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Marine Auxiliaries Driven by A.C. Supply.

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Chairman: W. Sampson (Vice-Chairman of Council).

Synopsis.

The use of A.C. supply for driving auxiliaries, lighting and heating for shipboard has been visualized for an appreciable time by the classification societies for all types of ships, and rules have been formulated for its application for all duties.

The change from D.C. to A.C. motors does not necessitate any radical changes in the types of auxiliaries, but the use of A.C. motors in general means that the auxiliaries must run at a constant speed, as reduced speeds can only be arranged by a sacrifice of efficiency, except in special cases where pole changing motors can be used. Details of the performance of the various types of motors and methods of starting are given consideration.

The A.C. supply can be provided by Diesel or turbo-driven alternators in exactly the same way as D.C.; alternatively, in Diesel-electric or turbo-electric vessels the auxiliary power may be taken from the main propulsion circuit whilst the ship is at sea. Particulars of such ships are given and the performance of auxiliaries under variable speed conditions is considered.

Winches and windlasses are still difficult to convert to A.C. but such machines are being made on the Continent.

Lighting and heating circuits for both methods of supply are given consideration.

Introduction.

The trend towards more economical running of ships which has been taking place during the last 20 years or so, brought the question of the most suitable auxiliary machinery to the fore. The motor ship and, more recently, the steam ship with high-pressure boilers and turbines, showed that the electrically-driven auxiliary, though more costly to purchase, was, except in special cases, much cheaper to operate than the equivalent steam-driven auxiliary.

The more general adoption of electrically-driven auxiliaries led to the development of special designs of pumps, winches, windlasses, steering gear, refrigerator machines, etc., to accommodate most efficiently the electric-motor drive. In many cases, the present-day accepted types of the various auxiliaries bear little resemblance to the steam-driven units which they replace, and due credit should be given to the manufacturers, superintendent engineers and ships' engineers who were responsible for the building and running of the earlier types and who thus made possible the efficient and reliable electrically-driven auxiliary as we know it to-day.

Direct Current Auxiliaries.

Most of the electrically-driven auxiliaries are designed to suit 110 volt or 220 volt D.C. motors, the speed of which can be readily varied over a fairly wide range, by means of shunt or series control, to give a variable output.

D.C. motors of any size above about 1 h.p. must each be provided with a suitable starter and the combined cost of shunt controllers and starters for large machinery installations is very appreciable. Automatic starters are frequently fitted, especially for motors above 30/40 h.p., to prevent hurried starting of the motors as well as for ease of operation. The view has been expressed that the extra cost involved in the provision of automatic starters is compensated by the reduced maintenance costs of the motors and starters. Special systems have been designed whereby a number of motors can be operated by a single starter, partly to reduce the cost of the starter system, but more particularly to save the space normally occupied by the starters.

The main troubles experienced with D.C. motors and equipment are burnt commutators, overheating of the winding due to the deposits of oil-laden vapour and burnt contacts in the starters. The equipment is, however, entirely satisfactory and compares favourably in performance with the steam-driven auxiliary, on which basis most marine equipment is judged.

The Use of A.C. in Ships.

The use of A.C. on shipboard has been visualized for an appreciably long time and the various classification societies have formulated rules for its application for lighting, heating and auxiliary power, as well as for propulsion. The following table gives the maximum voltage permitted by these societies for the various duties.

TABLE 1.
Comparison of Permissible Voltages for A.C. Acceptable to Classification Societies.

	I.E.E.	Lloyds	British Corporation	Bureau Veritas	American Bureau of Shipping
Propulsion	7,000	*3,500	6,600	6,600	7,500
Lighting	150	150	150	220	120
Heating	250	250	250	220	450
Aux. Power					
Single Phase	250	250	250	220	—
3-Phase	440	440	440	380	450

*It was pointed out by Mr. G. O. Watson, in his Thomas Lowe Gray lecture "Recent Developments in Alternating Current Turbo-electric Ship Propulsion" that this voltage was to safeguard the control gear and that sympathetic consideration would be given to a sound scheme using a higher voltage.

The comparable values of D.C. are shown in Table 2.

TABLE 2.
D.C. Voltages Permitted by Classification Societies.

	I.E.E.	Lloyds	British Corporation	Bureau Veritas	American Bureau of Shipping
Lighting	250	250	250	220	120
Heating					240
Power	500	500	500		

220 volts D.C. has been adopted as standard on many British ships for all purposes. The lower voltage for lighting required by the American Bureau of Shipping lines up with land practice in U.S.A.

The classification societies, with the exception of the American Bureau of Shipping, do not at the present time accept A.C. for lighting and heating on tankers built for carrying oil with a flash point of less than 150° F., without giving each proposal special consideration. The American Bureau of Shipping will accept the same voltages for such tankers as for other ships and subject only to the same restrictions as D.C. There is no evidence to show that electrical fires are more prevalent on American ships than on others.

The standard frequency of supply adopted in this country is 50 cycles, whilst that in Canada and U.S.A. is 60 cycles; the frequency generally adopted for propulsion is 50/80 cycles, and these frequencies are equally suitable for lighting, heating and auxiliary power. It is essential for ease and cheapness of manufacture that a standard voltage should be adopted and it appears that three-phase 400 volts 60 cycles is being favoured for marine work.

Types of Motors.

The types of A.C. motors available for driving auxiliaries are :—

(1) Induction motors.
(2) Synchronous motors.
(3) Synchronous induction motors.
(4) Universal motors (for single-phase A.C.).

Induction motors will form a big proportion of the motors used and are of two general types, viz. :—

(1) Squirrel cage.
(2) Slip ring or wound rotor.

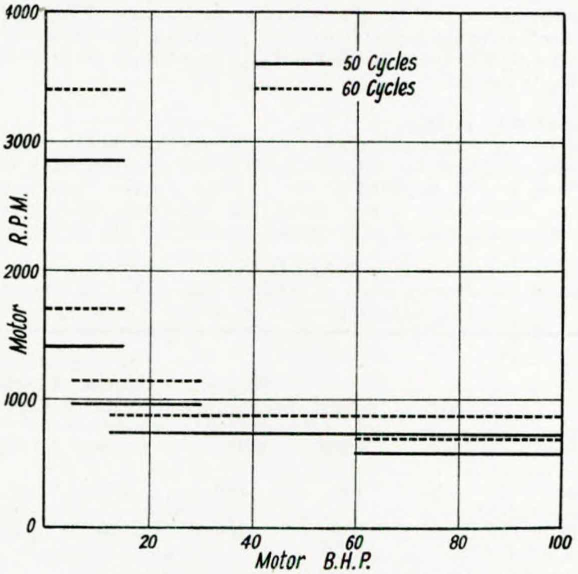

FIG. 1.—*Approximate speeds and powers of induction motors.*

Fig. 1 shows the speed of these motors at frequencies of 50 and 60 cycles. The range of powers indicated for the various speeds at 50 cycles, with the exception of 2,900 r.p.m., are those recommended in B.S. No. 169, but powers outside these ranges are available.

