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Notes on the Turbo-electric Propulsion Equipment of the Liner "Normandie".

READ

BY MONSIEUR E. ROTH.

On Tuesday, February 11th, 1936, at 6 p.m.

CHAIRMAN: THE PRESIDENT.

Synopsis.

PRINCIPAL characteristics of the "Normandie's" propulsion equipment. Speed regulation. Comparisons between turbo-electric and geared propulsion, showing that the first-named system gives the following advantages: (1) reduction of noise and vibration, (2) economy at reduced speeds during winter service, (3) low fuel consumption, due to greater freedom in the choice of the characteristics of the machinery, (4) superior manœuvring flexibility, (5) ease of braking and going astern, (6) reliability in rough weather, and (7) accuracy of measurement of torques and propelling powers.

Notes concerning equipment required for future vessels, and suggestions for improving the present steam cycle of the "Normandie".

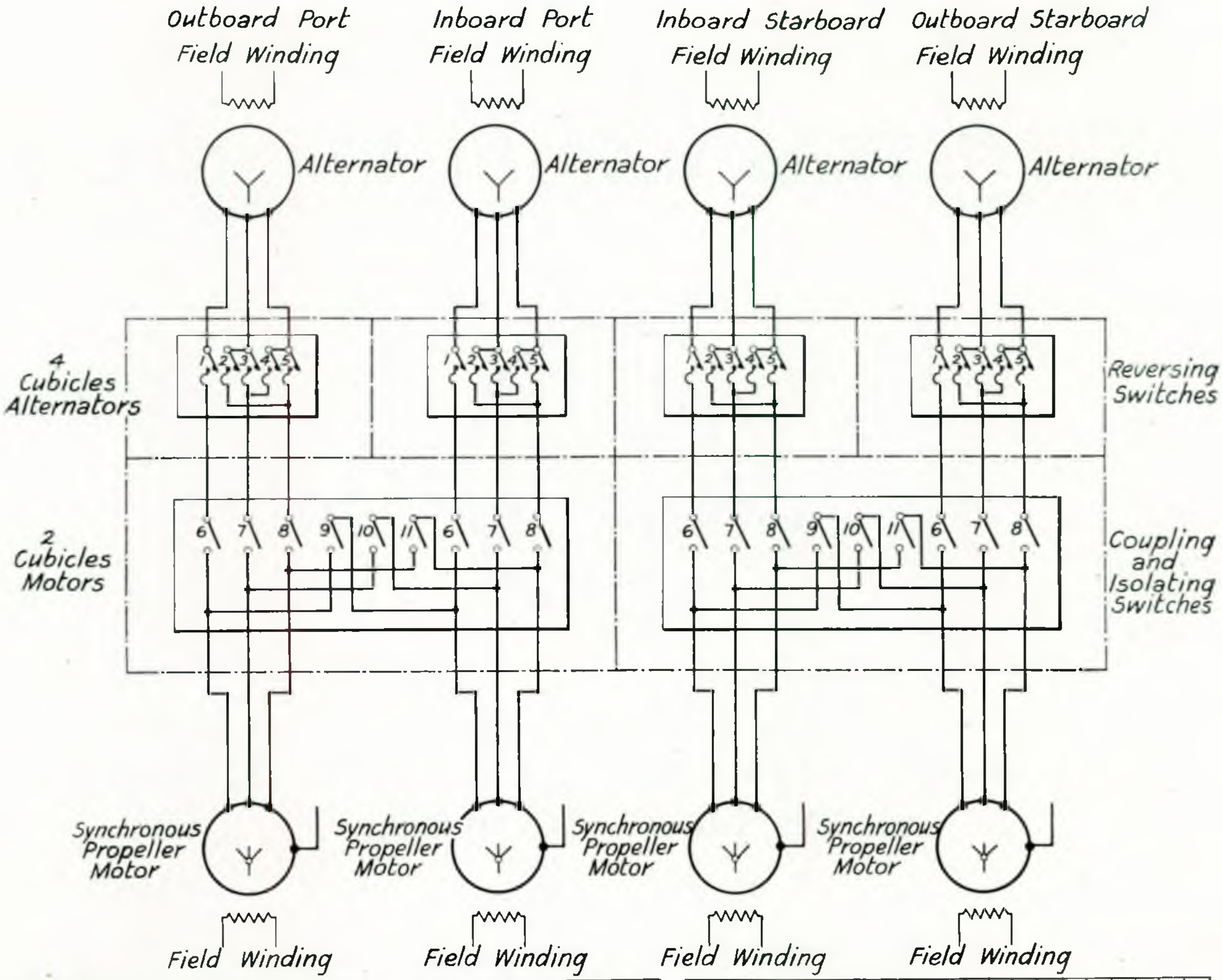
Turbo-electric propulsion for warships. Provision for important differences in characteristics of warships and liners. Advantages of the system for war vessels.

Conclusions Drawn from Service Performance.

After the many very full and detailed articles which appeared last May in the technical journals of the whole world, it may be asked whether there is still something new to be told about the turbo-electric propulsion equipment of the liner "Normandie". Actually all these articles were drawn up before the trials of the ship, and consequently do not take into account the evidence brought to light at sea. After five months of regular service between Le Havre and New York, it is possible, from an observation of facts, to obtain information useful for the future, both for commercial ships and warships.

First, let us recall briefly the principal characteristics of the engines of the "Normandie", which were designed and produced by the Société Alsthom in co-operation with the Cie. Générale Transatlantique and the Penhoet shipyards.

The propulsion equipment consists of four synchronous propeller motors fed by four



Position of Switches	Contacts made by the Switches	6	7	8	9	10	11	6	7	8
0	All circuits open									
1	Outboard Motor on Outboard Alternator Inboard Motor and Alternator disconnected	●	●	●						
2	Outboard and Inboard Motors in parallel on Outboard Alternator	●	●	●	●	●	●			
3	Outboard Motor on Outboard Alternator Inboard Motor on Inboard Alternator	●	●	●				●	●	●
4	Outboard and Inboard Motors in parallel on Inboard Alternator				●	●	●	●	●	●
5	Outboard Motor and Alternator disconnected Inboard Motor on Inboard Alternator							●	●	●

● Contact Closed

Diagram showing closing sequence of main contacts on coupling and isolating switches of one side

Position of Reversing Switches	Contacts made by the Reversing Switches	1	2	3	4	5	1	2	3	4	5
0	All circuits open										
1	Ahead	●		●		●	●		●		●
2	Astern	●	●		●		●	●		●	

● Contact Closed

Diagram showing closing sequence of main contacts on reversing switches of one side

FIG. 1.—Simplified connection diagram.

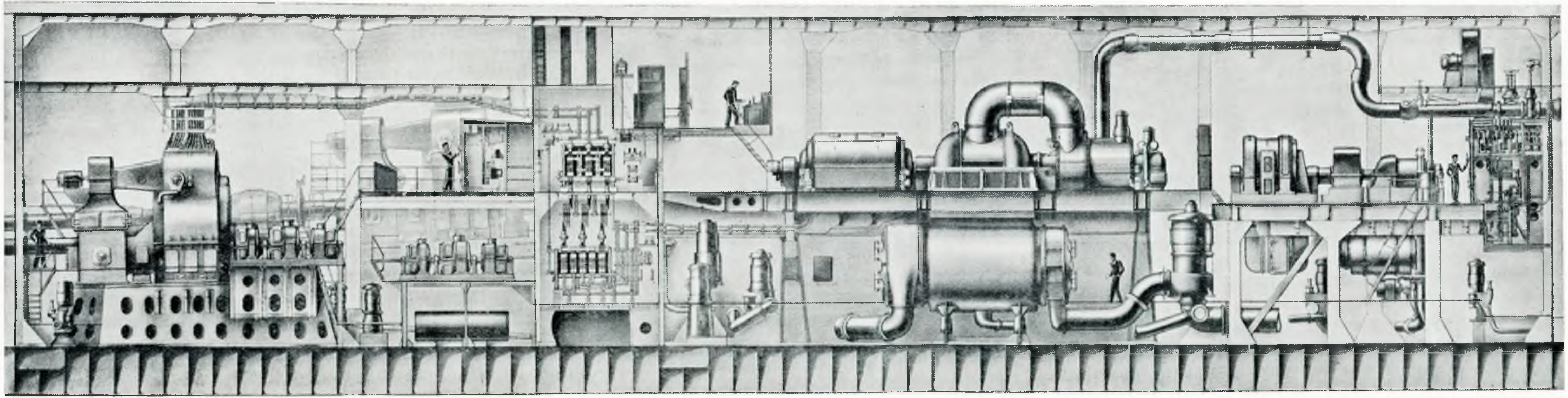


Fig. 2.—Longitudinal section.

FIG. 3.—General view of turbine room.

setting of which in relation to the steam inlet valves can be regulated at will.

The method of speed regulation is worthy of closer examination because herein lie certain important advantages of turbo-electric propulsion. At standstill, the circuit between motors and alternators is broken by reversing switches; as the name indicates, these switches also serve to reverse the direction of rotation of the propellers by changing over two of the three phases, of the three phase system; as there is now no connection between the motors and alternators it is possible to leave the turbo-alternators running at reduced speed; this "reduced" speed is about a quarter of the maximum speed.

To start up, the reversing switches are first closed in the required direction, then the alternators are excited; the propeller motors which are not yet excited, but which are provided with very robust

three-phase turbo-alternators, complete with switchgear, manœuvring equipment, and the necessary controls. No provision is made for connecting the turbo-alternator sets in parallel. The equipment on the two sides is completely independent (see Fig. 1). The "Set-up" switches only allow the two propeller motors of one side to be fed by either of the two alternators of that particular side.

The motors and alternators being synchronously connected, the ratio of the turbine speed to that of the propellers is fixed as in a mechanical coupling by gears. This ratio, which is that of the number of poles on the motors and alternators respectively, is equal to 10. The speed of the ship must, therefore, be set by varying the speed of the turbo-alternators, which are provided for this purpose with governors, the

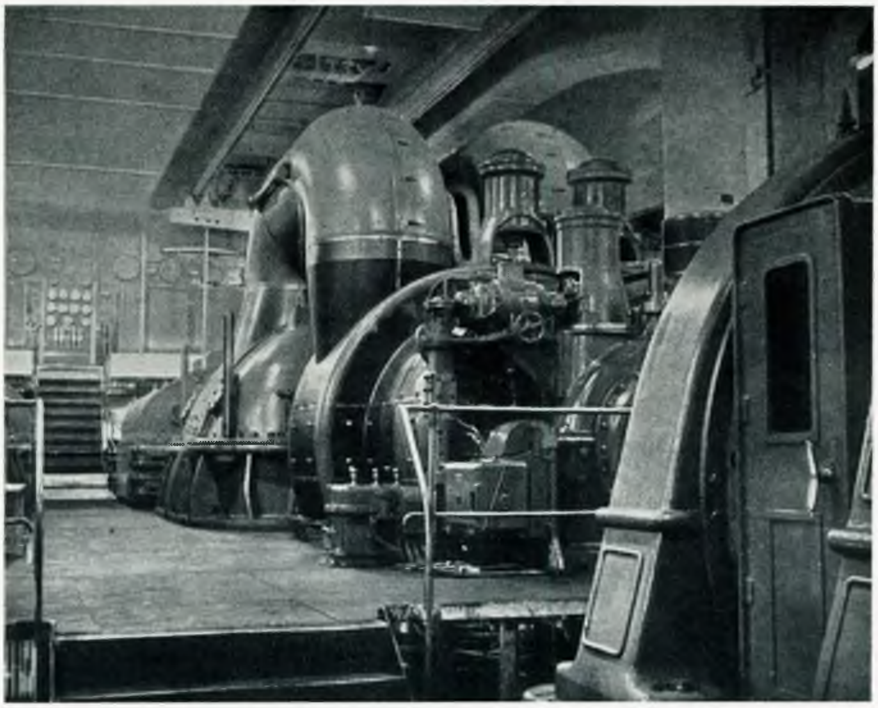


FIG. 4.—View of turbo-alternator set in the engine-room.

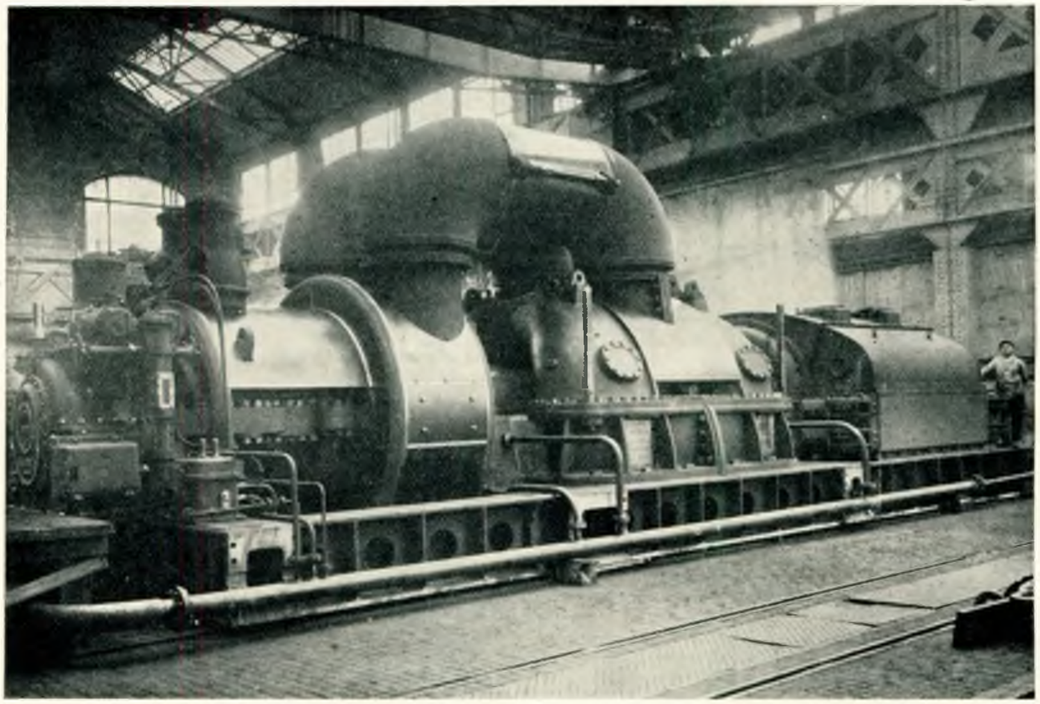


Fig. 5.—View of turbo-alternator set in the factory.

squirrel cage windings, start up as induction motors and rapidly attain a speed approaching synchronism, i.e. about one-quarter of the maximum speed. The propeller motors can then finally be brought into step as synchronous machines by applying excitation. During these various manœuvres the alternators are over-excited so as to accelerate the propellers rapidly; the excitation of the alternators can only be reduced when the running of the whole outfit has settled down. This series of operations is performed by means of a single lever for each set, called the "operating lever".

To accelerate the propellers from the manœuvring speed, that is, quarter speed up to full speed, a second lever, the "speed control lever", is actuated. This latter lever alters the setting between the governor and the inlet valve of the corresponding turbine in such a way that the "governor inlet-valve" system finds a new equilibrium position for all turbine speeds between manœuvring speed and full speed.

The installation of the engines was finished in December, 1934, and the time which passed between this date and the first trip to sea (5th May, 1935), a delay which was necessitated for the completion of the hull, was utilised for the most scrupulous finishing off of the equipment. The sea trials were also performed in a particularly short space of time; the liner started her maiden voyage on the 29th May and has since completed nine return journeys without mishap. As in the past, electric propulsion is thus shown to be an absolutely reliable propulsion system—at least as reliable as geared transmission. Moreover, many months' navigational experience has clearly shown that, as expected, this system gives the following indisputable advantages when compared with geared propulsion.

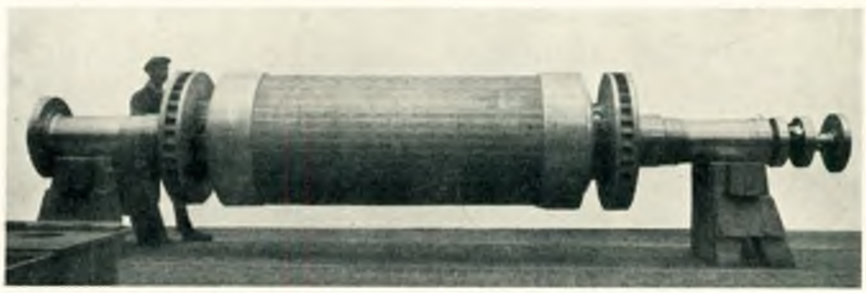


Fig. 6.—View of an alternator rotor.

1. Firstly, it is known that reduction gearing can give rise to noise and vibration, whereas electrical transmission, on the contrary, is practically silent and does not cause any vibration. The use of closed circuit air cooling with water circulated air coolers has the advantage of muffling the magnetic and ventilation noises which occur in the motors, as well as

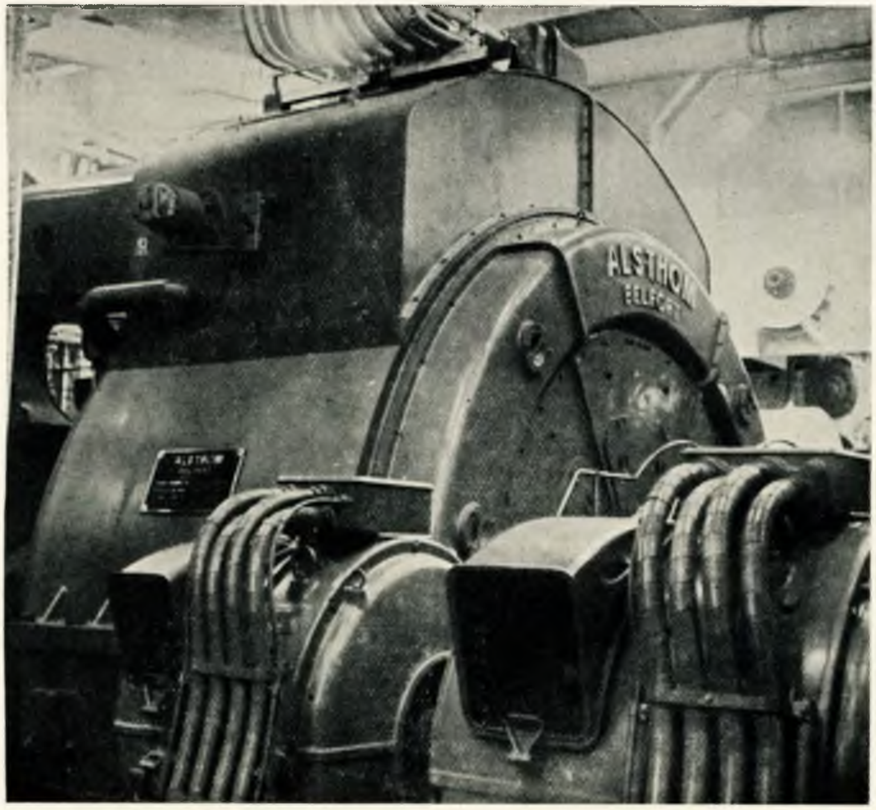


FIG. 7.—View of propeller motor and exciter set.

other advantages in simplicity and safety.

Moreover, the exactitude with which the turbines, alternators and motors have been balanced has avoided all mechanical vibrations, so that the only vibration felt on deck was due to causes inherent in fast moving ships—and particularly the propellers.

2. The speed of liners should be reduced in winter so as to avoid tiring the passengers and to reduce the stresses on the hull. By using electric propulsion, the ship can run at reduced speed with its four propellers and only two of the turbo-alternators.

As the power required to propel a ship varies approximately with the cube of the speed of the ship (within certain limits), this reduction by a half of the propelling power only corresponds to a decrease in speed of about 20 per cent. Actually it is not possible to develop exactly half power with two turbo-alternators working (without

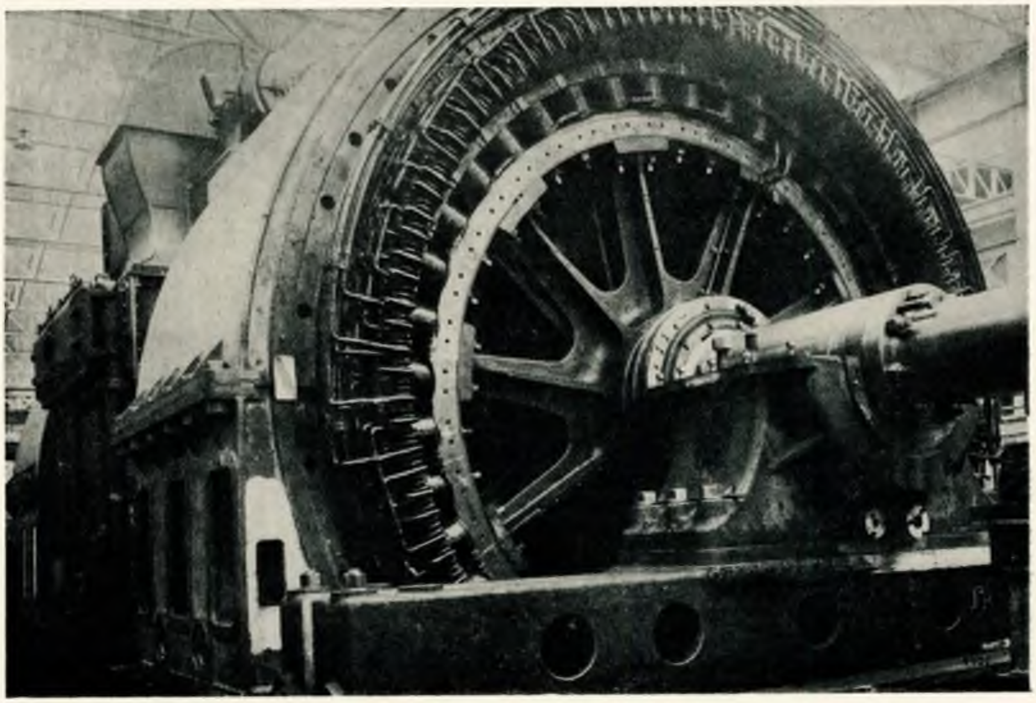


FIG. 8.—View of propeller motor with covers removed.

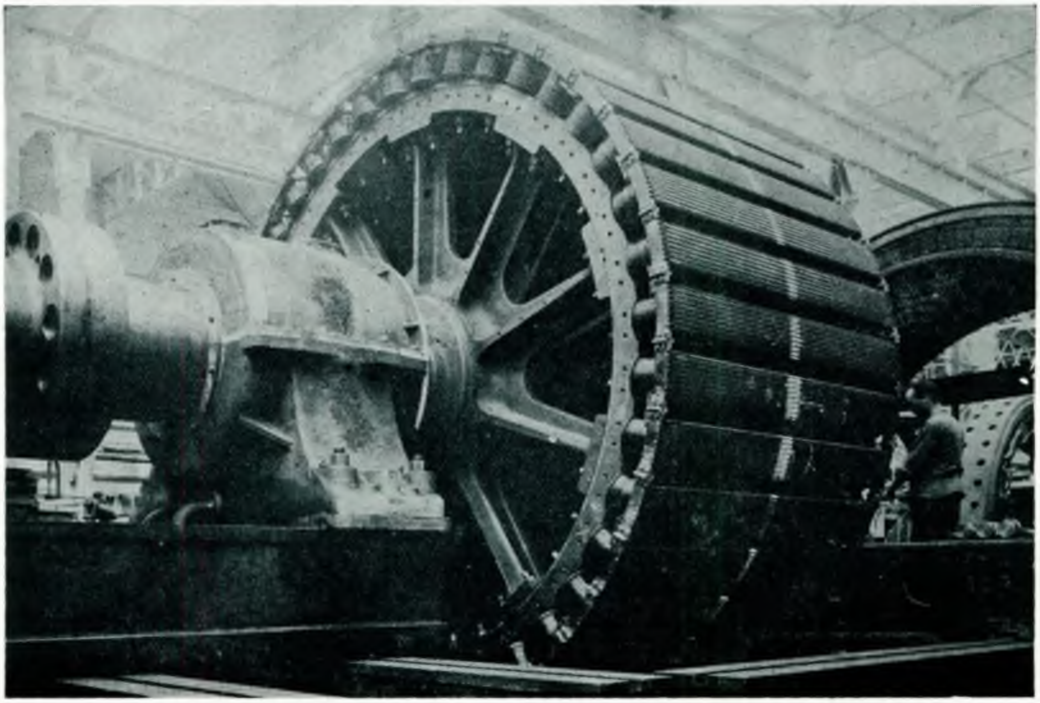


FIG. 9.—View of propeller motor rotor.

some special device, for, being synchronous with the propellers, they would have to develop their full power at a speed of 20 per cent. below normal. For this it would be necessary to overload them, but it *is* possible to obtain these conditions exactly by using smaller pitched propellers for winter service than those employed in summer.

Now the efficiency of the synchronous propeller motors does not change much between full load and half load; the same applies to the two alternators in use, which are working under practically the same conditions as in normal running. Also the efficiency of the two turbines in operation remains very near the maximum, especially if the power taken by the engine auxiliary equipment is taken into account, as the number of auxiliary machines in use is only half what would be required by a geared turbine propulsion equipment. The resulting saving in consumption obtained by stopping two of the four turbo-alternators for half load running is of the order of 8 to 10 per cent.

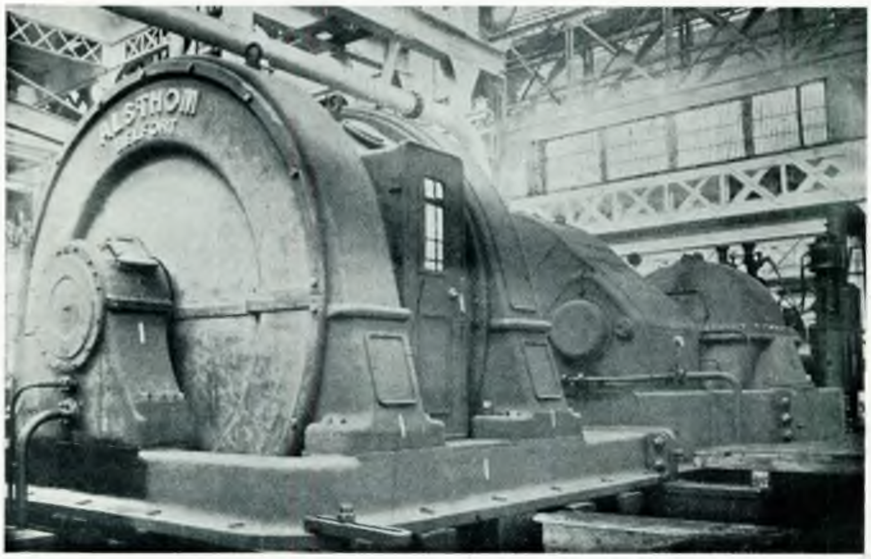


FIG. 10.—View of turbo-generator set—turbine end.

But economy in consumption is not the only consideration associated with this possibility of "paralleling" that is provided by electric propulsion. During winter service, the two turbo-alternators not in use can be taken down and carefully examined at leisure. Once the examination of the two turbo-sets is finished, they can be put into service and the examination of the other two can be proceeded with. Thus the "laying-up" periods of the ship can be reduced to a minimum.

