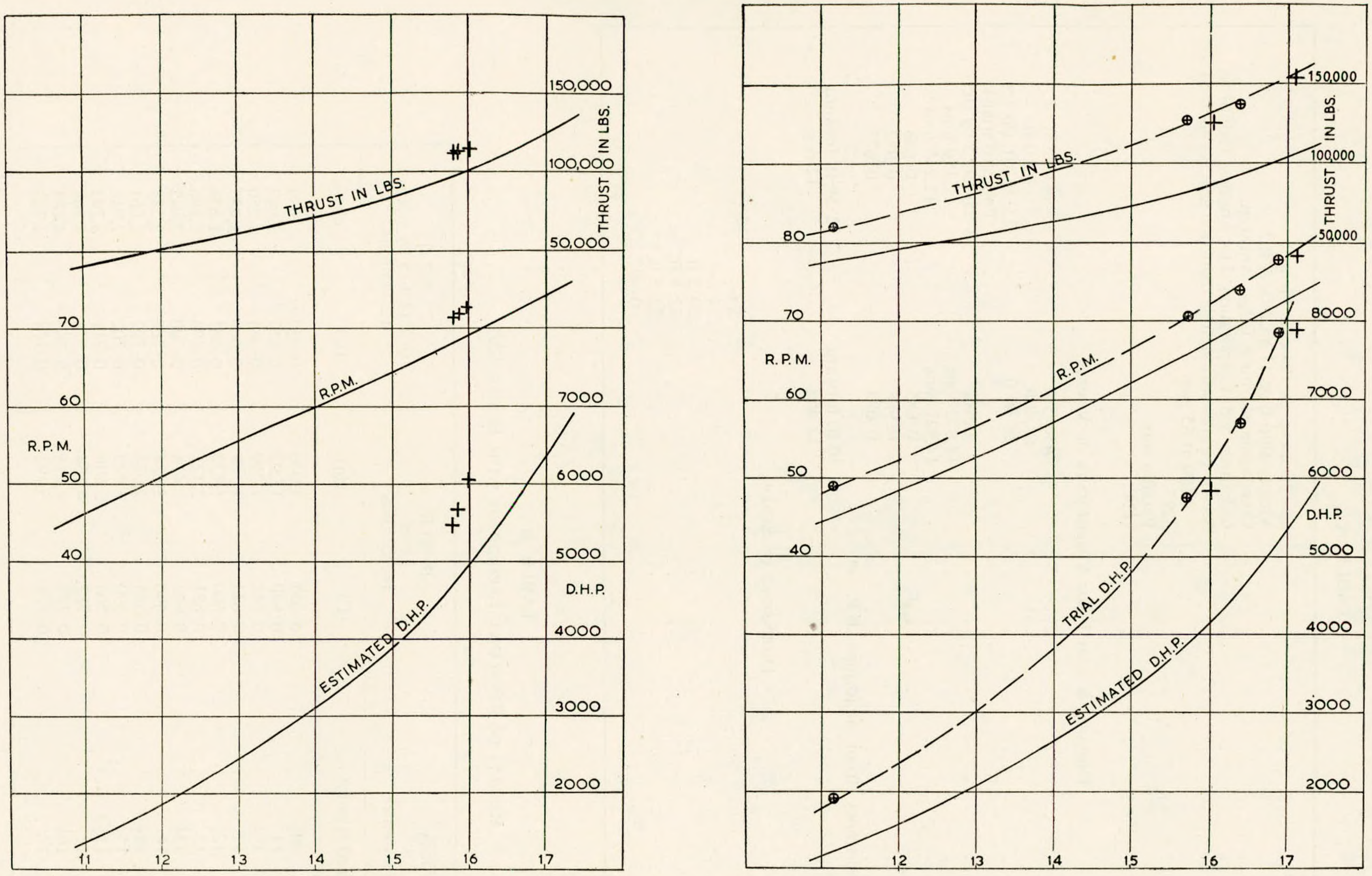
and estimates of the full-scale performance based on this factor are given in Table D.

The results of the model experiments and the full-scale results are compared in Fig. 15 (A) and (B). The full-scale data include both measured-mile trial results and observations on voyages in calm weather.

Fig. 15(A) shows the estimated performance of the vessel at the designed load draught of 28·0 ft. The voyage results were obtained at a date considerably earlier than the measured-mile trials and it is presumed that the vessel was then fairly clean. The full-scale delivered horsepowers are about 20 per cent higher, and the full-scale thrust about 15 per cent higher, than the predicted values.

Fig. 15(B) shows the comparison of the measured mile performance of the vessel with the predicted performance at the same condition. The full-scale horsepowers are of the order of 50 per cent above the predicted values, the corresponding discrepancies in thrust and revolutions being about 45 per cent and 9 per cent, respectively. The weather on trial was stated to be moderate and the vessel about four months out of dock. The additional voyage data shown for this condition were stated to be obtained in very calm weather. The delivered horsepowers then obtained are about 5 per cent lower than those on the measured mile, and this may be taken as some indication of the effect of the waves during the trials.

After making any reasonable allowance for weather conditions there remain considerable differences. If we accept the predicted dhp $\left(\text{i.e. dhp} = \frac{\text{ehp}}{\text{qpc}} \times 0{\cdot}9\right)$ as a datum, and if we assume that the results obtained in December 1951 represent a fairly clean ship, then the 20-per-cent margin shown in Fig. 15(A) may be considered to represent the difference



(A) (B)

FIG. 15.—REPORT ON SHIP-MODEL CORRELATION TESTS. S.S. "TERVAETE." MODEL NO. 3297. MODEL SCREW NO. S.6.

Draft Moulded = 28·00 ft. Trim = Level. Δext. = 14,992 tons

Vessel with all-welded shell. D.H.P. = $\frac{\text{E.H.P.}}{\text{Q.P.C.}}\times 0\cdot 9$

N.B.—Full scale data shown here were obtained during voyages in very calm weather, September and December 1951, at mean draught of 26 ft. 2 in. Results have been corrected to 28 ft. 0 in.

Draught Moulded = 23·562 ft. Trim = $\frac{0\cdot 25}{436\cdot 5}$ by stern. Δext. = 12,245 tons.

Vessel with all-welded shell. D.H.P. = $\frac{\text{E.H.P.}}{\text{Q.P.C.}}\times 0\cdot 9$

N.B.—Full scale data shown here were obtained during measured mile trial in moderate weather on April 10, 1952, and voyage in calm weather on April 18 and 19, 1952.

——— Estimates from model experiments.

⊕ — ⊕ Results from measured mile trial corrected to still air.

+ + + Voyage results at 22 ft. 9 in. mean draught corrected to 23·562 ft.

TABLE A

Name of ship	s.s. *Tervaete*, ex *Pomona Victory*.	
Type of vessel	Victory ship type 47 VC2–S–A.P.3.	
Owners	Compagnie Maritime Belge, Antwerp.	
Builders	California S.B. Corporation, Los Angeles, California.	
Machinery	Steam turbine with double reduction gear. Combined shp 8,500 at 85 *rpm*.	
Model hull number	3297.	
Material	Paraffin wax.	
Scale	1/24.	
Dimensions and Form Coefficients of Vessel		
Length B.P.	436·5 ft.	436·5 ft.
Breadth (moulded)	62·0 ft.	62·0 ft.
Draught (moulded)	28·00 ft.	23·562 ft. (as for Polperro trials)
Trim at rest	Level	0·25/436·5 by stern
Displacement (moulded)	14,832 tons	12,170 tons
Displacement (plated)	14,922 tons	12,245 tons
Block coefficient	0·685	0·668
Midship area coefficient	0·988	0·987
Prismatic coefficient	0·693	0·675
Longitudinal centre of buoyancy from amidships B.P. at level trim	1·10 ft. forward	2·59 ft. forward
Half angle of entrance	12 deg.	12 deg.
Dimensions of Screw		
Model screw number	S.6	
Number of blades	4	
Diameter	20·5 ft.	
Maximum pitch	22·9 ft.	
Mean pitch	22·5 ft.	
Blade Area ratio	0·497	

TABLE B

Results of Resistance Experiments with Model 3297

Draught (moulded) Trim Displacement (extreme)	28·00 ft. Level 14,922 tons		23·562 ft. 0·25/436·5 by stern 12,245 tons	
Speed (knots)	(C)	ehp	(C)	ehp
10½	0·637	1,046	0·652	939
11	0·640	1,208	0·657	1,087
11½	0·644	1,389	0·661	1,250
12	0·649	1,589	0·669	1,437
12½	0·660	1,828	0·681	1,654
13	0·681	2,121	0·694	1,896
13½	0·692	2,414	0·700	2,142
14	0·690	2,684	0·700	2,388
14½	0·688	2,974	0·702	2,661
15	0·690	3,299	0·702	2,946
15½	0·700	3,696	0·711	3,292
16	0·717	4,164	0·728	3,708
16½	0·745	4,745	0·749	4,184
17	0·774	5,392	0·778	4,753

TABLE C

RESULTS OF PROPULSION EXPERIMENTS WITH MODEL 3297: SCREW S.6

(*a*) Designed Load Draught

Draught (moulded)	28·00 ft.						
Trim at rest	Level						
Displacement (extreme)	14,992 tons						
Speed (knots)	11	12	13	14	15	16	17
Wake fraction (Froude)	0·495	0·498	0·489	0·479	0·465	0·433	0·391
Wake fraction (Taylor)	0·331	0·333	0·328	0·324	0·317	0·302	0·281
Thrust deduction fraction	0·228	0·230	0·230	0·233	0·235	0·244	0·256
Hull efficiency	1·154	1·145	1·146	1·134	1·122	1·082	1·035
Screw efficiency in open water	0·625	0·628	0·629	0·635	0·650	0·680	0·720
Screw efficiency behind hull	0·697	0·690	0·680	0·680	0·683	0·700	0·735
Relative rotative efficiency	1·115	1·100	1·082	1·071	0·051	1·030	1·022
Quasi-propulsive coefficient	0·805	0·789	0·778	0·771	0·766	0·758	0·760

(*b*) Trial Draught

Draught (moulded)	23·562 ft.						
Trim at rest	0·25/436·5 by stern						
Displacement (extreme)	12,245 tons						
Speed (knots)	11	12	13	14	15	16	17
Wake fraction (Froude)	0·545	0·545	0·537	0·510	0·479	0·489	0·490
Wake fraction (Taylor)	0·353	0·353	0·349	0·338	0·324	0·329	0·330
Thrust deduction fraction	0·205	0·210	0·220	0·220	0·220	0·217	0·220
Hull efficiency	1·229	1·220	1·201	1·178	1·165	1·166	1·160
Screw efficiency in open water	0·630	0·632	0·634	0·640	0·650	0·643	0·636
Screw efficiency behind hull	0·692	0·690	0·690	0·692	0·695	0·693	0·687
Relative rotative efficiency	1·099	1·093	1·088	1·081	1·069	1·077	1·080
Quasi-propulsive coefficient	0·850	0·842	0·830	0·815	0·805	0·810	0·797

TABLE D

ESTIMATED PERFORMANCE OF SHIP BASED ON TESTS WITH MODEL 3297: SCREW S.6

$\left(\text{Vessel has fully flush welded shell. Correlation factor} = 0{\cdot}9\text{, i.e. dhp} = \frac{\text{ehp}}{\text{qpc}} \times 0{\cdot}9\right)$

(*a*) Designed Load Draught

Draught (moulded)	28·00 ft.						
Trim at rest	Level						
Displacement (extreme)	14,992 tons						
Speed (knots)	11	12	13	14	15	16	17
Quasi-propulsive coefficient	0·80	0·79	0·78	0·77	0·77	0·76	0·76
Effective horsepower	1,208	1,589	2,121	2,684	3,299	4,164	5,392
Delivered horsepower	1,360	1,810	2,448	3,140	3,850	4,930	6,380
Revolutions per minute	46·0	51·0	55·0	60·0	64·0	69·0	74·0
Thrust	41,700	50,350	62,100	73,200	84,200	10,800	125,000

TABLE D—*continued* (*b*) Trial Draught

Draught (moulded)	23·562 ft.						
Trim at rest	0·25/436·5 by stern						
Displacement (extreme)	12,245 tons						
Speed (knots)	11	12	13	14	15	16	17
Quasi-propulsive coefficient	0·85	0·84	0·83	0·82	0·81	0·81	0·80
Effective horsepower	1,087	1,437	1,896	2,388	2,946	3,708	4,753
Delivered horsepower	1,150	1,540	2,050	2,620	3,280	4,120	5,350
Revolutions per minute	44·0	48·5	52·5	57·5	62·5	67·5	73·0
Thrust	37,500	44,400	54,800	64,200	73,500	86,700	105,200

between the actual hull finish at that time and the assumed datum condition. The trial results obtained four months later show a margin of about 45 per cent, and it is reasonable to suppose that this difference is mainly due to fouling during that period, although it is probable that a small part may be due to propulsion scale effect arising from the difference in draught. In the light condition adopted for the trials the screw tips are only slightly immersed. This results, on the model scale, in a considerable increase in propulsive efficiency as can be seen by comparing Tables C(*a*) and C(*b*), and it is probable that this increase is not fully realized in full-scale conditions because of air penetration to the screw disc on the full scale at the light draught.

It would be of great value and interest to compare these results with the original trial data of this type of vessel if that can be made available by the U.S.A.

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Appendix II

Pitching Diagrams

Analysis of pitching diagrams obtained in such confused seas as were seen in both passages of the North Atlantic during the third voyage is rather deceptive.

No regular oscillations were recorded. At the best, cycles of a number of oscillations not too varying the one from the other, can be remarked on the diagrams. The oscillations of these cycles are approximately regular in period for a record of ten minutes, the variation in period being generally more important in a heavy sea than in small waves. The pitching angles change periodically from a minimum to a maximum value.

Apart from this general shape of diagrams, which show appreciable pitch angles when wave height is more than 5 ft., and period of encounter does not differ more than 2 sec. from the ship's natural period; it may occur that the difference between period of encounter and the ship's natural period is no more than 1 sec. The diagram shows many consecutive regular oscillations of large amplitude. Co-periodicity is very rare, due to the irregularity of the sea, and even if co-periodicity exists for a short time in a nearly regular sea, it will not last because the heavy pitching which is the resulting motion has a decreasing effect on the ship's speed and breaks co-periodicity. Very few diagrams show long cycles of regular oscillations of large amplitude. The number of oscillations per cycle varies between very distant limits, as shown in Table XIII. It is understood that the maximum angles in the table are those amplitudes which are seen 5 to 6 times on a 10-minute record. The maximum maximorum is the highest amplitude of this record. In not too large but irregular waves, the oscillations, which have a

TABLE E

Summary of Full-Scale Trial Data

Trial on Polperro Measured Mile: April 10, 1952.
Draught before Trial: 23 ft. 6 in. forward; 23 ft. 9 in. aft.
Vessel Undocked: December 4, 1951.
Wind variable S.S.W. to S.E. Force 2–3 reaching 5 on gusts by end of trial.
Sea moderate. Average height varying from 1 to 1·5 metres, i.e. about 3·0 to 5·0 ft.
Water Temperature: 49° to 50° F.

Group	Mean speed, knots	Mean dhp	Mean *rpm*	Mean thrust, lb.	Mean dhp	Mean *rpm*	Mean thrust, lb.
		Uncorrected			Corrected to still air		
I	16·882	8,010	78·94	153,742	7,860	78·0	152,405
II	16·371	6,860	75·01	138,194	6,720	74·0	136,169
III	15·701	5,900	71·56	127,975	5,762	70·7	126,354
IV	11·163	1,955	49·72	59,652	1,894	49·7	58,501

Additional data supplied by Professor Aertssen:

Date	Mean draught	Speed	dhp	Thrust	*rpm*
April 18, 1952	22 ft. 9½ in.	17·1 knots	7,686	148,700 lb.	78·1
April 19, 1952	22 ft. 8½ in.	16·0 knots	5,681	119,900 lb.	71·4
September 21, 1951	26 ft. 2 in.	15·8 knots	5,319	112,200 lb.	70·5
September 22, 1951	26 ft. 2 in.	15·85 knots	5,419	113,600 lb.	70·7
December 17, 1951	26 ft. 7½ in.	15·99 knots	5,808	117,000 lb.	71·7

All these additional data apply to calm weather conditions.