The squirrel-cage motors are the simpler, cheaper and more robust of the two types, but they take a heavy starting current and are therefore not suitable in large sizes when the maximum current available is limited. The stator winding can be arranged to give two or three speeds with either constant h.p. or constant torque by switching, thereby changing the number of poles. These motors are more expensive and often larger than the single-speed machine; the control gear is also more complicated and expensive.

Heavy starting torque motors, which have two squirrel-cage windings on the rotor, are available and give an almost constant torque, at the maximum value, during the starting periods.

Slip-ring motors have a wound rotor instead of the cage, and are consequently not so robust. The starting current can be limited to about half that in a squirrel-cage motor by introducing a resistance into the rotor circuit via the slip rings. The starting torque is also increased to the maximum torque value.

The motors can be arranged to run at reduced speeds by leaving this resistance in circuit, but the efficiency is reduced with the r.p.m.

Typical efficiency, current and torque curves are shown in Figs. 2, 3, 4 and 5 and the construction of the motors in Figs. 6 and 7.

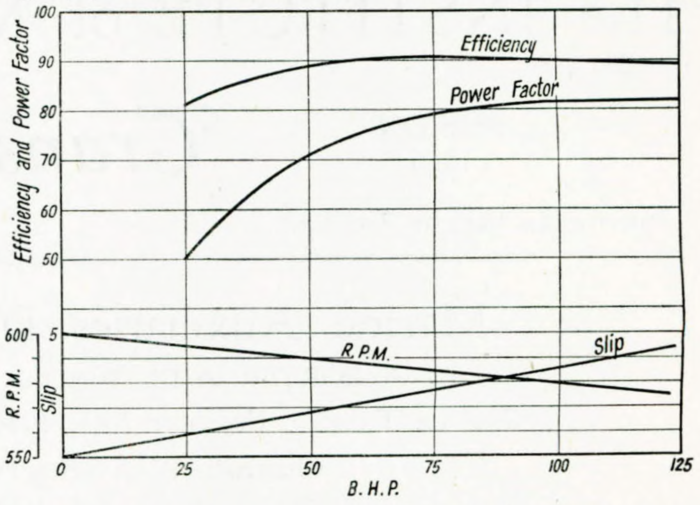

FIG. 2.—*Performance curves of 100-b.h.p. slip-ring induction motor.*

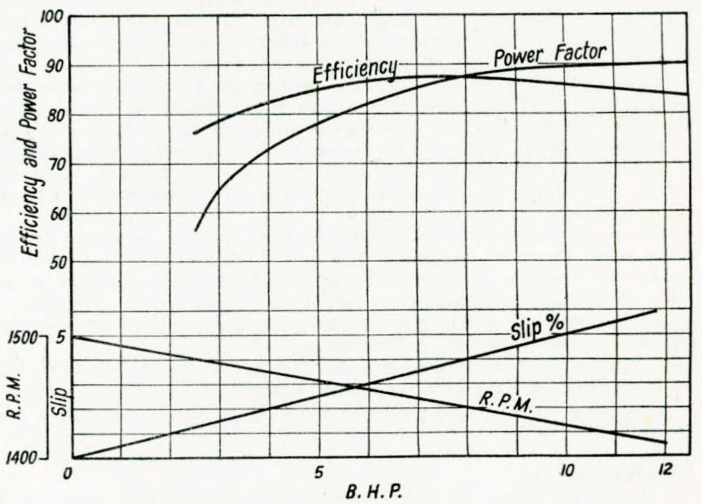

FIG. 3.—*Performance curves of 10 h.p. induction motor.*

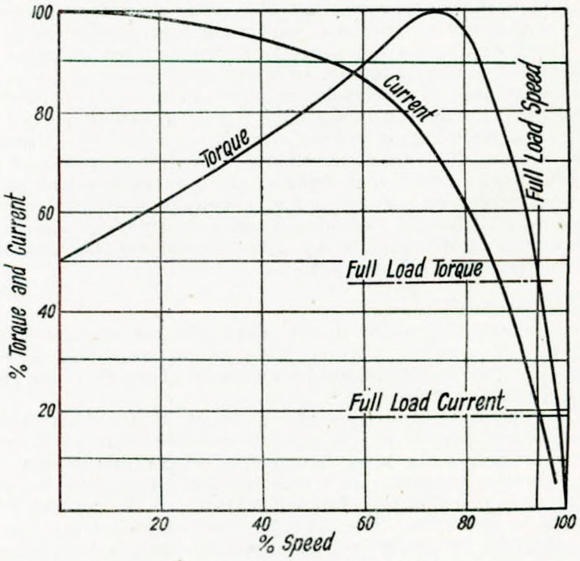

FIG. 4.—*Starting conditions for squirrel-cage motor.*

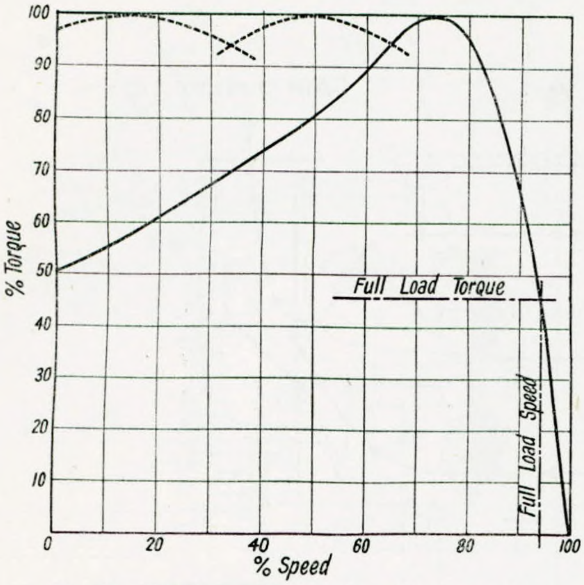

FIG. 5.—*Starting conditions for slip-ring motor.*

The advantages of induction motors are:—

1. The efficiency is good.
2. The cost is low.
3. The dimensions are smaller than corresponding D.C. machines.
4. They seldom give trouble in service.
5. The starting arrangements are simple and in many cases cheap.