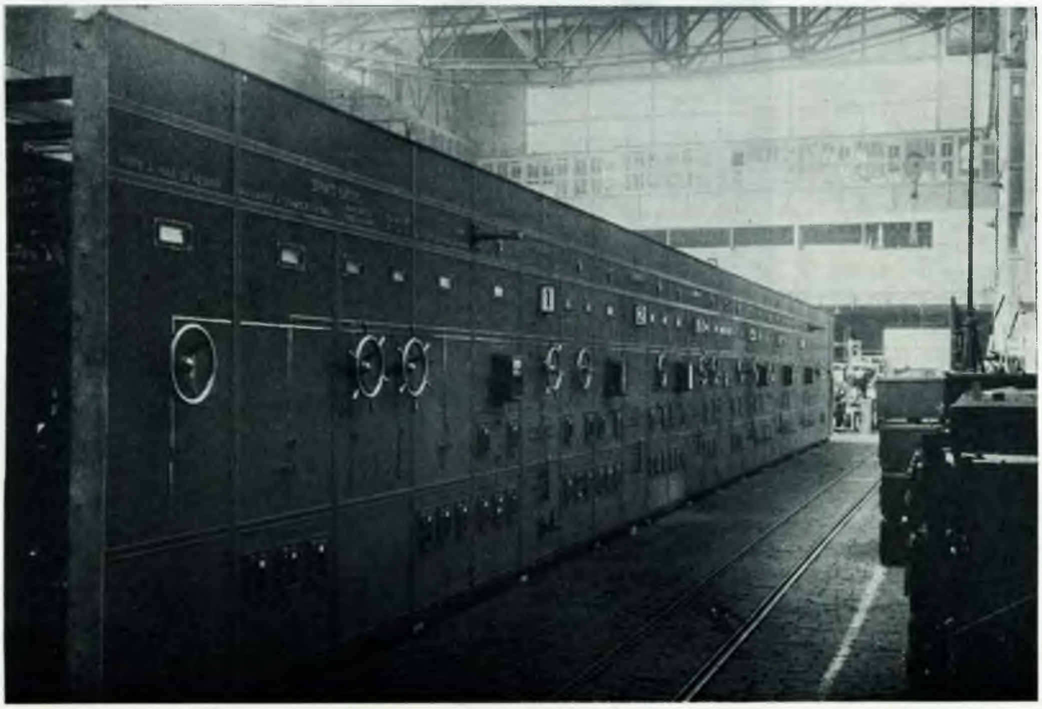


FIG. 11.—General view of main low-tension switchboard.

The advantage, from the point of view of safety, of being able to run with four propellers and a reduced number of turbines (with a practically instantaneous throwing out of gear of a turbine), was demonstrated in the course of the first crossing. Trouble in the condenser on one set having caused it to be shut down, it was possible to change from running with four turbines and four propellers, to running with three turbines and four propellers in the space of three minutes. The speed was only reduced a mere 2 knots during the repairs; also, this mishap did not prevent the setting up of a speed record during this first crossing.

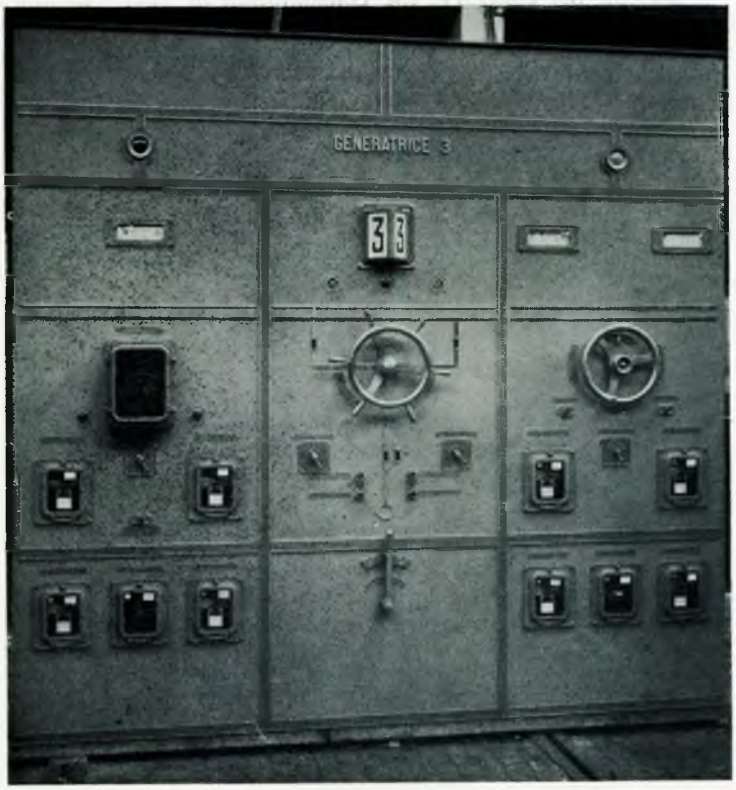


FIG. 12.—Detail view of main low-tension switchboard.

For this shutting down operation it is only necessary to throw open the field switches on the two sets concerned. The turbines on this side are brought automatically and progressively to a quarter of full speed; the excitation being switched off, the "Set-up" switch can be operated to bring the two propellers of that side on the still intact turbo-alternator set, which can then be run up to speed again.

What operations would have been necessary with geared transmission? Although it was necessary to stop the turbine whose condenser was damaged, it would have been quite out of the question to keep the corresponding propeller stopped, so that it would have necessitated disconnecting the turbine, which in turn would have meant stopping the tunnel shafting. The coupling is effected by bolts which must be taken out. But even to stop this tunnel shafting it would have been advisable to slow down the boat considerably, as braking at high speed by a mechanical brake is a very tricky operation.

We will not press the point, but we do not think we are being pessimistic in estimating a considerable slowing down of the ship over a period of several hours.

3. It might be feared that the steam and fuel consumption of the engines would be a little higher at all loads than that of a similar geared equipment. The efficiency of electrical transmission is actually slightly lower than that of gearing.

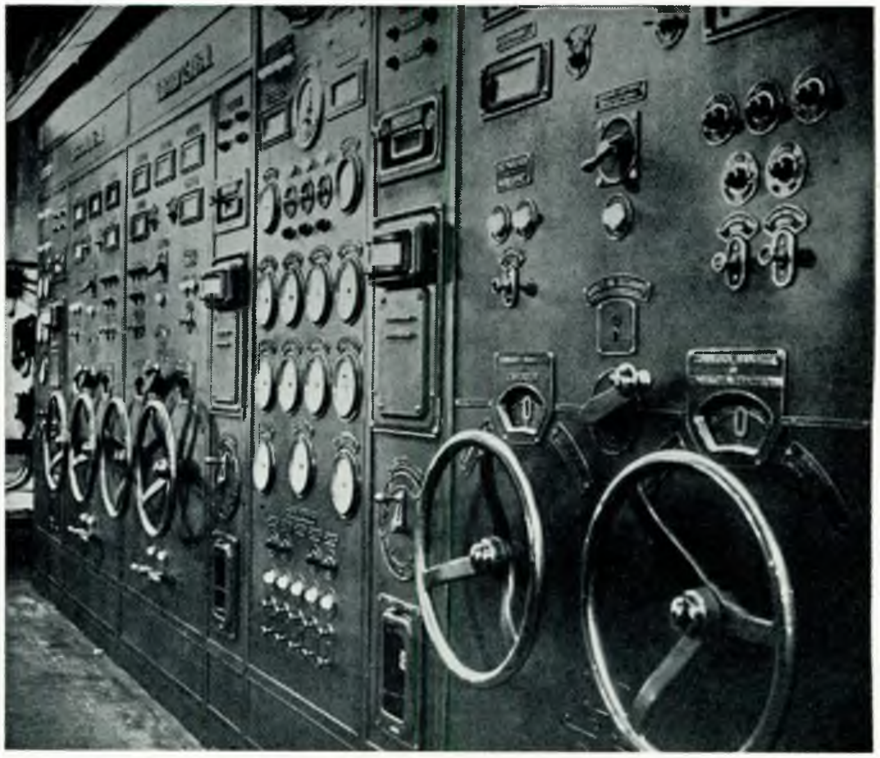


FIG. 13.—View of control switchboard.

But on the contrary, the consumption of fuel oil during the first few voyages was 290 grams per horsepower(*)-hour (·649 lb./h.p./hr.) including all ship and engine auxiliaries—a figure which is exceptionally low. (The consumption is corrected to what it would be for a fuel oil with a calorific value of 10,500 calories per kilogram).

The guaranteed steam consumptions and those obtained in tests are given in the following table.

Power output on propeller shafts... ...	120,000 h.p.	160,000 h.p.	70,000 h.p. (2 alternators working)
Guaranteed steam consumption in kg. per hp./hr.	3·725	3·760	4·110
Actual steam consumption (not corrected) in kg. per hp./hr.	3·627	3·687	4·009
Actual steam consumption in kg. per h.p./hr. corrected to guaranteed steam conditions	3·546	3·596	3·956

These particularly brilliant results are explained by the fact that in a turbo-electric propulsion equipment, the designer is permitted greater freedom in the choice of the characteristics of the machines.

In the case of the "Normandie":—

1. It has been possible to spread out the total available heat drop in such a way as to obtain the maximum hydraulic efficiency for each partial expansion. As is shown, this efficiency is a function of the ratio of the theoretical steam velocity "Vo" to the peripheral speed of the moving blades "u". In an impulse stage, it is a maximum for values of $\frac{Vo}{u}$ of about 2. Now, in the present case, the mean value of $\frac{Vo}{u}$ is 2·09 for economical running and 1·95 for running at full power.

2. It has been possible to obtain this result, while at the same time keeping a relatively small blade diameter for the first high pressure stages. The windage losses are thus reduced, and even for the first stages the blade height is large. These are favourable conditions for a high efficiency since, other things being equal, they lead to high values of "speed coefficient". (The "speed coefficient" of a guide-blade is called, for example, the ratio of the speed "V" of the steam leaving this blade to the theoretical speed "Vo" corresponding to the partial heat drop undergone. The more perfect the contour and machining of the blade and the greater the blade height the more nearly does this ratio become unity). In the turbines of the "Normandie" the blade height is more than 30mm. even in the first few stages. This promotes very satisfactory speed coefficients of the order of 0·98.

3. The splitting in two of the steam flow in the last stages leads to very low steam velocity

(*) 1 French horsepower = 736 Watts.

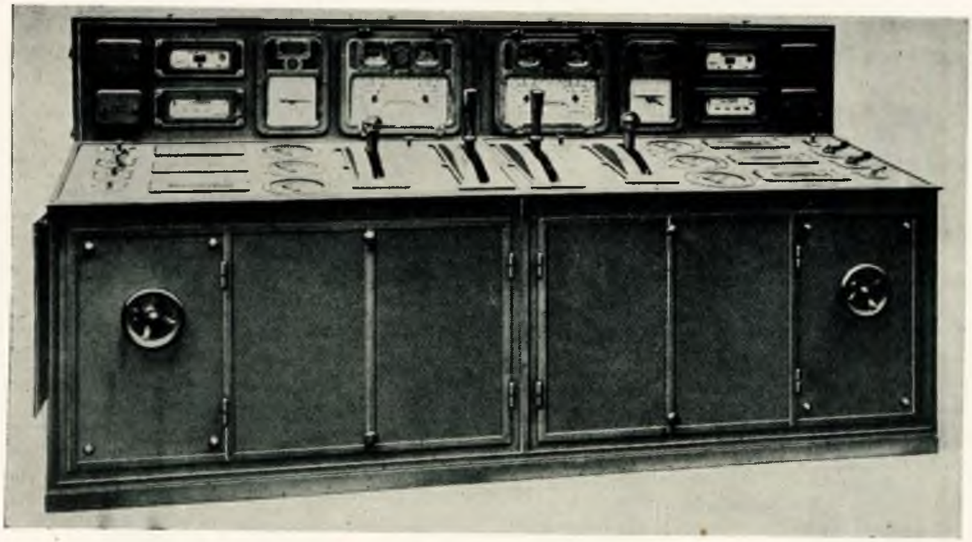


FIG. 14.—General view of control desk.

5. *Braking and going astern.* The damping windings of the propulsion motors had been designed to withstand a reversing manœuvre every 20 seconds for half an hour. This rate of manœuvring is much more rapid than is necessary for entering ports—even particularly tricky ones such as New York. There, 67 different manœuvres have been recorded in 1 hr. 34 min., but only 31 of these manœuvres required reversals—

at the exhaust, and at the same time allows the blade heights to be limited to values only entailing moderate stresses.

When running economically (i.e. two turbo-alternators and four propellers), the velocity of the steam leaving the last turbine wheel is only 150 m. : sec. (492 ft./sec.) and the resulting loss of efficiency is less than 2 per cent.

4. *Manœuvring Flexibility.* The exceptional manuœuvring power of the "Normandie" was particularly appreciated in the course of certain intricate manœuvres, such as going astern out of St. Nazaire on May 5th. This manœuvring power must be attributed principally to the electric propulsion. Actually one has at one's disposal a true clutch with a practically instantaneous action. With the turbines turning slowly and the ship stationary, suppose that the order is given "Slow Ahead". In a few seconds the propeller motors, which have started as asynchronous motors, have reached quarter full speed, as they have very nearly their normal running torque to accelerate them. The ship accordingly responds at once. The same applies to going astern.

With a geared propulsion equipment it would be impossible to leave the turbines running slowly with the ship at standstill, and it would be dangerous to fit quick-acting governors in a transmission of this kind, such as are used to control the turbines of the "Normandie".

FIG. 15.—View of control desk installed on board.

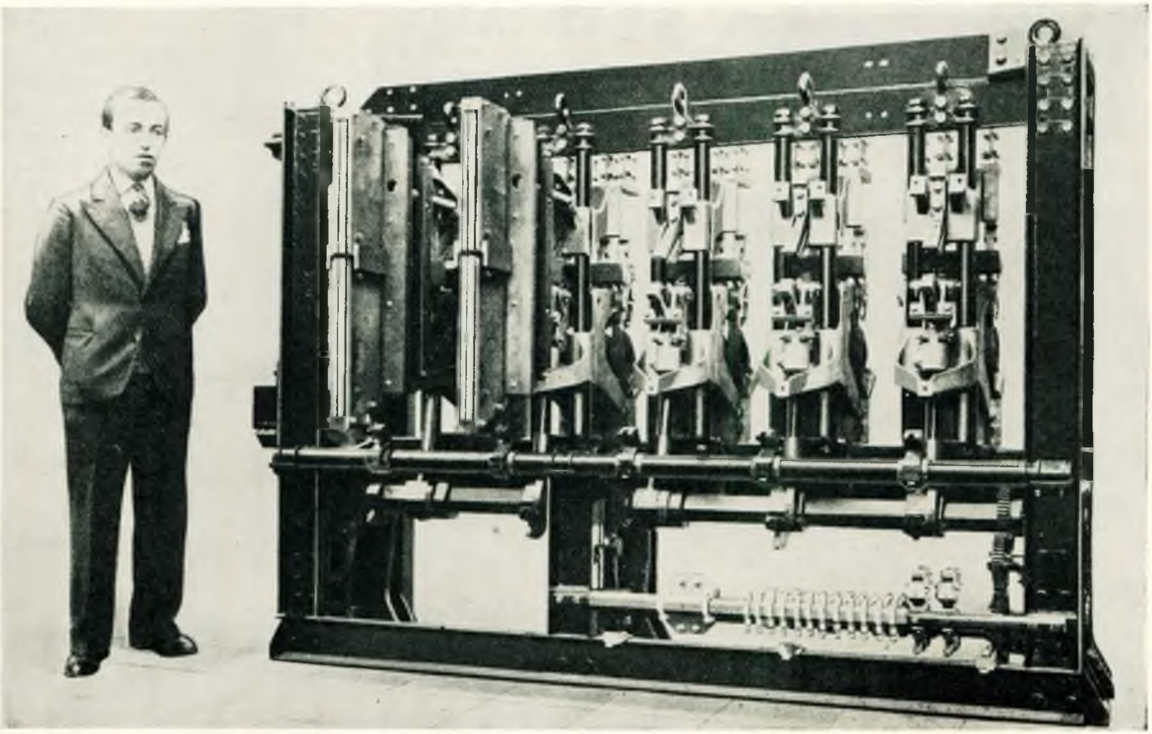


Fig. 16.—General view of a high tension reversing switch.

that is, an average of eight per turbo-alternator set, which is equivalent to a reversing manœuvre every 8 minutes.

Reversing tests have also been carried out at a speed of 28 knots. The only trial that was carried out at this speed caused the ship to stop in 1,760 metres. From the graphs recorded, it can be stated that by setting the over-excitation at higher values, and by going astern with the propellers under full power, the ship would have stopped in a much shorter distance. It must be added that these results were obtained although the propellers used had a greater pitch when going ahead than those for which the equipment was designed, and revealed an even greater pitch when going astern. The test, which had not been anticipated, succeeded because the equipment was of generous enough proportions to stand up to asynchronous running and the corresponding over-excitation for several minutes.

6. It might be feared that in rough weather the speed must be reduced on account of the violent power variations corresponding to the large variations in the depths of the propellers and the resulting "racing" and braking. In effect, it might be thought that there would then be the fear of motors and alternators

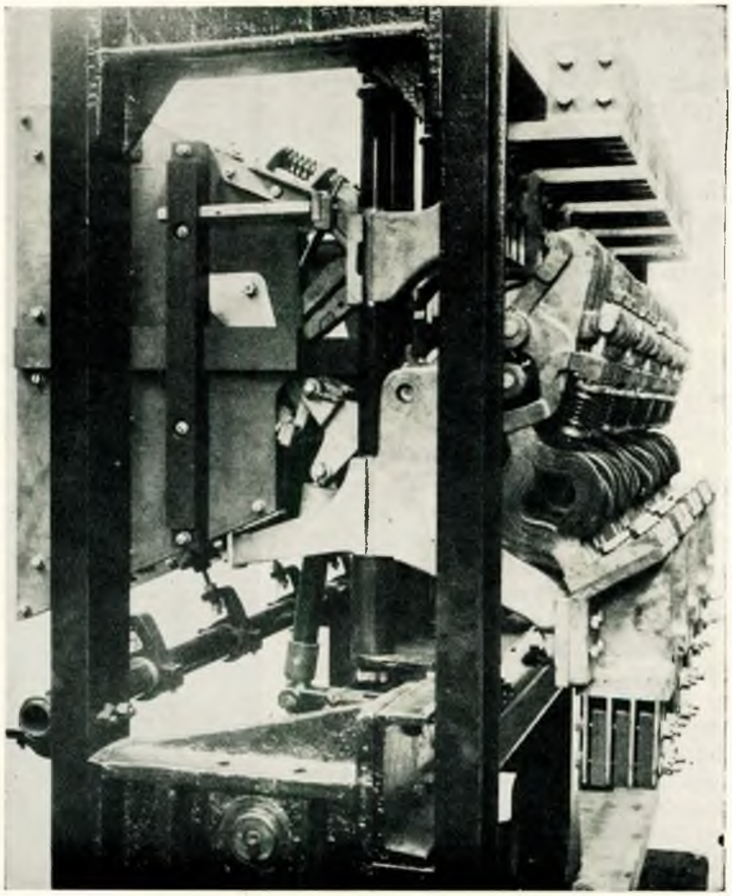


Fig. 17.—Detail view of high tension reversing switch.

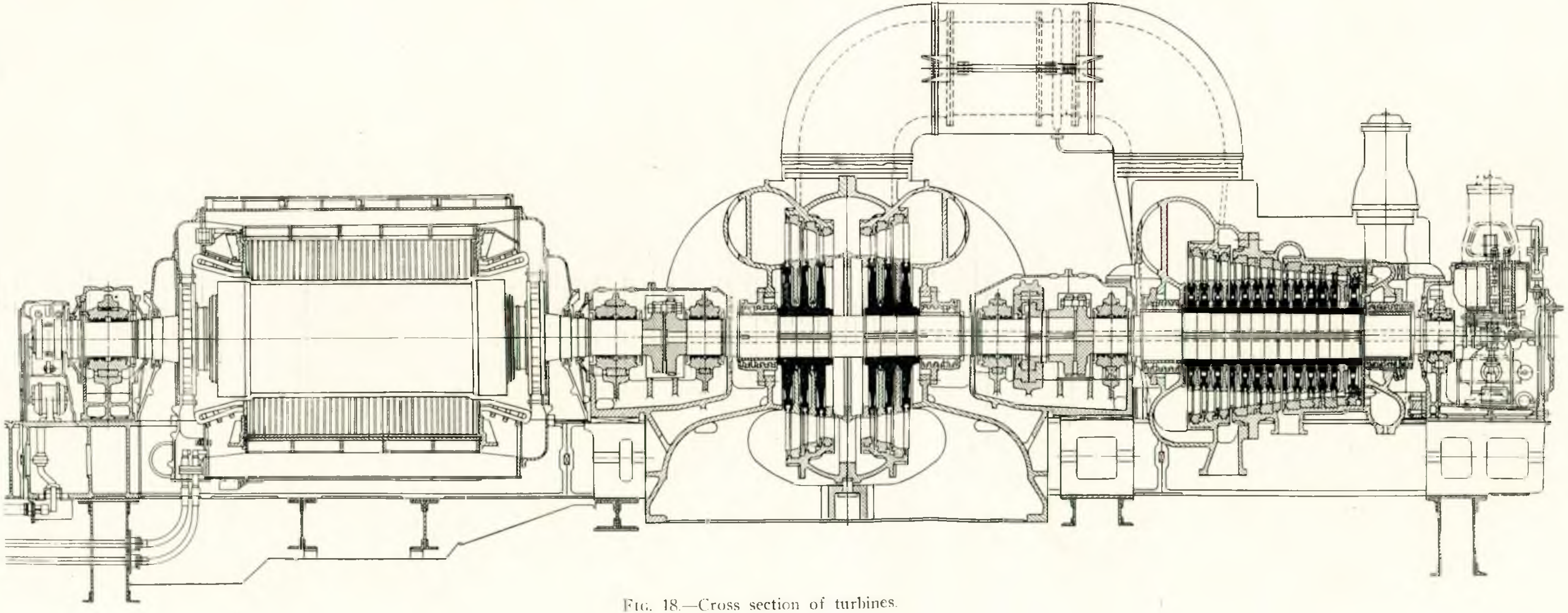


FIG. 18.—Cross section of turbines.

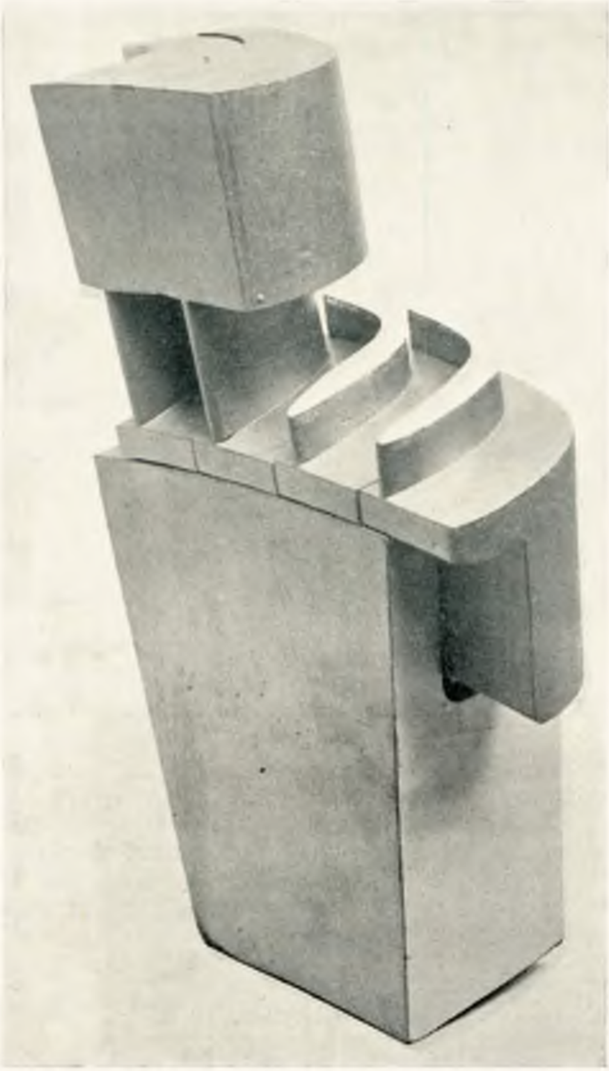


FIG. 19.—Model of milled nozzle blade.

getting out of step. Although the liner has undergone very considerable pitching and rolling during the last few crossings, which in some cases has been as much as to uncover partially the outside propellers, this has never caused the motors to drop out of step and the increase in speed has only been a few revs. per minute. On the other hand, the power at this instant on the corresponding turbo-set fell to 7,000 kW. This result must be attributed to two principal reasons—firstly, to the great stability of the synchronous coupling which had been provided to ensure a very high "drop-out" torque, and secondly to the properties of the governors, to which attention has already been drawn.

FIG. 21.—Thick blade for cast-in type nozzle.

7. Finally, although this is somewhat outside the subject, it must not be forgotten that an electrically-propelled liner constitutes a real experimental laboratory on a very large scale, on account of the exactitude it permits in the measurement of torques and propelling powers. A detailed examination of the curves recorded should therefore afford a very important contribution in the study of these phenomena.

Whether in relation to the effect of the movements of the sea and the ship, or the effect of shallows, or again, in relation to the functioning of the propellers during braking and going astern, electric equipment would undoubtedly allow much more accurate measurements to be taken than those which have been made up to the present.

FIG. 20.—Checking the guide passages in a nozzle ring.

To sum up, the use of turbo-electric propulsion in large ships offers the following unquestionable advantages :—

Reduction of noise and machinery vibration;

Fuel economy over a wide range of speeds;

Possibility of proceeding with the inspection of machines without stopping the vessel;

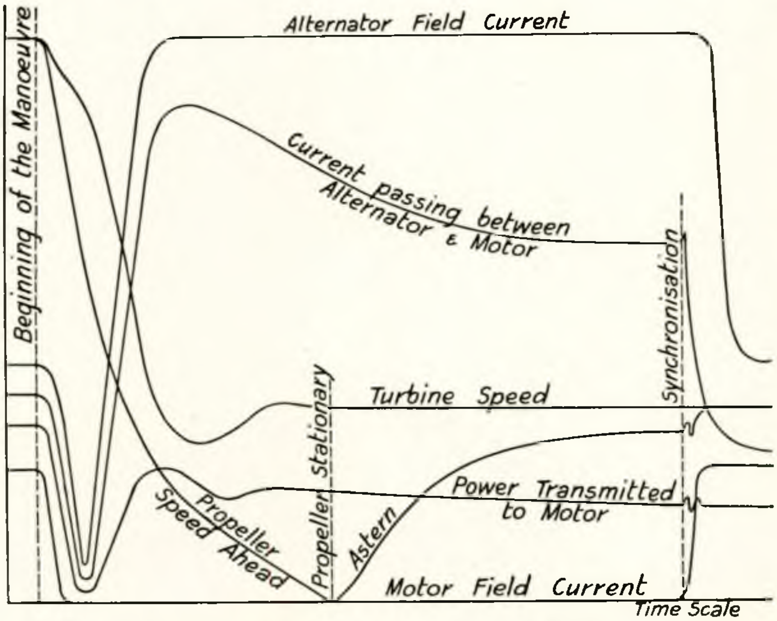


FIG. 22.—Variation of speeds, currents, and powers during a reversal. ("Normandie").

Flexibility of manœuvring;
Possibility of braking at high speed;
Reliability.

Equipment Required for Future Vessels.

It is evident that for this equipment the tendency has been, quite naturally, to follow the layout of a geared turbine installation. However, it would certainly be interesting to take advantage of "mechanical" independence between the turbines and the tunnel shafts by placing the turbo-alternator sets in the centre of the boiler compartments so as to reduce the steam piping. It is to be noted that the transmission under high tension (5,000 volts) of a power of 160,000 h.p. necessitates only 48 cables of 750 sq. mm. section, the laying of which does not present any difficulty.

The propeller motors could probably be moved towards the stern.

These remarks are intended to give an idea of the ease of installation which can be obtained with electric propulsion.

With regard to improvements in the equipment itself, one must look to the adoption of a high pressure steam cycle, approaching those actually used in land power stations.