TABLE XIII

Ship Motions Voyage Plymouth–New York and New York–Copenhagen

Observation number	Recording time min.	Pitching				Period of encounter, sec.	Rolling			Rudder angles, deg.
		Period, sec.	Max. angle, deg.	Maximum maximorum, deg.	Oscillations per cycle		Period, sec.	Max. angle, deg.	Oscillations per cycle	
31	63	4·4–5·7	1·9	2·4	—	4·0	10·7–12·6	9·3	—	—
33	59	5·7–7·9	7	12·8	4–13	4·5	10·8–12·0	10·7	—	—
34	10	5·8–8·2	7·7	8·6	—	4·9	9·5–11·4	6·9	—	—
35	10	5·4–7·6	6·2	6·5	—	5·3	9·5–11·4	9·3	—	—
36	10	6·9–8·2	3·5	4·8	14–15	4·0	9·5–12·0	5·9	—	—
37	10	5·0–7·6	5·7	6·9	4–7	4·7	9·5–12·6	4·4	—	—
38	10	6·0–7·6	5·7	7·7	9–13	4·8	10·1–12·6	9·3	—	—
39	15	5·7–6·9	2·5	3·8	3–11	4·2	10·7–13·2	5·1	—	—
40	15	5·0–7·6	3·8	6·6	—	4·8	10·1–12·0	3·4	—	—
41	10	5·7–7·6	7·5	7·7	—	4·5	9·5–12·6	5·9	—	—
42	10	5·7–7·6	5·4	7·4	—	4·4	8·8–12·0	5·9	—	—
43	10	5·7–7·6	3·8	5·0	—	3·2	9·5–12·6	5·0	—	—
44	10	5·4–7·6	2·9	4·0	—	3·2	10·7–13·9	3·4	—	—
45	10	—	No	No	—	—	9·5–12·6	4·5	—	—
46	10	4·9–6·6	0·7	0·9	—	—	10·7–13·2	4·5	—	—
47	10	—	No	No	—	—	± 12	1·5	—	—
48	10	5·7–7·2	0·9	0·9	—	—	9·5–10·4	4·5	—	—
49	10	5·7–6·9	0·7	0·9	—	—	10·1–11·3	5·4	—	—
51	10	6·3–7·6	0·6	0·7	—	—	10·1–11·3	4·4	—	—
53	10	5·2–7·2	0·6	0·8	—	—	10·7–11·3	3·2	—	3P 3SB
56	10	5·7–6·9	0·8	1·5	—	—	10·7–12·0	4·7	—	3P 4SB
57	10	5·7–6·9	1·8	2·2	6–10	2·3	10·1–10·7	5·9	—	3P 2SB
64	10	4·7–7·3	4·5	6·9	3–8	2·5	8·8–9·8	3·4	—	3P 1SB
65	10	6·9–8·2	6·9	9·1	—	6·4	9·5–10·7	11·8	—	3P 3SB
66	10	6·3–8·8	7·3	7·8	3–4	6·5	9·5–11·0	7·5	—	3P 5SB
67	5	5·7–8·2	4	9·5	—	6·4	8·8–11·0	12·6	—	3P 4SB
68	10	6·3–7·6	2·7	4·4	—	3·4	10·1–11·3	17·5	7–11	5P 1SB
69	20	5·7–6·9	2·3	2·6	—	2·4	9·5–11·3	13·8	—	4P 3SB
71	10	5·7–6·9	1·1	1·3	—	—	9·5–11·3	3·4	—	4P 1SB
72	10	4·9–6·3	1·1	1·3	3–7	—	10·7–11·3	2·6	—	3P 0SB

rather small amplitude, have an almost regular period very near the natural period. By statistical methods the most frequent period was calculated for a large number of diagrams. The natural pitching period was also calculated in the usual way from the repartition of weights in the ship. The evaluation of the very large quantity of oscillating water was made by augmenting the basic period by 42 per cent.

The pitching period obtained by calculation in this way had a value of 6·78 sec. April 14th for the voyage Plymouth–New York and a value of 6·69 sec. May 2nd for the voyage New York–Copenhagen. The values obtained from the diagrams are very near these calculated values.

Fig. 16 is a part of the record taken on April 14th with waves 10 deg. port bow during observation number 33. It is clear from the diagram that the motion is built up of an oscillation in the period 7·2 sec. and an oscillation in the period 5·6 sec. The main oscillation is in the natural period of the ship, the subsidiary oscillation of smaller amplitude is in the period of encounter.

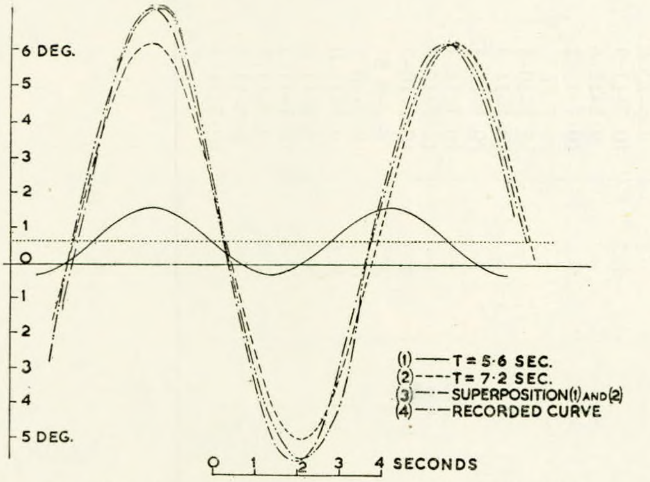

FIG. 16.—ANALYSIS OF PITCH DIAGRAM, APRIL 14, 1952

The diagram shows an amplitude which is the maximum maximorum of the 10-minute record. This amplitude was exceptional and met periodically in this sea with predominant waves from 10 deg. to port, 260 ft. long, 17 ft. high, but with subsidiary waves meeting to starboard. The ship periodically met waves of exceptional height when both wave trains were in phase, and water was then taken on board. Sometimes slamming occurred, too, at that moment. That maximum pitching angle of more than 12 deg. is very near the maximum slope of the wave.

Fig. 17 shows a part of a record with more regular oscillations and without exceptional amplitudes. That record was taken on April 16th during observation number 40, with waves meeting at the bow, 45 deg. to port. Although the waves were 20 ft. high, the amplitude of the oscillations was not exceptionally large. The part taken out of the record is one with large amplitudes, where waves and ship were nearly in phase. The motion was built up of an oscillation in the period 6·80 sec. and an oscillation in the period 5·76 sec. As in the foregoing example, the main oscillation is in the natural period of the ship, the subsidiary oscillation is in the period of encounter. Due in the first place to the fact that there were no disturbing trains of waves, and in the second place to the fact that the ship was meeting the waves under an angle of 45 deg., the pitching amplitude was not more than roughly 6 deg. The ship was also rolling and water was taken on board.

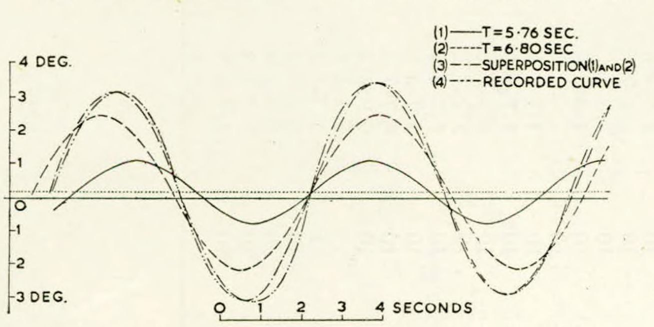

FIG. 17.—ANALYSIS OF PITCH DIAGRAM, APRIL 16, 1952

As a last example taken out of the numerous records, Fig. 18 gives a part of the diagram taken on May 7th during observation number 67, when there was a broadside sea. The ship met the waves 70 deg. to port. Both rolling and pitching motions had large amplitudes. The pitching record shows very irregular oscillations with moments of very large amplitudes, separated by baulked oscillations, of equal importance in time. The ship took water on board and sometimes slamming occurred. The motion was built up of an oscillation in the period 6·72 sec. and another in the period of 7·68 sec. Both oscillations are nearly of the same importance, the larger being given, however, by the oscillation in the period of encounter, which is here somewhat longer than the natural period of the ship.

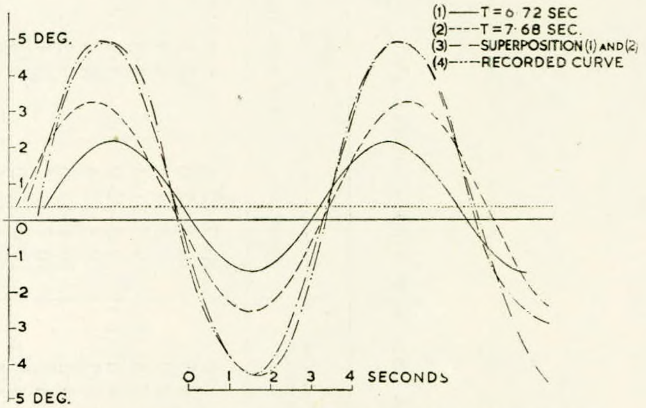

FIG. 18—ANALYSIS OF PITCH DIAGRAM, MAY 7, 1952

Appendix III

Some Investigations of the Boundary Layer of s.s. "Tervaete"

The installation of a log of the type made by the British Pitometer Company enabled the distribution of velocity in the boundary layer to be determined.

The investigations were carried out during the voyage to New York in May 1952, as weather was generally fine. The state of the sea during measurements was smooth or moderate. In order to have a clear statement of the distribution of velocity in the friction belt, not the absolute values of velocity but their ratio to the velocity at a distance of 3 ft. is given in Fig. 3.

There are three reasons for possible dispersion in the data. It is known that the state of the sea has an influence on the velocity distribution, in that rough weather makes the friction belt thinner. Though all the measurements were made in a smooth or, in the worst case, a smooth-moderate sea, a scattering of data may occur, as on no occasion was there a very calm sea.

The measurements were made at intervals of 2 or 3 in. and in time spaces sufficiently long to permit the mercury in the differential to give correctly the difference between the impact and static pressures. A fault may arise from not waiting long enough between two successive measurements.

From the rise of the rodmeter the distance from logholes to shell plating was estimated. These measurements were made in a cofferdam in very difficult conditions and some source of error may result from that fact.

The different curves A, May 1952, give the amount of dispersion which is possible.

All the curves are spread around a mean curve:

$$\frac{V}{V_{max}} = \left(\frac{Y}{Y_{max}}\right)^n$$

The curve is a fair exponential curve with $n = 0{\cdot}204$.

As already mentioned, the ship came back from a voyage of three months to India and East Africa and was five months out of dock. After another voyage to India and East Africa of four months' duration, the vessel then being ten months out of dock, the measurements in the friction belt were renewed by the ship's engineers and their data give the curve in full line on Fig. 3.

From the true exponential curve $\frac{V}{V_{max}} = \left(\frac{Y}{Y_{max}}\right)^{0{\cdot}29}$, which is drawn by a dotted line on Fig. 3, it is shown that the exponent has increased from 0·204 to 0·29 on that four months' India voyage. The degree of roughness has a large effect on the shape of the velocity curve and especially on the value of the exponent, assuming the curve is an exponential curve.

As it is rather difficult to have correct readings of speed in rough weather, and as waves disturb the boundary layer, it is recommended that the velocity distribution be determined in a calm sea. Fig. 3 shows that the values of the speed do not have any effect on the shape of the curve, but it should be emphasized that a great number of points of the curve have to be determined.

The velocity distribution was determined, too, on October 28th in the river Scheldt, the depth being some 70 ft. Fig. 3 shows the effect of shallow water which reduces considerably the thickness of the boundary layer. Fouling was the same as that characterized in deep water by the curve in full line.

Fig. 3 shows further that in the state of fouling of the ship in which she came from her second voyage to India, it is no longer possible to have a correct measurement of the speed with a rodmeter no longer than 3 ft. in the position it had on board s.s. *Tervaete*.

Appendix IV

General Data of the Ship

Ship's name: s.s. *Tervaete*, ex *Pomona Victory*—'47 VC2—S—AP3.

Ship's owners: Compagnie Maritime Belge (Lloyd Royal), Antwerp.

Shipbuilders: California S.B. Corp., Los Angeles, California.

Builders' hull n°V 27.

Built for U.S. Maritime Commission, Hull, n° MCV 31. August 1944.

Engine builders: Westinghouse, Pittsburgh, Pennsylvania.

Boiler builders: Babcock & Wilcox.

Dimensions:

Length between perpendiculars	436 ft. 6 in.
Length overall	455 ft. 3 in.
Length on 28-ft. waterline	444 ft. 0 in.
Beam moulded	62 ft. 0 in.
Beam over plating	62 ft. 1⅝ in.
Depth, moulded to main deck	38 ft. 0 in.
Sheer, main deck forward	4 ft. 1 in.
Sheer, main deck aft	6 ft. 2 in.
Draught, summer, moulded	28 ft. 6¾ in.
Draught, light ship displacement, moulded above keel	9 ft. 6½ in.

Displacement:

Heavy, 14,837 tons at 27 ft. 8½ in. Block coefficient, 0·672.

Medium, 10,077 tons at 19 ft. 9⅜ in. Block coefficient, 0·642.

Light, 5,268 tons at 11 ft. 2⅛ in. Block coefficient, 0·595.

Main propulsion units: High pressure turbine, cross compound impulse reaction.

Impulse: 2 rows of moving blades, 1 row of stationary blades.

Reaction blading: 1st group, 6 pairs of rows; 2nd group, 8 pairs of rows.

Shp 4,250; *rpm* 5,358; 440 lb. per sq. in.; 740° F.

Extraction from inlet low-pressure turbine.

Low-pressure turbine reaction: 1st group, 5 pairs of rows; 2nd group, 5 pairs of rows.

Shp 4,250; *rpm* 4,422; 25 lb. per sq. in.; 320° F.; 28·5 in. vacuum.

Reduction gear: Double reduction, double helical, *rpm* 85.

Propeller and stern arrangements: Diameter of screw, 20·5 ft.; pitch, 0·6 R to tip: 22·9 ft.

Number of blades: 4; MWR 0·237; PA : DA 0·413; BTF 0·047; right hand.

Appendages: Contrastern and contrarudder.

Steam generating units: Two boilers, double casing, sectional header type.

Heating surfaces per unit (sq. ft.): boiler, 5,722; superheater, 965; economizer, 1,443; waterwalls, 90.

Pressure, lb. per sq. in. gauge: Boiler drum (normal load), 482; at superheater outlet (*idem*), 465.

Temperatures, ° F.: at superheater outlet (normal load), 750; feedwater, 240.

Furnace volume, cubic feet: 605.

Capacity, normal load per boiler, lb. per hour: Superheated, 34,000; desuperheated, 3,500.

Oil burners: 4 per boiler.

Steam-driven auxiliaries (operation at sea):

A. Superheated steam:

Two turbo-generators, geared turbine drive, *rpm* 1,200. Each 300 kW., 120/240 V.; 440 lb. per sq. in.; 740° F.; 28·5 in. vacuum; one operating, normal load 225 kW.

B. Desuperheated steam:

Steam 440 lb. per sq. in.: 2 main feed pumps, 74 gpm norm. 515 disch. press.; 1 main feed standby, 150 gpm norm. 545 disch. press.

Steam 240 lb. per sq. in.: 2 fuel oil service pumps (1 standby), 20 gpm total head 350 lb. per sq. in.; 1 fuel oil transfer, 320 gpm, total head 75 lb. per sq. in.; 1 lubr. oil service standby, 325 gpm, total head 48 lb. per sq. in.; 2 forced draught fans, 11,000 cfm at 4·8 in.; miscellaneous pumps: bilge and ballast, general service, fire, standby fire and general service; heating oil, water, liquid cargo, evaporator, whistle, gland seals for main turbine and turbo-generators (after reducing stations).

Steam, 160 lb. per sq. in.: Main and auxiliary air ejector.

Exhaust steam: forced draught fans, feed pumps, fuel oil service pump, standby lubricating oil service pump (operating at idling speed) and other engine-room auxiliary pumps operating part time, such as the bilge and the fuel transfer pump, supply steam, together with the turbine bleeder, to the d.c. heater, evaporating plant, gland leak off ejector.

Generator Loads at Sea:

Unit:	*Input bhp*	*Duty*
Hull equipment:		
Steering gear	40	—
Vent fans, heaters, etc.:		
2 machinery space supply fans, each	15	28,000 cfm
1 machinery exhaust fan	5	12,000 cfm
Lubricating oil system:		
1 lubricating oil purifier pump	1	350gpm*
1 lubricating oil purifier	1·5	—
Salt water pumps:		
1 main circulating pump	100	13,000 gpm
1 auxiliary circulating pump	25	3,000 gpm
Feedwater pumps:		
1 main condensate pump	15	150 gpm
1 auxiliary condensate pump	5·6	30 gpm
Oil pumps:		
1 lubricating oil service pump	15	325 gpm

Generator Loads at Sea:—continued

Unit:	*Input bhp*	*Duty*
Evaporator pumps:		
1 fresh water distributing pump ..	0·5	6 gpm
1 brine overboard discharge and evaporator feed pump	0·75	10·2 gpm
Pressure sets:		
2 washing and drinking water pumps each	0·75	10 gpm
1 sanitary pump	7·5	60 gpm
Compressed air system:		
2 engine-room air compressors each	15	—
Machine shop in engine-room:		
1 lathe	2	—
1 drill	1	—
1 converter	1·5	115 V, 12·4 amp; 120 V, 6·25 amp.