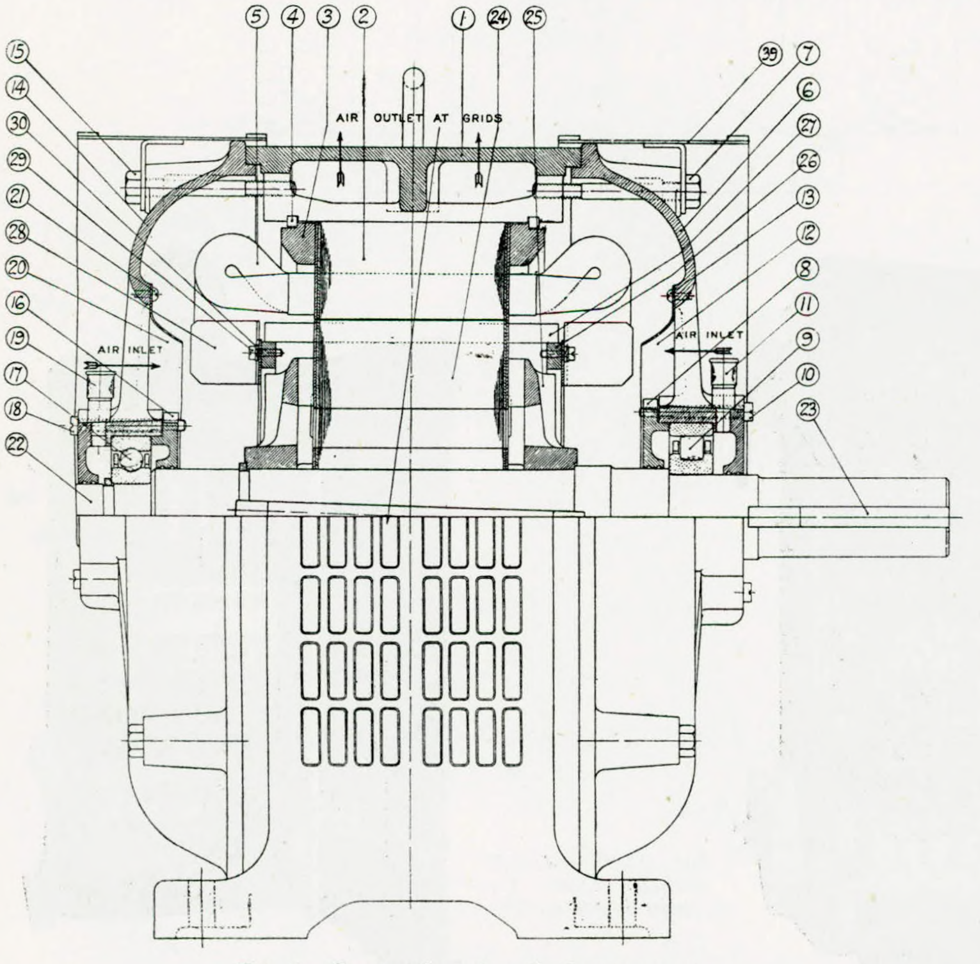

FIG. 6.—*Construction of squirrel-cage motor.*

The disadvantages are:—

1. Only certain speeds can be arranged and the speed cannot be efficiently varied except to definite ratios by pole changing.
2. The starting torque of squirrel-cage motors is inferior to shunt-wound D.C. motors, except when special rotors are fitted; the starting current is also appreciably in excess of that in D.C. motors.
3. The reversal of the motors necessitates changing over two of the three phases with main live switchgear compared to changing over the field connections in a D.C. shunt motor.

Synchronous motors are not generally suitable for driving auxiliaries, as they require an auxiliary starting device and are consequently used for special duties only, one of which is main propulsion. The advantage is a higher efficiency and unity power factor which make for smaller motors and alternators, and they run at a constant speed in synchronism with the alternators. D.C. excitation must also be supplied for the rotor windings.

The synchronous induction motor starts up as an induction motor and, when running at nearly synchronous speed, excitation can be switched on to the rotor to bring it into synchronism, after which it runs as a synchronous motor. They are used where a high starting torque is required and when synchronizing takes place against a heavy torque.

Universal motors are small D.C. type motors built with laminated frames. These run satisfactorily on either single-phase A.C. or D.C. and can be used for small fans, special tools, etc.

METHODS OF STARTING.

Squirrel-cage Motors.

Squirrel-cage motors can be switched directly to the mains, and this is now considered to be the most satisfactory method providing the alternators, transformers, etc. are capable of withstanding the heavy overload of four to five times full load current. Direct switching has been used for motors up to 250 b.h.p.

"Star Delta" switches are also used for starting squirrel-cage motors and these are arranged to connect the stator windings in "Star" or "Delta" formation, the former being used for starting and reduces the line current to one-third the normal starting value. This method of starting was frequently used for all but the small motors, but later experience showed that there was a heavy current surge between the "Star" and "Delta" positions sometimes up to 20 times full load current, which makes for worse conditions than direct switching.

Auto transformers are also used for starting these motors, the tapping point being arranged to give the required reduction in voltage and current to suit the particular starting conditions.

Slip-ring Motors.

The starter consists of a resistance which can be inserted in the rotor circuit via the slip rings. Generally, the full resistance can be arranged to reduce the starting current to about half the value of that when switched directly to the mains.

The starting resistances can also be arranged to reduce the speed of the motor, but would then need to be continuous rated as a great deal of heat is dissipated. Figs. 8 and 9 show the arrangement of various starters.

Supply of A.C. for Auxiliaries.