It is known that improvements in the steam cycle can be obtained :—

1. By increasing the pressure and the temperature of the steam, and by an improved vacuum at the condenser;

2. By heating to a higher temperature the feed water for the boilers, with steam extracted from the turbine;

3. Lastly, by re-superheating the steam at a suitably chosen stage of its expansion in the turbine.

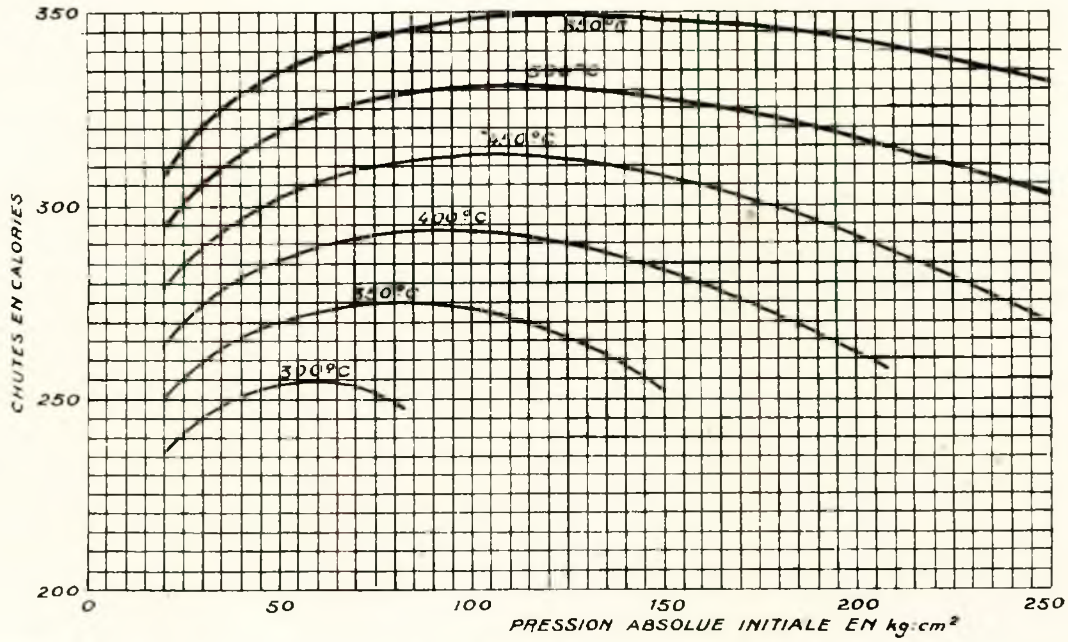


FIG. 23.—Heat drop in calories as a function of the initial pressure at a vacuum of 96 per cent. and for various initial pressures.

It may be said at once that re-superheating loses some of its advantages in practice, owing to the complicated installation required for its application, and it has only been mentioned for record.

The justification for these improvements is summed up by reference to the accompanying theoretical curves.

1. In Fig. 23 the curves give the variation in the heat available as a function of the pressure, each curve being for a given initial temperature. This shows that it is necessary to increase the temperature as well as the pressure when selecting a very high pressure. For a given temperature, if the pressure is raised beyond a certain point the heat available diminishes. The lower the temperature given, the lower will be the pressure at which this diminution will commence.

2. Fig. 24 gives the per-

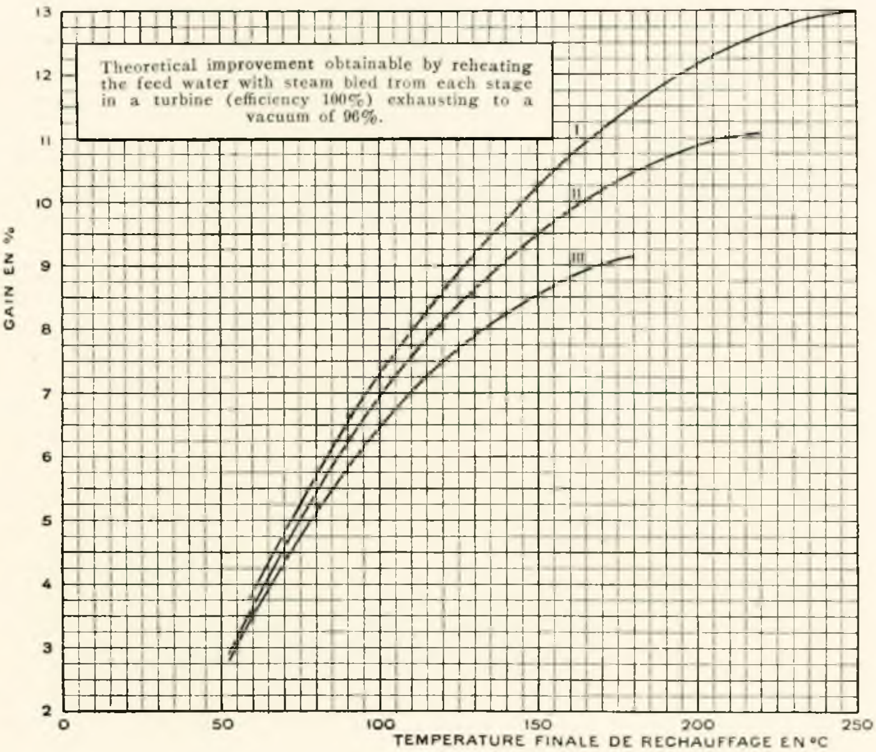


FIG. 24.

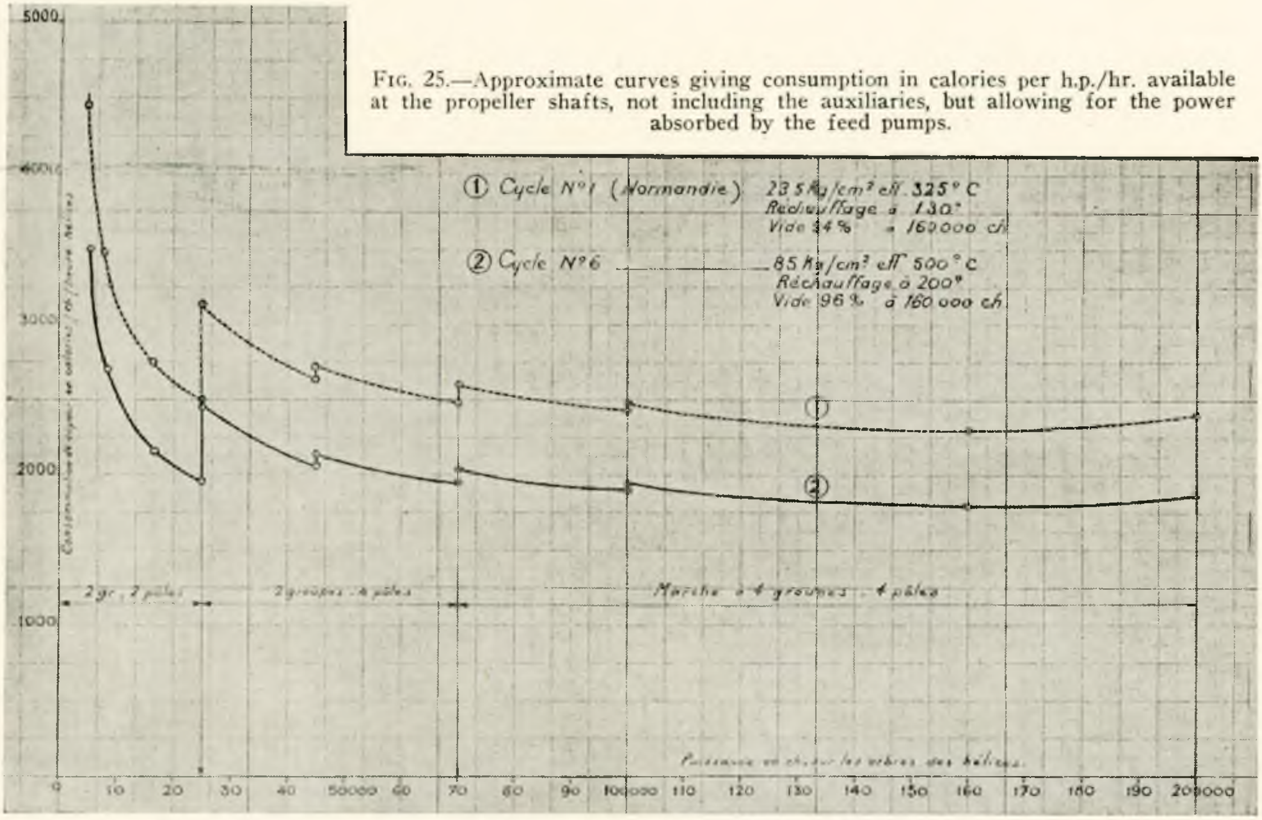


FIG. 25.—Approximate curves giving consumption in calories per h.p./hr. available at the propeller shafts, not including the auxiliaries, but allowing for the power absorbed by the feed pumps.

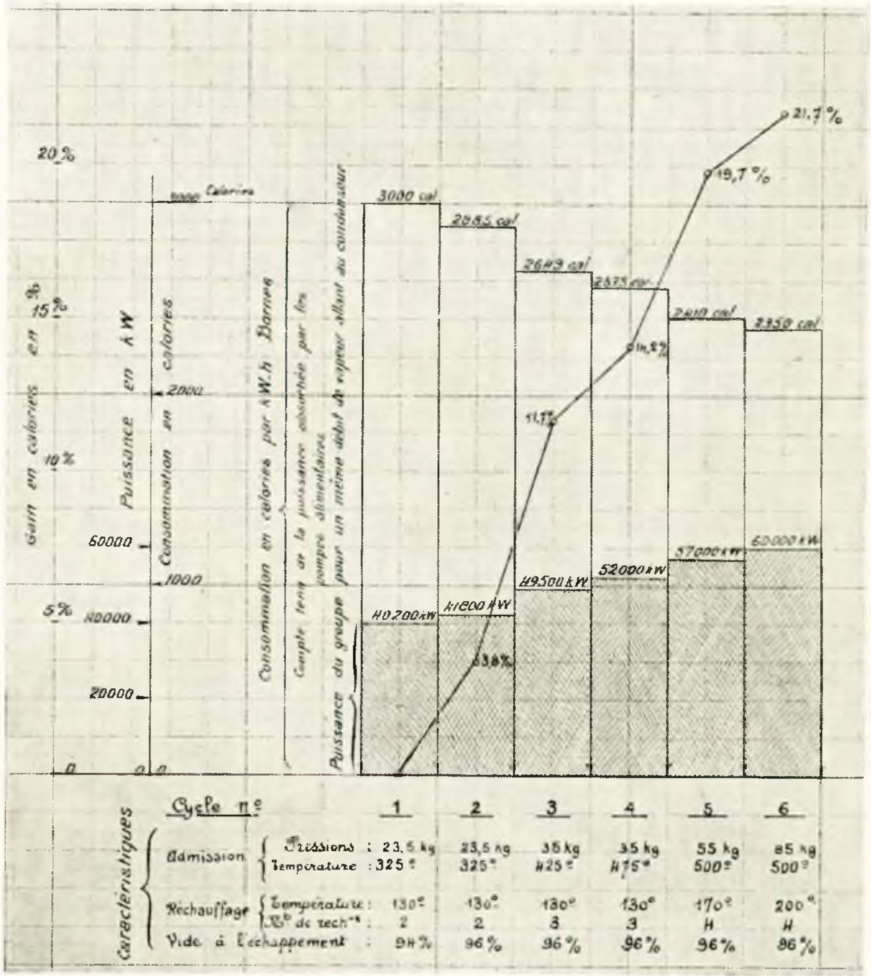


FIG. 26.—Comparison of different operating cycles. Consumption in calories per h.p./hr. available at the propeller shafts, not including the auxiliaries, but allowing for the power absorbed by the feed pumps.

centage gain theoretically obtainable as a function of the temperature of reheating (of the feed water) for various pressures, while maintaining a constant initial temperature. For the same temperature of reheating, the more the pressure increases the more appreciable is the gain obtainable. In practice the various considerations imposed by the conditions of installation and working may limit the pursuit of a high thermal efficiency.

Before deciding upon an alternative, it is proposed to examine a number of cycles obtainable and to calculate the saving in consumption effected by each one.

In this graph (Fig. 26) have been grouped the results of calculations with regard to six cycles, actually obtainable, and taking as reference the cycle used on the "Normandie" (cycle No. 1). Cycle No. 2 is the cycle of the "Normandie" slightly improved by an increase in the vacuum at the condenser. We see that a gain of 3·8 per cent. with reference to cycle No. 1 would be easily obtained by a small increase in the area of the condensers.

These figures are, above all, of value for comparison, and the various cycles chosen result from practical considerations bearing on the conditions of raising the steam, and on the temperatures of superheating actually admissible.

The consumptions shown correspond only to the flow of steam in the turbine; in other words, the efficiency of the boilers, the auxiliary services, and the losses of pressure and heat between the various apparatus, are not allowed for. On the other hand, allowance has been made for the efficiency of the feed heaters, and for the power taken by the feed pumps.

It will be noticed that the table, instead of being based on a constant output, includes values for output varying for each cycle. This is to keep, in each case investigated, the same turbine low pressure.

Experience of high pressure land installations and the similarity between land turbines and those installed on board the "Normandie" confirm that it is actually possible to obtain without any risks a similar equipment with a steam cycle which would have the following characteristics:—

At the turbine inlets ...	(Pressure:	85kg.: cm.² effective
	(Temperature:	500° C.
Reheating of feed water to		200° C.
Vacuum at exhaust		96 per cent.

According to this graph (Fig. 25), the adoption of this cycle would give the following advantages compared with the present cycle of the "Normandie", and for the same installed power:—

1. A saving in fuel oil of 21·5 per cent. or 2,000 tons per voyage (Le Havre-New York and return). On a basis of fuel oil at 105 francs per ton and on 24 crossings per year, the annual saving works out to approximately 5 million francs.

2. A reduction of 22·5 per cent. in the output of steam from the boilers, and consequently a reduction in their number.

3. A reduction of 33 per cent. in the quantity of steam to the condenser, which would enable, for an equal turbine output, the dimensions and weight of the low pressure end to be reduced to such proportions that it would be possible to design

sets of from 40 to 45,000 h.p. at 85 kg.: cm.^{2} and 500° with single exhaust, lighter than the sets of the same output at 23·5 kg.: cm.^{2} - 325°, which must have the double exhaust.

4. In consequence of the above facts, an appreciable reduction in the weight and space of the boilers, turbines, condensers, and fuel tanks.

It has been seen what savings may be expected from the increase in pressure and temperature. These savings are based only on modifications to the steam end of the equipment. In fact, they affect considerably the general design of the propelling machinery. The problem may now be considered of how to reconcile the necessity for reversal at high speed, by means of a reversing turbine, with such steam characteristics.

At the time of admitting steam to the reversing turbine, which is under vacuum, it is subjected to a violent increase in temperature, causing abnormal expansions, which will be more dangerous the higher the temperature and pressure of the steam.

It is claimed that at the beginning of a reversing manœuvre, the output of the boilers having been considerably reduced during the closing of the stop valve of the forward turbine, the boilers cannot give at once the initial conditions of pressure and superheat when the steam is admitted to the reversing turbine, a big consumer of steam. There is then a risk of heavy water shocks. Further, these conditions can only happen in reality during sea trials, when the staff is expecting a reversal. At the time of an unforeseen reversal, the burners are not turned off as quickly as during sea trials.

In conclusion, it may be said that turbo-electric propulsion, which offers positive advantages over turbine and gear propulsion, and which, by the elimination of the reversing turbine avoids the risks of accidents due to the adoption of high pressure, represents a considerable improvement in the efficiency of marine propelling equipment.

Turbo-electric Propulsion for Warships.

To recapitulate the various advantages which the Author has claimed in this paper for turbo-electric propulsion, they are:—

1. The possibility of using a high efficiency steam cycle, without limitation of the pressure or temperature of the steam, owing to the elimination of the reversing turbine;

2. The possibility of economical running at reduced speed;

3. Safety, due to the number of units, in case of damage to a turbo set, its condensers, or its auxiliaries;

4. The possibility of braking the ship by reversing the rotation of the propellers, even at maximum speed, and applying the full power of the propelling equipment to braking;

5. Flexibility of manœuvring and speed of operation;

6. Ease of installation;

7. Absence of noise and vibration in the machinery; to which may be added:—

8. Ease of repairs on site. All electrical plant is designed so that the replacement of an important part can be effected without it being necessary to remove any large apparatus from the ship. It is possible to replace poles, sections of stator winding, or main contactors, in a short time with the means on board.

These various advantages are certainly interesting in connection with warships, the efficiency of which can be considerably increased thereby. These advantages have been appreciated by the American Navy, since the latest American cruisers have electric propulsion.

It has been pointed out recently that the "New Mexico", the first of these vessels, has just been refitted and that during this refit turbines and gear propulsion had been substituted for the old electric equipment. Some seem to see in this change a condemnation of electric propulsion. In reality, the American Navy had three cruisers—"New Mexico", "Idaho", and "Mississipi", identical except for their propelling equipment; of the three the "New Mexico" only had electrical propulsion. When it became a question of modernising these three vessels the main consideration, the vessels being 13 years old, was the net cost of the new equipment, without too much thought for the technical advantages of the propelling equipment.

However, it must be pointed out that from the point of view of propulsion, a warship differs from a liner in two important characteristics:—

1. The warship must have two widely different speeds with low consumption—the cruising speed in the neighbourhood of 15 knots, which corresponds to a maximum radius of action, and the fighting speed, which is only used for very short periods during the life of the vessel;

2. The efficiency of a warship being far more important than the net cost, it is necessary to fit, in a given displacement, the maximum of apparatus, hence the pursuit of maximum lightness of the machinery put in the vessel.

Electric equipment lends itself particularly well to the adoption of two speeds in the ratio of 2 to 1, by changing the number of poles of the alternator. By this means, when the propellers are running at half speed, the turbines still run at their full speed, maintaining the highest efficiency. It is similar to a drive through gears, with a change in speed of 2 to 1.

The change in the number of poles of the alternator can be easily obtained, and with complete safety, without appreciable increase in the weight or dimensions of the equipment. It is, therefore, not necessary to provide cruising turbines as is done with geared turbines, which turbines have an efficiency very much lower than that of the main turbines. It may be mentioned that the electric machinery will maintain, during cruising, an efficiency very close to the efficiency at full output.

With regard to the weight of the installation, it must be admitted that electric propulsion equipment is in general more heavy than turbines and gears. The difference in weight decreases very quickly as the output increases. Moreover it would be altogether inaccurate to take as a basis the weight of the propelling equipment of the "Normandie". This weight, which is approximately 2,000 tons without the condensers, or, for an output of 170,000 h.p. 11,800 kgs. per h.p., could be considerably reduced.

In the first instance very different temperature rises may be allowed for the electrical apparatus, according to whether it is subjected to the maximum output for some hundreds of hours, or for some tens of thousands of hours.

The changes in the insulation, due to temperature, are essentially a function not only of the value of the temperature but also of the length of time it is applied.

Though temperatures very much lower than those allowed by the regulations were adopted for the "Normandie", there need be no hesitation in providing for the equipment of a warship to reach, or even slightly exceed, under full output the temperatures allowed by the regulations. This would result in a big saving in the weight of the alternators and motors. The temperature tests on the "Normandie" give a very accurate guide for fixing the dimensions of this type of apparatus, and a saving could certainly be obtained. This equipment in spite of its reduced weight would be capable of transmitting under equivalent conditions, the torque of the "Normandie" without risk of falling out of step. It would even be possible to fit a larger squirrel cage winding to get better manœuvring, which is far more important to a warship in action than to a liner. The use of light alloys would also give an appreciable reduction in weight.

With regard to the steam side, it follows from what has been previously stated that the use of high pressures which present no difficulties in the case of electric propulsion, is more important for a warship than for a liner, giving a saving in fuel of more than 25 per cent. owing to the better consumption obtained.

Taking into account these various points, there are summed up in the following table the weights of a 200,000 h.p. equipment for a battleship.

	Weight per s.h.p.	
	Gear propulsion $P=28$ kg. : cm.^{2}	Electric propulsion $P=85$ kg. : cm.^{2}
Evaporating plant (boilers)	6 kg.	4·5 kg.
Propelling equipment ...	2·85 „	6·9 „
Shafts, propellers, boilers (evaporators)	4·65 „	3·6 „
	13·50 „	15·0 „

It will be seen that the difference in weight is very small and does not exceed 300 tons. This also applies to a propelling equipment with a consumption per h.p./hour more than 25 per cent. lower than turbine and gear equipment, and with further important advantages of flexibility of manœuvring, efficiency of braking at maximum speed, and safety due to immediate use of emergency connections.

It should be pointed out that a saving of 25 per cent. in the consumption increases the range of the vessel by more than 33 per cent.

In conclusion it may be stated once more that the skill of the Naval Architect consists in effecting compromises.

Acknowledgments are due to the "Shipbuilder and Marine Engine Builder" for the loan of several blocks.

Discussion.

Prior to the reading of the paper, the President, who received a warm reception, said that he was very glad indeed to have the privilege of introducing M. Roth, the distinguished Author of the paper to be read that evening. M. Roth was the Chief Engineer of the firm of Alsthom and, with his colleagues, Mm. Belfils and Koch, was charged with the design and construction of the machinery of the greatest ship in commission to-day. M. Roth and his firm had to assume tremendous responsibilities, and those present knew how adequately they discharged them. He felt sure that the paper which M. Roth had prepared would provoke a discussion of an extremely interesting nature.

Mr. W. J. Belsey (Marine Department, British Thomson-Houston Co., Ltd.), opening the discussion, congratulated the Author on the paper and said he had had the pleasure of making the first trip on the "Normandie"from Havre to Southampton. During that trip the machinery developed about 160,000 s.h.p., and he certainly must say that the Société Alsthom were to be congratulated on the very fine job they had made of the propelling equipment.

He was very pleased that the Author pointed out so clearly the gain in economy which could be made by the adoption of higher pressures and temperatures, particularly higher temperatures. These high pressures and temperatures had been adopted in land power stations, and there was no reason why these steam conditions should not be adopted on steamships. For instance, at Barking power station the steam conditions were 600lb. gauge pressure per sq. in. and 850° F. temperature at the turbine stop valve. The Electricity Commissioners in their report credited Barking power station with an overall thermal efficiency at the feeders of 27·9 per cent., a figure not very far removed from the thermal efficiency of an internal combustion engine.

In making comparisons between turbine-electric drive and a geared turbine drive it was generally assumed that the turbines were equally efficient. The turbine was essentially a high speed machine, the higher the speed for a given output, the higher the efficiency. It was well known that the extraction capacity of a turbine increased as the square of the speed, and whilst admitting that the actual transmission losses between the turbine shaft and the propeller might be a little less with mechanical reduction gear, this was more than compensated for by the better efficiency of the turbine. If double reduction gears were adopted, then the turbine could run at an efficient speed.

One often heard the electric drive criticised on the score of its complication. To define complication was extremely difficult. A very intricate system of electrical and mechanical devices was in use in traffic control lights, but surely everyone would admit that its operation was the essence of simplicity—simply being the passage of a vehicle over a particular spot in the street.

It was suggested that particular attention should be given to the concluding paragraph of the paper in order that the full advantage of all electric drive offered might be obtained.

Mr. S. A. Smith, M.Sc. (Member) said that he was very pleased to see that the Author had made a strong point of one of the salient features of the turbo-electric drive inasmuch as he stated that the "Normandie" was a two-speed ship, and therefore advantage could be taken of running the machinery at high efficiency with only two alternators in service driving the four propellers, the ship's speed being 20 per cent. less than that obtained at full power.

The Author gave the fuel consumption and steam consumption corrected to the specified conditions and the speaker would ask him if he would kindly state what these steam conditions were. In the curves on page 60 a steam pressure of 334lb. gauge and temperature of 617° F. with 28·2in. vacuum were given and it certainly seemed that in the light of present-day practice these were extremely moderate, particularly in the case of the vacuum, for on Eastern-going ships with an average sea-water temperature of 72° F. the turbines were designed to take full advantage of a vacuum of 28½in., whilst a steam pressure of 400lb. gauge, 725° F. was normal practice.

The speaker would also ask the Author what means he had adopted for make-up feed on the ship. The speaker believed that the Company with which he was associated was the only one so far to have adopted the low-pressure evaporator incorporated in the closed-feed system. This evaporator received steam at a maximum pressure of about 16lb. gauge, varying according to the power output of the turbines, and the make-up feed vapour passed to the low-pressure heater. It could be shown that with this system the cost of distilling the make-up feed water was reduced to a minimum. On the one side the live steam equivalent was about ·6 of a lb. per lb. of water produced and on the other side of the equation the increase in the feed water temperature practically balanced the cost of making this quantity of steam. In practice this had been found to be the case.

The single-cylinder turbine usually adopted for the turbo-electric drive lent itself admirably to the most efficient bleeding points for feed heating and auxiliary purposes, such as calorifiers, galley, laundry and heating. In a particular ship the bleeding points available on the turbine offered by the makers were the 4th, 5th, 6th, 8th, 9th, 11th, 13th and 15th stages of an 18-stage turbine.

The fuel consumption of ·649 of a lb. per s.h.p. being equivalent to 834 tons oil fuel per day at 120,000 s.h.p., did not strike one as being expectionally good having regard to the figure of ·58 given by Mr. J. Johnson as the all-in consumption for the "Empress of Britain" when developing 60,000 s.h.p. With a consumption of ·58 the fuel consumption at 120,000 s.h.p. would be 746 tons per day, a reduction of 10·57 per cent.

What was the normal excitation of the "Normandie" in service and what approximately was the hotel load which for a large installation of this kind fell to a small percentage of the total, whereas with smaller installations of, say, 20,000 s.h.p. the hotel services became an appreciable percentage of the total fuel?

On the question of reliability, he could say that with the turbo-electric ships with which he had been associated there had been not the slightest trouble with the electrical side of the installations and the upkeep and repair costs had been practically negligible. In maintaining mail and passenger services, this feature was a pre-eminent one. He would mention, in passing, that the "Viceroy of India" had now completed over 550,000 miles without the slightest trouble with the electrical side of the installation.

Would the Author state what the percentage increase in weight of the installation was as compared with geared turbines, and whether the cost was higher?

In the curves on page 60, M. Roth gave an outline of a future ship and quoted a steam temperature of 500° C. This was about the critical temperature for steel tubes and the speaker would like to ask him if in adopting this temperature the superheater tubes would be of Sicromal or of a steel containing ·4 to ·5 per cent. molybdenum.

The speaker quite agreed with his statement that with the present disposition of machinery usually adopted in liners, where space was of vital importance, the adoption of super pressures involving the necessity of re-superheating was hardly practicable in the present stage of their progress.

He felt that his future ship, for which a pressure of 1,210lb. per sq. in. with steam having a total temperature of 932° F. was proposed, was rather too great a step forward and in his opinion the immediate future of steam propulsion lay in an increase of pressure to, say, 600lb. with a total temperature of 850° F.

Mr. C. Wallace Saunders (Member) said that Fig. 2 showed one very interesting feature, viz., that the whole of the propelling machinery, apart from the boilers, was under a closed deck and therefore the space above was all valuable earning space. He had often wondered why this was not done with geared turbine jobs; it was probably because of facilities required for repairs to the gear wheel.

The equivalent gear ratio was 10 to 1, and he would like to know if this meant, say, 2,500 revs. on the turbo-alternators, down to 250 revs. on the propeller. In much smaller ships, say 20,000 to 25,000 s.h.p., this ratio would be more like 20 to 1.

The fact that the turbo-alternators could run at a reduced speed of approximately a quarter of the maximum speed with the propellers standing, brought out one of the greatest advantages of the turbo-electric drive, i.e., that the steam turbines could be warmed up from cold by running them and gradually increasing the speed as slowly as was thought advisable for perfect warming up; they could be run right up to full speed and even to over-speed so that the over-speed device could be tested, the whole of this while the vessel was tied up to the quay. He personally had had a case where this was actually carried out in dry-dock by flooding the dock just sufficiently to get circulating water for the condenser. To his mind this eliminated all the anxiety which was always felt in warming up machinery which had to be ready for full power at a moment's notice. Just as great care was required in warming up machinery as that necessary in starting up boilers from cold. Marine engineers, he was sure, must realise the vast importance of this feature of warming up and also the actual operation of the over-speed tripping device every time the vessel was in port.