* The gallons are American gallons

Addendum

Since this paper was written it has become possible to gather valuable information about s.s. *Tervaete*. The ship had bad hull damage on her recent voyage back from New York which made dry-docking necessary. An opportunity was taken to send the torsionmeter shaft to the shop for calibration; the propeller was measured in horizontal position and the main thrust with thrust meter was taken off.

Table XIV gives the percentage variation in the face pitch of each blade. It is seen that blade I suffers the widest variation from the allowed one per cent variation.

TABLE XIV

Average Face Pitch of Propeller, expressed as Percentage Variation from Design Values

	Blade I	Blade II	Blade III	Blade IV
0·2 R	− 5·6	− 5·1	− 4·6	− 4·3
0·3 R	+ 1·94	+ 0·79	+ 0·07	+ 0·15
0·4 R	+ 2·64	+ 0·98	+ 0·65	− 0·59
0·5 R	+ 3·3	+ 0·85	+ 0·79	− 1·43
0·6 R	+ 6·2	+ 0·73	+ 0·19	− 1·46
0·7 R	+ 5·0	+ 1·5	+ 1·00	− 1·29
0·8 R	+ 6·1	+ 0·92	− 0·04	− 0·63
0·9 R	+ 9·7	+ 3·5	+ 1·76	+ 0·30
Mean	+ 3·9	+ 0·64	− 0·08	− 1·12
Mean for propeller: + 0·84				

Table XV gives the percentage variation in average thickness from three points at blade centre.

At measured mile trials tips of blades were 1·92 ft. below water surface.

TABLE XV

Average Thickness of Propeller from Three Points at Blade Centre, expressed as Percentage Variation from Design Values

	Blade I	Blade II	Blade III	Blade IV
0·3 R	+ 2·8	− 3·9	− 1·10	− 1·53
0·4 R	− 0·22	− 0·89	− 1·52	+ 0·82
0·5 R	− 1·94	− 1·70	− 2·49	− 0·30
0·6 R	− 0·26	− 4·23	− 3·25	− 3·3
0·7 R	− 1·09	− 3·17	− 3·9	− 0·93
0·8 R	− 1·98	+ 0·05	+ 0·67	+ 0·12
0·9 R	+ 8·5	+ 8·03	+ 0·23	+ 3·0

The inspection of the bearing surfaces of the levelling plates of main thrust showed some eccentricities; owing principally to these eccentricities it cannot be hoped to obtain an accuracy of thrust measurements better than 6 per cent in smooth water.

The most important information, however, was obtained from the calibration of the shaft, which on board was fitted with the torsionmeter. The calibration was done in the engine works of John Cockerill (Seraing). Measurement of deflection between pointers at 11·22 ft. distance on the shaft with weights going up to normal load gave a modulus of rigidity of 11,220,000 lb. per sq. in. This is a very low figure and may be somewhat in error because of the bending of the shaft during calibration. SHP is 4 per cent less than calculated with the assumed G of 11,700,000.

The assessment of power loss in the shaft, 1·5 per cent from the turbine to the torsionmeter at the end of the tunnel, was somewhat low. So the 4 per cent can be divided in 1·5 for the shaft and 2·5 for the turbine, bringing shaft losses in the tunnel, without loss at tailshaft, up to 3 per cent.

All values of turbine shp are then to be lowered by 2·5 per cent. The combined efficiency at normal power is then 73·5 per cent and the fuel consumption all purposes 0·692 lb. per shp.

DHP values are 4 per cent lower and propulsive efficiency values 4 per cent higher. Effects of fouling and weather as calculated remain unchanged.

The measured distance of the impact orifice of the Pitot log to the shell plating was 35 in., the assumed distance being 3 ft. Hence the basis of the velocity curves (Fig. 3) has to be raised 1 in., the lower end of the curves, beneath this new basis line, disappearing.

Renewed measurement of velocity distribution in the friction belt after dry-docking, the vessel being then clean, gave a curve, which, within a distance of 8 in. from shell plating, was fairly exponential, with $n = 0{\cdot}136$ in a smooth sea and nearly 0·127 in very rough water.

DISCUSSION

Dr. J. F. Allan (*Member of Council I.N.A.*): In the first place I wish to express our thanks to Professor Aertssen and to the Belgian Naval Research Association and also to the Compagnie Maritime Belge for having put this paper forward jointly to the Institution of Naval Architects and Institute of Marine Engineers. I am sure you will all agree that it contains a mass of valuable information on both the hull performance and machinery performance sides.

Having said that, I think it is also to the point to remark that the paper indicates the great difficulty of obtaining what we might call ideal data from a ship in her normal service. In spite of that limitation, however, the team of workers engaged in this investigation have accumulated for our information a very useful mass of data.

The thrustmeter, as Professor Aertssen has pointed out, is not ideal because it measures only the thrust on one levelling plate out of the six, and although the makers claim a high degree of accuracy, Professor Aertssen has limited that to some 6 per cent. He is right in doing that, and we must bear the point in mind when considering the whole picture presented in the results of the observations.

The author refers to temperature correction on the ship in tropical waters by the method proposed by the International Conference in Paris in 1935. I think that correction is one which should not be applied to the ship, for it is in error; as agreed in 1935 it was quite reasonably correct for the average model range used at that time, but it was never intended to be applied to the ship condition, especially over wide ranges of temperature up to 80° C. We must also keep that point in mind when considering the results.

In Fig. 3 we have a curve for the voyage from Plymouth to New York and another curve for the ship in very much dirtier condition; and Professor Aertssen has told me he has another curve, not plotted in the paper, which comes even lower, for the ship when she was comparatively clean. This indicates the effect of fouling on the boundary layer. In a recent paper to the North-East Coast Institution I put forward an empirical formula for the velocity distribution in the boundary layer, and it plots slightly lower than the curve for the clean ship. The point to which I draw attention is that the effect of fouling is not only to increase the characteristic of the curve, but to increase the thickness of the belt.

I come to Appendix I, containing the report from the N.P.L. on the experiments made there in collaboration with the Belgian Research Association; we were very pleased to do that work, to make this whole investigation to some extent an international effort. The experiments were carried out in the normal way, and I will not go into the details. In Appendix I we have the tank prediction for the clean ship, in the new condition. It is based on what we call an 0·9 correlation factor, which in its turn has arisen from a large amount of ship-model correlation work with which the N.P.L. has been concerned together with the B.S.R.A. during the last few years. It has not been published so far, but we find that the flush-welded ship is performing considerably better than the riveted ship.

You will note in Fig. 15 (A) there is a very considerable difference between the ship performance values and the estimate based on a flush-welded new hull. In Appendix I it is stated:—

> "Fig. 15 (A) shows the estimated performance of the vessel at the designed load draught of 28·0 ft. The voyage results were obtained at a date considerably earlier than the measured-mile trials, and it is presumed that the vessel was then fairly clean. The full-scale delivered horsepowers are about 20 per cent higher, and the full-scale thrust about 15 per cent higher, than the predicted values.
>
> "Fig. 15 (B) shows the comparison of the measured-mile performance of the vessel with the predicted performance at the same condition. The full-scale horsepowers are of the order of 50 per cent above the predicted values, the corresponding discrepancies in thrust and revolutions being about 45 per cent and 9 per cent respectively. The weather on trial was stated to be moderate and the vessel about four months out of dock. The additional voyage data shown for this condition were stated to be obtained in very calm weather. The delivered horsepowers then obtained are about 5 per cent lower than those of the measured mile, and this may be taken as some indication of the effect of the waves during the trials.
>
> "After making any reasonable allowance for weather conditions there remain considerable differences. If we accept the predicted dhp $\left(\text{i.e. dhp} = \frac{\text{ehp}}{\text{qpc}} \times 0{\cdot}9\right)$ as a datum, and if we assume that the results obtained in December 1951 represent a fairly clean ship, then the 20 per cent margin shown in Fig. 15 (A) may be considered to represent the difference between the actual hull finish at that time and the assumed datum condition. The trial results obtained four months later show a margin of about 45 per cent and it is reasonable to suppose that this difference is mainly due to fouling during that period. . . ."

These differences are very disturbing and serve to show that this ship when comparatively clean was not performing anything like so well as a completely new well-painted flush-welded form.

Referring again to diagram Fig. 15 (A), the Admiralty coefficient at 16 knots predicted by the tank results is about 490, and at 15 knots it is about 515, and these are figures which have been obtained during the last two or three years in somewhat similar ships. The Admiralty coefficient obtained for the vessel in service is of the order of 425, still quite a reasonable figure.

I draw attention also to the propulsive coefficients shown in Table D. In the region of 15–16 knots, in the deep condition, the propulsive coefficient was 0·76 and 0·77, and in the lighter condition at those speeds it was 0·81. In Figs. 7, 8, and 9 there are plotted the results of the sea trials. In these diagrams values for ehp/dhp have been deduced, and they are of the general order of 80 per cent or slightly above. They are in reasonable agreement with model figures, but seem to be on the high side. However, the accuracy of the whole process is not such that one could attempt to differentiate or draw a fine distinction as to scale effect in the results.

Finally I refer to Figs. 10, 11, 12, 13, and 14, which are very interesting. Therein the author has attempted to plot the effects produced by weather conditions in a variety of ways, and they seem to fall into some reasonable pattern. I have some doubt in my mind as to whether they should be straight lines; I should like the author to say whether these are just lines drawn through the spots as a mean or are based on certain assumptions with regard to the factors involved. Particularly with regard to Fig. 14, with a base of period of encounter, I feel that it should not be anything like a straight line; and probably the same remark applies to Fig. 10, showing the relation between C_s and wave height.

Prof. Dr. W. P. A. van Lammeren (*Member I.N.A.*): I have read this valuable paper with particular interest, not only because I had the pleasure of attending the measured mile trials at Polperro, but also because the Wageningen Model Basin is carrying out similar tests on a number of Victory ships as a part of an extensive research programme on the field of the correlation between tank predictions based on ship-model experiments and trial and service performance. This research does not cover the determination of the efficiency and economy of the machinery. My contribution to the discussion will be restricted, therefore, to those parts dealing with the correlation problem.

Besides some preliminary tests on one of the geosims at full draught and numerous tests on the 72-ft. model boat *D. C. Endert Jr.*, we carried out a series of tests on the 17 knots Victory ship *Arnedijk* of the Holland Amerika Lijn during a trip from Rotterdam to New York v.v. after an extensive overhaul of the ship in dry dock in September 1952 had been made. Contrary to the investigations made by the author we carried out series of measurements covering a speed range from 8 to 18 knots at various weather conditions. As it is not possible to give the full results of these tests in this contribution it will be enough to say that the allowance on dhp predicted by the tank for the self-propulsion point of ship varied from 54 per cent at relative wind speeds of 12 to 16 m./sec., the wind being slightly abaft the beam and a wave height of 0·75 m. to 14 per cent at a relative wind speed of 8 to 11 m./sec., the wind being about 40 deg. off the bow, and a wave height of 0·25 m.

The tank test results of the 19-ft. model (scale 1/23) corrected for the draughts given in Fig. 15 are in good agreement with those given by Dr. Allan, if we also apply the correlation factor of 0·9 as far as the dhp are concerned. By the way, this does not mean that I agree with the application of this factor, but I used it only for comparison. It is not clear to me what correlation in thrust corresponds with the correlation factor for dhp. For this reason I did not make an attempt to compare the curves of thrust.

The revolutions were corrected in such a way that the relation between dhp and *rpm* was kept constant, that is to say that the rpm were kept the same for the same dhp.

In considering Fig. 15 (B) it appears that the trial *rpm* at the same dhp are considerably lower than the estimated *rpm*. This puzzles me because it is true, in general, that the *rpm* decrease with increasing loading of the propeller at constant power (decreasing speed), but this effect is more than counterbalanced by the wake-scale effect even for a considerable increase of propeller loading. It may be, however, that this phenomenon can be explained to some extent by the discrepancy of the pitch of the actual propeller shown in Table XIV, but, on the other hand, the correlation between dhp and *rpm* is much better for the condition shown in Fig. 15 (A). With the *Arnedijk* the trial *rpm* were always somewhat higher than the estimated *rpm* at the same power, which is in accordance with our experience. I would like to ask Dr. Allan whether he could explain this phenomenon.

I have the impression that the rather disappointing precision of the measurements is partly due to the fact that the various measurements could not be carried out simultaneously. It is indeed very difficult to maintain exactly the same speed for time intervals of half an hour when running in bad weather.

Accurate speed measurement on the open sea is most difficult. For sake of security we therefore applied two different speed log devices on the *Arnedijk*. The application of two logs has also the advantage that the results of velocity measurements in the boundary layer carried out with one log can be corrected for eventual variations in the ship speed, measured with the other log.

Finally I would like to take advantage of this opportunity to compliment the author on this instructive paper and to thank him for his co-operation and willingness in putting all data at my disposal. This means a very valuable extension of the Victory ship performance data we are going to collect as a part of our model-ship correlation programme.

Professor Ir. J. W. Bonebakker:

Applying regression analysis to the author's measured values (corrected for variations in temperature) given in Tables X and XI, the following regression equations (column 4) are found:

Notation:—

N = *rpm*

S_a = apparent slip in per cent.

F = standard deviation.

(1) Voyage	(2) Displacement	(3) Draught	(4) $shp/(0{\cdot}1N)^3$	(5) F
Plymouth–New York	12 245–11,700	± 23 ft.	$0{\cdot}154\ S_a + 15{\cdot}53$	1·9 per cent
New York–Copenhagen ..	10,050– 9,620	± 20 ft.	$0{\cdot}162\ S_a + 14{\cdot}73$	2·4 per cent

Observations Nos. 65 and 66 have been excluded, the weather being too bad.

Generally speaking, a decrease in draught involves a decrease in wake.

The coefficient preceding S_a is proportional to $(1 - w)$; consequently, at the lower draught of the second voyage, this coefficient should have—and has—the higher value.

The equation, derived from records taken during the first voyage, is based on twenty-one observations, and the second equation on twenty-five observations. The F-values are small, which proves that the measurements were taken with a high degree of accuracy. In other words, a limited number of accurate observations was sufficient to get reliable equations. Such equations are the proper instrument for checking any set of records taken simultaneously, and for computing reliable figures for shp when only ship's speed and *rpm* are recorded. For it will be agreed that during bad weather it is much more difficult to get accurate measurements of torque and thrust than of *rpm* and ship's speed. In such instances the regression equation is a great help.

In the case of the *Tervaete* it might have been possible to collect quite a number of shp values computed from *rpm* and speed measurements only. This might have led to the computation of allowances on tank shp for weather conditions, for engine powers ranging from (say) 5,500–8,000 shp.

This subject is treated in Report No. 10 S of the "Studiencentrum T.N.O. voor Scheepsbouw en Navigatie," the Dutch equivalent of the B.S.R.A. and the "Centre Belge de Recherches Navales."

The use of C_s for eliminating the influence of variations in draught proved to be justified when applied to tank records of a C 3 vessel. These records covered the following ranges:

Speed	14–17 knots
Draught	21 ft. 0 in.–28 ft. 6 in.
Displacement	12,411–17,446 tons

the standard deviation of C_s being 2·8 per cent.

Note.—The standard deviation

$$F = \sqrt{\frac{\delta^2}{n}}$$

when n—the number of observations—is large, δ being the difference between "shp computed" and "shp recorded" in the table, and between the mean value and the actual values of C_s in the last paragraph, expressed as a percentage of the average shp or the average C_s value.

Dr. F. H. Todd, B.Sc. (*Member I.N.A.*) [*read by Secretary I.N.A.*]: For a considerable time we have been carrying out at the David Taylor Model Basin a correlation study between ship trial results and model predictions in order to determine suitable roughness allowances for different types of ship surfaces and paints. The available data on this subject were presented to the American Society of Naval Architects and Marine Engineers in a paper read in Washington in September 1951.* The ship predictions were made from the model tests by the use of Schoenherr's frictional line, and the necessary roughness allowance to make these agree with the ship trial data was represented by ΔC_f, this being the increase over and above the frictional coefficient $C_f\,(= R_f/\tfrac{1}{2}\,\rho\,S\,V^2)$ for a "smooth" ship as deduced directly from the Schoenherr curve.