The A.C. for auxiliaries may be generated by auxiliary Diesel or turbo-alternator sets, in which case it will generally be necessary, especially with Diesel sets, to have two machines working in parallel, as with D.C. machines, to ensure a constant supply in the event of one engine failing. Turbo-

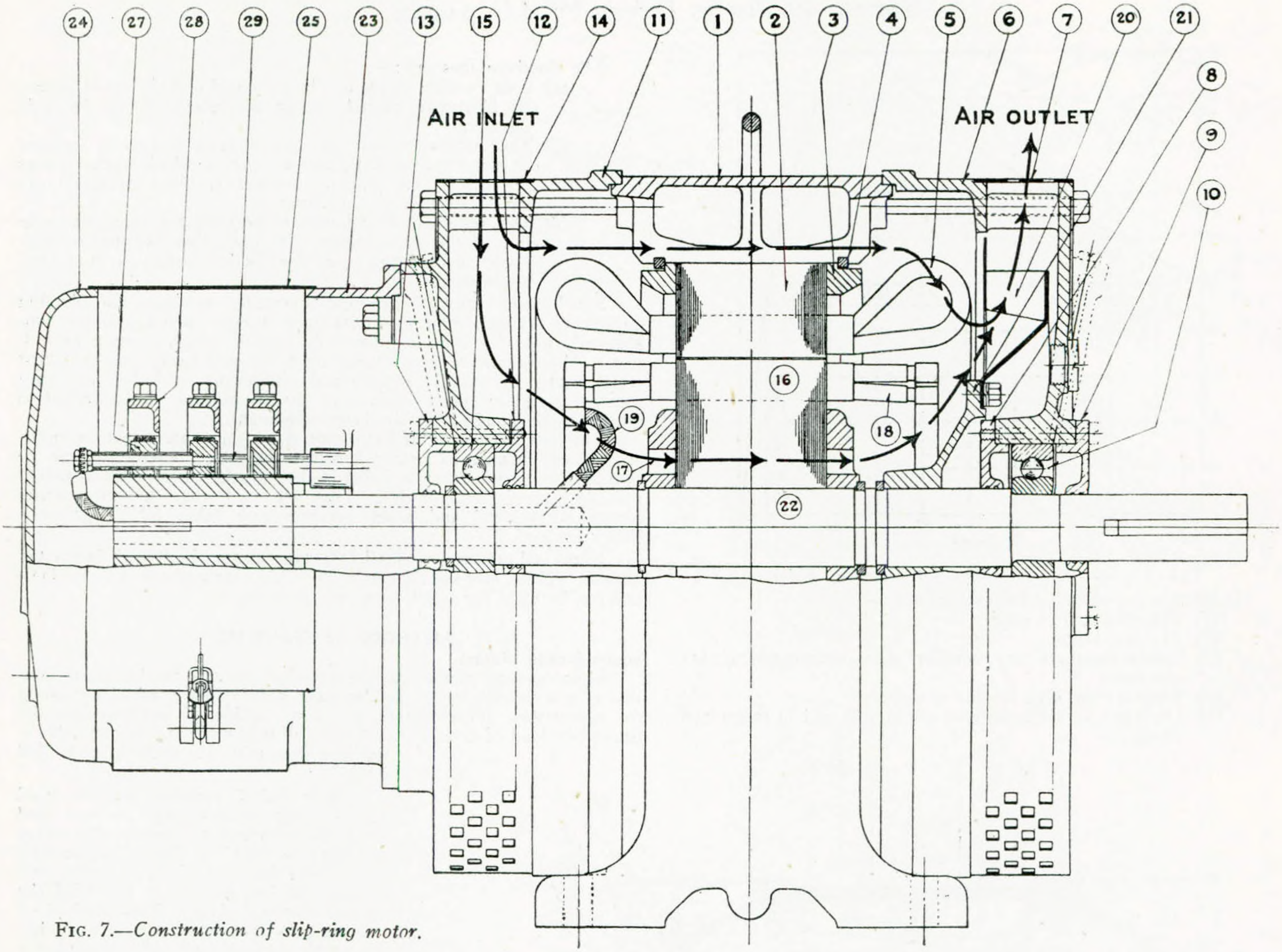

FIG. 7.—*Construction of slip-ring motor.*

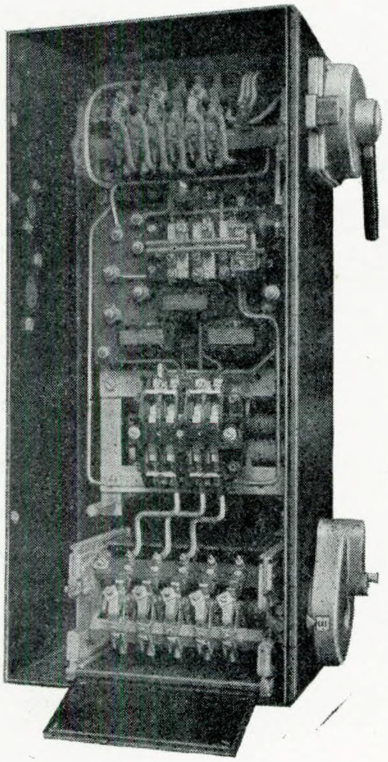

FIG. 8.—*Starting panel for slip-ring motor.*

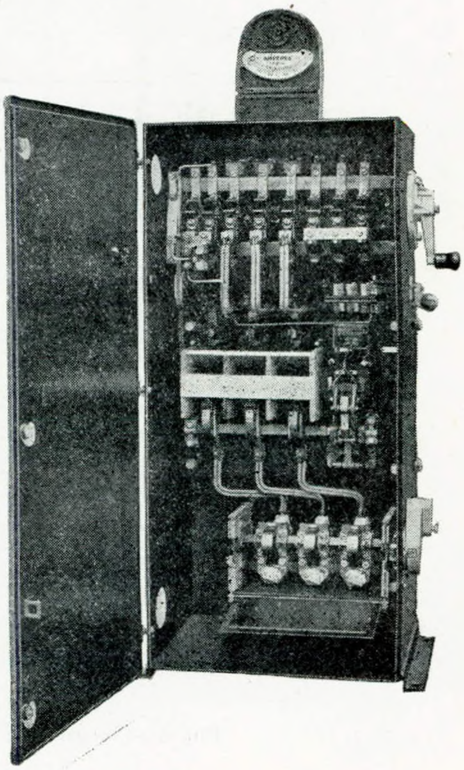

FIG. 9.—*"Star-Delta" starting panel for squirrel-cage motor.*

alternators and Diesel alternators, running at different speeds, can be designed to work satisfactorily in parallel, so that it will be possible to provide turbo-alternators principally for use at sea and Diesel alternators for use in port and to run them in parallel.