Were not the reversing switches closed in the required direction and the alternator then excited when starting up the motors rather than as stated? At this stage of manœuvring double excitation was applied to the alternator. Would not the direction switches have to make a rather heavy current, whereas with the closing of the direction switches first they would always make circuit without any current flowing until the alternator was excited? How were the direction switches and field switches operated? By solenoids or mechanically, or both, and was any alternative operation fitted?

The perfect balance obtained on turbo-alternators for marine propulsion was borne out in a repair job with which he was connected, where the turbine wheel, some 6ft. to 7ft. in diameter, was manufactured in England, sent abroad, and replaced a similar wheel, and the balance of the complete turbo-alternator was perfect and required no attention. This was carried out on two turbines during the ordinary dry-docking of the vessel, and she was not held up one minute for this change-over. All the work was done in the engine room below the closed-in deck.

The flexibility of running four propellers off two turbo-alternators was undoubtedly a great advantage and it was only necessary to make the alternators slightly larger to run the vessel actually at half power off two of them. The four motors were naturally capable of giving half the power and the turbines could always give extra torque to make up for the lower revolutions. In effect it meant that the alternators would have to give approximately 20 per cent. full load current at approximately 80 per cent. volts, or something of this order.

He would like to know if there was any special device, other than this, but in any case it should not be necessary to have to change the propellers for this slow running, because it was an expensive job to do so. The extra cost and weight of the larger alternators would not be very much and the extra cost would soon be saved if the propellers had not to be changed. No load limiting devices would be required under these conditions.

It would be noted that when running under the condition of only two engines, the equivalent boilers and condensers with all their auxiliaries were shut down, showing a very great economy over a geared turbine job.

It was interesting to note that on the maiden voyage of the "Normandie" it was necessary, owing to condenser trouble, to shut down one engine, and the four propellers were run off three engines. He would like to know why two engines were left running on, say, the port side and only one engine on the starboard side, because this would mean carrying a fair amount of helm owing to the unequal power. If the power on the four propellers was equal under this condition, it would have been possible to have shut down one engine on the port side as well. No doubt helm had to be carried and, if so, it was interesting to note that the speed of the ship was only reduced by two knots. One would have expected a bigger reduction in speed under this condition. The change-over took place in three minutes. He knew of similar changes in other ships where there were two engines and four propellers. After "full away" at sea was rung, the inner propellers were very often run off one engine and the other propellers off the other, and the change-over from normal running to this was done in less than a minute; in fact, nobody on the ship could say when the change took place and it was not even noticeable on the bridge.

All these points were undoubtedly advantages over geared turbine drive, and as the Author stated there need be no trailing propellers.

The Author stated it might be feared that the steam and fuel consumption of the engine would be higher at all loads than that of geared equipment, but this was a question involving many features, such as steam conditions, suitable propeller revolutions, etc. The speaker did think, however, that the Author's statement that the efficiency of electrical transmission was actually slightly lower than that of gearing, wanted some qualification, as it might be misread by many. It must be recognised that the actual electrical transmission, compared with the geared transmission of the power, must be some 7 per cent. less efficient. In a recent paper read by a well-known superintendent, it was stated that the land turbine gave 84 per cent. efficiency, and the marine turbine 77 per cent. efficiency for given conditions, and as this difference of 7, was 7 in 77 and equalled practically 9 per cent. it seemed to the speaker that this was where steam and fuel consumption comparisons might be made and found at least equal, because it would appear that the 7 per cent. loss in electrical transmission was more than balanced in the turbines. The lubricating oil would also show a large economy because less than a gallon a day had been achieved on a 20,000 h.p. installation.

With regard to manœuvring flexibility, here again he thought the Author brought out a very important advantage of the turbo-electric drive, in that when leaving St. Nazaire the turbo-alternators, the speaker was certain, were all thoroughly warm and running and had even had their over-speed trip tried out, so that when the bridge asked for ahead or astern, even up to full power, they got it, and in the form of a kick, because the engineers knew there was no question of doing any harm to the turbines. Full power was available in the shortest possible time that any propulsion machinery could possibly give it, and very much quicker than practically any other drive.

The number of manœuvres of which the electrical machinery was capable when manœuvring a ship, i.e., when there was no way on the ship to speak of, was practically infinite because the motors were in synchronism in a matter of seconds, ahead or astern, when of course normal excitation and therefore normal running was present. As the machinery is designed for full astern when the ship had full way on her, one of these reversals was a heavier duty than any number of reversals with no way on the ship.

The speaker would like to know the time taken to stop the vessel during the full reversal at 28 knots, i.e., the equivalent of the 1,760 metres in which the ship was stopped. It would be interesting to compare this with the stopping of a vessel of 22,000 tons displacement at 21½ knots in 2 minutes 50 seconds with a similar type of drive, i.e., turbo-electric drive. In this connection it would also be interesting to have the time scale, Fig. 22, page 59. After the motors were in synchronism the rate of admission of steam to the turbines and so speeding up of the propellers in the astern direction, would be found to be governed more by the vibration on the hull than the strength of the machinery, so that the time of stopping a ship from full ahead was really a function of the hull rather than of the engines with this type of machinery.

The calorific value given, he thought, approximated 19,000 B.T.U.'s, and for the steam conditions installed ·649lb. of fuel per s.h.p. per hour for all purposes seemed on the high side for such large power; this point should be pursued because he would expect it to be better.

He could vouch for the absence of racing in turbo-electric propulsion, because he had seen the s.h.p. meters in practically a hurricane, varying from no load at all up to full load (a cycle of 3½ seconds=7 seconds for full pitching cycle), and one could not read the variation in revolutions on the speed indicators because each division was 5 revolutions, and they did not vary a division.

He could also vouch for the fact that a motor could pull out of synchronism and no harm come to the machinery, because the alternator was only as big as the motor and therefore could not harm it, and in a second or two, by bringing the controls back, the motor could be brought into synchronism again and the power reduced slightly. This was the equivalent of stripping a gear. Racing, of course, was dependent on the governor of the turbine and with land turbines their governors were very efficient.

He thought the accuracy of reading the s.h.p. was well within the subject of the paper, and it really gave the naval architect actual authentic data on a full size ship for him to compare with his data on the tank models. He knew no-one more qualified to realise this point than their Chairman, the President. S.h.p. had been measured to within 20 h.p. on 18,000 h.p. over a 16 hours' run. This could not be obtained with any other form of s.h.p. measurement and, as the Author stated, the effects of shallows, weather, helm, turning of ship, etc., were all shown on the s.h.p. meters continuously, all very valuable data.

The advantages mentioned by the Author were all real advantages and of first-class importance to the shipowner. Full advantage should be taken of the flexibility of this type of drive in every direction, such as staggering of propeller motors, and alternators between boiler rooms, etc. There were ships in existence with their engines between the boiler rooms.

The application of turbo-electric propulsion to warships was well worthy of consideration for the reasons that the Author pointed out. In some cases at certain required powers, where four propellers were demanded, two engines could be installed instead of four with all the reliability and more flexibility than if four geared turbines were installed. In these cases probably, weight would come down below geared turbines.

The flexibility for warships or merchant ships, no matter what combination of engines and propellers, was demonstrated, apart from any other considerations, by the following:—

(1) No trailing propellers.

(2) If only two engines:

(*a*) All four propellers off either engine;

(*b*) Outers off one engine and inners off the other for equalling loads.

(3) The choice of direction of rotation of propellers which was very important.

With four propellers the inboard could turn outboard and the outboard inboard, or any combination of turn that it might be desired to try out.

Navigating officers considered that outboard turning propellers increased the turning facility of the ship, but it was immaterial because, as stated above, any direction or any combination of directions, could be tried with this form of drive.

The Author's explanation of the "New Mexico" being refitted with geared turbines was needed to answer critics of this drive who cited this case as condemning the turbo-electric drive.

The question of the weight of installations was very important and he saw no reason why the electrical machinery in a ship should not be built to the standards laid down by the regulations and interested authorities, because they had their own margins which were ample for marine work. This would keep the weights to a minimum which was always necessary.

He thought that this Institute could quite usefully enter into this question of weight, because holding the opinion as he did that given suitable steam conditions and propeller revolutions, turbo-electric propulsion could be shown to be equal in consumption of fuel per day to geared turbine drive, then everything else was common in the ship except the actual turbine and gears with their steam piping and oil system on the one hand, and the turbo-alternator, motors, control gear and connecting cable on the other. Assuming that this portion of the total installed machinery was 15 per cent. of the weight of the whole, then this difference in weight must be some percentage of this 15 per cent., and it was this point that The Institute could clear up to the great advantage of shipowners in general

Eng. Rear-Admiral W. R. Parnall (Member) said that the equipment of the "Normandie" with electrical transmission was a great enterprise on the part of the builders, but it seemed to him that it was a vast and extremely complicated piece of machinery to provide what was in effect a two-speed gear. It had claimed for it, as the Author pointed out, many advantages, but one naturally expected that advantages would be associated with such great weight and complication. Amongst these, stress had been laid on the flat steam consumption curve obtainable. One effect of the two-speed gear was that at half power as good a fuel figure was given as at full power, but to get that you had to put up with a loss in the alternator and motor at all powers. He submitted that much the same thing could be done in a straight turbine. If one was prepared to put up with a slight loss of efficiency at full power, that at lower powers could be improved with the result that from half to full power one would get a figure for fuel consumption which was practically constant throughout that range.

The Author also made a point of the convenience of having the machinery split up into so many different parts, a case being quoted in which a leaking condenser was cut off and the rest of the machinery run at its maximum efficiency. He thought that this convenience was only a matter of degree. For instance, in any steamship with more than one boiler, one had the facility, should one boiler go wrong, of running on the other. In the particular case cited of a condenser developing a fault, greater safety of the installation was attained, but if a motor went wrong the position was the same as if it were a geared turbine ship and a turbine were defective. In the particular case it was an advantage to be able to shut off a section of the machinery, yet he submitted that on the whole it was a doubtful advantage, as with electrical transmission there were so many more things which could go wrong with it than there were in the case of a plain geared turbine.

The Author also made a very great point of the reversibility of this transmission. He felt that the combination of an ahead turbine and an astern turbine in one casing was the best device at present attainable for the manœuvring of a ship. His reason was that if it was desired to go astern it was possible to throw the whole power of the boilers into the astern turbine, and in doing so a torque was obtained which was very much greater than the ahead torque. The energy of the ship, propellers, etc., had to be absorbed in the steam and the steam passed it on to the condenser, so that the condenser was really the brake and it had a braking capacity of four or five times that required for full power going ahead.

He would like to ask the Author what happened to the heat which he presumed would be generated in the motor when braking from, say, 28 knots ahead to astern, and whether trouble had been experienced on that account.

Mr. A. D. Constable (Director of Electrical Engineering, Admiralty) said that as a visitor he appreciated the privilege of being allowed to join in the discussion, and he proposed to confine his remarks to a few general observations on the interesting account they had heard of what was a very notable installation.

Marine engineering was at present advancing at such a rapid pace and such drastic changes were being made that it was what one might even call one of the tragedies in the life of the marine engineer that his design of the propulsion equipment of a great liner might, even on the ship's maiden voyage, show to the observant some signs of being a little behind the times.

The two or three years necessarily elapsing between the design stage and completion were sufficient to start this disappointing obsolescence, and in the twenty years or so of the ship's useful life the engines almost certainly would be eclipsed by the performance of others in new ships, embodying newer methods.

One could not well remedy this, as the marine engineer, of all men, dared not take the risk of installing in a ship anything which was not fully proved; the consequences of failure at sea might be too serious.

The owners of the "Normandie" were the first to decide on taking the bold step of installing electric propulsion in so large a liner. They had the assistance of a great Company in possession of all the necessary experience with such an equipment, but they were not justified in breaking new ground by going too far ahead of current practice in such an important ship. The result was a highly successful installation, but one which the Author would, as his own words showed, very much like to revise and improve upon. This was no reproach on the designers, but, as the speaker had already observed, it was their misfortune in having perforce to complete their designs so long ago.

The speaker would like to explain in a few words what the ideal electric propulsion scheme of this kind for the very near future looked like to him. The earliest railway coach consisted of a stage coach body put on a railway truck and the earliest motor car was very like a horse-drawn trap without the horse. It was soon found to be neither necessary nor convenient to copy so slavishly previous practice, and it was no more necessary in an electric propulsion scheme to copy the customary layout of the normal steam drive.

Putting aside for the moment the necessity for building the ship largely around the passenger accommodation, although he was aware of the serious limitations this imposed on the engineering part of the ship, one could start with the axiom that the propelling motors and the prime movers need have no definite relation to one another in space. True, there was not much choice as regards the motors, as presumably the propellers could only occupy the usual positions, but the motors could go as far aft as the lines of the ship permitted. There was no need for any control equipment for manœuvring purposes to be installed in the motor compartments and the motors required very little attention.

The turbo-generators, with their boilers, condensers and auxiliaries could be arranged in as many units as there were shafts, all the parts of one unit being in one compartment, self-contained and independent as far as normal steaming was concerned. With clean oil-fired boilers of modern type there was no need for their separation in a special boiler compartment unless this separation was required for the purpose of sub-division. They could be close alongside the turbines which took the steam. The complete generator units might be widely separated from the motors and from each other, if convenient for general construction purposes.

For simplicity, independent control of the units could be arranged for, co-ordinated by a system of telegraphs and repeats from and to the bridge, or if desired some degree of central power operated control could be provided as long as there was overriding local control for emergency use. Such a departure from the orthodox arrangement of machinery too much in evidence in the "Normandie", gave the advantage of the shortest possible main steam pipes, thus permitting the safe use of really high pressure and temperature of the steam, the opportunity of reheating the steam between stages without complication, and comparatively short and simple runs of piping for multistage feed water heating by extraction. The adoption of one of the modern types of boiler without heavy and expensive drums pierced for a multitude of tubes, some of which were already in use at sea and seemed to be quite suitable for marine work, completed the picture, which seemed to be very much like that visualised by the Author. Such an installation, which the speaker did not think was merely visionary, was the logical way to realise the full advantages of electric propulsion, and it would give an overall economy in operation a good deal better than would be possible with a purely mechanical drive designed with an equal margin of safety. Whatever might be said to the contrary, he did not think that a turbo-electric scheme laid out on orthodox lines could quite compete in operational economy with a plain gear drive, although it might have other considerable advantages to compensate for its somewhat lower overall efficiency. Where an electric drive was adopted, one would naturally like to see all its possibilities exploited to the utmost.

There was one point he would like to refer to which had not, he thought, so far been mentioned. He understood that two of the propellers had been reversed in direction of rotation in connection with the problem of hull vibration. This only involved fitting two new propellers and reversing the corresponding motors. This change could not have been made so simply with a gear drive.

He would add a few words on the auxiliary supply services of the ship. So large an amount of auxiliary electric power was required, that the use of direct current, as was customary, involved the installation of an almost prohibitive amount of copper in cables, switchgear and commutators with their mass of brush-gear. Technically there was no objection to alternating current for such supplies and its use would in many ways be of great advantage. He understood that the owners gave the matter full consideration but decided on the use of direct current mainly on the score of quieter operation in the passenger accommodation. The speaker thought that at this date sufficiently quiet a.c. machines and apparatus could be obtained so that this objection would be removed. There were many large hotels using alternating current throughout without inconvenience.

In an a.c. distribution scheme of this sort the current would be generated by small compact high-speed turbo-alternators at, say, 2,000 volts and used direct at this pressure for the largest engine room and other auxiliaries. An intermediate pressure of say 400 volts would be distributed by transformers for all the auxiliaries of moderate size. The same transformers would also supply groups of circuits for lighting, table fans and domestic appliances at 115 volts. It would not be difficult to ensure complete safety and reliability for such an installation in a much more satisfactory way than was possible when dealing with so large an amount of d.c. power. The very large central switchboard normally installed to control the auxiliary circuits would be dispensed with. The necessary d.c. supplies for excitation would either be generated separately for each propulsion unit or converted from the general a.c. auxiliary supply as found desirable.

He did not wish his remarks to be misinterpreted as uncalled for criticism of what was certainly an outstanding achievement, but as a suggestion, in line with the Author's own remarks, of what very recent progress might enable to be done for a future vessel like the "Normandie", with benefit to all concerned.

Mr. G. O. Watson (Member) said that the owners of the "Normandie" were to be congratulated on the successful running so far achieved with their electric propelling equipment.

As one who was particularly interested in electric propelling equipments he would appreciate some enlightenment on various points.

In the first place it was well known that in four-screw equipments with all screws running at the same speed, the power did not divide equally over the four screws. The motors were usually rated equally, which meant that they had to be sufficiently large to deal with the screw taking the highest power. Therefore normally two of the motors would be running at less than full power. Alternatively the shafts might be run at different speeds so that they shared the load equally, but this was not possible when two of the motors were connected to one alternator. In the case of the quadruple-screw vessels "Queen of Bermuda" and "Monarch of Bermuda" the set-up switches provided for this by enabling the two inner propellers to be connected to one alternator and the two outers to another. It would be interesting and useful to know what distribution of power was obtained on the "Normandie"

(*a*) when on a straight course,

(*b*) when turning.

It had been stated elsewhere that in order to reduce vibration the direction of rotation of the propellers was altered so that the inner propellers turned outboard and the outer propellers turned outboard. Was any alteration in the distribution of load experienced after this change? It had also been stated that vibration was reduced by synchronising the propellers. Could the Author give further information and were the alternators paralleled in order to effect synchronisation?

Incidentally, the reported alteration in rotation of propellers was another example of the flexibility of electric drive, as it would not appear feasible to accomplish this with direct turbine drive. The electric motors could deliver their full power either clockwise or counter clockwise.

The Author referred to the fact that during winter service two of the turbo alternators could be laid off and examined without interruption of service. This advantage applied to all multi-engined electric propulsion schemes including Diesel-electric.

On page 55 it was stated that the blade height in the first few stages was 300mm., i.e., more than 12 inches. Was this correct?

With regard to the graph shown in Fig. 22, the maximum current passing between the alternator and motor was about 2·4 times the full load current. This was somewhat lower than that usually experienced with synchronous motors and appeared to denote a high internal reactance in the machines. Could the Author say whether reversing was done with the slip rings of the motors completely open-circuited or was a discharge resistance left parallel with the direct current winding? If the former was the case, had any record of the induced voltage across the slip rings been made? Maximum torque was obtained under the former condition, but the induced voltage was very high. If a resistance was used the voltage could be reduced but at the expense of starting torque.

It would also be interesting to know what type of insulation was used on the 5,000 volt cables.

Mr. A. C. Hardy, B.Sc. (Associate Member) said that he was glad to add his remarks to those of the prominent marine engineers and marine electricians who had discussed M. Roth's paper. He had been afforded unique opportunities, thanks to the courtesy of M. de Malglaive, of inspecting the "Normandie" during construction, on trials and in service, and felt that as a result of these observations the Author had, if anything, understated the case.

For the first time in the history of electricity, a ship was in service with four motors, each of 40,000 s.h.p. and with a single armature. As perhaps Mr. Belsey would be prepared to agree, this was a tremendous stride forward when consideration was taken of the fact that only a few years ago turbo-electric drive was considered as impossible by many shipowners and their advisers.

As he saw it, a great point to be emphasised in this matter was the extreme flexibility of the power plant. This showed itself particularly in the way in which the turbo alternators and screws could be changed round as regards duty, and was practically demonstrated on the maiden voyage of the "Normandie" when owing to condenser trouble, one turbo generator set was completely cut out.

Mr. Saunders had referred to the small amount of space sometimes available for machinery in the modern passenger liner. This was shown very clearly in two quadruple-screw ships now operating out of the port of New York, in which it seemed that the only space left by the passengers for machinery was a few wood compartments above the tank top. Electricity represented the only practical solution to the powering problem in this case, and in order that it could be accommodated it was necessary to divide the boilers into two boiler rooms separated by a machinery space containing the turbo alternators and switch gear. The deck was brought down very low over these. Four propeller motors were arranged at the aft end of the ship. So too it was with the "Normandie". A complete deck came down very near to the top of the turbo alternators and the whole layout was extremely compact. If a new "Normandie" were built, undoubtedly the boiler space would be less owing to high pressure developments, for this would seem rather extravagant compared with the actual turbo alternators and motor space for generating 160,000 s.h.p.

He thought that the vessel when she came back into service would show many improvements on her previous performance and the trouble due to vibration would be found to have been cured.

Mr. H. S. Humphreys (Vice-Chairman of Council), prior to moving a vote of thanks to the Author, said that there were two points of primary importance to be considered by the shipowner when placing an order for a vessel, and they were reliability and manœuvrability. The reliability of both geared turbine and electric propulsion was established. With regard to manœuvrability, it was generally accepted that average size reciprocating-engined vessels, of both the steam and Diesel types, were more easily handled in narrow and congested channels than straight turbines. This was particularly noticeable when it was required to turn the vessel round in confined waterways.

The Author had shown them that there was a difference in weight between the straight turbine and electric drive as 13·5 was to 15, i.e. roughly about 11 per cent. in favour of the straight turbine. He would suggest that some of that 11 per cent. might be used in giving a little more astern power in a straight turbine.

Mr. Humphreys then proposed a vote of thanks to the Author, which was very warmly accorded.

By Correspondence.

Mr. W. Hamilton Martin (Member) wrote that seldom had a paper been presented before this Institute which expressed in such a thoroughly convincing manner the many good points the electrical method of propulsion had to offer to those who were responsible for having to decide what would be the best compromise for a given duty of a vessel which had to show economic operation over a number of years of its life during which rapid changes in types of drive were bound to occur. High initial cost and to some extent its extra weight would limit the application of turbo-electric drive to vessels for which the requirements were special, but the Author had certainly put forward a strong case for its many merits. The writer thought that the name of Engineer Captain W. Durtnall might be recalled as one of the earliest pioneers of this means of propulsion. His participation in the discussion would have been very interesting.

Mr. Smith referred to the question of materials required for the higher temperatures and pressures which the Author mentioned as likely to be adopted in the near future to obtain greater efficiency. He referred in particular to molybdenum boiler tubing and Sicromal superheater tubing, and asked for particulars of these. The Author pointed out that this propulsion system would allow of shorter steam piping, as the turbines and boilers could be more suitably disposed in the vessel. In regard to the latter, the writer would suggest that with these higher temperatures the steam piping, whatever its length, would have to be of special material to stand up to the wide temperature variations and resulting expansions and heat stresses to which it might be subjected. As to the molybdenum tubing mentioned by Mr. Smith, this had found wide application on the Continent for high-pressure high-superheat boiler work on land and in marine work, amongst which might be mentioned Wagner, Loeffler and Benson boilers, and the boilers of the turbo-electric vessels s.s. "Scharnhorst" and "Gneisenau", as well as those of the s.s. "Uckermark".

The boiler tubes in these cases were of small diameter and all *cold* drawn and of low-molybdenum content, which was a fractional percentage only. It was a hot-tough steel and had exceptionally good heat-resisting qualities between 750 and 1,000° F. Known as Th.30, Th.31, Th.32 and Th.33 steel, it had specially good yield and creep figures over the range mentioned, and was very workable and had good welding features which had led to its adoption for drumless boilers having long lengths of tubing. Its cost was low. Sicromal, mentioned by Mr. Smith, was used largely for superheater elements. Sicromal CS65 was a quality steel which was finding wide adoption, as it withstood temperatures up to 1,200° F. without scaling, and could be worked cold easily. It was entirely free of any nickel, an element which was so apt to absorb sulphur at high temperatures and led to early disintegration of any alloy in which it might be used. Low chromium content and aluminium were the main alloying elements of Sicromal which was now finding very wide use in power stations and marine installations abroad for parts of Velox boilers, oil refining plant, heat exchangers, soot blowers, etc. Its cost was comparatively low and where it was not affected by hot gases within its working range, it had been found after building out elements which had been in prolonged service that notch impact values were practically unimpaired, and no scaling had taken place on its surface. Superheater elements, supports and soot blowers were made from Sicromal in its various qualities, and it had also been used on German vessels for such purposes.

As to material for steam piping working at high temperatures, a copper-nickel-molybdenum steel was proving very satisfactory. This was known as Th. 40, Th. 41, and Th.42 steel which showed exceptionally great toughness and physical qualities between 650 and 1,050° F. especially as to yield and creep.

It might not be out of place to mention here the special steels used for water and steam drums of boilers. Th.10 was one of these 26/32 tons tensile steels, as used for the water gas welded steam drums and radial-rolled water drums fitted in the "Scharnhorst" and "Gneisenau's" boilers which operated at 710lb. pressure and a steam temperature of 880° F. These were shown in Fig. 27. The water gas welded steam drums on the right were passed by all the inspection authorities and registration societies concerned, which permitted of their operation at these high temperatures and pressures in a passenger-carrying liner.

Fig. 27.—Forged welded steam drums and radial-rolled water drums.

For those members and others who would like more information on these boiler steels, the writer would refer them to his illustrated contribution to Mr. T. H. Burnham's paper "Steels in Marine Engineering Service", Vol. XLVI, No. 1, pages 27 to 36 of The Institute's Transactions.

Mr. Archibald Walker, M.A. (Associate Member) wrote that he put forward the following questions for the consideration of the Author and would be grateful for his opinion.

What did the Author estimate to be the life of the propelling motors mechanically, due to alteration in alignment, and electrically due to the rather severe reversal of the motors? Presumably the propelling motors were fairly well towards the stern of the vessel. Was there any possibility of the ship vibrations being increased due to the extra weight of the revolving masses at the after end of the ship? Alternatively, if propeller vibration was set up, was there not more chance of mechanical breakdown of the propelling motors due to bad alignment?

Was the danger of fire increased by electric propulsion?

If the steam cycle of the "Normandie" was improved to give a maximum saving in consumption of 25 per cent., her consumption would be similar or perhaps a little better than projected geared turbine vessels in this country. Had the Author in his weight comparison table on the last page taken into account the increase in weight of such things as feed heaters, superheaters and air-heaters, which would be necessary with such an increased pressure and temperature steam cycle in order to give the 25 per cent. reduction in steam consumption?

Mr. Charles Rettie wrote that there seemed to be no radical change in the system adopted for the "Normandie" from that in general use which had been developed by American engineers, i.e. the use of synchronous motors with damper windings for merchant ships, though the asynchronous type was still retained for the United States battleships (where the question of economy did not arise) on account of the better manœuvrability as compared with the synchronous type.

The writer had hoped that the French engineers would have developed a system of their own, especially as he believed that more had been done in France than any other country in the matter of research work and development of alternating current machinery. For instance, the Boucherat type of motor—a French invention—was the first used in some of the American battleships, and was still in use in a modified form.

The synchronous type of motor might be best for ships such as the "Normandie" using the southern course of the Atlantic and going full speed in all weathers in either direction to maintain schedule. The navigator need not fear fog as much as when icebergs were likely to be encountered. On the southern course, which the

New York liners generally took, there were few, if any, icebergs. The northern course, however, was different, as when crossing the Banks of Newfoundland in foggy weather, with icebergs and icefloes present in the Straits of Belle Isle, ships had to go very slow and signals were sent to the engine room every few minutes either to change speed or to stop or reverse. As an electrical engineer the writer had been on a ship going through the Straits when these conditions were maintained for twenty-four hours, and it was a question whether the synchronous type of motor would stand up to it.

He had been informed that the propeller motors of the "Queen of Bermuda", which were of the synchronous type, were designed for an overload of 80 per cent. His informant was very enthusiastic for the use of synchronous motors in preference to the asynchronous type. However, the writer would like M. Roth's opinion on this matter.

Another interesting point was the proposal by the Author to use propellers of smaller pitch for winter work. In connection with the two proposed super liners for the United States Lines, the designer referred to the necessity in the case of the electrically-driven ship for the generators and motors to be made larger and more powerful to overcome the difficulty when running at reduced speeds. On the other hand, one of the advantages of the electric drive would be nullified if the ship had to go into dry-dock to have her propellers changed as suggested by M. Roth. Mr. Johnson referred in a paper to the relative advantages of the electric drive over the geared direct drive, and said that in the case of the "Empress of Britain" being used for cruising purposes the outboard propellers could be taken off, whereas it was pointed out by the electrical interests that the motors could all be switched on to either generator without the necessity of changing the propellers to get the desired effect.