Values of ΔC_f given in that paper ranged from 0·0001 to 0·0010, the range of values for clean, newly painted merchant ships lying in the range 0·00015 to 0·0004. The present standard figure for ship prediction as adopted in 1947 by the American Towing Tank Conference is 0·0004, and this is evidently in line with the above trial analysis for such ships.

During the course of the voyage of the *Tervaete* she called at New York, and Professor Aertssen visited the Model Basin and showed us some of his results. We were naturally very interested in these, and as we had a model of the Victory ship available we offered to run some tests in the condition corresponding to the ship during the new trials. Professor Aertssen in due course furnished us with the Polperro data, and we ran self-propulsion tests at the correct draught and displacements.

Before discussing any comparison between model and ship, it is essential to set down the exact procedure adopted for the analysis.

The model was of wood, 20 ft. in length, finished with standard grey glossy paint. It was run in the large model basin at Carderock, which has a width of 51 ft. and a depth of 22 ft. Turbulence was artificially stimulated by means of studs as proposed by Hughes and Allan at the National Physical Laboratory. A small effect was noted over the speed range of the trials. The results with studs were used in the comparison. This model had already been run at the time the Victory ships were designed. It was re-finished for these tests and run at the exact displacement and draughts to conform with the ship conditions on the Polperro mile.

The standard practice in running propulsion tests at the Taylor Model Basin is to pre-load the resistance dynamometer to take account of the difference in specific frictional resistance between model and ship, so that the model propeller may be running under correct thrust loading intensity. The amount of pre-loading will obviously depend upon the ΔC_f used in any given case. This is normally taken as 0·0004 in new designs, but for trial correlation the thrusts on model and ship are compared, after preliminary runs, and a value

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* "Skin Friction Resistance and the Effects of Surface Roughness," by Dr. F. H. Todd, p. 315 of Transactions of S.N.A.M.E., 1951.

of ΔC_f chosen to bring these values into agreement. For the *Tervaete* trials this was found to be 0·0016.

The trial data supplied by Professor Aertssen refer to two separate occasions—the first in calm seas at two speeds, the latter being measured by pitot-log, the second in moderate weather on the Polperro measured mile, when four runs were made at each of four speeds. On the first trial the displacement was estimated to be 11,716 tons, on the second 12,245 tons.

Since the trials the shaft has been calibrated and the value of the torsional modulus G has been found to be 11,220,000 lb./sq. in. The earlier power figures supplied to the Taylor Model Basin by Professor Aertssen have been corrected in this respect. Since the torsionmeter was at the aft end of the tunnel, an allowance of 1½ per cent has been made for the friction in the stern tube to obtain the delivered horsepower (dhp) at the propeller. Since the calm-water trials were made after those at Polperro, it is presumed that the pitot-log speeds have been corrected for the calibration error found on the measured mile. The latter tests showed the actual speed to be from 0·8 to 2·1 per cent greater than shown by the pitot log.

In order to compare the results of the two trials, the figures for the calm-water tests have been corrected to estimated figures at 12,245 tons displacement, as shown in the table below.

In order to eliminate so far as possible the effect of weather, the values of the torque ϕ were plotted against the speed V and it was found that the ϕ in the moderate seas was some 6 per cent higher than in calm weather. This is not a large effect, which might be expected in view of the very short wave-length of 60 ft. compared with the length of the ship. A plot was also made of the values of ϕ against N for the ship in rough and smooth water and also for the model propulsion tests. These curves were all consistent, and indicated that a change of 6 per cent in ϕ was accompanied by a similar change of 1½ per cent in N. If we accept these figures, the resulting effect of weather is equivalent to a change in dhp of some 7½ per cent.

Fig. 19 shows the trial results for calm water corrected to the larger displacement and those in moderate weather after correction to calm sea conditions as outlined above. The five sets of spots are now reasonably consistent. The lowest set at 11·16 knots is probably not as accurate as the others due to the difficulties of measuring ship powers at this speed, and has been omitted.

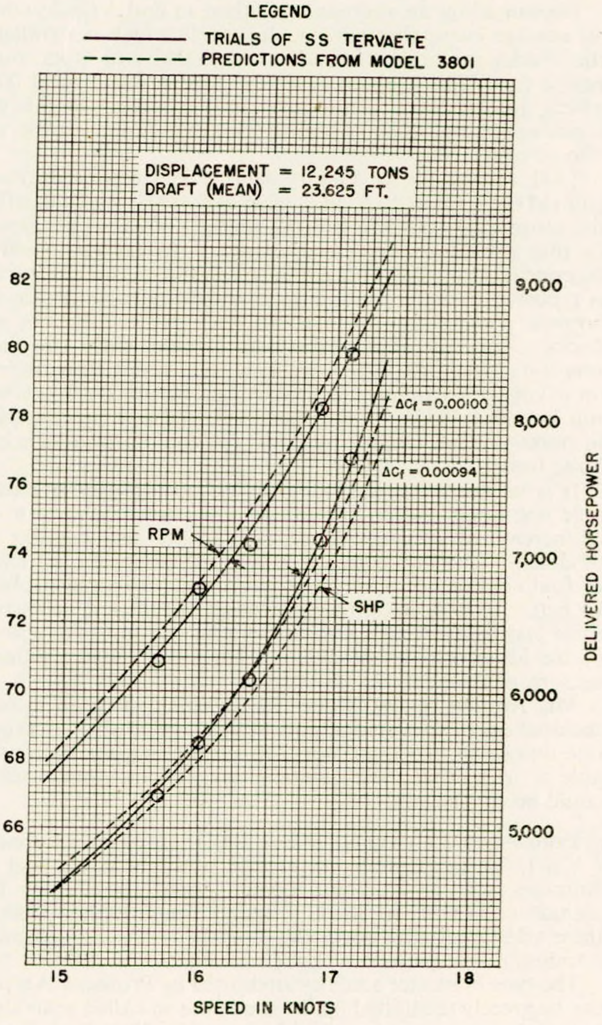


FIG. 19

As stated above, a ΔC_f of 0·0016 was used in running the model tests, based upon a comparison of model and ship thrusts. After they were completed, it was found that this allowance was too great for correlation between ship and model powers. Professor Aertssen has commented on the difficulties experienced in obtaining steady and accurate thrust readings, and after careful consideration we believe that the comparison should be made on the basis of power rather than thrust. Examination of the trial thrust values indicates that they are rather high. The ship propulsive coefficient calculated using the model $(l - t)$ would become about 0·9, which when compared to the model results appears too high. Furthermore, the thrust coefficient also appears to be too high. The predicted power and revolutions were plotted to a base of speed for the allowance of 0·0016, and were found to be higher than the ship figures as set out above. The values of N were then reduced at each speed until they coincided with the trial values of N, and the new dhp figures worked out on the basis that dhp varied with N^3. From a knowledge of the model ehp and the propulsive coefficient, the value of ΔC_f can be found, and was in this instance 0·00094. The corresponding power curve is shown in Fig. 19, with the appropriate ΔC_f label.

Trial	Δ tons	V knots	dhp	*rpm* N	Torque ϕ lb. ft.	Thrust T lb.	Weather
18.4.52	12,245	17·10	7,709	79·9	506,740	155,420	Calm sea
19.4.52	12,245	16·00	5,617	73·0	404,100	125,320	
10.4.52	12,245	16·88	7,684	78·9	511,260	153,742	Waves 60 ft. long, 2 ft. to 5 ft. high. Wind Beaufort force 2–3
	12,245	16·37	6,576	75·0	460,460	138,194	
	12,245	15·70	5,654	71·6	415,150	127,975	
	12,245	11·16	1,874	49·7	198,000	59,652	

Using this method of bringing the *rpm* into agreement has led to very consistent results in the analysis of the trials of a number of naval ships of all types. In this case it will be observed that the resultant power curve is somewhat below the ship curve, which may in part be due to wind, although we would then no longer be justified in bringing the *rpm* curves together.

We can adopt an alternative method to find ΔC_f—to draw an average curve through the ship spots which is parallel to the model prediction for $\Delta C_f = 0{\cdot}00094$ and work out a new ΔC_f. This leads to a slightly higher ΔC_f, i.e. 0·0010, which, for all practical purposes, is the same. In this case a new *rpm* curve slightly higher than that found on the ship also results.

Trial results for a Victory ship when new and freshly painted correspond to a ΔC_f value of 0·0003, which is within the range of 0·00015 to 0·0004 quoted above. The increase in this allowance on the *Tervaete* is to be attributed to deterioration of the surface and to fouling. The hull surface is reported to suffer from a general deformation of side and bottom plating by indentations between the frames and floors. The fouling may be considerable, since the vessel was last docked in December 1951, and spent three months on a voyage to India and East Africa before the trials were run in April 1952. If she spent any appreciable time lying in ports in such tropical regions, the fouling may have been quite heavy.

It is believed that the value of ΔC_f is therefore a reasonable one under the circumstances. It corresponds to a rate of increase of total resistance of 0·15 per cent per day out of dock. This is a convenient way of measuring the effects of fouling, but not a very scientific one. It would probably be better to base it on the percentage time spent in harbour since last painted, although this would still not take account of the idiosyncracies of different harbours and the different seasons of the year.

Mr. Aquino of the Model Basin staff has made most of the analysis of these trials, and we would both like to express our thanks to Professor Aertssen for making the data available to us so that these comparisons with our model results could be carried out.

Professor E. V. Telfer, D.Sc., Ph.D. (*Member of Council I.N.A.*): This is a very useful and practical paper and encourages one to ask for more. Could the author also include copies of the lines, propeller, and rudder plans, as these additional data are really essential to the proper understanding of the paper?

The type of service analysis attempted by Professor Aertssen can be greatly facilitated by the use of the so-called generalized power diagram first described in my 1926–27 N.E.C. Institution paper dealing with the subject. I have attempted to prepare such a diagram from the data given by Professor Aertssen (Fig. 20). If one accepts the Polperro trial data, analysis of torque constant variation with apparent slip results in the ship propeller evidently having a higher absorption than the model, even after duly allowing for the reduced tail-shaft modulus. This, of course, is extremely unlikely and would point to two explanations. Either the hull was very badly fouled and was greatly increasing the wake into the propeller, or the ship propeller mean pitch was considerably greater than the designed value. There is no doubt that the hull *was* foul during the trials, but investigating all the observations given by the author, there is no clear evidence of any significant change in the absorption rate at any time over the period of the observations. The alternative explanation that the true mean pitch of the ship screw is greater than the designed value receives full support from the actual measurement given by the author. It is not clear, however, how the mean pitch errors at each radius were established. If they represent the mean of measurements taken over the blade leading half, at the blade centre, and over the trailing half, they are probably useless for their intended purpose if the two former tend to cancel out a greater error over the trailing half. Only the trailing half pitch should be used for such checking. Further, it is clear that a simple sum of the errors does not give the mean error over the whole propeller. The errors must be at least weighted by the radius. Proceeding thus would give twice the error indicated by the author in Appendix IV and would suggest that the mean pitch was nearer 22·9 ft. than the designed value of 22·5.

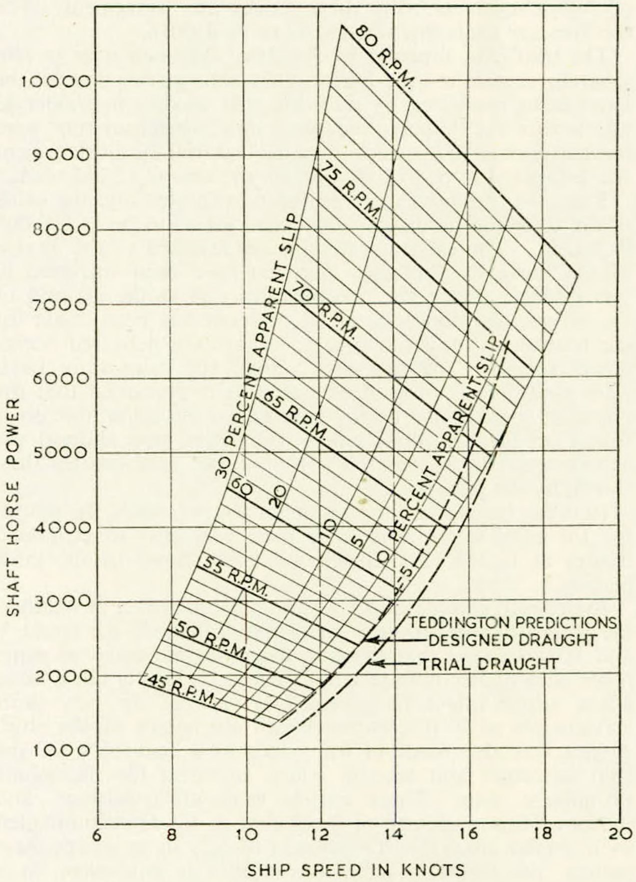


FIG. 20.—S.S. "TERVAETE." GENERALIZED POWER DIAGRAM

Whilst the use of this pitch now brings the ship absorption below that of the model (using the designed pitch) a greater difference would normally have been expected. Lewis (*Trans. S.N.A.M.E.*, 1951, p. 617) has a reference to the ship-model correlation of the Victory ship (vessel O, his Table I) and comments on the model torque wake being much lower than that of the ship. The very "approximate" nature of the ship screw might evidently be a sufficient explanation in both cases.

However, despite the discrepancy in pitch a generalized power diagram has been prepared from the Polperro mile data using a mean pitch of 22·9 ft. This is shown in Fig. 20 and I trust that the diagram may be found useful, particularly in view of the current concerted attack on the Victory ship correlation problem.

I am greatly interested in Professor Aertssen's showing that ship propulsive losses due to weather can be expressed as linear functions of such disturbing causes as wave height, etc.; and further, that these losses are relatively the greater the lower the relative power with which the vessel faces the weather. I drew attention to these facts of ship behaviour in the N.E.C. paper above referred to and also in a later paper of 1934–35 before the same Institution. In a further paper to be read in June of this year in Belgium, on Professor Aertssen's home wicket, I will give a development of this work and show that a simple power-loss factor can be devised to measure non-dimensionally the effect of weather on ship performance. The idea of non-dimensional weather is also introduced; and the data now given by Professor Aertssen should prove useful in developing the new approach.

Professor Aertssen's reference to the state of the hull between the light and load draughts on inspection in New York after the Polperro trials is of special value. Accepting the barnacle height of 1/48 in., this corresponds to a relative roughness of 4×10^{-6}, which in turn corresponds to a fully saturated roughness specific resistance of 2·39. At a Reynolds number of 10^9, the corresponding resistance of a smooth surface is 1·54; and as the roughness density is said to have been 30 per cent, reference to my 1951 Institution paper (Section 11) shows that $\sqrt{2} \times 0{\cdot}30$ or 0·775 of the difference between 2·39 and 1·54, i.e. 0·66, will be the additional resistance due to this roughness and density. The frictional resistance at 10^9 is thus increased 43 per cent by the roughness described by Professor Aertssen. As shell fouling is generally worse on the bottom than on the sides, this calculated excess is not likely to be an over-estimate. Allowing for the actual weather on the Polperro mile, it follows that the very large difference between the model and ship is capable of simple quantitative evaluation. This ship-model correlation work would be increased in value if the author could persuade Dr. Allan to supply a tabulation of the actual data measured on the model. Such data are always better presented in factual rather than in what may now be pardonably termed Froude fictional form!