In ships propelled by Diesel or turbo A.C. electric machinery, it is possible to take the auxiliary supply from the main propulsion circuit or, alternatively, to provide auxiliary alternators driven in tandem with the main alternators. It is in such ships that auxiliaries driven by A.C. motors would be a very definite advantage.

The type of alternator likely to be used on shipboard will be generally similar to those used in land power stations and as shown in Fig. 10. These are generally simpler and cheaper machines than D.C. generators as there is no commutator and all the power windings are on the stator. A small D.C. generator is required to supply the excitation to the rotor windings and this is often built as an overhung machine into the alternator which is to be used for auxiliary supply.

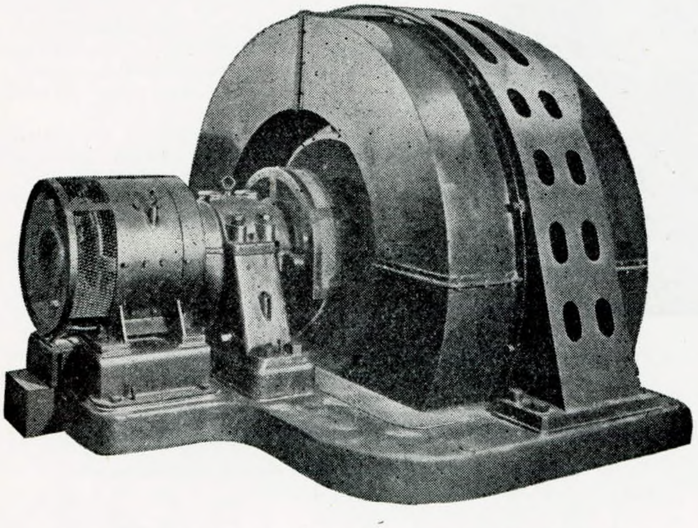

FIG. 10.—*Diesel-driven alternator and exciter.*

Two alternators must be synchronised before they can run in parallel and this necessitates :—

(1) The voltage on both machines to be the same.
(2) The frequency must be very nearly the same.
(3) The voltage waves must be brought into phase.

Synchronising can be carried out easily with the instruments available.

The electrical load will consist partly of induction motors and the alternators must therefore be designed to suit a power factor of 0·8.

PARTICULARS OF SOME SHIPS WITH A.C. AUXILIARIES.

A number of Diesel-electric and turbo-electric propelled vessels have been fitted with A.C. auxiliaries taking power from the propulsion mains, and Table 3 below gives some particulars of them.

In general, when the auxiliary power is required for a large number of auxiliaries, the voltage is reduced by means of transformers to 380/440 volts to comply with the classification societies' requirements, but when one or two large auxiliaries only are to be driven by A.C. motors, *e.g.* condenser circulating water pumps, cargo oil pumps, etc., the motors may then be arranged for the full propulsion circuit voltage.

TABLE 3.

Vessel	Type of machinery	Total b.h.p. at propellers	Main circuit voltage	Auxiliary voltage	Frequency	Type of motor	Method of starting
Wuppertal	Diesel-electric	7,800	2,000	380	50/36	Induction	Direct
Patria	Diesel-electric	15,000	3,500	380	50/42	Induction	Direct
Platano	Turbo-electric	6,750	2,600	—	51	Induction	Direct
J. W. van Dyke	Turbo-electric	5,080	2,300	440	60	Induction	—

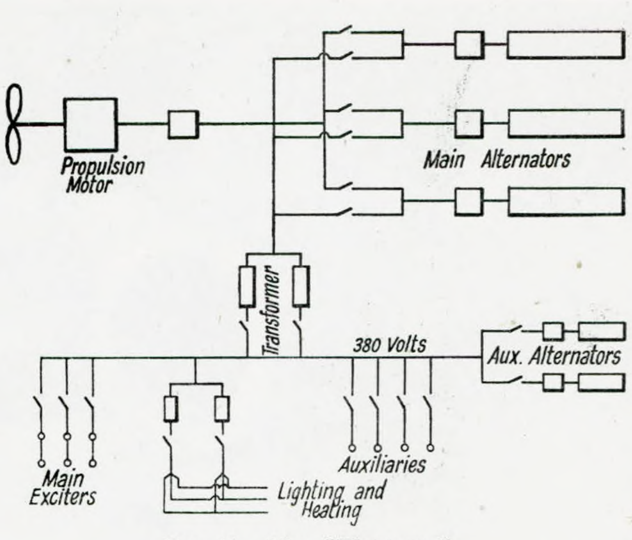

FIG. 11.—*M.v. "Wuppertal".*

The *Wuppertal,* built for the Hamburg America Line in 1938, now renamed *Noesaniwi,* is a Diesel-electric propelled vessel, fitted with M.A.N. engines and Brown-Boveri electrical equipment, particulars of which have been given elsewhere.

All the auxiliary power at sea is supplied from the main busbars through transformers, and from any one of the three main alternators through the transformers whilst manœuvring and in port; the small auxiliary generators are seldom used. The main and auxiliary circuits are arranged as shown in Fig. 11.

The engine-room pumps are driven by squirrel-cage motors switched directly to the auxiliary mains, the voltage and frequency of which varies with the ship speed. The pumps connected with the working of the machinery give outputs, at reduced speeds, corresponding to the engine requirements, whilst the bilge, ballast and fresh-water pumps, ventilating fans, etc., are liberally rated, so that outputs sufficient for the individual requirements are obtained at the lower ship speeds, when the pumps will be driven at about 70 per cent. of full speed.

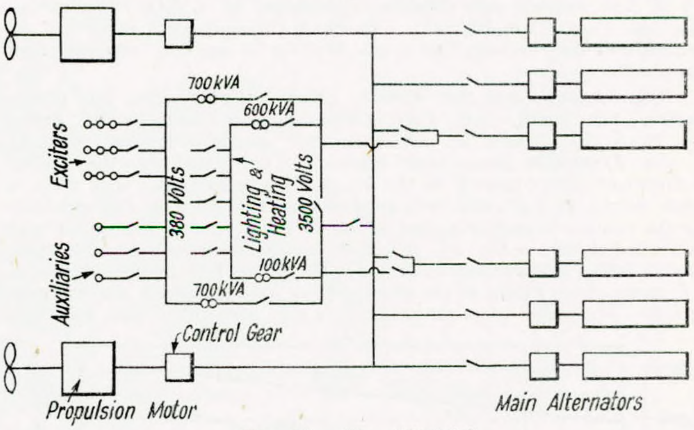

FIG. 12.—*M.v. "Patria".*

The lighting and heating circuits are taken through regulating transformers which maintain, as nearly as possible, a constant voltage irrespective of the main circuit voltage variations and within the limit of 36 to 50 cycles.