The Author's Reply to the Discussion.

The Author, in reply, had pleasure in stating that he agreed entirely with Mr. Belsey, whose ideas on electric propulsion carried weight abroad as well as in England. He wished to thank him for his contribution to the discussion, and he took this opportunity of expressing his gratitude for the help which he received from Mr. Belsey and his firm, The British Thomson-Houston Co., Ltd. His advice, based on experience, and the data at his disposal, were extremely valuable during the construction of the machinery for the "Normandie".

The Author, in reply to Mr. S. A. Smith, stated that the guaranteed steam conditions at the turbine stop valve were 335lb. gauge pressure, 617° F. temperature. With regard to the fuel consumption figure of ·649lb. per s.h.p./hour for all purposes, several factors entered into this over which the makers of the turbines and electrical machinery had no control—for instance the boiler and condenser efficiencies—and the Author suggested that Mr. Smith should look at the steam consumption figures as given on page 54. The Author further pointed out that somewhat remarkable fuel consumption figures per s.h.p. were often obtained on trials, when every non-essential service was cut down to the barest minimum and the turbine clearances were almost at the danger point, the powers being measured by a torsionmeter, the accuracy of which was not to be compared with electrical measurement. After these trials had taken place the turbine clearances were opened up to the safe limit which increased the steam consumption. What really mattered was the fuel consumption per day at a given speed and displacement, and in this respect the Author considered that the "Normandie" would compare very favourably with any vessel of her class.

The average load on the busbars supplying the hotel load reached nearly 3,000kW.

With regard to the weight of the propulsion equipment, this was obviously rather greater than that of a single reduction gear and also just greater than that of a double reduction gear. But it should be pointed out that on vessels of this type, the shipbuilder was never troubled by heavy weights low down in the hull and it had often been necessary to add extra weight in the ship's bottom. Moreover, in those cases where the question of weight was of great importance, i.e. warships, the Author had already pointed out that the use of high-pressure, high-temperature steam combined with electric transmission, made possible an equipment of light weight.

Finally, the total price of the electric propulsion equipment was very little higher than that of one incorporating a double reduction gear.

In reply to Mr. Saunders, the Author confirmed that the reduction ratio of 10 : 1 meant a speed of 2,500 r.p.m. at the turbo-alternators, and 250 r.p.m. at the propellers. The propeller speed was fixed by the shipbuilder, and the turbine speed was chosen so as to have on the one hand the maximum efficiency, and on the other very robust revolving parts with the critical speed well above the maximum operating speed. It was these considerations which determined the ratio of 10 : 1, but one could also provide ratios of 12 : 1 or 15 : 1 if the propellers had to turn at a lower speed.

The Author regretted that a slip (which had now been remedied) occurred in the paper in describing the method for starting up a propeller motor, where it was stated that the alternator was first excited and the stator switches were closed afterwards. This of course was wrong, as the stator switches were closed on a dead circuit. The main contactors were operated either mechanically by means of an electric motor or manually by means of a handwheel.

When Mr. Saunders referred to half power operation with oversize alternators, the Author imagined that he meant 120 per cent. full load current, not 20 per cent. The reason why three alternators were used when a breakdown occurred on a fourth condenser, was that the vessel was making a record trip, and naturally the utmost power available was utilised.

The Author would suggest that one point to be gathered from this incident was that with a turbine-gear drive the propeller would have to be locked at standstill with a faulty condenser; otherwise to let it trail without steam passing through the turbine would overheat the casing and blading, and the faulty condenser prevented even cooling steam being used. One would not expect a record trip with a 12-hours period with a locked propeller. Further, it went to show that the propulsive efficiency of the propellers at half power must be very good.

Regarding the change over taking three minutes, the Author pointed out that it was an unexpected happening on the first voyage, and no doubt the switching could be done every bit as quickly as indicated by Mr. Saunders if it were a regular occurrence.

With regard to the comparison between the efficiency of the electric and the gear transmission, the difference of 7 per cent. was certainly too great. In the "Normandie" equipment the losses in the electric transmission were actually only 5·5 per cent. made up as follows:—2 per cent. in the motors, 2·3 per cent. in the alternators, and 1·2 per cent. in the excitation and ventilating auxiliaries.

Assuming a loss of 1·5 per cent. in a gear, the difference would be only 4 per cent. Since the gain in turbine efficiency was 9 per cent., the extra loss due to the electric transmission was not only compensated but there remained a balance of 5 per cent. in its favour.

At the time of the stopping trial from a speed of 28 knots, the total time for a distance of 1,760 metres was 3 minutes 50 seconds; but as pointed out by Mr. Saunders, the acceleration of the propellers when synchronised in the reverse direction was considerably reduced on account of hull limitations, otherwise the machinery would have permitted far more energetic braking.

In reply to Admiral Parnall, the Author would point out that if the ship was going ahead when the propeller was stopped, as they all knew, instead of the usual 60 per cent. power allowed for any mechanically geared turbines, the electric drive gave 100 per cent. and it was during this period when it served the most useful purpose in stopping the ship or propelling it astern. Also this feature was available without entailing constant rotation losses, as was the case with astern turbines; and it could also safely be brought into action at a moment's notice with the use of high-temperature steam, such as might conceivably happen in a sudden fog out at sea when the superheat temperature had not been reduced.

As regards the kinetic energy of the propellers being absorbed in the steam and ultimately passed into the condensers, the Author suggested that this was not strictly the case as the ship was far from being at rest when the propeller stopped, and from that point most of the kinetic energy of the vessel, in addition to the power developed when rotating the propeller astern, was dissipated when churning the water at the propeller. The Author would also point out that the heat generated in the squirrel-cage motor windings during a reversal went into the sea via the air coolers without the temperature at any point exceeding 220° F., and that on an uninsulated copper alloy bar.

The Author thanked Mr. A. D. Constable for his remarks, which called for no comment.

In reply to Mr. Watson, the Author pointed out that on the "Normandie" there was no difficulty arising from the unequal distribution of power between the four shafts all running at the same speed, even when operating at full power.

The "hold-in" torque was high enough to eliminate all risk of falling out of step, even when the state of the sea or manœuvring added to the load variations.

With regard to the height of the blades in the first stages of the turbine, there was a typographical error, for the blade height in the first stages was only 30mm. and not 300mm. as stated. This had now been corrected in the paper.

As for the voltage induced in the motor rotors during reversal, special precautions were taken to limit the voltage without affecting the torque developed; in fact during full speed reversal it did not exceed 1,900 volts.

The 5,000-volt cables between the alternators and motors were special high frequency cables designed for marine service, with particular regard to waterproofing, high ambient temperature and resistance to vibration.

The Author thanked Mr. Hardy for his remarks, which required no comment.

The Author noted that Mr. Humphreys held the opposite opinion to a previous speaker, Admiral Parnall, in that he criticized the poor manœuvring qualities of a geared turbine installation. The Author would further point out that the reciprocating engine compared very closely with the turbine-electric drive under reversing conditions, but there remained, nevertheless, a definite advantage on this score in favour of the electric transmission.

The Author thanked Mr. Hamilton Martin for a great deal of information on steam-pipe and boiler-tube material, which did not call for any further comment.

In reply to Mr. A. Walker, the Author would point out that the motors and electrical gear should easily outlast the vessel itself. This estimate was based on observed results on all modern turbine-electric vessels, and allowed for no further overhauling than a periodical inspection of the vessel which called for practically no labour costs, and the cleaning and re-varnishing of the windings say once every two years.

The Author stated that the mechanical clearance between the rotor and stator was ·50″, and the bearing load 160lb. per sq. in. at the full power journal speed of 25ft. per second.

It was generally agreed by experienced engineers that vibration on high-powered fast ships was chiefly the naval architect's problem, especially when the propelling machinery was of the rotary type which included geared turbines as well as turbo-electric, and the weight of the revolving masses which were in dynamic balance had no direct effect on this vibration. As regards the ability of electric motors to withstand any vibration on board ship, the particulars given above about the bearings and the air gap clearance of the motor should be ample evidence to any experienced engineer that the motors were far superior in respect of withstanding the effects of vibrating foundations than it was possible to make the mechanical turbine gearing normally used for ships' drives.

As regards danger of fire in the machinery space, this was definitely less on a turbine-electric vessel than on any vessel which used mechanical gearing as a transmitting medium between the prime mover and the propeller shaft; and this was recognised by the precautions which were generally taken in order to prevent a naked flame being used in the vicinity of a gearbox, which had accounted for explosions in addition to fire.

The Author would also point out that the oil used in the lubricating system of a gear drive was far greater in quantity than was necessary merely for the bearings in a turbine-electric driven vessel. Further, as this oil had to deal with practically the whole of the transmission losses, it frequently reached a high temperature when the coolers were subjected to tropical conditions.

In case Mr. Walker had the idea that the insulation of the electrical system entailed an element of fire risk, the Author stated that as regards the windings on the electrical machines themselves, these were mainly of mica and asbestos, which would not flame up even when subjected to blow lamp heat. As regards the cables, these were far more resistant to fire and much better isolated from other inflammable material than was at all possible in the case of the miles of smaller rubber covered cables used in the wiring of the lighting and other domestic circuits common to all classes of ships, hotels and private houses.

In reply to Mr. Rettie, the Author enumerated below the disadvantages of the induction motor and explained why a synchronous transmission was adopted.

The disadvantages common to all induction motors were on the one hand the smallness of the air gap, which rendered these machines more delicate than synchronous motors which had a large air gap, and on the other hand the power factor in the case of the low speeds required for propellers was rather poor, and involved an increase in the size of the alternators and hence an increase in the losses. Moreover, the squirrel-cage induction motor with single or multiple cage could not be used without accepting either a reduction in the torque developed during manœuvring, or a considerable increase in the rotor losses during normal operation. Finally, the wound rotor induction motor had the disadvantage of being much less robust and of needing complicated and bulky auxiliary apparatus.

The synchronous motor, on the other hand, had none of these disadvantages. It had a large air gap and the rotor, which was very robust mechanically, carried two separate windings, one for manœuvring and the other for normal operation. The first of these, which was a true squirrel cage, had been specially designed to obtain a suitable torque-speed characteristic for manœuvring. It was originally proposed to fit a double cage, but this solution was abandoned in favour of concentrating all the metal in a single cage, in order to give the maximum heat capacity for absorbing the heat liberated during manœuvring without a large temperature rise. The second winding, which was the actual field winding, enabled the motor, once it had been synchronised, to operate normally at unity power factor with excellent stability and high efficiency. It was the application of the principle that in all transmission of electric energy it was preferable to produce the magnetising force in the place where it was consumed. All these reasons naturally led to the adoption of the synchronous motor.

Finally, the Author would state that he keenly appreciated the very great honour of being invited to read before your Institute a paper on the turbo-electric propulsion equipment of the trans-Atlantic liner "Normandie". He wished to express to the President and to the members of The Institute his gratitude for this opportunity, and to thank the many highly competent contributors to the discussion.

In conclusion, he wished to mention again the names of Messrs. G. Belfils and R. Koch, Engineers of the Alsthom Co. at Belfort, who aided by their colleagues had made such a success of the electric propulsion equipment of the "Normandie".

The History of Technical Education.

Read by J. Paley Yorke, M.Sc., A.M.I.E.E., on Thursday, January 30th, 1936, at 6 p.m.
Chairman: T. R. Thomas, B.Sc. (Chairman of Council).

I must apologise for the pretentious title of this talk about the development of technical education, though I do not suppose that any one of you imagines that the history of technical education could be unfolded in the course of an hour or less. My simple purpose is to point out the principal landmarks in the development of technical education, and to show the direction in which it has moved, with particular reference to engineering. You are naturally interested in engineering, and, as a matter of fact, it is mainly through engineering that technical education has developed at all.

I take it that no one will dispute that in the beginning all learning must have developed through *doing*—and doing for the convenience and comfort of mankind. It is, therefore, easy to establish the case that the beginnings of learning were essentially technical and essentially engineering in character. The son learned by the example of the father: the servant by the example of his master.

The arts and crafts of "writing" and deciphering or "reading" were essentially technical. There was no pose of "education for education's sake"—that came later when some found it desirable to indicate to the world at large that it was not necessary for them to *do* things in order to live. The beginnings of the universities were essentially wrapt up in vocational training—the educational processes of the priest, the doctor and the lawyer are technical. It is the more remarkable, therefore, that the first movements towards the provision of education for engineers should have been regarded as a kind of impertinent gate-crashing into the educational mansion. There could be no *education* in doing! And as for *culture*—preposterous! I have no doubt that much of this opposition arose from the use of the adjective "technical"—and the word is still a canker in our midst! "Technical" education could not be a legitimate member of the family of education—where were its books? Moreover, was it not intended for engineers, and were not engineers artisans, hewers of wood and drawers of water who should be content to remain in the station to which God had called them? If, however, classes were to be provided for the improvement of the artisan, let them be for and of the artisan. A kind of tradesman's entrance might be provided to the mansion of education, by which the lower and backstairs portions could enter and leave without offending those who had entry to the front.

But the attitude of established education was not the only hindrance to development. There was considerable difficulty from the attitude of industry, which has always had a profound distrust of what it will call "theory", but what it should call "knowledge of principles on which practice is built", and an even profounder distrust of the "college man". Is it distrust, or is it fear, or is it just prejudice? Let us freely admit the foolishness of many callow youths who go straight into works from college with a mighty conceit of themselves and a complete ignorance of practical processes. Let us also freely admit that the beginnings of engineering progress (in the widest sense of the word engineering) were determined by "trial and error". What we call research to-day is essentially the modern methodical, ordered, reasoned and recorded development of the fundamental and essential method of "trying things out".

Thank Heaven this distrust of theory is dying out, and it is gradually being recognised that the man who loudly and boastfully proclaims himself to be just "a practical man" is, as Sir Josiah Stamp said a few days ago, "the kind of man who to-day is putting into practice the theories of thirty years ago". There is, however, some irony in the thought that the gradual acceptance of theory may have been due more to a recognition of its probable economic value (in the reduction of costs of production and materials) than to its value in development. Nevertheless, the findings of the scientists of to-day are examined by a better educated, less biassed, and more understanding engineering world—and I think that it may be claimed quite fairly that this desirable state has been brought about by the efforts of technical education during the last half-century.

How far the beginnings of conscious training in the principles of crafts came through the old craft guilds is not very clear. The masters did teach the apprentices their crafts—but there was no definite educational provision, and the indentures of apprentices of those days make little mention of the master's obligations to the pupil, but considerable mention of the pupil's obligation to his master both in the matter of what he shall do and what he shall not do. I have copies of the old indentures in one of which the master undertakes to teach the pupil. In that contract the pupil is not to receive any payment. In the other there is no undertaking on the part of the master to teach the apprentice, but as an offset, a sum of 30s. per annum (payable quarterly) will be paid to him! Probably a generous *quid pro quo!*

It was in 1799 that Dr. Birkbeck opened a class in Glasgow primarily for the workmen who made his apparatus and who wanted to know what it was all about. Twenty-four years later the Glasgow Mechanics' Institute was formed. There we seem to have the beginnings of ultimate provision of classes with "engineering" as the core. These beginnings came through voluntary effort and out of private funds. At the same time that the Glasgow Mechanics' Institute was formed, the Birkbeck Literary and Scientific Institute was formed in London by Dr. Birkbeck, who had left

Glasgow. (This is now the Birkbeck College of London University). In the course of a very few years mechanics' institutes were established in many towns up and down the country, but their work was hindered by the low educational calibre of their students—a natural result of the defective state of elementary education—and by the difficulty of finding teachers who could appreciate and meet their educational limitations and their professional needs.

In 1851, as one of the results of the great exhibition of that year, the Science and Art Department was established as a department of Government to encourage and develop the teaching of science and art. Classes were established and Government grants were made—the grants being made on the results of annual examinations. This Science and Art Department was put under the control of the Board of Trade, but in 1857 the Board of Education was established, and the Department was transferred to it.

It is of some importance to note at this point that the encouragement towards the establishment of classes and the direction of the subject matter which should be taught came through the establishment of examinations. Furthermore, financial assistance depended upon examination *results*—and this applied not only to the establishment costs but also to the payment of the teachers! Notwithstanding this, development in educational provision was very limited, and a feeling grew up that it was not sufficient to teach art and science to young industrialists: they must also be taught how practically to use that knowledge.

In 1876 the livery companies of London decided jointly "to make efforts to educate young artisans and others in the scientific and artistic branches of their trades". This represented joint action in place of, or in addition to, the actions which most of the livery companies had taken themselves. It was also an indication that the decay of apprenticeship was being felt then.

The outcome of this action was the establishment in 1880 of the City and Guilds of London Institute for the advancement of technical education. This is a very important landmark. The new institute was to promote the development of technical education by means of examinations which should be definitely technical (or "applied" science and art) in character, and which would deal with "processes" and the application of science to the various industries. To this end the technical examinations of the Society of Arts were transferred to the new Institute—and in passing one must pause to pay a tribute to the splendid pioneer work of the Royal Society of Arts and to note the excellent work which it still does. In addition to the establishment of this technical examination system which would serve the whole country, the City and Guilds of London Institute established a trade school (Finsbury Technical College of happy memory and now, alas! defunct), and a central institution (at South Kensington) which should provide technical education of a high standard, and serve as a training school for teachers of technology. Furthermore, it was authorised to give grants to assist technical classes at King's College, London, and to establish chairs at University College, London.

It is the examination system of the City and Guilds which is best known to industry, and we know how the system developed, and how industry came to "recognise" its certificates. Let us again note that the encouragement and guidance towards the provision of appropriate technical classes came through an examination system.

In 1880 a Royal Commission on Technical Education called attention to what was being done in other countries. There has been no other Royal Commission on Technical Education, but in spite of this fact—or because of it—there has been tremendous development since those days. In the early "eighties" the Charity Commission called attention to the fact that the incomes for charity purposes of 112 London parishes had increased out of all proportion to the size of the resident populations. As a result an Act was passed providing for the application of the surplus funds to education, to provision of playing fields and institutes, etc., for the benefit of the poorer inhabitants of the Metropolis. The City companies nobly came to the support of this idea, and in the course of a dozen years we saw the establishment of a ring of polytechnics in Greater London. The establishment of the Polytechnic in Regent Street by Quintin Hogg was certainly a much more important factor in *educational* development than he had anticipated—for it was owing to the Polytechnic that the City Parochial Foundation applied funds for the establishment of others.

This was a wonderful advance in London—for here at last proper provision was being made for the establishment of *classes*. The examinations had been provided, but the means of educating probable candidates had been sadly lacking.

Coincident with the beginning of this development of polytechnics by the great charity organisations, the London County Council adopted the provisions of the Technical Instruction Acts of 1889 by which an annual sum of money (arising from a tax on beer and spirits and originally intended for the compensation of any publicans who might have their licences revoked) should be diverted to the promotion of technical education. This money was known to us as "whisky money", and the L.C.C. set up a "Technical Education Board" to utilise this money in further developing technical education in London. It established a number of technical institutes and technical schools, and proceeded on a general idea of providing a series of "monotechnics" rather than polytechnics—a monotechnic being a technical school providing for the educational needs of one industry. Thus we saw the establishment of The School of Building, The School of Engineering and Navigation, The School of Printing, and so on.

In 1902-3 the technical instruction acts were repealed when the new education acts came into force, whereby the old school boards ceased to exist, and all types of education were placed under the control of local education authorities. During this very important period we saw the development of London University in the direction of a *teaching* university and away from the function of a purely external examining body. Courses were approved within technical colleges as being "internal courses", and some teachers were "recognised" as internal teachers of the University. Schools were being looked for, and there was some competition amongst the several polytechnics for absorption into the University. Eventually the People's Palace —now Queen Mary's College—and the Birkbeck Institute (shades of Birkbeck!) became Schools of the University, and those polytechnics which had been thinning out their technical work in their ardent courtship of university status and so drifting away from their main purpose, found it necessary to make considerable efforts in fresh directions in order to recover a certain amount of lost ground. But the interesting point of this tragi-comedy lies chiefly in the fact that at about the same time that London University began to expand as a teaching university and place the stress upon the teaching and the training. technical education began also to shake off the domination of the examination, and to develop on the sound principle that education is the thing, and that the examination is a function of education which has its place at the end of the training, and which should be used to test the work done in the course, and not to prescribe the course.

And thus we come in this rapid review to a most important educational landmark—the abolition in 1911 by the Board of Education of its examinations (formerly the examinations of the Science and Art Dept.). In the famous circular 776 the Board suggested that the examinations had played their part in setting standards and in establishing something of a tradition. Teachers had found their feet. Syllabuses could be and should be less rigid and moulded to local needs. This was a sound educational move, but the abolition of some form of national certification was too sudden to be successful. The Board said in effect: "Cut out single subject certificates, cut out elementary certificates, and substitute a certificate of attendance and success at a *grouped* course of associated subjects which we will endorse". Industry did not understand it, and industry was not prepared to accept local certificates even though the Board of Education endorsed them. Industry was not quite sure about the importance of grouped courses—still regarding fundamental sciences and mathematics as something in the nature of fussy and unnecessary trimmings designed by college folk.

Then came the Great War, and with it a realisation as never before of the importance of a technically educated nation, not only for the making of the munitions of war but for the making of all the things which we then discovered we had neglected. Realised, too, was the conservatism of our methods of production—of our stiff-necked inadaptability--of our insular pride in those methods which were good enough for our fathers. Even the press—so prone to regard education as a non-productive spending department—actually urged the need for a greater provision of technical education facilities. And it must be said that from that date the press has continued to give intelligent and informed support to the development of technical education. In the years following more technical colleges were built, existing colleges were extended and equipment was improved.

In 1922 came the establishment of the National Certificate scheme based on the original grouped course idea of the Board, but with the vital addition of the co-operation of industry through its learned societies. We now have National Certificates in Mechanical Engineering, Electrical Engineering, Building and Chemistry, and Commerce is on the way. The whole system is based on internal courses designed by each college and approved by a joint committee of the Board and the learned society concerned. The examinations are internal, and are assessed by the joint committee which issues the appropriate certificates. It has had a 15-year trial, and has been found good. It is in my opinion the most valuable development in the history of part time technical education, and may yet be an invaluable pointer to those other inhabitants of the educational world who are finding themselves strangled in the coils of examination systems which set the pace and dictate the studies.

During this development the City and Guilds proceeded to follow on parallel lines. The elementary examinations were abolished. The group course idea was embraced. Advisory committees were set up to draw up group course schemes, and candidates were not accepted for examination unless they had attended satisfactorily approved courses. All along the line was adopted the obvious truth that the *course* is the real thing, and the examination is a servant and not a master.

I have said nothing about the junior technical schools for the provision of pre-apprenticeship courses. They require a paper to themselves. They have developed tremendously since their origin, and have forced themselves to the serious consideration of the educational world as a whole. They are not substitutes for apprenticeship: they are schools having an enormous advantage over their fellows in that their pupils have chosen one career, and the curriculum can be so moulded that every subject is shot through with significance. The teaching can be live and related to life as a whole as well as to the chosen career of its pupils. They have been extremely successful, and their wide provision may well solve some of the big educational problems of our schools to-day. Industry as a whole does not yet appreciate their existence or their work, but those grades of industry which have looked at them have found them very good and have readily absorbed their products. They have only been in existence since the beginning of the century, and they have developed along good educational lines largely because they were not restricted by predetermined examination requirements. They were started on a rather narrow trade basis—but many soon developed themselves on the basis of providing a fundamental education for entry into an industry as a whole rather than for entry to any one particular occupation within the industry, and such schools provide a three-year full time course with an age of entry of 13. Their establishment and their successful development to date stands out as one of the high spots in the history of education.

I should not conclude this survey without making a reference to the fact that some local education authorities established departments in technical colleges to meet the needs of the officer personnel of the mercantile marine in preparation for their several certificates of proficiency issued by the Board of Trade. This provision has undoubtedly been a great boon to the officers, and if it has not already produced as much beneficial and rationalising effect on the professional examinations as we should like, it has done *something,* and is bound to produce more development on educational lines consistent with modern knowledge.

Technical education is steadily winning its kingdom, but the greatest need to-day is the more complete co-operation of industry. By industry I am not referring to employers only. Employers and employees have been enthusiastic and suspicious in turns. Employers have been fearful lest we were educating all to be works managers. The employees have been fearful lest we were short-circuiting apprenticeship and creating cheap labour. Technical colleges cannot make engineers: they can and do help men to become better engineers—to be understanding and adaptable. I look forward to a closer co-operation with industry. I urge it to come amongst us and advise us about our courses and help us in the selection of our equipment—and in its provision, too!—and tell us of its needs. I hope to see it co-operate by helping towards some measure of part-time day class work for its apprentices arising from a review of its methods of recruitment and conditions of service. The fuller co-operation of industry as a whole is the next most urgent need in the development of technical education.

Discussion.

Mr. John Weir (Companion), upon being called upon to open the discussion, said that he had had the great pleasure of working with the Lecturer at the L.C.C. School of Engineering and Navigation, Poplar, from 1915 to 1932, as Member and latterly as Chairman of the Advisory Committee, and had learned to form a high opinion of Mr. Paley Yorke's work, his noteworthy enthusiasm in the education of young men, and his kindly interest in their welfare, just at their impressionable and adolescent stage.

A tribute, he thought, was due to the profession of teaching, in which comparatively few "plums" were obtainable. It was a very self-sacrificing job, involving long hours and duty at awkward times, and he thought that the community as a whole owed a great debt of gratitude to the teaching profession.

With regard to education in industry, the firm with which their President, Mr. Denny, was associated were pioneers in the matter of encouraging young men to educate themselves, and offered facilities to their employees long before education authorities made provision for technical education. He knew that from personal knowledge and experience. Mr. Weir strongly supported the Lecturer's plea for co-operation between industry and the educationalists. It would be a fine thing if employers would do as much as they could to encourage young men to study the problems which arose in their work—a pet subject of his own.

He was happy and proud to think that this Institute had done a great deal in encouraging the educational side of marine engineering work. In the early days it was difficult to induce the young apprentices to attend classes in the evening after their long day's work, starting at 6 a.m.

He noticed that the Lecturer's remarks referred very largely to the work of London instead of, as he had expected, to the national developments. London, of course, did lead the way in the matter of educational facilities, but such places as Liverpool, Newcastle and Glasgow were proud of their efforts, especially in education for the shipbuilding and engineering industries.

Nowadays there were naturally far more students anxious to attend the classes at the many splendid and well-equipped schools, polytechnics and colleges, the provision of which by municipalities had been a feature of the wonderful advance made in the past fifty years. The increased but as yet not wholly satisfactory co-operation of industry had assisted materially in this respect. More and more of the private firms had their welfare schemes, a foremost place in which was given to education. It was now expected that young boys should attach themselves to the local institute.

He was inclined to agree with the Lecturer in his views on examinations, in which many young people seemed unable to do themselves justice, due to nervous tension. In the end, not always was "The race to the swift and the battle to the strong", and the very encouragement of study by youngsters for study's sake, as a mental exercise, a challenge, a sort of discipline, making for a well-ordered mind, was incumbent upon all who were interested in the training of youth.

Mr. Weir concluded by thanking the Chairman for giving him an opportunity of tendering his personal thanks to his old "Chief" for his interesting and timely paper, delivered in that racy and at times pawky manner of his, which endeared him to his students. He expressed the hope that everyone present would do his best to persuade any young lad in whom he was interested, be he son or nephew or employee, to take advantage of the existing facilities for the acquirement of technical education, the better to equip him for the battle of life.

Mr. G. F. O'Riordan, B.Sc. (Member) said that he was in complete agreement with the Lecturer and wished to associate himself with the view of the previous speaker that The Institute had contributed greatly towards improving the general educational status of the marine engineer. The formation of the Education Group in The Institute was an important development on which their Council was to be warmly congratulated, and more particularly for obtaining the services of Mr. Paley Yorke as a lecturer.