Turning now to a more detailed examination of the self-propelled model results, a study of Table C suggests that correlation between ship and model in the elements of propulsive efficiency is evidently not going to prove too easy in these Victory ship tests. Whilst on both trial and designed conditions the behaviour of the propulsive coefficient and $\textcircled{C}$ is quite rational, i.e. the former decreases as the latter increases, it is curious that in the designed condition both open and behind efficiencies perversely show the opposite behaviour. Thus, despite the drop in propulsive coefficient, both propeller efficiencies improve with speed increase. In a ship this behaviour is extremely unlikely. In the model it is difficult to say what it means. That the results are so anomalous that one is tempted to dismiss them as erroneous might be unfair to Dr. Allan, but if for each speed one calculates the quantity $\textcircled{C}/(1 - t)(1 - W_t)^2$, which is equivalent to thrust over speed squared, and plots open efficiency against this function, the resulting behaviour appears to be physically impossible. Since the very purpose of the author's work is to help straighten out all these exasperations, I wonder whether Dr. Allan would care to re-examine the constituent efficiency analysis for the designed condition and particularly at speed 15 knots and above. The behaviour of rotative efficiency is quite different in the two conditions. The trial condition behaviour appears to be normal and rational, but the designed condition is again irrational. I suggest that the time is long overdue for the professional reassessment of the real physics of relative rotative efficiency. It is not the experimental dust-bin sometimes imagined, although careless testing may evidently have made it so; and I am not referring here to the present tests. As now universally measured it is erroneous in principle, for as such it is not an efficiency but at best a wake distribution factor. When the factor is unity the feed into the propeller is equivalent to uniform. When the factor exceeds unity the wake is greater at the inner radii than at the outer. To obtain real relative rotative efficiency the thrust horsepower distribution and integral over the blade must be known. This real rotative appears to vary inversely as the wake distribution factor, i.e. inversely as the classic rotative. I have previously suggested that this loss in thrust horsepower is equivalent to a loss in effective pitch, and this provides one method of approximating the real rotative without experimentally determining the thrust horsepower distribution. I interpose these observations to incite Dr. Allan to find some physical explanation of the curious rotative behaviour in the present case. If greater knowledge of the behaviour can lead to improved overall efficiency, the fact that so many Victory ships are concerned could lead to a commercial economy fully justifying much further experimenting.

Mr. K. D. A. Shearer (*Associate-Member I.N.A.*): In making any comments on Professor Aertssen's very interesting paper, it is fully appreciated that in research of this nature the scientific requirements must generally be seconded to the economic service requirements of the vessel.

As is seen from the paper the thickness of the boundary layer was generally greater than the length of the rodmeter and therefore the value of the calibration factor k would be expected to vary depending on the degree of fouling. In voyages I and II, Boma–New York and Antwerp–Gibraltar, the vessel was approximately seven to eight months and two weeks respectively out of dock, but the same k value was used for both voyages, and this would appear to be a possible source of error. A knowledge of the velocity distribution within the boundary layer during voyages I and II would have assisted in indicating whether the assumption of a constant k value on these two voyages was justified. The velocity distributions shown in Fig. 3 appear to relate only to the hull conditions on voyage III and subsequent voyages.

The method of obtaining the approximate preliminary calibration involving the assumption of an unchanged current on two occasions nearly ten days apart must always be open to considerable doubt. Although the current was probably weak, it does appear essential to calibrate the log using pairs of runs carried out with the minimum time interval, as is the practice on standard measured mile trials.

Monsieur G. Dufour (*Member I.N.A.*): I represent the owners of the *Tervaete* so perhaps you are now looking at the victim of all this discussion.

When Professor Aertssen asked me if we would allow him to make the experiments, we could well appreciate their scientific interest, but we also saw that he wanted to do to the ship all sorts of things which are not easy to carry out in ordinary service.

In the end we agreed to the experiment being made, but we did not allow a loaded trial trip nor the calibration of the shaft.

Professor Aertssen, however, is a very accurate, exacting, stubborn and obstinate fellow, and in the end he got his way in everything he asked.

Now that it is all over, we are glad the trials took place. The data which Professor Aertssen and his staff have collected are impossible for an owner to obtain from the analysis of ordinary logbooks.

Apart from the scientific lesson which you, gentlemen, seem to have drawn from those data, we have learned, I think, a practical commercial lesson. We knew that in the course of years, even in a well-kept ship, the hull of that ship is never as smooth as it is when new. Professor Aertssen's experiments have shown us that perhaps the increase in roughness due to years is greater than we had expected. From this we have drawn the conclusion that we would do well to be more careful of drydocking and painting than we have been in the past, especially when a ship is comparatively new. Frequent drydocking, good brushing and first quality paint applied properly might save us more money than many complicated mechanical gadgets.

Written Contributions to the Discussion

Mr. R. E. Clements, B.Sc. (*Associate-Member I.N.A.*): Professor Aertssen is to be congratulated on presenting us with what must be the most comprehensive set of voyage data yet published.

Perhaps their best feature from the point of view of hull performance is the fact that the ship speeds have been measured by means of a pitometer log, thus enabling a higher degree of accuracy to be obtained than is generally possible. This is particularly useful when measuring service performance by means of the Admiralty coefficient, where any error in speed measurement is cubed. Quite considerable errors in estimating Admiralty coefficient can be introduced by this means.

Another interesting feature is the good agreement between the wind speed as measured and as estimated by the ship's officers. If the agreement is as good in all voyage abstracts, here is at least one estimate of external conditions which can be relied upon. It is unfortunate that a similar comparison was not made with regard to wave height.

The estimates of wave heights (which do not of course appear in a normal log) and the description of the state of the sea attached to waves of a given height vary so considerably that I feel it would be most useful to have a standard scale for use by all vessels supplying service data. I have extended Fig. 11 to cover all displacements and waves up to 30 deg. off the bow, the resulting plot being shown in the accompanying figure (Fig. 21). The fact that decrease in speed with increase in wave height is so nearly linear suggests that a scale may be used which increases linearly with wave height. This will have the added attraction of giving the mariner a ready means of estimating what his loss of speed for a given day under given external conditions is likely to be. Such a scale is already used by some Dutch owners, the direction of encounter being given in intervals of 10 deg. from the bow while the wave heights are divided into a scale of half-metre intervals. It is not suggested that such a closely graded scale is necessary, but the introduction of such a scale would help to eliminate human reaction to external conditions and at the same time provide a good basis on which the sea-going qualities of different vessels can be compared, a basis which at present is non-existent.

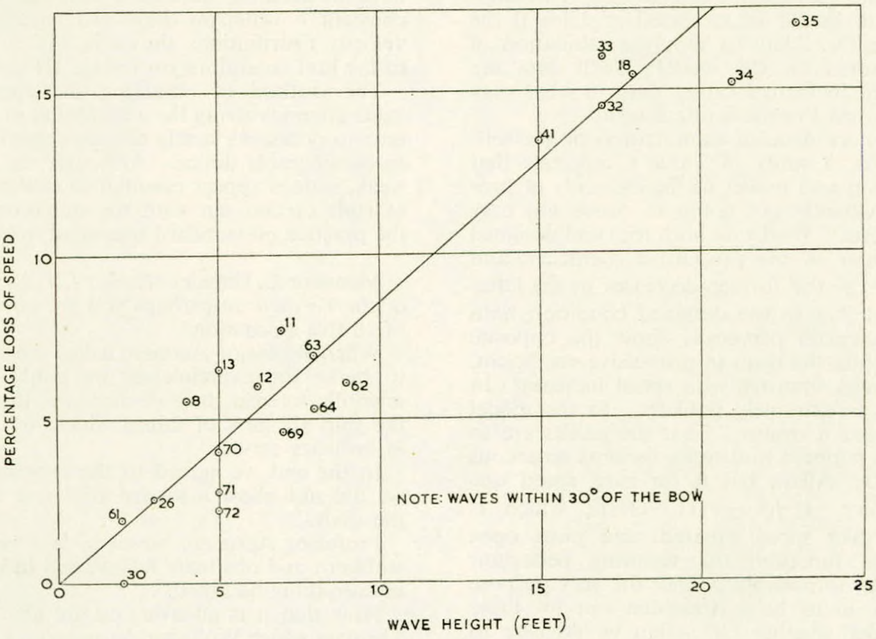


FIG. 21.—LOSS OF SPEED IN WAVES

I am not quite clear as to what Professor Aertssen has taken as his fine weather datum on which the increases in power due to weather are based; whether he has taken fine weather data for a given speed and displacement and related all the voyages to this datum, or whether the increases in power relate to the fine weather performance at the corresponding displacement for each voyage.

One of the great difficulties in analysing service performance is to analyse the data in such a manner as to give a true representation of the facts, and I am inclined to think that neither C_s nor Admiralty coefficient can do this for us. The ideal coefficient to use is, of course, one which does not vary with either displacement or speed, so that all service results can then be related to the fine weather loaded trial data of the new ship. Now neither C_s nor Admiralty coefficient satisfy either of these conditions. For example, the increase in C_s with speed on the Polperro measured mile trials is 17 per cent, of which, according to Table X, 9 per cent can be attributed to changes in the weather during the course of the trials, leaving an 8 per cent increase with speed. Therefore, if speed is reduced under adverse conditions from, say, 16·88 to 11·16 knots, the maximum and minimum trial speeds, the effect of the weather conditions on C_s will immediately be under-estimated by 8 per cent.

A better method of analysing service performance is to use the propeller as a measuring dynamometer and analyse in terms of dhp/N^3 and apparent slip. The relationship between dhp/N^3 and apparent slip can be determined either statistically or by a simple plotting or by modifying the $k_Q - J$ curve to represent the propeller working in fields of various wake strengths and assuming a linear relationship over the normal working range of slip. The values of dhp/N^3 and apparent slip under various conditions can then be determined and the power necessary to maintain a given speed under those conditions estimated.

This estimate of the increase in power to maintain a certain speed may be somewhat hypothetical, since obviously under certain conditions speed must be reduced. Nevertheless, it has a distinct value in comparing the performance of the vessel at different seasons of the year, in different conditions of fouling and at periods throughout her life.

Author's Reply

Reply to Dr. Allan

The accuracy of the thrustmeter indeed was not better than 6 per cent in dead calm. The probable error was larger in waves, even when their height was not considerable, due to the wide oscillations of the needle of the gauge. Dr. Allan says that the propulsive coefficients deduced from the measurements at sea are in reasonable agreement with model figures. I agree with his statement that the accuracy of our measurements at sea is not such that one could attempt to establish a scale effect from the results. I feel that Dr. Allan supposes the ehp/dhp values of the tables were corrected for the reduced modulus of rigidity which was found ultimately to have a value of 11,220,000 lb. per sq. in. Such was not the case; after due allowance for the reduced modulus the ehp/dhp values are somewhat higher than 80, say generally 83 per cent. They are indeed on the high side and the eccentricities at the bearing surfaces of the levelling plates of main thrust are probably responsible for it.

Dr. Allan's statement that temperature corrections should not be applied to the ship is true, in so far that they are not usual. However, different textbooks, "Speed and Power of Ships" (Taylor), "Resistance, Propulsion, and Steering of Ships" (Van Lammeren, Troost, Koning, p. 57), "Theory of Naval Architecture" (Robb, p. 409), recommend the temperature correction, though these authors do not make any difference between models and ships. The Paris Conference in 1935 recommended a skin friction correction of 0·43 per cent for a change of one degree C.

Professor Telfer: It was agreed only as a model change and not as a ship change.

Professor Aertssen: I agree with the fact that for a fouled ship, which is roughened, the correction is questionable. But I think that, as the viscosity decreases with increasing temperature, it is not erroneous to make the correction for a smooth hull.

Fig. 3 gives indeed the velocity distribution in the boundary layer for the voyage Plymouth–New York and for the ship in very much dirtier condition. The velocity distribution for a clean ship was not measured during previous voyages. However, at the end of 1952, that was the year of the voyages Plymouth–New York and New York–Copenhagen, the ship having afterwards made another voyage to India, she was dry-docked, and at the beginning of 1953 the velocities in the boundary layer were measured on the clean vessel. This was the velocity curve I showed Dr. Allan, and as this curve comes even lower than the curves Plymouth–New York and New York–Copenhagen I think it may be interesting to give a new diagram, Fig. 22, completing Fig. 3 wherein the curve clean ship is included. At the same time the diagram Fig. 3 is corrected for the 1-in. error of the distance of the impact orifice to the shell plating I mentioned in the addendum. In the addendum, too, I mentioned that this curve clean ship was, within a distance of 8 in. from shell plating, fairly exponential with $n = 0 \cdot 136$ in smooth water.

Dr. Allan comments upon the correlation ship-model. We must keep in mind that all the dhp measured at sea and given in the tables are to be lowered by 4 per cent. If we do that, the difference between the performance of the clean *Tervaete* and a new well-painted flush-welded form, a difference which was substantial, decreases: the allowance of 20 per cent for dhp is reduced to 15 per cent. Furthermore, referring to diagram Fig. 15 (A), showing the performance of the clean ship, it is mentioned there that full-scale data were corrected to 28 ft. 0 in. As these full-scale data were obtained with draughts some 2 or 1½ ft. less than 28 ft. 0 in., there may be a slight error in this correlation, especially if we take into consideration the large difference of propulsive efficiency from 28 ft. to 23·562 ft. The comparison of C_s for clean ship and dirty ship, four months later, gives some 12 per cent, which is in contrast with the more than 20 per cent given by the tank correlation. A comparison of C_s for varying draughts is somewhat questionable, and probably the fouling effect is more than 12 per cent, but I guess a similar error, although not so large, is made in correcting full-scale data from 26 to 28 ft. Altogether, the fouling effect will be somewhat less than given by the ship-model correlation.

Dr. Allan gives an Admiralty coefficient of 490 at 16 knots predicted by the tank results. For the vessel in service, with a clean hull, that coefficient is 440 after due allowance for the reduced shaft modulus.

I agree with Dr. Allan's statement that, strictly speaking, weather effect in Figs. 10, 11, 12, 13, and 14 should be given by curves, not by straight lines. More results in bad weather than the few I obtained could perhaps have helped to find more correct lines. However, with the results I obtained, no better than approximate straight lines could be drawn through the spots. It should be emphasized that it is not possible to obtain very accurate measurements in high seas. It is probable that when the period of encounter is near the pitching period of the ship the relation loss of speed–period of encounter is no longer linear; that region, however, with large pitching angles is very difficult to explore and is not covered by the relation which does not extend beyond 4 to 5 seconds period of encounter.

Reply to Prof. van Lammeren

I am glad to learn some results of the trials of the 17 knots Victory ship *Arnedijk*. The allowance on dhp predicted by the tank for the self-propulsion point of ship is for this ship 14 per cent at a relative wind speed of 8 to 11 m./sec., the wind being about 40 deg. off the bow, and a wave height of 0·25 m. This allowance is very close to the allowance on dhp of 15 per cent given in Fig. 15 (A), after due allowance for the reduced shaft modulus.

In comparing trial *rpm* and estimated *rpm* at the same dhp, Prof. van Lammeren found an increase in Fig. 15 (A) and a decrease in Fig. 15 (B) for the trial *rpm* on the estimated *rpm*. No doubt simultaneous readings of dhp, thrust, *rpm* and speed would have given better results and I admit that it is very difficult to maintain exactly the same speed in bad weather during half an hour. However, the curves Fig. 15 (A) are obtained from calm water tests, while the curves Fig. 15 (B) relate to the trials on the measured mile in moderate weather, when no large variation in *rpm* was stated from run to run. Therefore the curves in Fig. 15 must give a good picture of the trial conditions. I wonder whether Prof. van Lammeren has applied to the dhp curves the allowance due to the reduced shaft modulus obtained from calibration after the paper was printed (see addendum). After due allowance for the reduced shaft modulus I confess that there still remains a difference which cannot be explained by the discrepancy of the actual pitch only. Probably there is a slight difference of wake scale effect between conditions (A) and (B), and Prof. Bonebakker gives the explanation, I think, where he states in his contribution: "Generally speaking, a decrease in draught involves a decrease in wake." Indeed, the lower draught in condition B involves a lower wake.

Reply to Prof. Bonebakker

Applying regression analysis to our results, Prof. Bonebakker finds F values which are characteristic for the accuracy of our measurements. I am glad to see that the standard deviations we obtained during our voyages Plymouth–New York and New York–Copenhagen are very close to the standard deviations 1·97 and 1·94 per cent Prof. Bonebakker finds in the sample calculations I and II of his paper he referred to in his contribution. Prof. Bonebakker writes column (4) $\text{shp}/(0 \cdot 1\ \text{N})^3$: this is understood to be $\text{dhp}/(0 \cdot 1\ \text{N})^3$.

I certainly agree with Prof. Bonebakker's remark on the great difficulties of getting accurate measurements of torque and thrust during bad weather and that the regression equation will be of great help in such circumstances for computing reliable figures of dhp from *rpm* and speed values. I think, however, that, though *rpm* can be measured with a good approximation even in bad weather, speed measurement by a pitot log—and Prof. Bonebakker will agree it is the best instrument to use for this purpose—is very difficult, too, in high seas.

Reply to Dr. Todd

As the T.M.B. had a model of Victory ship available I was very glad to hear that Dr. Todd offered to run some tests.

The correlation model–ship was established by Dr. Todd only for the voyage Plymouth–New York during which the Polperro trials took place. The result of that correlation is a roughness allowance on the Schoenherr formula of $\Delta C_f = 0 \cdot 0010$.