The ship is interesting in that some A.C. winches were originally fitted but found unsatisfactory, and were not in general use. It should be mentioned that they were of a much simpler type than the

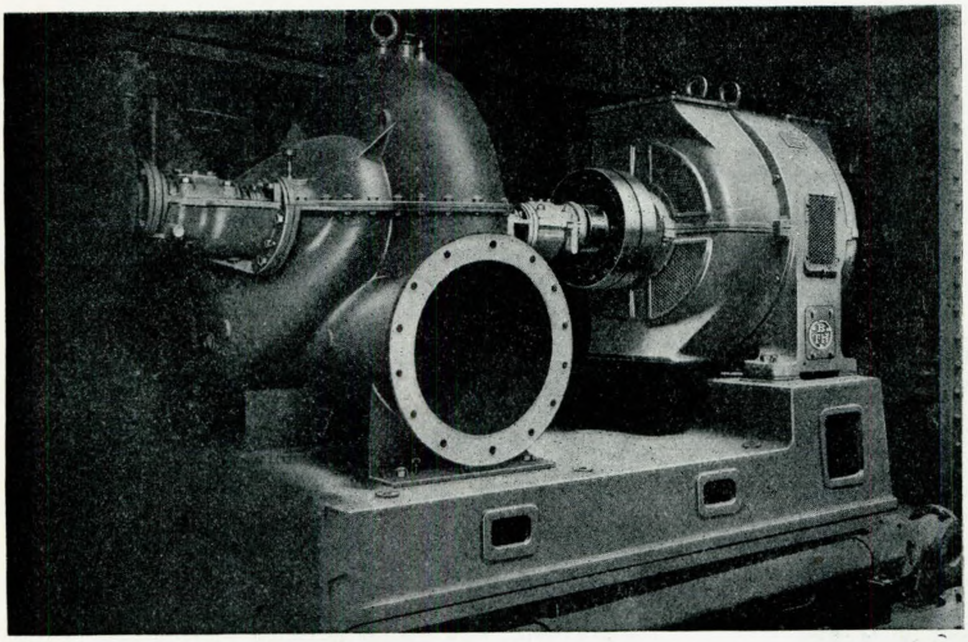

FIG. 13.—*135-h.p., 320 r.p.m., 2,600-volt, three-phase induction motor driving circulating water pump on s.s. "Platano".*

D.C. winches fitted, and it may not be fair to draw too definite conclusions.

The power for the D.C. winches was taken from the motor generator sets provided for the main propulsion machinery excitation.

The *Patria* is a twin-screw passenger ship, also built for the Hamburg America Line, and now renamed *Rossia.* It is fitted with six M.A.N. engines and electrical equipment by A.E.G. The circuit diagram is shown in Fig. 12. The electrical equipment is similar to, but more extensive than, that in the *Wuppertal* and has been described elsewhere.

The *Platano,* built for Messrs. Elder & Fyffes, Ltd., has turbo-electric machinery, the main condenser circulating-water pump of which is driven by an induction motor switched directly to the 2,600-volt propulsion mains. The speed of the motor is therefore proportioned to the r.p.m. of the propeller and gives a water discharge approximately proportional to the r.p.m. and sufficient for the condenser requirements at the various speeds. The pump and motor are shown in Fig. 13. All other auxiliaries, lighting and heating on this vessel are arranged for D.C., therefore this pump also has a D.C. motor (not shown in the photograph) for use during manœuvring periods. A number of other ships have also been fitted with this type of pump drive.

The *J. W. van Dyke* is an American-built tanker, representative of many, in which the cargo-oil pumps take their power from the main propulsion alternator. As these will be used in port only, the speed of the turbine can be regulated to give the required output of the pumps.

The *Oranje* had some of the constant-speed engine-room pumps driven by A.C. motors, the power being supplied by three 220-KVA alternators. The engine-room ventilating fans were also driven by two-speed squirrel-cage motors.

The *Hornby Grange* is a refrigerated motor vessel just completed in which two-speed induction-motor-driven circulating fans are fitted in 74 of the refrigerated compartments. Particulars of these have recently been published.

The power is supplied by two motor generator sets supplying power at three-phase 230 volts 100 cycles.

Auxiliary Supply Conditions.

Fig. 14 shows the main circuit voltage, frequency and propeller r.p.m. for an 18-knot turbo-electric or Diesel-electric vessel proceeding under good weather conditions, also the mean power available from an induction motor taking the power directly or through a transformer from the propulsion circuit.

The supply voltage will vary appreciably in bad weather when the vessel is pitching, due to the variation in transmitted power. Mr. J. L.

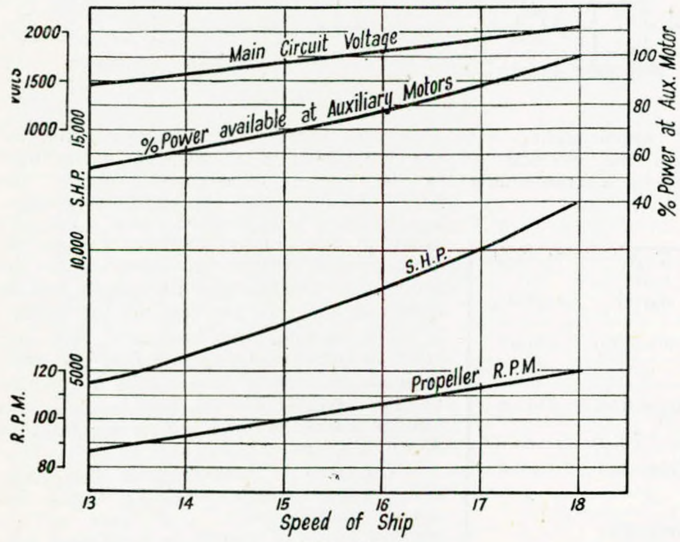

FIG. 14.