The term "technical" as applied to technical education, was an unfortunate one, and one which seemed to mislead the public, tending to give quite a wrong impression of what this type of education involved. The terms "primary", "secondary" and "university" needed no explanation, but the term "technical" always seemed to convey the idea that it was education for workmen, tradesmen, and more often for people of the poorer classes (in mentality).

For many years principals of technical colleges throughout the country had, with the approval of their local education authority, conducted what were known as "open days", when the colleges were open to the public to show the scope and range of the work performed, the nature and extent of the equipment, and more directly to educate the public in what technical education represented. These "open days" were always well and enthusiastically attended, and the press found it very convenient to allocate a considerable portion of their columns to reports on the exhibitions of work done. The impression gained was that advancement had been made and that business men, having expressed their appreciation of the movement, would more effectively co-operate with the college. But almost invariably, after a few days had elapsed, the position remained as it was for another twelve months, until the next "open day" occurred, with nothing done.

Technical colleges had contributed enormously towards the success of their national industries, and it was most important that representatives of these industries should associate themselves closely with what was going on inside these technical colleges. Members of the teaching staffs of the colleges possessed academic qualifications and industrial experience, but it was important for them to be kept in touch with the latest developments in industry. A large number of technical colleges had gained this healthy co-operation with industries by forming advisory committees; firms had rendered valuable assistance by providing equipment for the laboratories, equipment which most probably could not have been obtained otherwise; and as a result the students, as well as the public, had felt the existence of the real contact of their classes with industry.

Reference was made by the Lecturer to the "no passes, no pay" system of some years ago. It was to be hoped that education authorities were not going to revert to this system, for, even in a huge place like London, there seemed to be a tendency for educational aims to be overlooked and the progress of education to be measured in terms of the number of individuals who entered the school and the number of hours of attendance per week. Statistics such as these were grossly misleading, especially in technical colleges of a higher rank.

If the other more important scientific and professional institutions could be persuaded to follow the excellent practical example created by this Institute, then there was hope for the future of technical education.

Mr. A. B. Blake, B.Sc. (Member) said that in common with all those present he had listened with much interest to the paper given with point and humour by Principal Paley Yorke. The only personal contribution he could offer was that The Institute should invite Principal Paley Yorke to return here this day twelvemonth and give another paper entitled "Technical Education in the Future".

It was difficult to follow Mr. John Weir and others whose right to speak on this subject was attested by their experience and appointments. For this reason he felt that there might have been some advantage in following the procedure adopted at Navy courts martial, where the junior officer present had the right to give his verdict first, subsequent verdicts being given in ascending order of seniority. In that case it would have fallen to his lot to speak immediately after the paper had been given, for he had the least title of any present.

Something had been said in the discussion about the disadvantages of the word "technical" as applied to education, although no alternative differentiation between other forms of education had been suggested. Surely the Greek for both "art" and "craft" was *techni,* and until the nineteenth century "art" in English meant much the same as "craft", and "craft" was synonymous with "trade". (Even now, when one said that a man had "learnt his trade" or "had a trade" one meant not that he was a clever salesman but that he was a good technician).

Principal Paley Yorke referred to the well-known reliance placed by the business man upon the matriculation certificate. What alternative was there? Surely it was the duty of educationists to provide an alternative. If a suggestion was permissible it was that colleges engaged in instruction of this kind should devise curriculum books in which would be recorded the *facts* of the training of all students, not only in works and offices, but in the college, thereby providing a continuous record of achievement either complementary to or a substitution for examination results.

Again, employment might be considered from such standpoints as the social, the educational, the vocational and the industrial; in each case there was a local and a general or national significance. It could scarcely be doubted that the task of selecting and embarking upon a suitable career was more complex and beset with difficulty than ever it was. Among the main factors which had combined to create this difficulty were these:—(1) the system of free and compulsory education; (2) the gradual extinction of traditional rights associated with advantages of birth in the realm of professional life; (3) the breaking down of hereditary customs; (4) a labour market open to both sexes with decreasing discrimination; (5) rising standards of qualification, efficiency and skill, including double qualification; (6) specialisation; (7) rapid changes in technique rendering even recent training obsolete.

The economic outlook of the nation had changed so much that a return to pre-War conditions was impossible. An unprecedented volume of unemployment, contributed to by mechanisation as well as by shrinkage in total trade, was a matter that affected not only the operative but the intermediary and administrative worker in industry. Similarly, economic pressure, restlessness, and the continual urge for sex equality, combined to extend the problem already so intensified. It was against this background that the would-be entrant to the professions, commerce, industry and trade had to relate his or her personal fitness for work and place.

Broadly, vocational success had been considered in three phases: (1) the individual, (2) the job, (3) supply and demand. "It is the first of all problems for a man to find out what kind of work he is to do in this universe".* That direct exhortation to the student body of Edinburgh University was an authoritative statement of priority from a Lord Rector who preached the gospel of work. To quote another authority—"it is the duty of parents and guardian to endeavour, with the utmost care, to discover the capacities and fitness of youth for any business before they engage in it" . . . "But the fondness of parents for their offspring is mostly such as to blind them in forming a judgment, and disappointment is sure to follow" . . "a man may be so formed in body and mind—with such symmetry and health in the one, and such energy in the other—that he may advance a great way towards perfection in anything he ardently pursues".†

The personal problem of selection should be made on the basis of preference and aptitude, without severe restriction of choice and by the avoidance of the blind-alley occupation. Even so the horizon of opportunity was not unlike that presented to the navigator, one of varying visibility, and sometimes hypothetical. Apparently the choice was limitless—the boundless ocean of human endeavour—but in practice it was much circumscribed by home influence and environment, by education, health and financial considerations. The two outlines which followed revealed something of the work to be done by various hands if vocational success was to be achieved.

VOCATIONAL SELECTION AND GUIDANCE.

(1) Preparatory school training.
- (*a*) Mental age test.
  - (i) Intelligence quotient classification after 9 years of age.
  - (ii) Scholarship level of I.Q.
  - (iii) Special abilities and disabilities as shown by mental age test.
  - (iv) I.Q. level of principal vocations.

(2) School training.
(3) Knowledge of careers open.
(4) University education.
- (*a*) Recruitment of graduates by professions, industry and commerce.
- (*b*) Promotion of graduates engaged in industry and commerce.
- (*c*) Statistical analysis of turnover of graduates in industry and commerce.

(5) Job analysis.
(6) Placement.
(7) Job specification or man specification.
- (*a*) Duties of the position.
- (*b*) Essential qualifications.
- (*c*) Qualifications which are not essential but may be of value.
- (*d*) Route to the job.
  - (i) Learn and begin at the bottom.
  - (ii) Advance after proof in and adequate knowledge of original work.
- (*e*) Probable line of promotion.
- (*f*) Recommendations.
- (*g*) Vocational success.

REQUISITES FOR SUCCESS IN BUSINESS.

A. Objective factors.
- (1) Capital resources.
- (2) Business connection.
- (3) Suitable location and timeliness.

B. Subjective factors.
- (1) Innate.

* Inaugural Address as Lord Rector of Edinburgh University. Thomas Carlyle, 2nd April, 1866.

† Memoir of Thomas Bewick—p. 252. London, 1862: Longmans.

(*a*) Social and moral.
(i) Good character.
(ii) Attractive personality.
(iii) Capacity for making friends.
(iv) Good manners.
(*b*) Business qualities.
(i) Organising ability.
(ii) Knowledge of human nature.
(iii) Business acumen.

(2) Acquired.
(*a*) Education.
(i) General business training.
(ii) Specialised knowledge of trade.
(*b*) Practical experience.
(i) Technical.
(ii) Commercial.

In conclusion it was perhaps not inappropriate in this Hall to quote from the late Lord Moulton, whose trenchant remarks upon the problems of technical employment were worthy of full consideration. It was his opinion that this country was far behind in this respect, and he had no faith in mere workshop experience for repairing this deficiency. In his opinion those who merely depended on this made progress only at the cost of exorbitant expenditure of time and trouble. In one address he put this point as follows:—

"Let me try by another parallel to impress on you how great is the difference between the position of those who have and those who have not received technical education. Suppose two ships were running an ocean race, say through the Straits of Magellan to Australia. When they get to the Straits of Magellan it is found that one captain has a chart which shows him the rocks, and the other has to go on sounding, sounding, sounding in order to bring his ship safely through. The work that he does would have been smart seamanship two centuries ago, and would probably have led to a profitable return, but to-day it is past its day and must lead to failure. The one who has got the chart has only to look at the chart to learn all that the other competitor arrives at by labour and care, and hence he is at his journey's end before the other has faced half his dangers".

The speaker would like to associate himself with the expressions of previous speakers in thanking Principal Paley Yorke for his interesting and instructing review of a problem which could only be solved in any real sense of the word if industry would co-operate with education to work out study group outlines and other instructional methods to meet the rapid changes in industrial and commercial conditions. For example, co-operative education such as the Cincinnati experiment and the courses for university graduates and others who had had three to five years' practical work in industrial employment, such as had been established by the Department of Business and Engineering Administration in the Massachusetts Institute of Technology.

Lastly, the common failure to overlook the importance of a *vertical* consideration of this problem should be remedied by asking individual firms to collaborate with a college in preparing an integrated system of education for (*a*) apprentices, (*b*) trainees, (*c*) foremen and (*d*) junior executives, on a progressive basis involving, where necessary, part-time education and arrangements for foremen and others to receive some instruction in the principles of subjects recognised either as "background", "tool" or "operative", partly in the time of their firms and partly in their own time.

Mr. J. Hamilton Gibson, O.B.E., M.Eng. (Member of Council) said that the lecture must inevitably have turned the minds of older Members back to their youthful days and the difficulties that then beset the young man anxious to obtain education in technical subjects. In those days schools of art were going strong. As a boy of fourteen the speaker had been anxious to attend technical evening classes, but with no one to advise him he went to the School of Art and it was two years before he discovered the Science and Art classes. No centre existed, and the classes in various subjects were held in different parts of the town. For instance, machine drawing was taught in a garret over a bicycle shop, and another class was held in the school room under a chapel. An apprentice in those days started work at 6 a.m. and by the time he had return from his classes at night it was often after 10 p.m.

He confessed that all his life he had found it difficult to follow what exactly was going on in the technical education world. Mr. Paley Yorke had explained the numerous changes.

The Lecturer made reference to the suspicion with which educated men were regarded by some employers. This reminded him of a story he read recently of an employer interviewing an applicant. On being told that the candidate had a B.Sc. degree he said "Never mind about the degree, have you matriculated?" (Laughter).

Mr. G. W. Roger (Member) said that his own experience as a boy coincided with that of Mr. Hamilton Gibson. No advice was available in those days, in contrast with present-day facilities, to guide a youth in the matter of technical education. Things had changed very much—a change with which the Lecturer that evening had been closely associated—and now a boy could go to any of the schools and get the best advice obtainable.

Even to-day, however, things were not as they should be. For a good many years it had been his duty to engage boys for employment as apprentices in the Works of which he had been Manager, and he had found that parents were only too ready to allow their children to take up employment for which they might not be suited, and regardless of the prospects for the future. Enlightened parents would do well to consult such experts as the Lecturer at the School of Engineering, who was well able to guide these boys in the vocation they should follow.

Mr. H. J. Vose (Vice-President) said that in The Institute's Library there was a book by an ex-Chief Inspector of Technical Colleges, Mr. Abbott, in which was a statement that Germany and some of the other Continental countries could give us good advice on the organisation of technical education. Apparently this country had been very much behind in this development. The Author of this book also had some interesting comments to make on the "Whisky Money" referred to by the Lecturer.

There was still a lot to be learned in connection with technical education, and if only both the technical and the practical people would keep an open mind and be ready to help each other, good would result. The technical people themselves could not get what they were aiming at without the help of the practical men.

Regarding examinations, etc., the Board of Trade had several advisory committees, and the interested parties should put forward a particular case and the Board of Trade would no doubt get the relative advisory committee to work. An advisory committee was composed of people outside Government circles. If the question was one concerning shipping or shipbuilding, then the representatives of these industries would be invited to give the Board their views. The Board of Trade examinations were not merely the work of the Board of Trade but also of the advisory committees, and if only the outside bodies would get together and insist upon the advisory committees acting, then the Board would do what was wanted. When an advisory committee drew blank it was due to the fact that it had not advised the Board efficiently. The outside bodies should come forward with some constructive policy.

Sea-going engineers needed a certain amount of relaxation when they were ashore, and he did not see how they were going to get these men to work on the lines that were customary at the universities, where students went through a systematic course. This entailed considerable expense and in most cases the pay of the engineer ceased when he signed off the ship.

The Chairman congratulated the Lecturer on giving such a clear and entertaining resumé of the history of technical education. He was interested in the Lecturer's remark that in the beginning technical education consisted of learning by doing, and he understood that from this technical education naturally developed into not only learning how to do things but how to do them intelligently. He thought that the educationalists might sometimes draw a more definite line of demarcation between the type of education particularly suited to the craftsman to enable him to do his work as efficiently and as easily as possible, and the education which the man who "created" the work required. This amounted to divorcing the education of the craftsman from that of the research worker, and although there were many objections to this kind of segregation, yet it seemed that industry would be well served by concentrating on the few men of higher technical education who could be usefully employed.

He was glad to note the Lecturer's appreciation of the contact there always had been between the schools of engineering and this Institute. Technical institutions of the character of our own were doing a proper service when they formed a link between the industry they represented and the educationalists who were training the men for that industry. It was through an institution of this description that industry should be advised of the views of educationalists on their particular problems and, similarly, that educationalists should be kept abreast of the requirements of the industry. It was only by this means that they could ensure that technical education bore its proper relation to industry.

On the proposal of **the Chairman** a very cordial vote of thanks was accorded to the Lecturer.

The Author's Reply to the Discussion.

The Author thanked Mr. Weir for his remarks. Mr. Weir had justly reproached him for dwelling on the London developments. He should, of course, have made it clear that the provincial developments went hand in hand with those which took place in London. Speaking generally, however, one might say that the development in London had been greater and more thorough than elsewhere.

He agreed with Mr. O'Riordan about the fetish of numbers in estimating the success of the technical colleges. One of the many things from which they suffered was the general inability of officials on the one hand and the public on the other to measure educational success at all.

Mr. Blake spoke about the rapid changes in technique. He quite agreed, and it was one of the strongest reasons for ensuring the adaptability of the individual by a higher standard of education.

The Greek version of the term "technical" might be "right doing" but in English it was not. He quite agreed that if its meaning was understood, they would be very, very proud.

Mr. Blake asked how they converted vocational failures into educational successes and vice versa. They did not necessarily do either. There was an idea in the world that the boy who was no use with books would be successful in practical things, and that the practical boy would be no use with books. That was entirely wrong; it was the boy who was good with books who was good with his hands. So far as the general principle was concerned the law of the jungle would prevail and the fittest would survive ultimately. All they could do was to give all a chance by educating them.

So far as matriculation was concerned, it was the employers who were largely to blame. They must educate themselves to see that the *course of study* which a boy had followed was the essential thing. He also agreed on the point of supply and demand, but so far as the training of boys was concerned, they were miles away from saturation point. There was no need to fear anything like that this side of thirty years. They were not only educating those who were going into industry, but their big battalions came from those who were already in industry, some of whom attended evening classes three times a week for years. Education was their aim; make the man first in the widest sense and the engineer second.

The sandwich system depended upon the co-operation of industry, and all the difficulty, he thought, lay on the economic side. They were always ready to co-operate with industry—were indeed anxious to do so, but industry in general had so far not come to meet them.

He thanked Mr. Hamilton Gibson for his extremely interesting remarks.

He did not agree with the statement quoted by Mr. Vose to the effect that this country had a lot to learn from Germany and the Continent regarding technical education. These countries were not always providing technical education, but trade classes. In the matter of buildings and equipment, he agreed that they had a lot to learn and so had industry. So far as the rest was concerned, England was providing education and not a substitute for apprenticeship.

He would not say that the Board of Trade Examinations were too hard, but from the point of view of educationalists they were too indefinite, too wide and too secretive, and there was no reasonable syllabus. Take the man who wished to get his Extra-Chief's Certificate. He had to know something about electricity, and he might get two questions—one in one paper and one in another. It might be anything at all and was delightfully vague. The candidate should be given a whole paper in electrical engineering as a test of his knowledge of this subject. It was not fair to push in a question here and there.

The Chairman was urging two types of education. He would go part of the way with him and say that they had two types of courses all the time. One was the minor course (workshop practice) and the other the major course which was more on academic lines, preparing students for the National Certificates, associate memberships of institutions and so on. Students had a free choice into which course they went, but there was no unscalable wall between the two courses, and he would be sorry to see anything like that happen. He did not agree that anyone could be *educated* too highly.

INSTITUTE NOTES.

ELECTION OF MEMBERS.

List of those elected at Council Meeting held on Monday March 9th, 1936.

Members.

John Thomas Claireaux, 8, Boswall Loan, Wardie, Edinburgh.

Edward Helier Deslandes, 60, Lansdowne Avenue, Bexley Heath, Kent.

Walter John Donaldson, 6, Slade Street, Crows Nest, New South Wales.

Alfred Batho Edwards, 29, Park View, Waterloo, Liverpool, 22.

George Howard Forsyth, Langdale, Princes Avenue, Petts Wood, Kent.

Arthur James Harding, Kits Coty, 21, Maple Crescent, Glanmor, Swansea.

Alexander William Hildrew, 55, North View, Eastcote (Pinner), Middlesex.

Ian Campbell Howden, Lieut. (E.), R.N., Apple Tree Cottage, Taplow, Bucks.

John Eric Kinghorn, 155A, Old Chester Road, Bebington, Cheshire.

Hugh Lewis Pirie, 38, Cadogan Road, Surbiton, Surrey.

Erwin Albert Stirling, 28, Ceylon Street, Hull, Yorks.

John Cyril Venables, 196, Garston Old Road, Liverpool, 19.

Alec Gee Willis, 18, Henry Street, Gordon, Sydney, N.S.W.

George Frederick Winterburn, 220, Clendenan Avenue, Toronto, Ontario, Canada.

Associates.

Frederick George Farmer, 5, East Avenue, Manor Park, E.12.

Bal Krishna Gupta, 141, Victoria Road North, Portsmouth.

Karinchet Kunhen Kumaran, Melbourne House Hotel, 119/121, Gower Street, W.C.1.

Sylvester Mathews, 17, Circular Road East, Liverpool, 11.

Frank Gordon Morris, 32, Lyndhurst Avenue, Tolworth, Surrey.

Student.

William Frank Spanner, Cons. Sub-Lieut., R.N., R.N. Barracks, Devonport, Devon.

Transfer from Associate Member to Member.

Cyril Gordon Crawford, Central Foundry, Ltd., Post Office Box 20, Barbados, B.W.I.

Archibald Walker, 180, Willesden Lane, N.W.6.

ADDITIONS TO THE LIBRARY.

Purchased.

"Merchant Ships, 1936". Compiled and edited by Pay-Lieut. E. C. Talbot-Booth, R.N.R. Sampson Low, Marston & Co., Ltd., 42s. net.

Instructions as to the Survey of Life Saving Appliances. H.M. Stationery Office, 3s. net.

Merchant Shipping, Acts of Parliament, Regulations, etc., issued prior to 1st January, 1936. H.M. Stationery Office, 6d. net.

Kings Regulations and A.I. Amendments (K.R. 1/36). H.M. Stationery Office, 3d. net.

Presented by Mr. C. Mace (Member).

"The Artizan" Vol. XIII, 1855, and Vol. XIV, 1856.

Presented by the Publishers.

British Corporation Register of Shipping and Aircraft—Register of Ships, 1936.

British Standard Specification No. 659-1936 for Light Gauge Copper Tubes.

"Mercury Arc Rectifier Practice", by F. C. Orchard, Chapman & Hall, Ltd., 224pp., illus., 15s. net.

The Author has avoided an analytical treatment of the subject, but in the first chapters gives a very clear account, with the aid of numerous line diagrams, of the fundamental theory of polyphase operation. The manufacture of glass bulb and steel tank rectifier plant is dealt with in succeeding chapters, which also contain a useful account of modern practice in the construction of the rectifier and its more important auxiliaries. Rectifier plant installation and sub-station layout, testing, operation and maintenance are also dealt with at some length. An unusual amount of quantitative data, current density ratings, percentage reactances, and prices crops up in the text at appropriate places, and numerous extracts from British Standard and other specifications are quoted, while at the end of the book is a useful bibliography. The grid control of rectifiers is dealt with in a separate chapter, but unfortunately only a small paragraph is devoted to their inverted running.

The numerous diagrams considerably enhance the value of the book and the photographs are clear and well chosen, while the binding and printing of the book are excellent. This volume should be of great service to a plant or maintenance engineer who desires a thorough working knowledge of rectifier plant.

"Schools, 1936", 13th edn. Truman & Knightley, Ltd., 61, Conduit Street, W.1, 772pp., 2s. 6d. net, post free 3s. 0d.

Claimed as the most useful and comprehensive guide obtainable to the scholastic facilities of Great Britain, this issue maintains the high level of its predecessors. It has been brought right up to date, and we warmly recommend it to any Members anxious to obtain information regarding suitable schools for the education of their children.

"How to Build Flying Boat Hulls and Seaplane Floats", by J. Streeter. Sir Isaac Pitman & Sons, Ltd., 90pp. illus., 6s. net.

The Author is to be congratulated for producing this small but comprehensive manual relating to the construction of all-metal aircraft hulls and floats. It is a book of practical utility which, written primarily for the constructor, will also be of value to apprentices, students, draughtsmen, designers and ground engineers.

The theories of structures and designs are not treated except for the few notes upon the general principles of air- and sea-worthiness contained in the introduction, and the Author has confined himself to the detailed explanation of the various methods of construction adopted by the leading aircraft manufacturers. He has treated his subject in a lucid and masterly fashion and has adequately illustrated his text by carefully prepared diagrams and working drawings.

The book is divided into five parts. The first two parts deal with the construction of hulls and floats respectively, commencing with the laying-off of the sheer draught upon the scrieve board to the final tests for water-tightness and the transportation of the hulls to the erecting shops where the planes and control surfaces are rigged. Each stage of construction including erection of stocks, preparation of jigs and templates, assembly of frames and shell plating, and painting and storage is described in a manner which shows the Author's intimate knowledge of his art.

Part III, which deals with the repairs of hulls and floats, is unique in character. Aircraft structures are necessarily of very light scantling and consequently the slightest mishap usually entails damage. The Author has apparently given considerable study to the question of efficient and economic repairs, and this portion of the book will be particularly useful to ground engineers and riggers stationed at marine operating depôts.

The remaining two parts deal with the method of working duralumin and alclad sheets, their riveting and their heat treatment. The latter is described solely for the practical worker and the metallurgical and chemical aspects of potassium and sodium nitrate baths for annealing and normalizing are excluded.

The book is a valuable addition to Messrs. Pitman's Aeronautical Engineering Series, and is worthy of better and more robust binding even at the risk of a higher publishing price.

"Training in Industry", by R. W. Ferguson, B.Sc. Sir Isaac Pitman & Sons, Ltd., 156pp., 6s. net.

This book is really a report embodying the results of enquiries conducted between 1931 and 1934 by the Association for Education in Industry and Commerce.

The Association was founded in 1919 under the Presidency of the first Viscount Leverhulme and was designed primarily to establish contact between British firms carrying on schemes of education and training for their employees. Addresses by leaders in industry or in education have suggested new lines of activity and given a very real impetus to enquiries which were subsequently pursued by specially appointed committees. The work of these committees has been to collect and correlate information bearing on the question under investigation, and these reports are now contained in this particular book.

There are some ten chapters dealing with such matters as attendance at external classes; training by lectures, discussions and conferences; training and pupilship schemes; and preparation for salesmanship. There are also some fifteen appendices giving precise details of the methods adopted by some of the largest firms in the country for training their employees.

It will thus be realised that the scope of the book includes matters which are of vital importance to every business executive. It presents a plain unvarnished account of what is being done to secure the right type of recruit and the right type of training for the recruits to industry, and contains no controversial opinions or extraneous matter.

It has often been said that many business executives are ignorant of the facilities provided by educational authorities, or if not ignorant altogether then apathetic towards them. This book should go a long way towards convincing the leaders of industry of the necessity for making the fullest use of such facilities if we are to maintain our premier place in world industry and commerce.

It may be said that the last ten years have seen almost a revolution in technical education. The old haphazard system of single subjects has been replaced by group courses which are constantly being revised and improved. Examples of such courses are to be found in the National Certificate Schemes in Engineering, Building and Chemistry, and in the new Endorsed Certificate in Commerce.

It is most gratifying to an educationalist to notice the enlightened outlook of many firms whose names are household words towards the training and welfare of their employees, and it goes without saying that these are the very firms whose annual balance sheets show an increasing prosperity.

The reviewer cordially recommends this book, which is excellently printed and set up. It is full of most stimulating ideas and should be found on the bookshelves of every leader in an industrial or commercial concern.

"Heat Engines", by S. H. Moorfield, M.Sc., and H. H. Winstanley, M.Sc. Edward Arnold & Co., 2nd edn., 326pp. illus., 6s. 6d. net.

The first edition of this book was published in 1931 and since that time it has been the recognised text book for S.3 Heat Engines at a large number of technical colleges. The book was written with the object of providing a self-contained textbook on heat engines suitable for students taking the Ordinary National Certificate in Mechanical Engineering. Various errors which occurred in the first edition have been corrected and a chapter has been added on steam turbines. Chapters I - VII deal in the usual orthodox manner with the elementary thermodynamics of gases and with the Carnot and Otto cycles. On page 44, R should be in ft. lb. *per lb.* per degree, and on page 67, it would be an advantage if the statement "the ratio of isothermal compression is equal to the ratio of isothermal expansion" were proved. On page 68 it is very necessary to state in connection with the Carnot cycle for a vapour, that the vapour is dry-saturated at *B* since the heat supplied is L_1, the latent heat. The formation and properties of steam, together with the various methods of determining the dryness fraction are fully discussed in chapter VIII. Here one must take exception to the continued use of the old value of 0·48 for the specific heat of superheated steam. The treatment of steam boilers in chapter IX is rather curtailed; the few line diagrams are well drawn and should be easily understood by the student.

The steam engine, condensers of the surface and jet types, with elementary theory of condensers, are dealt with in chapter X, and the hypothetical indicator diagram for the steam engine is explained in chapter XI. The subject matter of chapters XII and XIII has been well written, for the Authors seem to be fully aware that students generally regard entropy as something very mysterious. It would be better in a future edition if the method of determining the dryness fraction after adiabatic expansion, given on page 315, were introduced into Art. 98, and the cumbersome logarithmic expressions deleted. Now that values for the entropy for water are included in Callendar's tables, adiabatic equations involving the use of $\log_e T_1/T_2$ are definitely out of date.

Chapter XIV deals with valves and valve gears, and the Reuleaux valve diagram is explained very thoroughly. Sufficient elementary chemistry is included in chapter XV to enable students to understand the process of combustion and to make the usual calculations for air requirements, etc.

Chapters XVI and XVII are devoted to descriptions of the various types of internal combustion engines and a proof of the ideal efficiency of the Diesel cycle is included. The Authors make the common mistake of misspelling Akroyd as Ackroyd throughout chapter XVII.

Engine efficiencies, cylinder condensation, and the method of conducting engine trials and working out results from trial data, form the subject matters of chapters XVIII and XIX.

Speed control by governing is dealt with in chapter XX and the theory of the Porter and Hartnell governors is discussed in detail. Chapter XXI on steam turbines is new to the second edition, and it includes descriptions of impulse and reaction turbines, blading and labyrinth packings, elementary theory of the flow of steam through nozzles, and blading velocity diagrams. In the example on page 295 the equation $PV^{1 \cdot 3} = $ a const. cannot be used throughout the expansion, since the steam ceases to be super-saturated at a pressure of 60lb. per sq. in. abs. The same applies to the example on page 297. "See page 276" on page 296 should read *"see page 315"*. Centigrade heat units have been used throughout the book and typical examples have been worked out in each chapter. Examples, many of them taken from the examination papers of the U.E.I. and the U.L.C.I., are included at the end of each chapter. Answers are given so that the student is able to check his result. The book can be well recommended to apprentices who are studying for the Ordinary National Certificate in Mechanical Engineering, and to marine engineering apprentices who may be needing a textbook suitable for The Institute Student Examination.