I undertook to compare the correlation T.M.B. with the N.P.L. correlation and I attempted to determine ΔC_f for the Plymouth–New York voyage from the results N.P.L. The Polperro data were used as well as the data obtained later in calm seas. The T.M.B. omitted the lowest set at 11·16 knots, so I omitted it too. Further, the third group

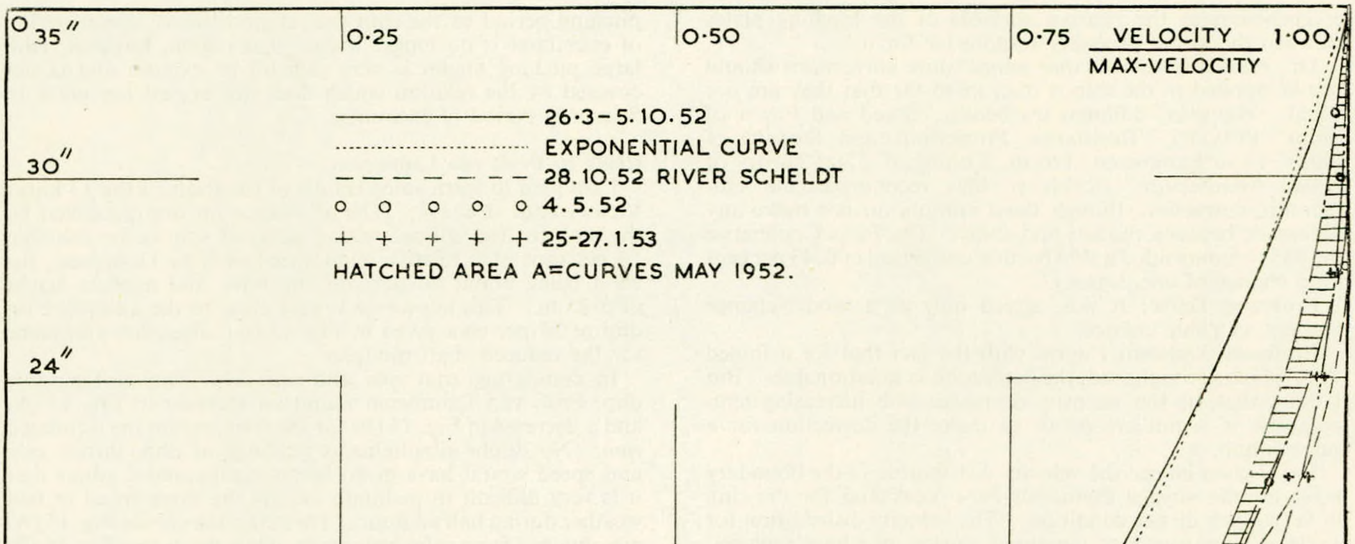


FIG. 22.—VELOCITY DISTRIBUTION IN BOUNDARY LAYER

of Polperro giving a thrust which was extraordinarily high I omitted it too. Finally I had to examine the two first groups of Polperro and three speeds in calm seas corresponding to observation numbers 27, 28, 45, 46, 47 of Table X. For the Polperro groups 27, 28 the data still air are taken from Table D.

The calculations are shown in Table XVI. From the N.P.L. resistance experiments (Table B) the residuary resistance is determined. The propulsion experiments (Table C) give the thrust deduction coefficient, and this is assumed to be the same for model and ship. From thrust T the ship resistance is calculated $T(1 - t)$. Subtracting from ship resistance the residuary resistance and the air resistance calculated from the Baker method (Ref. 6) I obtain the skin friction resistance. This is finally reduced by 2 per cent on account of the resistance due to rudder deviations and bilge keels. C_f is then calculated on a basis of a wetted surface obtained from the hydrostatic curves of the Victory ship.

It is also possible to calculate C_f from dhp and a quasi-propulsive coefficient taken from propulsion experiments (Table C). The dhp values are corrected for the reduced modulus of the shaft and the propulsive coefficient is reduced by 2 per cent on account of the propeller overload.

The Polperro trials give a mean ΔC_f value of 0·00117 calculated from thrust against 0·00099 calculated from power, while the later trials in calm seas give a mean ΔC_f value of 0·00099 from thrust and 0·00079 from power.

These values are in general agreement with the ΔC_f values given by Dr. Todd.

However, there is a considerable difference between the ΔC_f from Polperro results and the trials later on. The Polperro trials were run in moderate weather, whereas the trials later on were run in calm seas. The Polperro results were corrected to still air, although the effect of waves was not eliminated. As the residuary resistance was taken from tank resistance experiments, the whole weather effect falls on the frictional resistance. The ΔC_f difference of 0·0002 corresponds to an increase in frictional resistance of some 10 per cent, which is in agreement with the change on dhp of 7½ per cent given by Dr. Todd as weather effect for the Polperro trials.

On the other hand there is a difference of 0·0002 between

TABLE XVI

ΔC_f FROM N.P.L. SHIP-MODEL CORRELATION

1	Date	10.4.52	10.4.52	18.4.52	18.4.52	19.4.52
2	Observation number	27	28	45	46	47
3	Beaufort scale	2–3	2–3	3	3–4	2
4	Speed in knots	16·88	16·37	17·1	17·1	16
5	Reynolds number	$8 \cdot 77 \times 10^8$	$8 \cdot 52 \times 10^8$	$9 \cdot 6 \times 10^8$	$9 \cdot 6 \times 10^8$	$7 \cdot 77 \times 10^8$
6	Displacement in tons	12,245	12,245	11,760	11,760	11,700
7	ehp as predicted by N.P.L.	4,616	4,060	4,760	4,760	3,620
8	Total resistance in kg. from 7	40,350	36,620	41,050	41,050	33,420
9	Frictional resistance in kg. from Froude	25,260	23,870	25,400	25,400	22,420
10	Residuary resistance in kg.: 8–9	15,090	12,750	15,650	15,650	11,000
11	Thrust in lb. as measured T	152,405	136,169	149,600	148,700	119,900
12	Thrust deduction factor t from N.P.L.	0·22	0·22	0·22	0·22	0·22
13	Calculated resistance in kg. $T(1-t)$	53,850	48,150	52,850	52,600	42,400
14	Calculated air resistance in kg.	1,050	988	1,610	1,610	1,800
15	Calculated frictional resistance $13-(10+14)$	37,710	34,412	35,590	35,340	29,600
16	Correction for rudder deviation and bilge keels	754	688	712	707	592
17	Corrected frictional resistance in kg.	36,956	33,724	34,878	34,633	29,008
18	C_f calculated from thrust	0·00277	0·00269	0·00259	0·00258	0·00247
19	C_f from Reynolds number—Schoenherr	0·00155	0·00156	0·00154	0·00154	0·00158
20	ΔC_f from thrust measurement	0·00122	0·00113	0·00105	0·00104	0·00089
21	dhp as measured	7,545	6,450	7,460	7,380	5,455
22	Quasi-propulsive coefficient from N.P.L.	0·78	0·785	0·78	0·78	0·79
23	ehp from dhp	5,885	5,060	5,815	5,755	4,310
24	Total resistance from ehp 23 in kg.	51,500	45,600	50,150	49,700	39,800
25	Corrected frictional resistance from 24	34,653	31,223	32,232	31,791	26,460
26	C_f calculated from dhp	0·00260	0·00249	0·00240	0·00237	0·00226
27	ΔC_f from torque measurement	0·00105	0·00093	0·00086	0·00083	0·00068

the ΔC_f obtained from thrust and the ΔC_f obtained from power. One would be inclined to accept that difference as a scale effect, although I feel that at least a part of it, as I mentioned in my reply to Dr. Allan, should be imputed to the lack of accuracy of the thrustmeter.

We may conclude that, if we ignore the third and the fourth group of runs of Polperro, the thrust values are acceptable. The propulsive efficiency never exceeds 0·85. I admit that the thrust coefficient is somewhat high, due to a low *rpm*. That can be explained by the discrepancy of the pitch of the actual propeller shown in Table XIV and Table XVII (Reply to Dr. Telfer).

I thank Dr. Todd and Mr. Aquino for this contribution to our Victory research.

Reply to Prof. Telfer

As asked by Professor Telfer, I include copies of lines (Fig. 23), propeller (Fig. 24), and rudder plans (Fig. 25).

If one looks at the ship-model comparison diagram included in the contribution of Dr. Todd, which contains due allowance for the reduced modulus of rigidity, the discrepancy in the revolutions ship-model is not large at all, roughly 1 revolution for $\Delta C_f = 0 \cdot 00094$, somewhat more, say 2 revolutions, for $\Delta C_f = 0 \cdot 00100$. Now, from measurements, the mean pitch, 2 per cent more as compared with design pitch—I take that 2 per cent from Prof. Telfer's suggestion—might evidently be a sufficient explanation for the discrepancy of nearly 2 per cent in revolutions.

Although I am not clear that "only the trailing half pitch

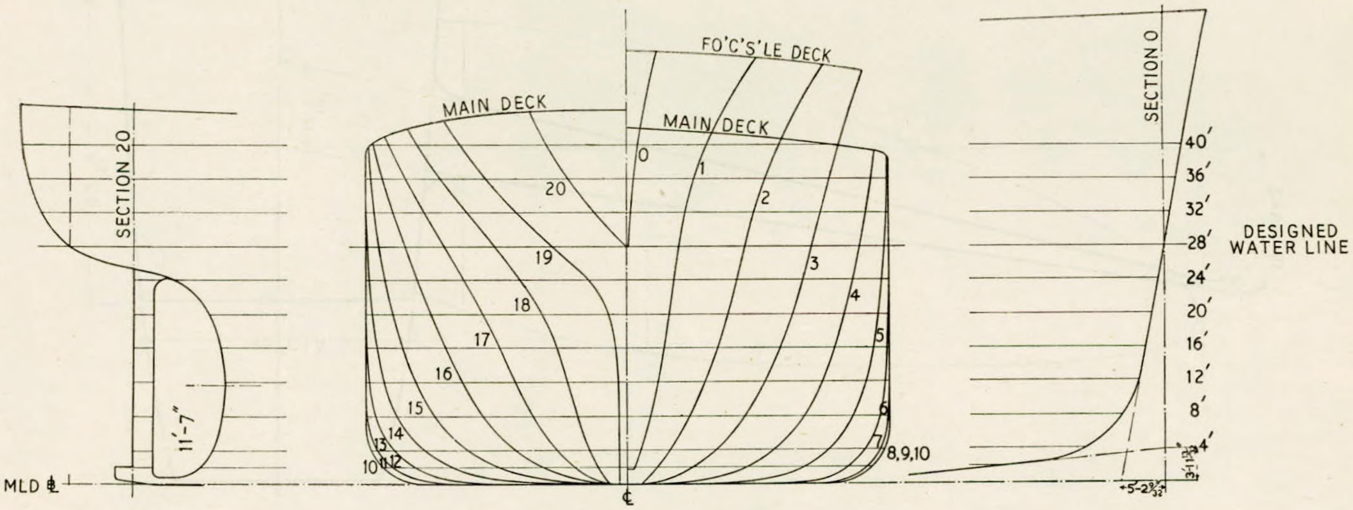
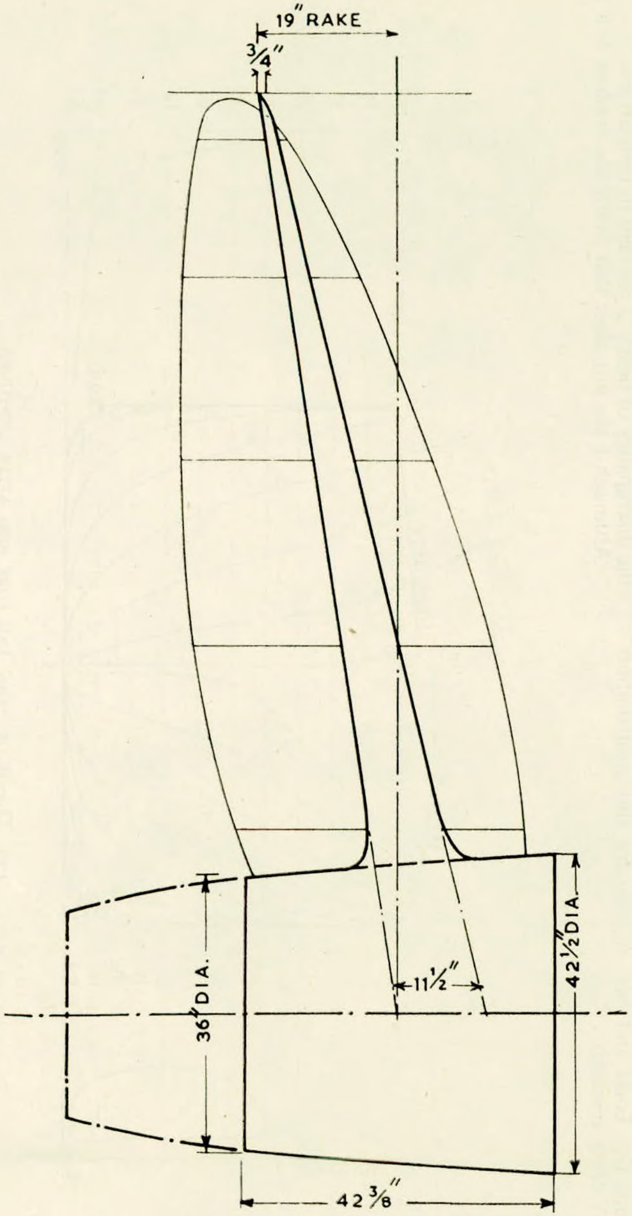


FIG. 23.—BODY PLAN AND FORE AND AFTER CONTOURS



PROPELLER DATA

Diameter	20·5 ft.
Pitch 0·6 R to tip ..	22·9 ft.
Pitch ratio	1·117
M.W.R.	0·237
B.T.F.	0·468