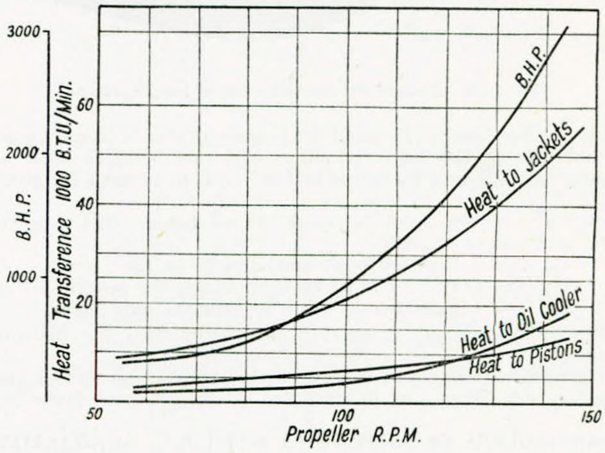

FIG. 15.—*Four-stroke cycle supercharged engine.*

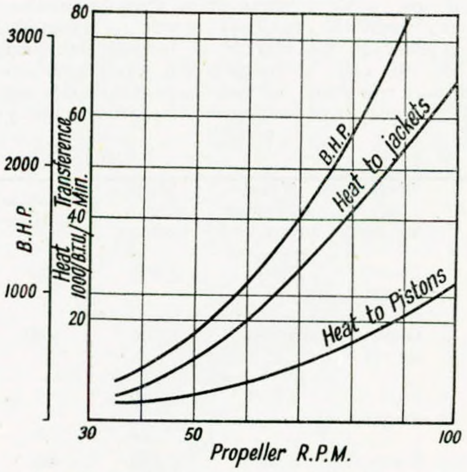

FIG. 16.—*Two-stroke cycle opposed-piston engine.*

TABLE 4.

Duty	Type of auxiliary	Approx. h.p.	R.p.m. at 60 cycles	Type of motor	Method of starting	Number fitted	
Circulating water	Centrifugal	20/40	1700	Squirrel-cage	Direct	3	
Lubricating oil	Gear wheel or screw	20/60	1100 3500	—	—	3	
Fire and bilge	Centrifugal	20	1100/1700	Two-speed squirrel-cage	Direct	3	
Ballast	Centrifugal	40	1700	Squirrel-cage	Direct	1	
Fresh water	Centrifugal	5	1700	Squirrel-cage	Direct	2	
Fuel transfer	Gear wheel or screw	20	1100	Slip-ring	Rotor Resistance	1	To give variable speed
Oil separators	—	4	1700	Squirrel-cage	Direct	4	
Air compressors	—	20/60	700	Squirrel-cage Slip-ring	Direct Rotor Resis.	2	
Refrig. compressors	—	30/100	350	Squirrel-cage Slip-ring	Direct Rotor Resis.	3	
Brine pumps	Centrifugal	5	1700	Squirrel-cage	Direct	6	
Circulating fans	—	10	1700/1100	Two-speed squirrel-cage	Direct	—	
Ventilating fans	—	10	1700/1100	Two-speed squirrel-cage	Direct	6	
Workshop motor	—	5	1100	Squirrel-cage	Direct	1	
Boiler fans	—	20/30	850	Slip-ring	Rotor Resis	4	
Condenser Circulating water	Centrifugal	100/200	580	Squirrel-cage	Star Delta	2	If altern. not large enough for direct switch.
Fuel pumps	Gear wheel	10	1100	Squirrel-cage	Direct	2	

Kent, in his paper "Propulsion of Ships under Different Weather Conditions" presented to the Institution of Naval Architects in 1926, gives the following particulars of the performance of the s.s. *Oroya* owned by the Pacific Steam Navigation Co.

Height of waves.	*% Torque variation.*
Less than 3ft.	Never more than 30% of mean torque.
Over 20ft.	Over 100% of mean torque.

The natural pitching period of the ship was 7·1 seconds measured in calm water, and the actual period of pitch measured during the bad weather ranged between 6·5 and 8·5 seconds. It was found that the torque variation was periodical and coincided roughly with the ship's pitching period.

In addition to the periodic variation of torque, there were also occasionally torque variations up to 100 per cent. during one propeller r.p.m., attributed to rapid rudder movements.

The variations in main circuit voltage corresponding to these torque variations in an A.C. Diesel- or turbo-electric propulsion installation will be:—

Total variation in torque.	*Approximate variation in voltage.*
30% of mean	+10−20%
100% of mean.	+20−30%

The frequency of the supply and therefore the speed of the motors would be controlled by the Diesel or turbine governors to within about ±7 per cent. of the mean value, under the worst conditions.

The motors driving the pumps must operate satisfactorily under these conditions, and develop the necessary power at the lower voltages.

A voltage with not more than ±5 per cent. variation must also be available for lighting and heating. The regulating transformers or induction regulators fitted to the *Wuppertal* were reported to operate satisfactorily under all weather conditions.

Engine Room Auxiliaries.

Table 4 gives the particulars of the various auxiliaries likely to be fitted in modern ships, also the type of motor and the method of starting likely to be used.

Pumps Dealing with Engine Services.

Figs. 15 and 16 show the heat transference to the jacket and pistons of a four-stroke cycle and two-stroke cycle engine based on results obtained by the Marine Oil Engine Trials Committee. The cooling-water and/or lubricating-oil pumps will be required to deal with sufficient cooling medium to carry away these heat quantities.

Figs. 17 and 18 show the characteristics of a lubricating-oil and a cooling-water pump when driven by A.C. motors taking the supply from the propulsion mains.