JUNIOR SECTION.

Film Display: (1) The Voith-Schneider System of Propulsion; (2) A New German Ship; (3) The s.s. "Normandie".

On Thursday evening, February 20th, three highly instructive technical films were displayed to a large and appreciative audience in the Lecture Hall of The Institute.

The Voith-Schneider system of propulsion formed the subject of the first film, which was shown by courtesy of Messrs. Hardy, Tobin & Co. Captain E. C. Goldsworthy of this Company prefaced this very interesting film with a selection of slides and a short lecture describing the system and its advantages.

An exceptionally valuable film depicting the building and launch of the s.s. "Scharnhorst", one of the three new express passenger liners built for the Norddeutscher Lloyd's Far Eastern Service, followed. For the loan of this film we are indebted to the owners of the vessel.

To conclude the programme an outstanding film was shown of the building and launch of the s.s. "Normandie", provided by the Compagnie Générale Transatlantique. This Company's valuable contribution to the display was supplemented by a series of slides and a most instructive lecture by their London representative, Mr. A. P. de Malglaive. Supplies of a printed account of some of the notable points of technical interest of the "Normandie", prepared by Mr. de Malglaive, were also provided by the Company and distributed to the audience.

At the conclusion of the meeting warm thanks were accorded to the three Companies named, and to Captain Goldsworthy and Mr. de Malglaive, on the proposal of Mr. H. R. Tyrrell (Associate Member).

ABSTRACTS.

The Council are indebted to the respective Journals for permission to reprint the following abstracts and for the loan of the various blocks.

Co-ordination of Tank and Trial Results.

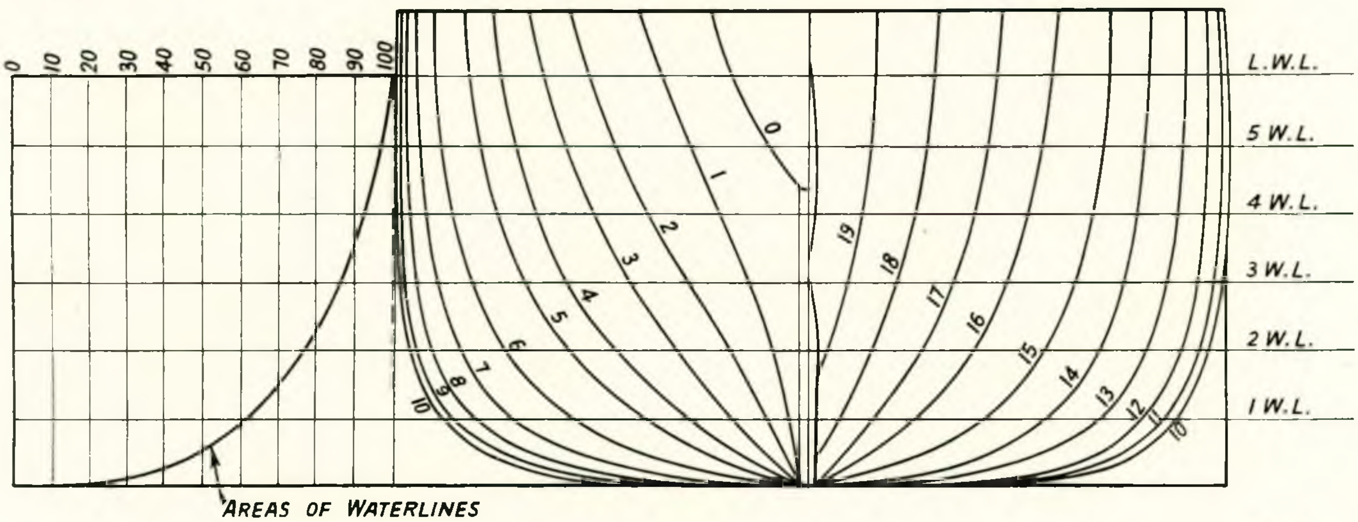
Decisions made at the Paris Meeting of Experiment Tank Superintendents.

"Shipbuilding and Shipping Record", November 7th and 14th, 1935.

In last week's issue we commented editorially on the steps which had just been taken at the Paris meeting of the superintendents of the various experiment tanks with a view to co-ordinating the results obtained both in model experiments and in full-scale ship trials. We now present a detailed account of the decisions arrived at together with diagrams showing the suggested method of presentation of the tank and trial results. The decisions which are embodied in what are to be known as the "Paris 1935 Rules" are as follows:—

I.—The decisions cover the method of execu-

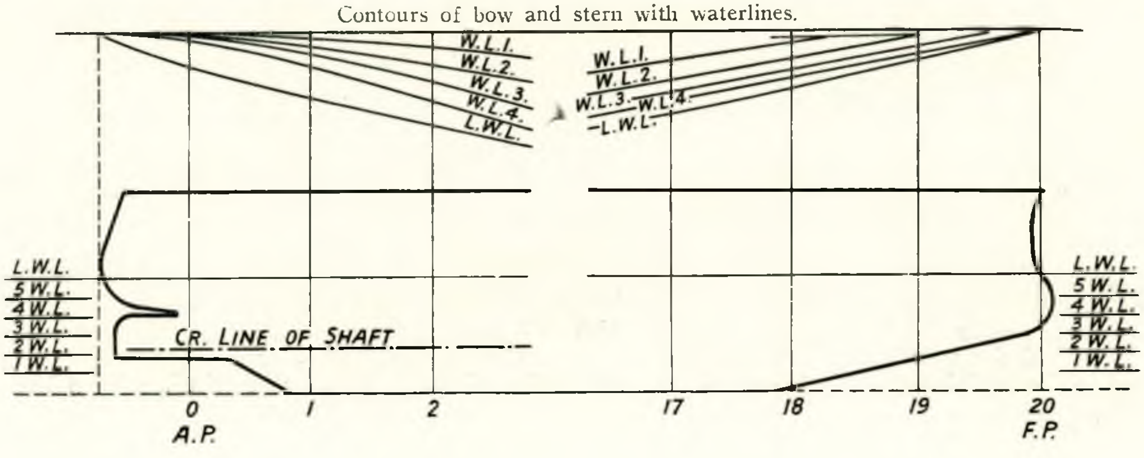
Body plan with curve of areas of waterlines.



WATERLINE	1	2	3	4	5	6
SECTION 2	5·9	11·5	19	28·7	37	53·2
SECTION 4	22·7	40·0	52·6	62·2	68	73·4
SECTION 6	56·8	73	81·5	86·5	89	90
SECTION 10	90	96·2	99	100	100	100
SECTION 14	57·2	70·6	76	79·4	81·4	82·3
SECTION 16	25·8	40·6	48·7	53·7	56·8	58·5
SECTION 18	8	15·9	21·6	26·3	29·3	31
AREAS OF WATERLINES	63·4	77·9	86·5	92·9	97·1	100

PERCENTAGE OF HALF BREADTH AND OF AREA OF LOAD WATERLINE

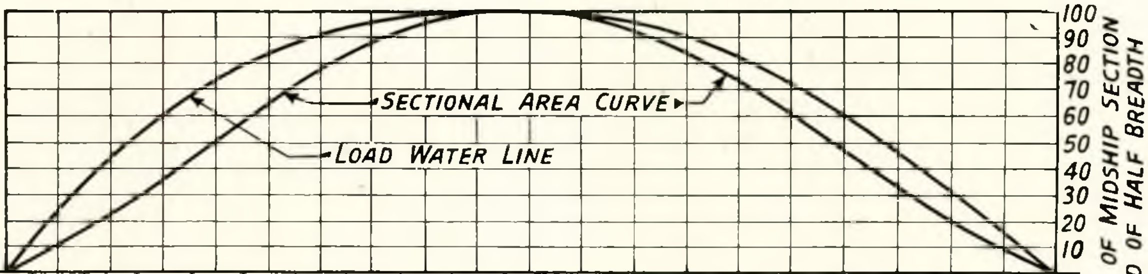
Contours of bow and stern with waterlines.



Non-dimensional characteristics of model.

LOAD WATERLINE COEF. α = MIDSHIP SECTION COEF. β = BLOCK COEF. $\delta = \frac{\nabla}{LBT}$

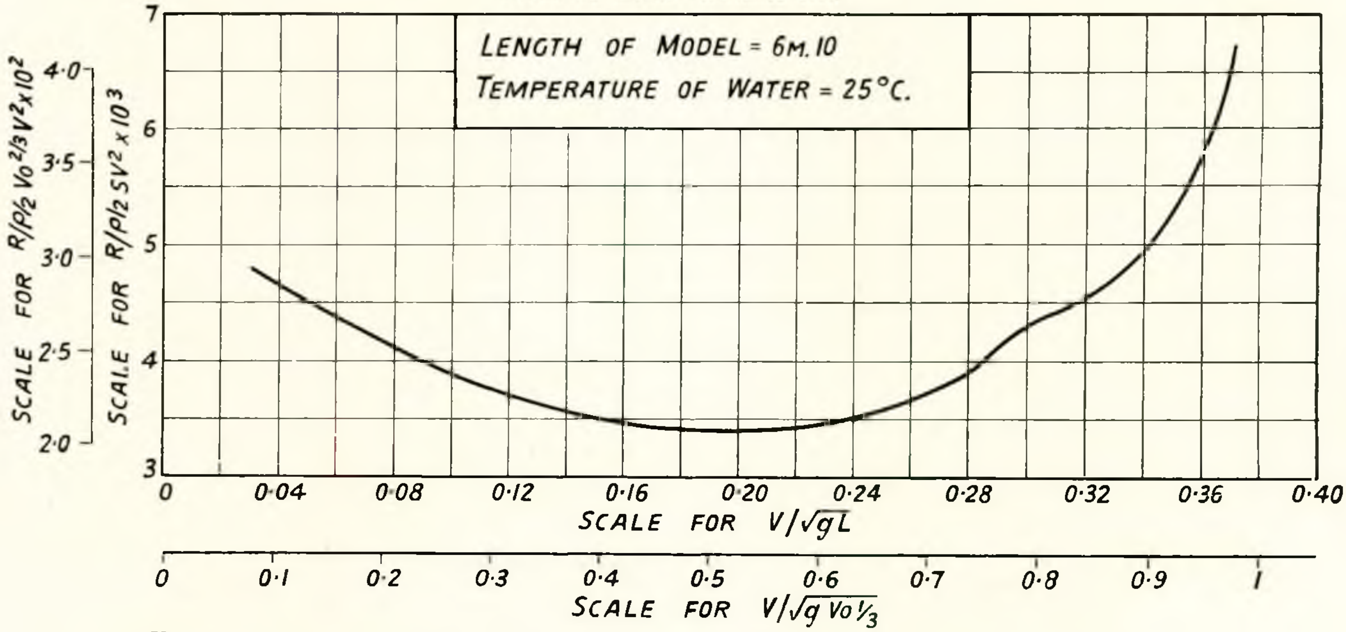
PRISMATIC COEF. $\phi = \frac{\nabla}{OL}$ AFTER BODY PRISMATIC COEF. ϕ_a = FORE BODY PRISMATIC COEF. ϕ_f =



SECTION	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
SECTIONAL AREA	0	9·8	21·4	35	50	65	78·3	88·8	95·4	99·3	100	98·1	92·6	85	73·6	60·6	46·8	32·9	19·4	8·4	0·9
LOAD W.L.	0	24	43·6	59·3	73	83	90·6	95·5	98·3	99·6	100	99	96·2	90·8	82·8	72	59·3	46	31·2	15·7	0

PARALLEL MIDDLE BODY ....%. L AFT TO ....% L FORWARD OF ORDINATE 10
CENTRE OF BUOYANCY ....% OF L FROM ORDINATE 10
O IS THE AFTER PERPENDICULAR. 20 IS THE FORWARD PERPENDICULAR

Result of model resistance test.



$\frac{V}{\sqrt{9L}}$	0·04	0·06	0·08	0·10	0·12	0·14	0·16	0·18	0·20	0·22	0·24	0·26	0·28	0·30	0·32	0·34	0·36	0·38
$\frac{R}{\rho/_2 \, S \, V^2} 10^3$	4·63	4·4	4·09	3·88	3·70	3·56	3·48	3·40	3·38	3·40	3·49	3·66	3·90	4·32	4·55	4·92	5·82	
$\frac{V \times L}{\nu} 10^{-6}$	2·18	3·27	4·36	5·45	6·54	7·63	8·72	9·81	10·90	11·99	13·08	14·17	15·26	16·35	17·44	18·53	19·62	20·71

tion and publication for all scientific model experiment work. If, in future, publications are made it is sufficient to state that they are in agreement with the rules laid down in Paris, 1935.

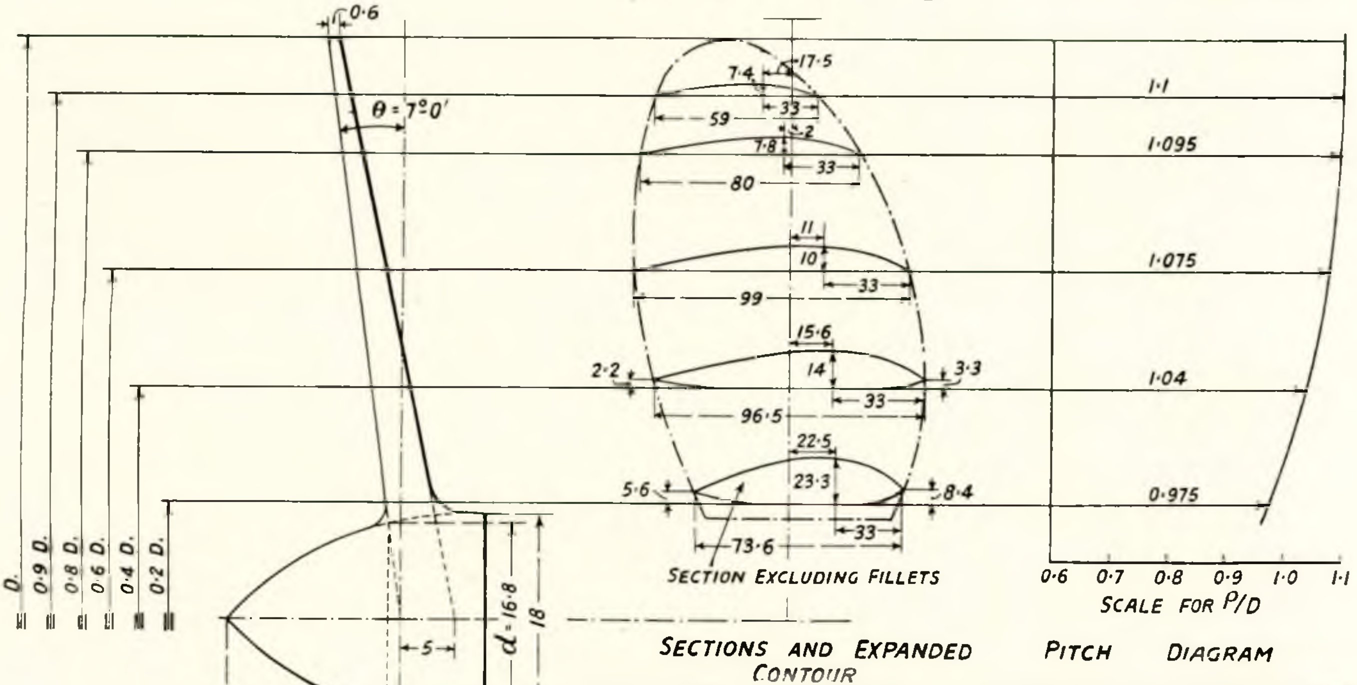
II.—The decisions are in force till the next meeting.

III.—Many papers, particularly on screw propellers, published in the technical press give diagrams quite useless, due to the smallness of the scale. It is agreed that measurement diagrams should not be smaller in printings than 11·5 cm.× 16·5 cm. ($4\frac{1}{2}$in. × $6\frac{1}{2}$in.).

General plan of screw propeller.

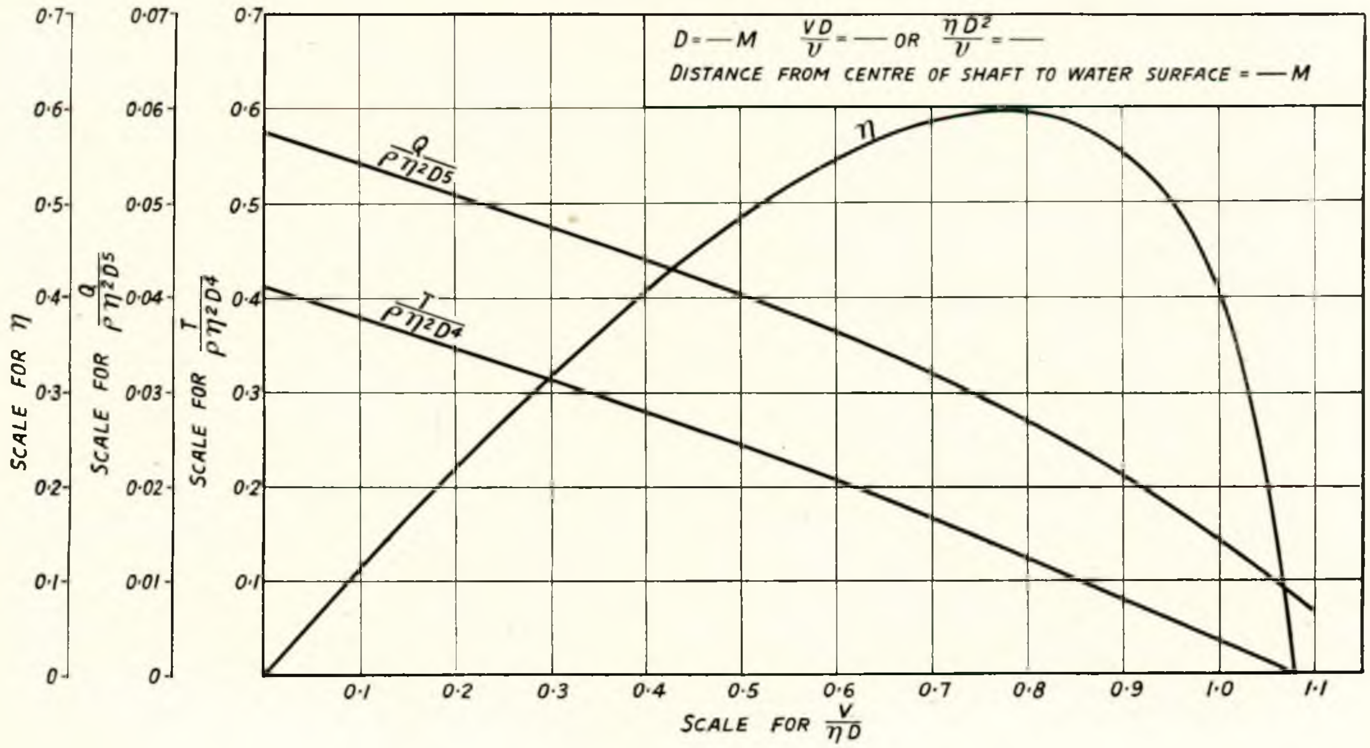
CHARACTERISTICS: NUMBER OF BLADES 4 – B.W.R. = 0·24

B.T.R. = 0·05 – $\frac{P}{D}$ = VARIABLE – $\frac{d}{D}$ = 0·168



NOTE: THE DIMENSIONS AND POSITION OF SECTIONS ARE EXPRESSED IN PERCENTAGES OF THE WIDTH. THE WIDTHS OF THE SECTIONS IN PERCENTAGES OF MAXIMUM WIDTH. ALL OTHER DIMENSIONS IN PERCENTAGES OF D.

Result of propeller test.



IV.—On the dimensions and finish of models.

(*a*) The dimensions of the model should be sufficiently large to ensure that the turbulent boundary layer is formed over the major portion of the length of hull. When the Reynold's number is lower than $3 \cdot 10^6$ the resistance curve is marked in dotted line. (*b*) All paraffin models should have model-smooth surface. By model smoothness is understood the state of surface similar to the hull-model surface or to the propeller model surface. By technical smoothness is understood the state of surface similar to the ship-hull surface or to the ship-propeller surface.

V.—On the determination of the length and wetted surface.

(*a*) For every kind of vessel the length on waterline should be used. (*b*) The mean girth multiplied by the length is adopted as wetted surface.

VI.—*Physical Constants.*—The tables of Lyle and Hosking for the kinematic viscosity of fresh and salt water are adopted.

ν in m²/sec. × 10

Temperature, °C.	0	10	15	20	30
Fresh water ...	1·794	1·309	1·144	1·011	0·806
Salt water ...	1·78	1·318	1·158	1·025	0·825

VII.—Froude's method of calculation.

(*a*) The Committee adhere to the skin friction deduced from Froude's O values, and take these to be represented by the formulæ below since this gives the same values of friction for model and ships within the limits of experimental errors.

$$R_f = \left(0{\cdot}1392 + \frac{0{\cdot}258}{2{\cdot}68 + L}\right) S.V.^{1{\cdot}825} \qquad R_f = \left(0{\cdot}008486 + \frac{0{\cdot}05160}{8{\cdot}79265 + L}\right) S.V.^{1{\cdot}825}$$

R_f expressed in kg.	R expressed in lb.
L expressed in m.	L expressed in ft.
S expressed in sq. m.	S expressed in sq. ft.
V expressed in m/sec.	V expressed in knots.

(*b*) All model results should be corrected to a standard of temperature of 15° C. or 59° F. by a correction 0·43 per cent. of the frictional resistance per +1° C. or 0.24 per cent. per +1° F.

VIII.—On the representation of ship model tests.

(*a*) The delegates agree in the representation of model particulars in the manner presented in the diagrams on pages 9 and 10. In the upper diagram on page 9 the curve of areas of waterlines has been added. The body plan is made with reduced ordinates adopted in Hague, the depth on the design being 1 and the total breadth being 2. L/B D/T, depending on proportions and not on forms, are to be placed after the design of "Contours of Bow and Stern with Waterlines". $\frac{S}{LB}$ is given after L/B and B/T for two different values of B/T.

(*b*) The delegates agree in giving the resistance experiment data for an isolated model in one or more of the constant forms as shown in the lower diagram on page 10, using as a base one or the other of the "constant forms" and stating the length of the model and temperature of water.

IX.—Definition of a screw propeller.

(*a*) Design or Propeller.—The principal form factors affecting the operation of a propeller of certain diameter are: (1) number of blades; (2) the blade outline; (3) the type of sections; (4) the face pitch at a number of sections; (5) the shape of the hub; (6) the rake. Thus the propeller is defined by: (1) the non-dimensional characteristics; number of blades, maximum width ratio, blade thickness ratio, face pitch ratio, hub diameter ratio, rake angle; (2) a drawing opposite showing: expanded outline and a number of blade sections, pitch diagram if pitch is not constant, the shape of hub with strickling line indicating the rake angle, the maximum thickness of blade sections and the tip thickness.

(*b*) Remarks.—(1) The expanded area taken outside of the bossline, as shown on the central part of diagram shall be used instead of the developed area; (2) the sections are taken at 20, 40, 60, 80 and 90 per cent. of D. The widths of sections are given in percentages of the maximum width. The position of sections to the strickling line is stated as a percentage of the width of each blade as well as the radial thickness which is to be measured on a co-axial cylinder. The maximum thickness extrapolated to the shaft is to be measured on the axis and not normal to the face. The position of maximum thickness is given in percentages of the width, as well as other particulars on the sections. The diameter of hub is to be determined as indicated on the drawing opposite.

X.—*Presentation of Experimental Data.*—(1) The experiment data must be plotted as $\frac{T}{\rho n^2 D^4}$, $\frac{Q}{\rho n^2 D^5}$, and propeller efficiency $\left(\frac{T}{\rho n^2 D^4} \cdot \frac{Q}{\rho n^2 D^5}\right) \frac{V}{2\pi n D}$, on a base of $\frac{V}{nD}$ (see lower diagram). (2) In publications of results of model screw test in open water the immersion of centre of shaft has to be stated if this is less than 0·8 D.

XI.—The following symbols are adopted: Length on waterline L, breadth B, draught T, largest section area O, wetted surface S, volume ∇ or V, screw diameter D, speed v, screw revolutions per second n, gravity constant g, specific weight V^0, specific mass $\frac{V^0}{g} = \rho$, kinematic viscosity ν, displacement (weight) Δ, total resistance R, screw thrust T, screw torque Q, frictional resistance by formula R_f, wave making resistance (theoretical)

R_w, load waterline α, midship section β, prismatic coefficient $\frac{V}{O.L.} = \phi$, block coefficient $\frac{V}{LBT} = \delta$, propeller efficiency η, index adopted for models m, index adopted for test behind e.

Ship Trials.

With reference to actual ship trials, it was agreed that: (1) Any measurement made on the ship ought to be recorded continuously. (2) The present state of accuracy of measurements in ship trials especially of thrust indicators is not yet satisfactory. (3) A statement of the expected degree of accuracy of every thrust and torsionmeter must be given. (4) The most satisfactory method of measuring power on a ship is by means of a torsionmeter; the use of a thrust measurement on ship trials is to be encouraged by experiment tanks. (5) In every scientific report on comparison of model and ship work the following must be given: Material of screw propeller, statement that the real screw propeller has been checked, area and type of superstructures, time out of dock, angle of rudder, true wind speed and direction, depth of water. (6) The result should be given in the form of diagrams

$\frac{n.D.}{v}$ over v; $\frac{Q}{\rho n^2 D^5}$ over $\frac{T}{\rho n^2 D^4}$; and $\frac{Q}{n^2}$ over n.

The Motor Tanker "Elona".

The First of 17 9,100-ton 12-knot Standard Ships for the Anglo-Saxon Petroleum Company.

"The Motor Ship", March, 1936.

The "Elona" was built by Swan, Hunter and Wigham Richardson at their Wallsend yard, and the trials were carried out off the Tyne, during the course of which, with the ship loaded down to her marks, a speed of about 13·3 knots was attained. It is an exact statement of the position that with the vessel proceeding at full speed there was no noticeable trace of vibration from stem to stern in any part. Whilst freedom from vibration has been one of the characteristics of "Ancylus" class with eight-cylinder engines, it was interesting to note that an equal performance in this respect was attained in a smaller ship with a six-cylinder unit of the same type.

The main particulars of the "Elona" and of all the other vessels are given in the following table:—

Deadweight capacity...	9,100 tons
Length b.p.	425ft.
Moulded beam	54ft. 3in.
Moulded depth	31ft.
Normal machinery output	2,700b.h.p.
Service speed	12 knots
Daily fuel consumption for all purposes	10 tons

There are two longitudinal bulkheads, and the vessel is divided into 24 compartments. A pump-room is arranged between Nos. 3 and 4 main tanks, and another between Nos. 5 and 6 tanks, with a cross bunker between the engine-room and No. 1 tank, a cofferdam forward of No. 8 tank, and a deep tank forward of this with a cargo hold above. In each pumproom are two Hayward Tyler Duplex 12in. by 10in. by 24in. pumps, also a 6in. by 6in. by 6in. drain pump, all being steam-driven.

Cargo Oil Tanks.

The cargo oil is carried in the centre and wing tanks in accordance with the following details:—

Tanks. Centre No.	Tons.	Tanks. Wing No.	Tons.
1	452	1	2×293
2	445	2	2×317
3	441	3	2×401
4	439	4	2×321
5	443	5	2×405
6	457	6	2×333
7	473	7	2×334
8	494	8	2×279
Total	3,644 tons		2+2,683 tons
		Total	=5,366 tons

The capacities for the various tanks are reckoned on the basis of 50 cubic ft. to the ton.

Oil fuel for the machinery and boilers totals 585 tons, the details being as under:—

Oil Fuel Tank Capacities.