4 blades single screw right hand

PITCH VARIATION

0·2 R	18·82′
0·3 R	20·31′
0·4 R	21·75′
0·5 R	22·72′
0·6 R to tip	22·90′

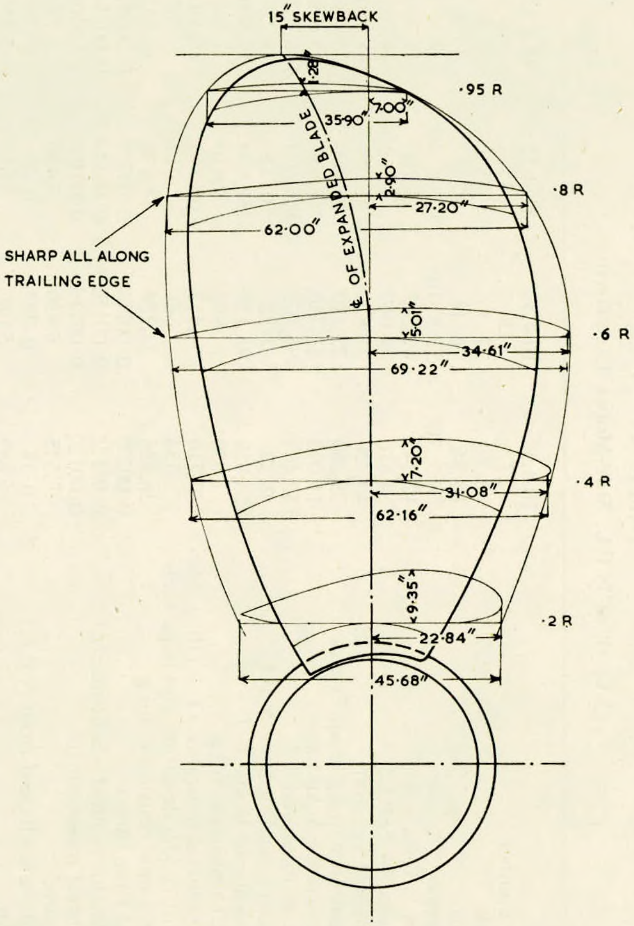


FIG. 24.—PROPELLER

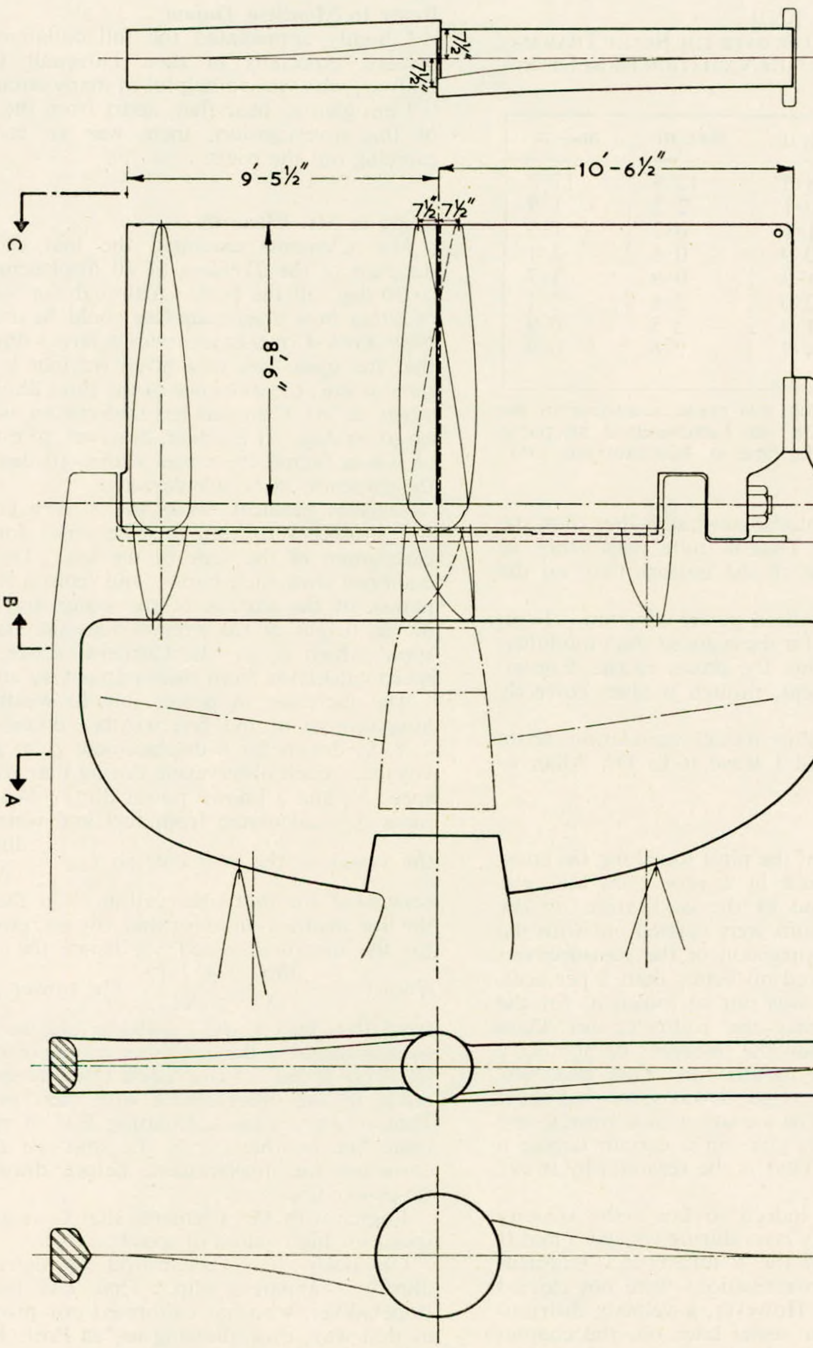


FIG. 25.—RUDDER AND STERN FRAME

should be used for the checking of the pitch," I include a new table giving the average face pitch of the propeller with mean measurements, as suggested by Prof. Telfer, only over the blade trailing half.

It is obvious that neither hull nor propeller of this eight years old ship were smooth, but the propeller was, as might be called, "commercially good."

I am much indebted for the generalized power diagram Prof. Telfer worked out for the *Tervaete* on a basis of our measurements, and I am sure the diagram will be found useful. However, a mean pitch of 22·9 ft. has been used, say 2 per cent more than the value 22·5 which Prof. Telfer takes as the designed mean pitch. Now the designed pitch variation is quite the same as the variation on the Dutch propellers A4 and B4 (Fig. 21). Hence the mean designed pitch is close to 22·7 ft., say 1 per cent less than the maximum designed pitch (Van Lammeren, Troost, Koning, "Resistance, Propulsion, and Steering of Ships," p. 208), and with the 2 per cent increase due to the variation from designed values 23·1 ft.

I was much interested in the development of Prof. Telfer's power-loss factor and for the *Ceberena* symposium in Brussels 1953. As a contribution to Prof. Telfer's paper there, I computed that power-loss factor for the *Tervaete* voyages.

Although calculations made on a basis of some measurements of barnacles' heights are to a certain extent questionable, they are certainly worth being made. Prof. Telfer finds a frictional resistance at 10^9 increased 43 per cent by the roughness I described, as compared to the resistance of a smooth surface: C_f is approximately $0 \cdot 0024$ as results

TABLE XVII

AVERAGE FACE PITCH OF PROPELLER OVER THE BLADE TRAILING HALF, EXPRESSED AS PERCENTAGE VARIATION FROM DESIGN VALUES*

	Blade I	Blade II	Blade III	Blade IV
0·2 R	− 12·9	− 8·5	− 12·9	− 17·2
0·3 R	+ 1·3	− 0·1	− 2·2	− 1·9
0·4 R	+ 3·7	+ 1·1	− 0·2	− 1·5
0·5 R	+ 4·8	+ 0·9	+ 0·6	− 2·1
0·6 R	+ 8·4	+ 1·3	+ 0·9	− 1·7
0·7 R	+ 8·9	+ 2·0	+ 2·6	− 2·1
0·8 R	+ 9·5	+ 1·2	+ 2·5	+ 0·9
0·9 R	+ 11·1	+ 4·7	+ 2·6	+ 0·9

* The measurement of the pitch was made according to the method number three given by Dr. van Lammeren in his paper to the Association Technique Maritime et Aéronautique, 1951: "Standardisation des Hélices."

from ship-model correlation, thus somewhat higher than the figure found by Prof. Telfer. That is quite reasonable, as shell fouling is generally worse on the bottom than on the sides.

A final remark on the generalized power diagram. I feel that the dhp were not corrected for the reduced shaft modulus; so, when used to obtain the dhp, the power of the diagram has to be reduced by 4 per cent, though it gives correctly engine shp.

Prof. Telfer's remarks on ship model correlation relate more to Dr. Allan's work, and I leave it to Dr. Allan to answer here.

Reply to Mr. Shearer

The preliminary calibration of the pitot log along the coast of Angola, although carried out in a very calm sea, was indeed far from being so good as the calibration on the Polperro mile, where pairs of runs were carried out with the minimum time interval. The precision of the measurement of speed was therefore considered no better than 2 per cent. For voyages I and II the hull was not so fouled as for the subsequent voyages: I feel that the rodmeter for these voyages I and II was longer than the thickness of boundary layer, while for the voyages Plymouth–New York and New York–Copenhagen with a dirty vessel it was somewhat short for the thicker friction belt. The variation of k from 0·992 to 1·015, oscillation around 1, gives in a certain degree a picture of the phenomenon. That is the reason why 0·992 was admitted.

It would have been useful indeed to know the velocity distribution within the boundary layer during voyages I and II for a better comprehension of the k difference. Unfortunately those boundary layer investigations were not carried out during voyages I and II. However, a velocity distribution was measured on a clean vessel later on, the characteristics being given in the addendum. In my reply to Dr. Allan I give a new boundary layer diagram (Fig. 22) which now includes the velocity curve for a clean vessel.

It is clear, however, that the data of Table IX have not the accuracy of the data of Tables X and XI.

Reply to Monsieur Dufour

I highly appreciated the full collaboration of the shipowners, especially of their Directeur General, Monsieur Dufour, who was so helpful in many circumstances.

I am glad to hear that, apart from the scientific character of this investigation, there was an economic interest in carrying out the trials.

Reply to Mr. Clements

Mr. Clements extended the loss of speed-wave-height diagram of the *Tervaete* to all displacements and waves up to 30 deg. off the bow. Although for waves within 10 deg. of either bow a separate line could be drawn for the voyage New York–Copenhagen with a larger dhp/Δ, demonstrating that the speed loss in a given weather is less at high power than at low, the influence of the ratio dhp/Δ is not so evident when, as Mr. Clements has undertaken, waves are considered up to 30 deg. It is easier, however, to estimate the direction of waves facing the vessel within 10 deg. off the bow than the direction of broadside waves.

Modern nautical books are a very good guide allowing ship's officers to estimate the wind force from a precise description of the state of the sea. The *Tervaete* was well equipped with such books, and from a conscientious examination of the surface of the water and a good estimation of the height of the irregularities the staff deduced a wind speed which is, as Mr. Clements states, close to the wind speed calculated from measurement by an anemometer.

The increases in power due to weather relate for each long voyage to the fine weather power-speed curve (Figs. 7, 8, 9) drawn for a displacement Δ at a given day of that voyage. Each observation during that voyage gives a known speed V_1 and a known power dhp$_1$. We know the displacement Δ_1—calculated from fuel and water consumption—of the vessel at the moment, so $C_{s1} = \dfrac{\text{dhp}_1 \times 427{\cdot}1}{\Delta_1^{2/3} \times V_1^3}$ can be calculated for that observation. On the other hand, from the fine weather curve for that voyage, power dhp$_2$ is deduced for the measured speed V_1, hence the ideal C_{s2} is known from $C_{s2} = \dfrac{\text{dhp}_2 \times 427{\cdot}1.}{\Delta^{2/3} \times V_1^3}$ The power increase is deduced from the ratio C_{s1}/C_{s2}. Hence our increase in power, to be introduced in the diagrams, results from bad weather only, not from speed. I emphasize that the spots in the diagrams relate to the observations with their proper displacement. That is why, when calculating loss of speed related to the basic fine weather curve, the spot—or the dhp—has to be corrected for displacement before drawing the horizontal iso-power line.

I agree with Mr. Clements that C_s is greatly influenced by speed for high values of speed.

Obviously it is interesting to determine the relation dhp/N^3 — apparent slip. That has been done by Prof. Bonebakker, who has calibrated our propeller-dynamometer in that way, thus allowing us, as Prof. Bonebakker says, to collect quite a number of values computed from *rpm* and speed measurements only. But it remains necessary to compare those dhp values with the dhp values in fine weather in order to obtain weather influence on power for a given speed. This is a different point of view.

INSTITUTE ACTIVITIES

South Wales Section

Summer Tour

A tour of the Llandarcy Oil Refineries, Ltd., made possible through the courtesy of the general manager, Mr. R. B. Southall, C.B.E., took place on Friday, 17th July 1953. The party, which was led by Mr. J. H. Evans, M.B.E., included seventeen students from Cardiff Technical College.

The refineries, the first of their kind in the British Isles for the treatment of imported crude oil, commenced operations in July 1921, and before the war had a throughput of 360,000 tons per annum. Since the end of the war the refineries have been greatly enlarged by the installation of new machinery, and the target now was to process 3,500,000 tons of crude oil per annum to provide for an expanding United Kingdom market. In 1949 a new atmospheric distillation plant was installed to provide the basis of high octane motor spirit.

After Mr. G. M. Dalley, the chief engineer, had welcomed the party, the training superintendent, Mr. P. F. Ellis, gave a brief survey of the refineries and explained the principles underlining the refining of crude oil. Two films were shown, one illustrating the distillation processes and the other on the development of the oil tanker.

After lunch the party was taken to Queens Dock, where the company's five wooden jetties had recently been replaced by reinforced concrete jetties of modern design. Boarding the British Tanker Company's tanker *British Yeoman,* the party was conducted round the various departments of the ship, and the general features of a tanker were explained to the students by Mr. W. Gracey (Member).

Returning to the refineries, a visit was made to the new power station and central sub-station under the direction of Mr. D. G. Curtis, the power engineer. A new boiler house with an installed capacity of 600,000lb. of steam per hour at 550lb. per sq. in. was nearing completion, and would be followed by the installation of three turbo alternators having a capacity of 13,000 kW. A landmark in the district were three cooling towers, each capable of cooling a total of 15,000 gallons of water per minute from 120 degrees to 80 degrees.

The members of the party showed great interest in all they saw, and their appreciation of the knowledge gained and the hospitality shown was well expressed by Mr. J. H. Evans (Member). Among the officials who entertained the party and did much to make the occasion a success were Major W. S. Bryan, who was in attendance during the whole of the tour, Mr. M. Morgan (Member), boiler house superintendent, and Mr. R. Pritchard (Member), development engineer.

Election of Members

Elected 21st July 1953

MEMBERS

Frank Carter
Frederick Henry Deal
Robert Elwood Ellis
David John Fairley
James Foulkes
Ronald Graham Groves
Hugh James Houston
David Keddie Lynn
David Meikle
Wilfred Allan Plummer, Lieut.(E), D.S.C., R.N.
Norman Reid
Thomas Smeaton
Norman Turner
Victor Alfred Tom Wade, Lieut. Com'r(E), R.N.

ASSOCIATE MEMBERS

Kenneth Chisholm Barnes-Moss
Donald Charles Cooper
George Charles Scott
Richard Newrick Thompson

ASSOCIATES

John Beck
Joseph Bezzina
Robert Bowie
Frederick Thomas Brown
Leslie Seymour Brown
Percival Kenneth Coles
John Bernard Cowan
Laurence Thompson Davidson
Michael James Ferrers Giddings
Jack Holt
John Francis Richard Ince
John Macaskill
Donald Ernest McKelvey
Murray Robert Osborne
Patrick Moran Peden
Bruce Pragnell, Comm'd Eng'r, R.N.
Harold Alfred Pugh
Ghosh Rameswar
Andrew Shaw
Anthony Bennett Smith
Charles Leslie Smith
Maurice Herbert Stevens
Ronald Stott
Dennis Keith Tappin
Kenneth Milburn Thompson
Joe Turner

GRADUATE

William Patrick Lawler

STUDENT

Hugh Alexander McDowall Cowan

PROBATIONER STUDENT

Keith Dalton Seiler

TRANSFER FROM ASSOCIATE MEMBER TO MEMBER

Mark Hamilton Freer Chaytor, Lieut. Com'r(E), R.N.

TRANSFER FROM ASSOCIATE TO MEMBER

Eric Burden
John Francis Crane
John Francis Fraser
Charles Noel Lamb
John Desmond McCarten
Andrew Moore
Jal Pestonjee
Raymond Harry Rowe
Andrew Cochrane Smith

TRANSFER FROM GRADUATE TO ASSOCIATE MEMBER

John James Springate

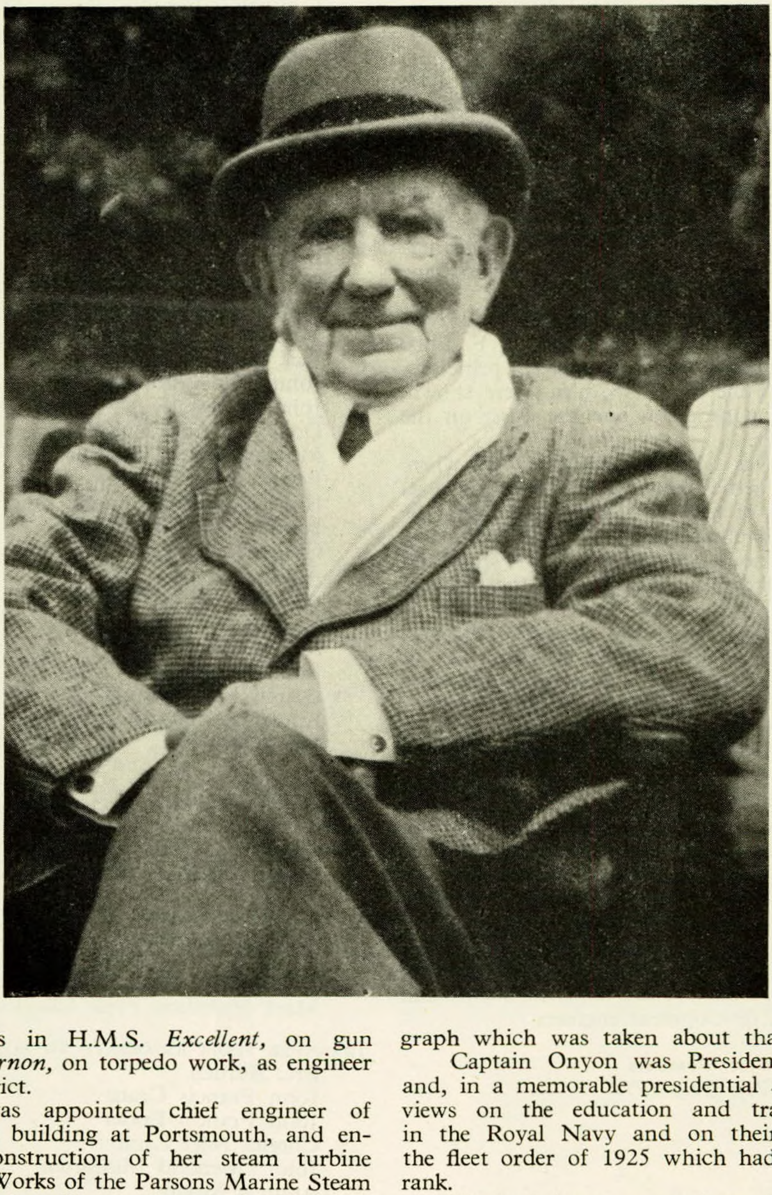
TRANSFER FROM GRADUATE TO ASSOCIATE

Peter Beaumont Wishart

ENGINEER CAPTAIN WILLIAM ONYON, M.V.O., R.N.

By the death, on 19th July 1953, of Engineer-Captain William Onyon, M.V.O., R.N.(ret.), marine engineering has lost one of its most colourful personalities; for Captain Onyon, who entered the Royal Navy at a time when some of the older capital ships still carried square rig as auxiliary to their steam reciprocating propelling machinery, was the first chief engineer of the famous *Dreadnought,* the first turbine-driven battleship, and was closely associated also with the design and construction of H.M.S. *Argus,* one of the earliest aircraft carriers.

Captain Onyon was born at Belvedere, Kent, on 24th June 1862, and so was in his ninety-second year at the time of his death. He was educated at Christ's Hospital and, on joining the Navy in 1878, in H.M.S. *Marlborough,* for many years the engineer students' training ship at Portsmouth. Later, he attended the Royal Naval College at Greenwich, leaving at the end of 1884 on appointment to H.M.S. *Monarch,* an ironclad turret ship. Subsequently, he served in H.M. ships *Ajax, Alexandra, Thunderer* and *Agamemnon* before being transferred in 1891, for a short period, to the engineering department at the Admiralty. From September 1891 to the end of 1893, he was the engineer officer in charge of the hulls and machinery of the flotillas of torpedo boats based on Malta. After this, he was sent to the shipyard of Yarrow and Company at Poplar as engineer overseer for the destroyers *Dasher* and *Hasty.* He served for a time at sea in both these vessels before being appointed, in November 1898, manager of the engineering department at H.M. Dockyard, Jamaica, where he was stationed until the beginning of 1902. During the next three years he was engaged, after short periods in H.M.S. *Excellent,* on gun mountings, and H.M.S. *Vernon,* on torpedo work, as engineer overseer for the Clyde district.



In July 1905 he was appointed chief engineer of H.M.S. *Dreadnought,* then building at Portsmouth, and engineer overseer on the construction of her steam turbine machinery at the Turbinia Works of the Parsons Marine Steam Turbine Company, Wallsend-on-Tyne. He remained in this pioneer warship for three years, gaining experience in the use of steam turbines which made it almost inevitable that his next appointment should be to the Engineer-in-Chief's department at the Admiralty, since the decision had been taken that all new warships should have steam turbine machinery. He was promoted engineer captain in June 1911 and almost immediately was appointed to H.M.S. *Medina,* the P. and O. liner chartered to take King George V and Queen Mary to India for the Durbar at Delhi. For this service, he was made a Member of the Royal Victorian Order. He continued at sea as staff engineer of the First Battle-Cruiser Squadron, his last ship being H.M.S. *Lion.* At that time, he was the senior naval engineer officer to be serving afloat. He retired from the Navy in January 1913.

Immediately after his retirement, Captain Onyon was appointed engineering manager at the Dalmuir shipyard of William Beardmore and Co., Ltd., where he remained for twelve years, during which time he was responsible for the construction of machinery for a large number of warships and merchant vessels. Among them were the Italian liners *Conte Rosso, Conte Verde* and *Conte Biancamano,* and also H.M.S. *Argus,* originally designed as a liner for the Lloyd Sabaudo Line of Genoa, which was acquired by the Admiralty and converted to an aircraft carrier. She was notable for having a completely flush flight-deck, the boiler flue gases being discharged astern through horizontal ducts. In 1926, Captain Onyon was transferred to the London office of Beardmore and Company, where he remained until the Dalmuir shipyard was closed. Subsequently, he was retained in a consultative capacity by Vickers-Armstrongs, Ltd., and was also associated with the Perfecta Tube Co., Ltd. Eventually, he retired to Plymstock, Devon, where he lived for the rest of his life with his younger daughter and her husband, Lieut. Com'r T. H. B. Pounds, his wife having died in 1938. Captain Onyon enjoyed excellent health until his ninetieth birthday in June 1952, as will be seen from the accompanying photograph graph which was taken about that time.

Captain Onyon was President of the Institute in 1927 and, in a memorable presidential address he expressed strong views on the education and training of engineer officers in the Royal Navy and on their status, as exemplified by the fleet order of 1925 which had deprived them of military rank.

He had been a member of the Institution of Naval Architects since 1910 and served on the Council from 1926-33; he was also a member of the Institution of Civil Engineers. During the period that he spent at Dalmuir, he was a member of council, and eventually a vice-president, of the Institution of Engineers and Shipbuilders in Scotland; and for a number of years he was a member, and an active supporter, of the Institute of Metals.

Obituary

EDWARD FRANK SPANNER

Edward Frank Spanner, R.C.N.C. (ret.), was born at Portsmouth in 1888 and entered H.M. Dockyard, Portsmouth, as a shipwright apprentice in 1902. At the age of eighteen he was awarded a scholarship to the Royal Naval Engineering College, Keyham, and in 1907 went to the Royal Naval College, Greenwich, where he had the distinction of being first of his year in the passing-out examination.

[By courtesy of "Shipbuilding and Shipping Record".

Following a year's seagoing experience in H.M.S. *Temeraire,* Mr. Spanner served as an assistant constructor at the Admiralty. At the end of the 1914-18 war he resigned from the Royal Corps of Naval Constructors to take up an appointment as assistant general manager to R. and H. Green and Silley Weir, Ltd., the London ship repairers. He left this company and started in private practice as a consulting naval architect in 1923, devoting particular attention to the development of new methods of ship design and construction. It was during this period that he began to attract notice as an inventor, notably of the duct keel and of the "soft" stem, constructed of fashioned plate instead of the forged bar, which is now in general use. At this time, the Government were spending large sums on the construction of rigid airships; Mr. Spanner vigorously opposed that policy and wrote several books to ridicule it. His great interest in the Royal National Lifeboat Institution was reflected in his study of life saving apparatus, and in 1940 he produced the Spanner life raft, many thousands of which were manufactured during the war. A buoyant rocket head for use with the Schermuly piston rocket apparatus was another of Mr. Spanner's inventions and this equipment was standard for certain war time Royal Air Force and similar rescue services.

Waste heat recovery had attracted his attention as early as 1924 and in 1934 Mr. Spanner formed a company (now Spanner Boilers, Ltd.) to develop new ideas and improved designs of thimble tube boilers for waste heat recovery plant for land installations, railways and marine services. Four years later, he invented the helically grooved fire tube which he named to "Swirlyflo" tube.

At the outbreak of the 1939 war, he was recalled for Admiralty services with the Director of Naval Construction at Bath, but was released after three months' service to attend to the numerous contracts that his company were undertaking for the Admiralty. The Department of Merchant Shipbuilding later engaged his services as the consultant responsible for the economical production of ferro-concrete craft. He had been a naval architect assessor to the Board of Trade, and subsequently to the Ministry of Transport, since 1924.

Mr. Spanner was a member of the Institution of Naval Architects, the Institution of Engineers and Shipbuilders in Scotland, the North-East Coast Institution of Engineers and Shipbuilders, and the Society of Naval Architects and Marine Engineers in New York, and had contributed papers to all of them. He was also a Fellow of the Society of Consulting Marine Engineers and Ship Surveyors, and a Liveryman of the Worshipful Company of Shipwrights.

Mr. Spanner became a Member of the Institute in 1919 and took an active and generous interest in its affairs from that time until his death. He presented several papers between 1919 and 1935 and frequently contributed to discussions on the subjects in which he was interested. He served on the Council for two three-year periods, from 1932-34 and from 1936-1938. He gave special support at all times to matters concerning the junior members and attended their social functions to the last. He was a member of the Junior Section Committee during 1933 and 1934 and then, for the next ten years, until 1945, he was convener. Mr. Spanner died suddenly on 3rd August 1953.

OBITUARY

Emile Isidore Alexandre Buchard (Member 12912) was well known in marine engineering circles at Le Havre, where he had been in business as a consulting marine engineer and ship surveyor since 1948. He was born in 1890 and, after four years at the Institut Technique Maritime du Havre, he went to sea for a year as an engineer officer in the French Navy. From 1913-45 he served as third to chief engineer (as chief from 1922) with the Compagnie Générale Transatlantique, having obtained a French First Class Certificate of Competency in 1914. From 1946-48, M. Buchard was manager for Béliard, Crighton and Co., Ltd., before setting up his own business. He died of heart trouble on 7th July 1953. He had been a Member of the Institute since 1950.

James Carnie (Member 9291) was born in 1884. He served an engineering apprenticeship with Wilson and Vass, Oban, from 1900-04, and with Caird and Company of Greenock from 1904-05. For the next two years he sailed as second engineer with G. and J. Burns in their Glasgow and Belfast steamers and then joined the British India Steam Navigation Company, serving as fifth to third engineer with them until 1911. From 1911-13, Mr. Carnie was chief engineer and dredging master of the harbour works, P.W.D. and marine department, Madras; from 1913-34 he was chief engineer of the Madura Mills Co., Ltd., Madura, Southern India, when he retired on pension. Mr. Carnie lived in retirement until his death on 19th July 1953. He was elected a Member of the Institute in 1941.

Philip Wadsworth Crabtree (Member 7172) was born in 1886. From 1896-02 he attended Christ's Hospital (the Bluecoat School) and then started an engineering apprenticeship with the Fordingham Iron and Steel Company; his apprenticeship was continued when, from 1905-07, he was an indentured pupil with Richardsons, Westgarth and Co., Ltd., Middlesbrough. From 1907-11 he served as a seagoing engineer with Furness, Withy and Co., Ltd., the International Line Steamship Co., Ltd., and Rowland and Marwoods Steamship Co., Ltd.; he also spent a short time in 1908 working as a mechanic on the gun turrets of H.M.S. *Invincible,* then building at Sir W. G. Armstrong Whitworth and Co., Ltd., Newcastle-on-Tyne. From 1912-20 Mr. Crabtree sailed exclusively in vessels of the Peninsular and Oriental Steam Navigation Company. He obtained a First Class Board of Trade Certificate.

For the next two years he was an engineer surveyor for the London Guarantee and Accident Co., Ltd., Municipal Mutual Insurance, Ltd., the Motor Union Insurance Co., Ltd., and the United British Insurance Co., Ltd. From 1923-27 he was inspecting engineer with the European branch of the Robert W. Hunt Company (U.S.A.). on work involving the inspection and tests of railway and engineering materials, building of locomotives, and so on. At the time of his election to membership of the Institute in 1932, Mr. Crabtree had been engaged since 1928 as inspecting engineer with Imperial Chemical Industries, Ltd., principally in the testing and supervision of manufacture of large high pressure vessels for chemical processes. During the second world war he was employed as a senior examiner in the stores division of the Air Ministry.

He died on 17th July 1953. He had been an Associate Member of the Institution of Mechanical Engineers and a Member of the Institution of Engineering Inspection.

FRANK S. EVANS (Member 1748) was born in 1871. He served an apprenticeship with the City Engine Works, Eagle Wharf Road, London, E., and first went to sea in 1890 on a voyage to the Far East in the s.s. *Keemun.* In 1896 he joined M. Samuel and Company, then managers of the Shell Line, as the tanker fleet of the Anglo-Saxon Petroleum Co., Ltd., was then known, as third engineer; after serving the company as chief engineer for some years, Mr. Evans was appointed superintendent engineer in 1913. Some years later he was promoted senior superintendent engineer, a position he held until ill health and failing eyesight obliged him to retire in 1940. He died on 2nd April 1953.

When Mr. Evans joined the company, Shell tankers carried general cargo on alternate voyages and steam generation was by means of coal; he therefore saw the beginning of oil fuel burning in ships' boilers and was largely instrumental in overcoming the difficulties of this revolutionary development. He had been a Member of the Institute since 1904.

JOHN EDWARD PAKENHAM GRANT (Member 12231) was born in 1884. He served an apprenticeship with Earles Shipbuilding and Engineering Co., Ltd., at Hull, after attending Hull Technical College for three years. In 1909 he went to America and his subsequent experience was all gained in that country. From 1909-17 he was a draughtsman consecutively with the Staten Island Shipbuilding Company, the Atlantic Gulf and Pacific Dredging Company, the New York Shipbuilding Company, the Seattle Construction and Dry Dock Company, and the Union Iron Works. For the next six years he was chief designing engineer with the Merchants Shipbuilding Company of Chester and Bristol, Pa. From 1923-26 he was factory superintendent with the Globe Ticket Company, Philadelphia, and from 1926-29 superintendent of the National Freight and Delivery Company in the same town. In 1929 he was appointed chief draughtsman of the Philadelphia Electric Power Equipment Corporation and continued in this position until the beginning of the war in 1939, when he was employed (until 1948) by the U.S. Maritime Commission; in 1948 he was transferred to the United States Embassy as an attaché. He died on 16th June 1951.

Mr. Grant was a Member of the American Society of Naval Architects and Marine Engineers and was elected to membership of the Institute in 1949.

DANIEL THOMAS HORSNELL (Member 1803) was born in 1880 and died suddenly at his home on 1st November 1952. He received his early training at the Regent Street Polytechnic, later serving an engineering apprenticeship with R. Hoe and Co., Ltd., printing machinery and general engineers of South East London, and was responsible for supervising the erection of machinery in all parts of the British Isles.

In 1904 he was recalled to take up the managing directorship of Matthew Keenan and Co., Ltd., on the company's incorporation as a limited company, under his father, and the late James Dore, first chairman of the company, who were old friends of the late Matthew Keenan, who first began the manufacture of non-conducting coverings in the year 1858. In 1919 he assumed the chairmanship of the company on the death of the first chairman, holding both positions until he relinquished his managing directorship in 1944.

Mr. Horsnell was a Freeman of the City of London, an Associate Member of the Institution of Mechanical Engineers and a Member of the Institution of Engineers-in-Charge; he was elected a Member of the Institute of Marine Engineers in 1905.

JOSEPH S. MACKIE (Member 1996) died early in 1953. He served an apprenticeship with Hunter and English, Bow, London, E., and spent seven years at sea, mostly in vessels owned by the Orient Line, obtaining a First Class Board of Trade Certificate. For the last forty years of his working life he was chief engineer in vessels of the Amazon Telegraph Company. Mr. Mackie was elected a Member of the Institute in 1907.

ROBERT MORAN (Associate 3891) was born in Bury, Lancashire, in 1890. He served an apprenticeship with John Whitehead and Co., Ltd., of Elton, near Bury, and spent a short time at sea before emigrating, in 1930, to the United States. He worked as a diemaker in Utica and Syracuse before settling in Lockport, N.Y., in 1936, as a tool designer with the Harrison Radiator Division of the General Motors Corporation, a position he held at the time of his death on 6th August 1953. Mr. Moran had been an Associate of the Institute since 1920.

WILLIAM L. PULLEN (Member 1928) was born in 1880. His career followed closely that of his twin brother, George A. Pullen (also a Member of the Institute), who died in August 1951. He attended a private school and Birkbeck College, London, and then followed three years as a pupil at the Royal Shipbuilding and Engineering Co., Ltd., "De Schelde", Flushing, Holland, from 1895-98. For a further year, he was an improver fitter and erector with Maudsley, Son and Field, Ltd., of Lambeth.

Mr. Pullen then entered the business of his father, the late Frederick A. Pullen, a machinery merchant having a large connexion with the principal shipbuilders and engineers of Holland. The merchanting side of the business did not greatly interest him or his brother, however, and soon afterwards they formed the firm of Frederick A. Pullen and Company, which specialized in pumping machinery, which business they carried on together until April 1950 when the firm was made into a limited company, of which they were both directors.

Mr. Pullen was elected a Member of the Institute in 1907.

JOHN JAMES ROGERS (Member 1701), who was born in 1864, died on 28th June 1953 aged eighty-eight years. He served an engineering apprenticeship with Alexander Stephen and Son, Govan, from 1881-86 and then spent the next fourteen years at sea, sailing as chief engineer for the Marbella Iron Ore Co., Ltd., and Lindsay, Gracie and Ward, both of Cardiff. He attended W. Aitken's School for Marine Engineers in Cardiff to prepare for his Board of Trade Examinations. In 1901 he was appointed superintendent engineer for W. R. Nicholson (Corinthian Steamship Company) and for Joseph Brown and Company and shortly afterwards he set up in business as a consulting engineer. Mr. Rogers had lived in retirement since 1921. He was elected to membership of the Institute in 1903.