Tank.	Tons.
Cross bunker	234
Settling tank (port)	22
Do. (starboard)	22
Engine-room double bottom ...	83
Deep tank	224
	585

Total when 98 per cent. full ... 575 tons.

The capacities are taken at 40·8 cubic ft. per ton.

Of lubricating oil 36 tons are carried, comprising 13 tons in a storage tank on the port side, 11 tons in one on the starboard side, and 12 tons in the drain tank. This capacity is reckoned at 35·96 cubic ft. per ton.

Particulars of the water ballast are given below:—

Water Ballast.	Tons.
Fore peak	104
Forward deep tank	261
Forward cofferdam	120
After cofferdam	129
After peak	59
Total	673*

* At 35 cubic ft. per ton.

The following are the details of the fresh-water tanks:—

Fresh Water.	Tons.
Double-bottom tank	25
Fresh-water tank, aft	41
Tank in forward 'tween deck ...	10
Total	76*

* At 35·96 cubic ft. per ton.

The navigation equipment is most comprehensive. The new Hastie type of steering gear of the steam hydraulic design, which we described in connection with the article on the "Ancylus", is employed, the steam for the engine, as well as for certain necessary auxiliaries in the engine-room, being raised from the exhaust gases, which are passed through the boiler, of which details will be given later. A MacTaggart Scott telemotor gear is employed.

Machinery.

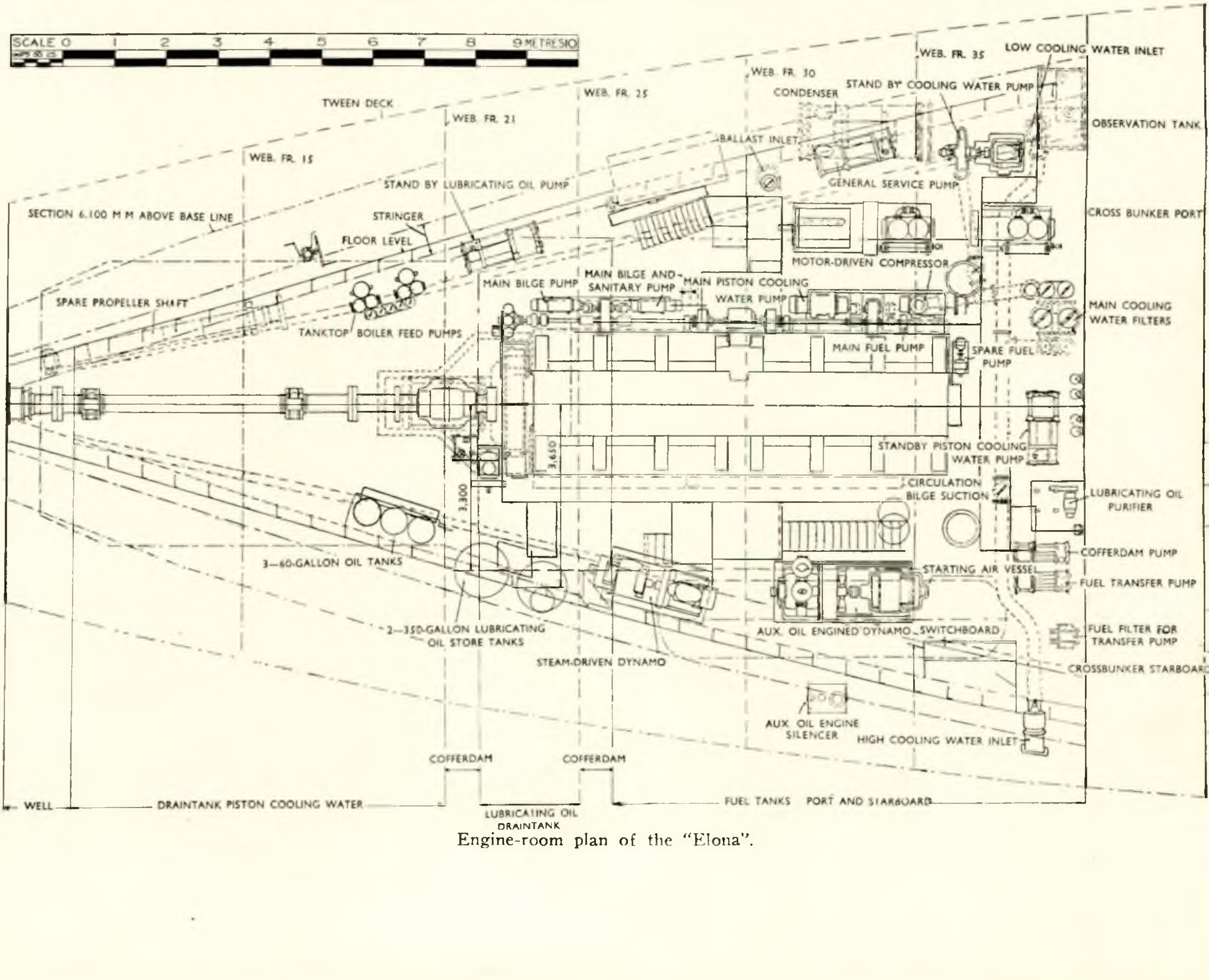
The engine is of the same type as that installed in the "Ancylus", but, as we have mentioned, with six cylinders instead of eight. It has cylinders 650mm. in diameter, with a piston stroke of 1,400mm., and is of the four-stroke single-acting type, pressure-charged on the Werkspoor system.

Air is supplied through the inlet valve at a supercharging pressure up to about 5lb. per sq. in. During the course of the trials we noticed that the temperature of the exhaust gases was practically constant at 360° C. at full power.

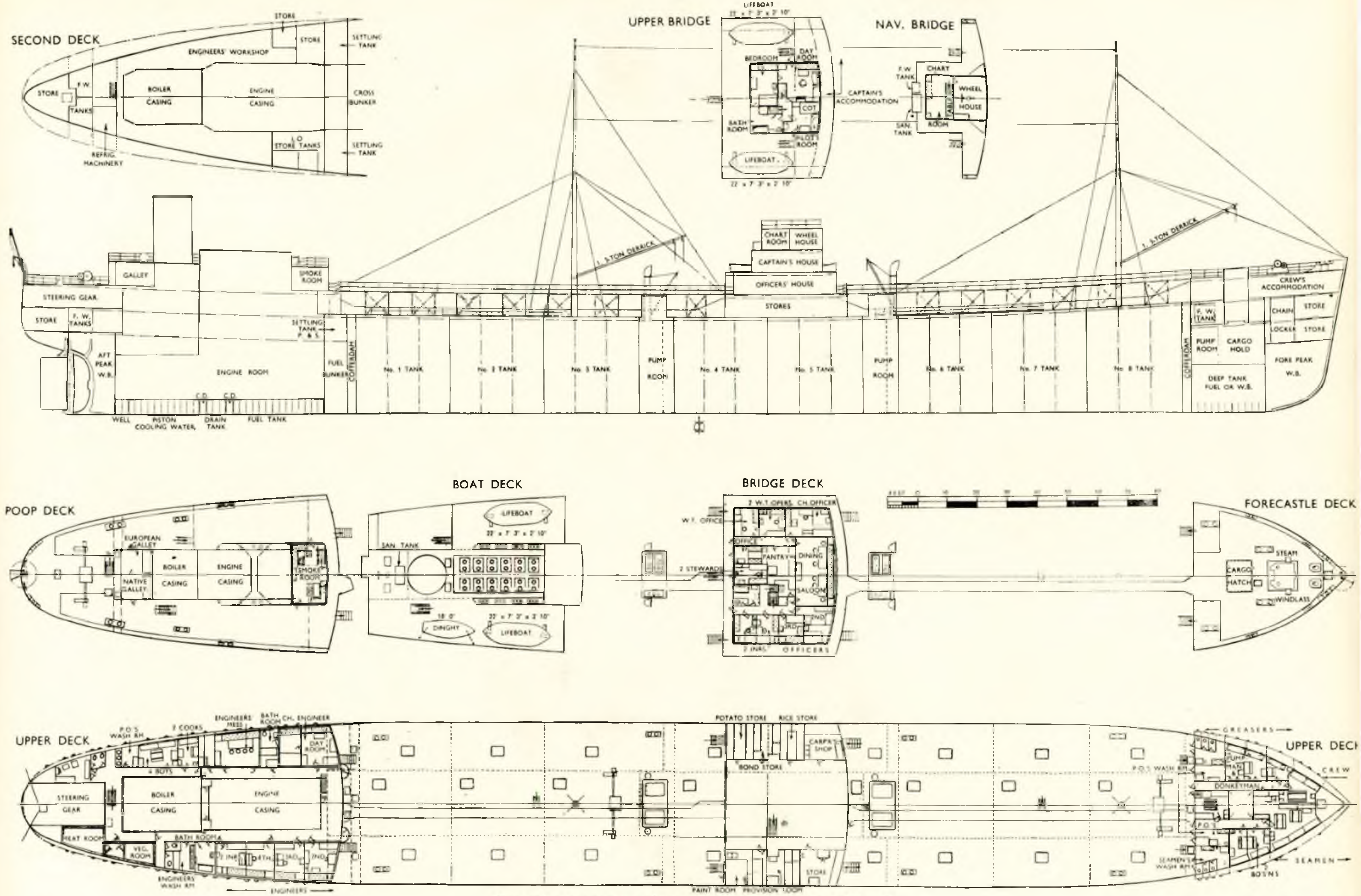
The valves, valve mechanism and overhead camshaft, as one of the illustrations shows, are of the standard Werkspoor design. It will be recalled, in this arrangement, that the manœuvring shaft is turned for reversal, and a skew motion is given to each valve lever whereby the roller at the end is caused to come into contact with the astern cam.

The fuel pump arrangement is unusual. For each cylinder there is a main delivery pump of a large size, and a Bosch pump which discharges at the same instant into a common pipe through the fuel valve. The object of this is to enable the complete control to be effected on the relatively small Bosch pump. We are informed that during a year's service on the engine of the "Ancylus" this fuel pump system has given no trouble. Injection takes place when the piston is at the top of its stroke, so that no alteration is required when the engine is reversed. The air starting valves in the cylinder head are automatic, their opening being controlled from an air distributor through the intermediary of pilot valves.

The operation of reversing is carried out from



Engine-room plan of the "Elona".

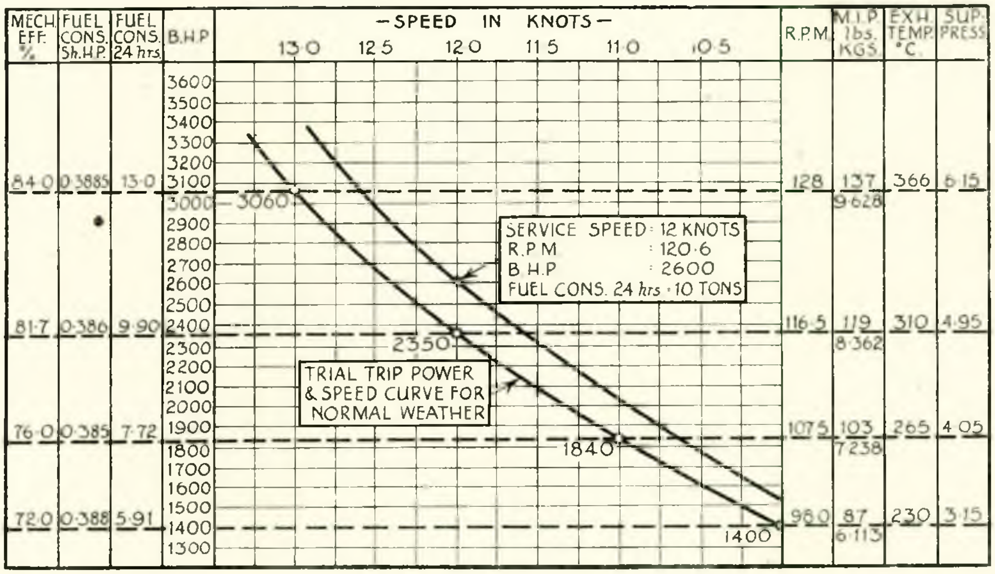


General arrangement plans of the motor tanker "Elona".

the starting platform (seen in one of the illustrations not reproduced) by actuating a lever, which through a servo motor causes the valve levers for the air and exhaust valves to move eccentrically on the manœuvring shaft, so that they are then actuated by the astern cams. The starting lever is raised to the starting position, and after the engine turns the lever is pushed to the running position, and the engine speeded up by further movement of this lever. It was found during the trials that a period of nine seconds elapsed before the engine reversed from full speed ahead to full astern, and that the total time with the ship proceeding at full speed until it attained full astern speed was six minutes.

We have already indicated that chain-driven rotary auxiliary pumps are a feature of this engine. All of the pumps are of the same size and capacity as those of the eight-cylinder 3,600 b.h.p. engine, but they run at a lower speed. At the after end of the control station is a shaft driven at about 210 r.p.m., and in front is a second horizontal shaft driven at about 620 r.p.m. The arrangement is duplicated at the forward end, and there are clutches between the low-speed shafts and the main drive both forward and aft, so that it is possible to disconnect either of these with the engine running. A new form of clutch has been adopted with this unit.

The pumps driven by the high-speed shaft at the forward end are the main cooling pump and the piston cooling pump, and at the after end a bilge pump and a bilge and sanitary pump. The high-speed shaft at the after end drives a Stothert and Pitt lubricating oil pump, and at the forward end a fuel transfer pump. Except for these the pumps are all of the Houttuin design. We are informed that in the "Ancylus" these rotary pumps have come up to expectations in every respect.



Standard 9,100-ton tanker of the "Elona" class. Engilne and ship performance graphs.

The engine-room auxiliaries include a Ruston oil engine driving a Brotherhood compressor, also a Brotherhood steam-driven compressor, whilst there is a steam-driven dynamo as well as a generator coupled to a Kromhout oil engine. As stand-by plant a Hayward Tyler piston cooling steam-driven 8in. by 8in. by 10in. pump is installed, and a 7in. Drysdale main cooling water pump. A 6in. by 5in. by 6in. oil transfer pump, an 8in. by 8in. by 10in. general service pump, a 6in. by 8½in. by 18in. feed pump, and an 8in. by 8in. by 10in. stand-by lubricating oil pump are installed in the engine-room, the arrangement being seen in the engine-room plans. For the purification of the lubricating oil a Vickeen centrifugal separator is installed, and a Turbulo filter deals with the oil fuel.

The boiler, 14ft. 6in. in diameter and 11ft. 6in. long, at the after end of the engine-room, may either be oil-fired or the exhaust gases may be passed through it. It is of the single-ended Scotch type with three furnaces, any or all of which may be oil-fired or exhaust-fired. In normal service at sea, all of the steam needed for every requirement, including the operation of the auxiliaries and the heating of the ship, is met by steam raised from the exhaust gases.

The graphs give details of the performance of the ship based on the trial-trip results and the vessel proceeding under service conditions. It may be expected that at the service speed of 12 knots the normal propeller speed will be 120·6 r.p.m., the output of machinery 2,600 b.h.p., and the total fuel consumption per day 10 tons. During her maiden voyage it was found that the vessel was able to average 12 knots comfortably, and her performance has been highly satisfactory.

Control of Superheat Temperature.

"Shipbuilding and Shipping Record", 20th February, 1936.

Marine engineers have made a general, if belated, recognition of the fact that the use of superheated steam on board ship results in economies which easily outweigh any disadvantages which accompany its adoption. Indeed, as a consequence of continued experience, it may be said that with a more complete understanding of the problems involved in the use of high-temperature superheated steam, these disadvantages are gradually being overcome. The principal difficulty, due to the effects of high temperature on the materials used in the construction of the superheater itself, the steam pipes and the high-pressure parts of the engine or turbine, is being surmounted by the development of high-grade alloy steels which can successfully withstand the onerous conditions imposed. Perhaps more difficult to overcome is the effect of the fluctuation in the temperature of the steam at the superheater outlet, but even here, recent installations on board ship had shown that despite the wide variations in the other factors affecting the final steam temperature, practically uniform conditions at the main stop valve could be ensured. A very valuable survey of the question of superheat temperature as it affects the marine engineer was given at the recent meetings of the American Society of Naval Architects and Marine Engineers by Thomas B. Stillman, who is associated with one of the largest manufacturers of marine boilers in the United States.

Taking as his subject "Control of Superheat", the author suggested that owing to the radical differences between steam requirements in port and those when under way, means of controlling the degree of superheat are necessary in order to ensure safe operation of the superheater itself as well as of the engines or turbines under all normal conditions of working. Before, however, dealing with the methods whereby this control is to be effected, the author first of all surveyed the causes which affect the final temperature of the steam, since a complete recognition of these is obviously necessary before the problem of control can be correctly solved. The first and most important cause of variation in steam temperature is the variation in the demand for steam for the main engines during manœuvring and for the auxiliaries. If the auxiliary steam is taken directly from the boiler without passing through the superheater elements, any increase in the auxiliary load causes a decrease in the quantity passing through the superheater and it is found that the consequent increase in the superheat temperature varies almost directly as the proportion of steam generated, which passes to the auxiliary line. For this reason, desuperheaters are gradually coming into use on board ship, all the steam generated passing through the superheater, the auxiliary steam being subsequently desuperheated as required. The feed-water temperature is another factor affecting the superheat temperature, an increase in the feed inlet temperature decreasing the superheat for a given rating because it increases the steam flow through the elements with no corresponding change in the gas flow over them. Again, unless the superheater is of the strictly radiant type, the superheat temperature increases with an increase in the excess of air in the products of combustion, and finally, the author gives figures showing the effect of initial moisture in the steam, 1 per cent. of moisture reducing the superheat by 14° F.

There are two fundamental principles employed in the control of the final superheat temperature, viz., (i) to provide an excess of superheating surface to give the desired final steam temperature at low rates, with provision for cooling the steam at the higher rates; and (ii) to control the flow of the furnace gases over the superheater tubes so that the steam temperature always remains within certain limits, irrespective of the boiler rating. The first method has no measureable effect on the efficiency of the boiler unit and is applied by either injecting water into the steam or passing the steam through a heat exchanger. The second method which does, of course, affect the efficiency, can be effected by means of dampers in the boiler or, better still, by fitting separately-fired superheaters. The use of dampers leads to a condition of unbalanced gas distribution which may result in a concentration of the hot gases on portions only of the heating surface, although this can be obviated by fitting dampers which close off only a certain percentage of the free gas flow area. The ideal method, the author concluded, is to use the separately-fixed superheater and since it is difficult to arrange for this except on the largest and most powerful ships, he called attention to the integral separately fired type, which has been developed, in which the superheater elements with their independent oil burners are screened off from the main combustion chamber of the boiler. The burners and their air supply on the saturated steam side of the unit are controlled by the steam pressure in the boiler drum, while the burners and the air supply on the superheater side are controlled by the steam temperature at the superheater outlet.

BOARD OF TRADE EXAMINATIONS.

List of Candidates who are reported as having passed examinations for certificates of competency as Sea-Going Engineers under the provisions of the Merchant Shipping Acts.

Name.	Grade.	Port of Examination.
For week ended 28th November, 1935:—		
Coey, Thomas	2.C.	London
Elliott, George H.	2.C.	Liverpool
Howie, Adam...	2.C.	"
Piper, Rocco R.	2.C.	"
Turner, Norman	2.C.	"
Williamson, Charles... ...	2.C.	"
Rogerson, Robert	2.C.M.	"
Bruce, Alexander	2.C.	Glasgow
Henderson, James	2.C.	"
Johnston, Malcolm	2.C.	"
Johnstone, Alexander T. ...	2.C.	"
McArthur, Donald	2.C.	"
McColm, Andrew	2.C.	"
McQuarrie, Charles... ...	2.C.	"
Robertson, Alexander P. ...	2.C.	"
Steven, Charles D.	2.C.	"
Watson, William	2.C.	"
Alexander, Albert P. ...	2.C.M.	"
Conway, William	2.C.M.	"
Wilson, John	2.C.M.	"
Cady, Ernest N.	2.C.	Newcastle
Metcalf, Herbert D. ...	2.C.	"
Rea, John R.	2.C.	"
Story, Thomas W.	2.C.	"
Crosby, William	2.C.M.	"
Nicholson, Guy H.	2.C.M.	"
Nicholson, John J.	2.C.M.	"

For week ended 5th December, 1935 :—

Name.	Grade.	Port of Examination.
Armstrong, William W. ...	1.C.	Newcastle
Loynes, Robert R.	1.C.	"
Lumsdon, Joseph O. ...	1.C.	"
Lowes, Robert H.	1.C.M.	"
Skay, Philip	1.C.M.	"
Essam, Frank A.	1.C.	London
Topley, Eva F. St. V. ...	1.C.	"
Rushton, Douglas B. ...	1.C.M.	"
Hill, Henry E.	1.C.	Liverpool
Martin, James	1.C.	"
Price, David	1.C.	"
Stockham, Stanley E. ...	1.C.	"
Brown, John D.	1.C.	Glasgow
Good, Robert L.	1.C.	"
Johnston, John	1.C.	"
Wallace, James	1.C.	"
Welch, William	1.C.	"
Ritchie, James C.	1.C.M.	"
Lenaghan, Henry P. ...	1.C.	Dublin
Scott, William	1.C.M.E.	Liverpool
Seubert, Karl W.	1.C.M.E.	London
Wood, Robert C.	1.C.M.E.	Glasgow
Harrison, Robert	1.C.M.E.	Liverpool
Gladstone, William E. ...	1.C.M.E.	Newcastle
Mainprize, Kenneth G. ...	1.C.M.E.	Liverpool

For week ended 12th December, 1935 :—

Name.	Grade.	Port of Examination.
Heighton, Charles E. ...	2.C.M.	London
Rolston, Bernard J.	2.C.	Liverpool
Waterworth, Harry	2.C.	"
Crighton, Andrew	2.C.	Glasgow
Kilday, Robert C.	2.C.	"
Bootland, Leslie	2.C.	Newcastle
Lawson, Albert R.	2.C.	"
Slimin, James R.	2.C.	"
Leason, Albert O.	2.C.M.	"
Ord, Harold	2.C.M.	"
Reay, Sidney	2.C.M.	"

For week ended 19th December, 1935 :—

Name.	Grade.	Port of Examination.
Boothroyd, Alexander ...	1.C.	Liverpool
Orcherton, Charles	1.C.	"
Cassingham, Jack	1.C.	London
Evans, Edgar C.	1.C.	"
Logan, Stanley C.	1.C.	"
Norman, Harry H.	1.C.	"
McKay, Stanley L.	1.C.M.	"
Downey, Wilfred	1.C.	Cardiff
Powell, James H.	1.C.	"
Aubin, Phillip J. N.	1.C.M.	"
Cowe, Henry A.	1.C.	Newcastle
Driffill, Frank...	1.C.	"
Grieve, John W.	1.C.	"
Jones, Edward	1.C.	"
Simm, John	1.C.	"
Thompson, Harold	1.C.	"
Edden, George R.	1.C.M.	"
Forman, Cedric	1.C.M.	"
Forman, Charles E. ...	1.C.M.	"
Buchan, Alexander	1.C.	Glasgow
Calderwood, William H. ...	1.C.	"
Conkie, William G.	1.C.	"
Moodie, Ernest J.	1.C.	"
Murray, Andrew H. ...	1.C.	"
McLean, John G.	1.C.M.E.	"
Jackson, John M.	1.C.M.E.	"
Coulter, James T.	1.C.M.E.	Liverpool
Evans, Jack D.	1.C.M.E.	Cardiff
Johnston, John B.	1.C.M.E.	London
Towers, Frederick	1.C.M.E.	Liverpool
Milligan, Robert B. ...	1.C.M.E.	"
Robson, Thomas W. ...	1.C.M.E.	Newcastle
Murray, William C. H. ...	1.C.S.E.	Liverpool

For week ended 24th December, 1935 :—

Name.	Grade.	Port of Examination.
Fagan, John	2.C.	Liverpool
Ormesher, Leslie	2.C.	"
Atkin, Horace E.	2.C.M.	"
Fraser, Joseph S.	2.C.M.	"
Russell, John	2 C.M.	"
Gilfillan, Robert G.	2.C.	Glasgow
Wilkinson, Stanley G. ...	2.C.	"
Crawford, Andrew A. ...	2.C.M.	"
Elliott, George K.	2.C.M.	"
Kinnaird, James R.	2.C.M.	"
Noble, John R.	2.C.M.	"
Cameron, Ian	2.C.	Newcastle
Moore, Bernard	2.C.	"
Sidgwick, Robert	2.C.	"
Sinclair, George H.	2.C.	"
Ward, Brian	2.C.	"
Dobson, Joseph	2.C.M.	"
George, Wilfred	2.C.M.	"
Richardson, Edward H. ...	2.C.M.	"
Southern, William F. ...	2.C.M.	"
French, Horace F.	2.C.	London
Weston, Henry W. H. ...	2.C.	"

For week ended 2nd January, 1936 :—

Name.	Grade.	Port of Examination.
Aird, Peter U.	1.C.	Glasgow
Gow, William L.	1.C.	"
McDowall, Robert D. ...	1.C.	"
Templeton, John	1.C.	"
Walker, David L.	1.C.	"
Birnie, John S.	1.C.M.	"
Murphy, Arthur	1.C.M.E.	"
Izat, Alexander	2.C.S.E.	"

For week ended 9th January, 1936 :—

Name.	Grade.	Port of Examination.
Temple, Henry N.	1.C.	Newcastle
Coulthard, John W. ...	1.C.M.	"
Murphy, William A. ...	1.C.	London
Bage, James W.	1.C.	Liverpool
Brown, Alfred K.	1.C.	"
Richardson, Frank F. ...	1.C.	"
Clarke, Wilfred	1.C.M.	"
Beaumont, Sidney C. ...	1.C.M.E.	"
Cobban, George	1.C.M.E.	"
Rothwell, Edward O. C. ...	1.C.M.E.	"
Alexander, W.	1.C.M.E.	London
Auty, George W.	1.C.M.E.	Newcastle

For week ended 16th January, 1936 :—

Name.	Grade.	Port of Examination.
Eltringham, James	2.C.	Newcastle
Clark, James E.	2.C.M.	"
Tame, Sidney C.	2.C.	Liverpool
Elordieta, Vincent	2.C.M.	"
Piercy, James C.	2.C.	Glasgow
Ross, Thomas	2.C.	"
Annan, Leslie G.	2.C.	Cardiff
Harrison, Francis V. ...	2.C.M.	"
Smith, Harold V.	2.C.M.E.	London

For week ended 23rd January, 1936 :—

Name.	Grade.	Port of Examination.
Ashworth, James	1.C.	Newcastle
Barker, Thomas	1.C.	"
Summerbell, James	1.C.	"
Elvin, Arthur M.	1.C.M.	"
Suddick, Alexander... ...	1.C.M.	"
Moffat, Thomas A.	1.C.	Glasgow
Gallagher, James	1.C.M.	"
McGilvray, Neil	1.C.M.	"
Freemantle, Percy J. ...	1.C.	London
Stephen, James R.	1.C.M.	"
Scott, Andrew H.	1.C.M.	"
Cameron, Alexander C. ...	1.C.	Liverpool
Hinde, Geoffrey F.	1.C.	"
Smart, John A.	1.C.	"
Thomas, Peredur W. ...	1.C.	"
Redford, Vernon	1.C.M.	"
Graham-Cumming, John C.	1.C.S.E.	Cardiff
Morgan, Horace N.	1.C.M.E.	"
Izat, Alexander	1.C.S.E.	Glasgow
Blundell, William G. ...	1.C.M.E.	Liverpool
Richardson, Frank F. ...	1.C.M.E.	"
Rogers, Gerald R.	1.C.M.E.	"
Nicholls, Edward E. ...	1.C.M.E.	London
Waugh, William G.	1.C.M.E.	"
Pickard, Norman	1.C.M.E.	Newcastle
Ferguson, Peter H.	1.C.M.E.	"
Chapman, John H. P. ...	1.C.M.E.	"