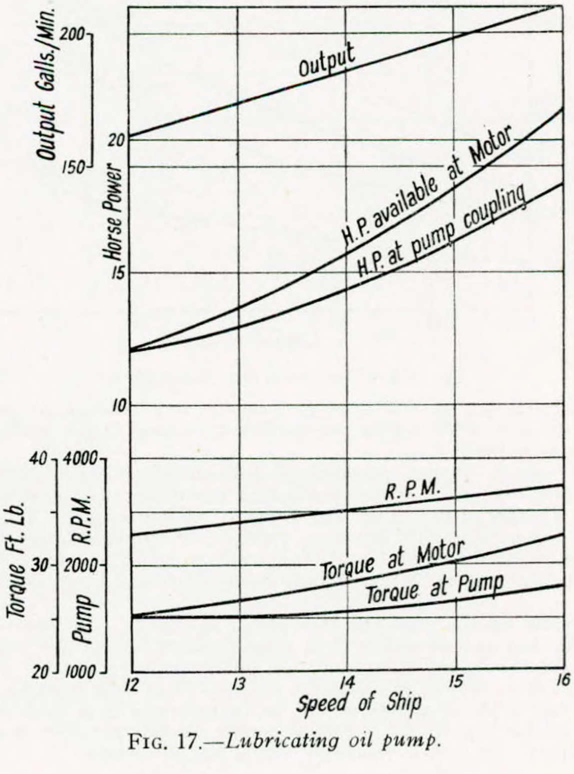

FIG. 17.—*Lubricating oil pump.*

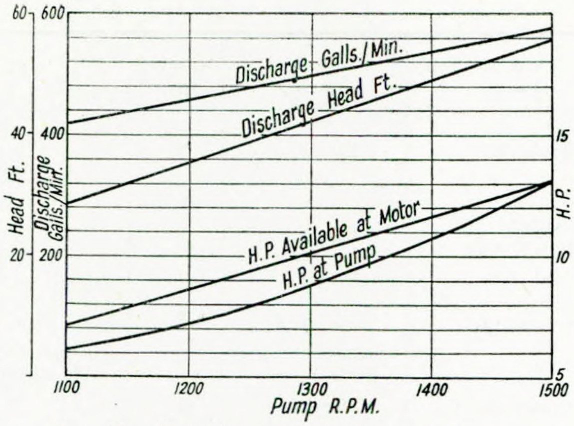

FIG. 18.—*Centrifugal circulating water pump.*

Fig. 19 shows the steam, forced-draught air and cooling-water for an 8,000 s.h.p. turbo-electric ship; the values shown will vary about 10 per cent. due to differences in the sea-water and air temperatures. The characteristics of the condensate extraction pump are shown in Fig. 20.

Forced- and Induced-draught Fans.

Forced- and induced-draught fans for boilers require a wide range of control of speed, such that with D.C. motors it is necessary to fit both shunt and series control.

In large boiler installations, especially when remote control is required, it is possible to use squirrel-cage motors and electro-magnetic slip couplings which will give an easy control of speed from 0 to full speed.

For the smaller units normally used in merchant ship installations, a slip-ring motor using a rotor resistance speed control can be used. The maximum heat loss is approximately 15 per cent. of the full-load output of the motor and occurs at about two-thirds full-load speed.

Engine-room Pumps.

The fire and bilge pumps, ballast, fuel transfer, fresh-water and other similar pumps will need to give the required output and heat at the reduced speed. This necessitates somewhat larger pumps than are normally fitted.

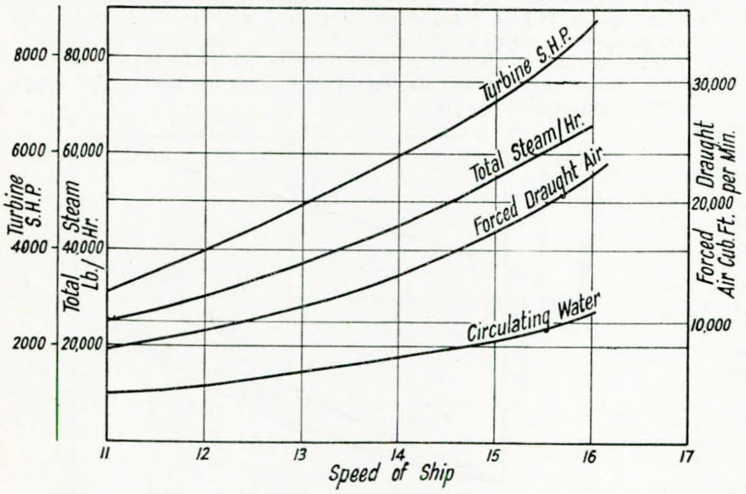

FIG. 19.—*Turbo-electric machinery.*

The extent of the speed range through which these pumps can be usefully employed will depend upon the design and size selected. In the *Wuppertal* the range was from 70 to 100 per cent. and in the *Patria* from 85 to 100 per cent., which are similar ranges to that obtained by shunt control with D.C. motors and give approximately 15 to 30 per cent. reduction in output for centrifugal and gear wheel pumps.

Control of the fuel transfer pump discharge will generally be required, and can be obtained in a gear wheel or similar pump by fitting a full-size bye-pass from the pump discharge to the suction. If an actual reduction in discharge is required to help draining of the tanks, then a slip-ring motor will be necessary with a continuously-rated resistance starter. As these pumps do not normally work for long periods, the loss in efficiency would not be serious.

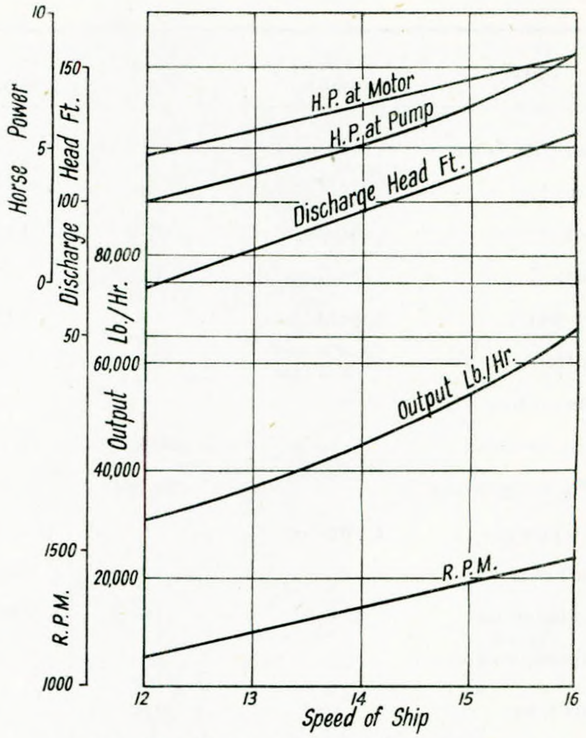

FIG. 20.—*Condensate extraction pump.*

Air Compressors.

The air compressors on motor ships run most frequently prior to or during manœuvring periods, but in Diesel-electric propelled ships the main engines run continuously and the demand for air will be much reduced. It is therefore probable that the power supply will be taken from the auxiliary alternator. With large compressors having motors of 80/100 h.p. it will be necessary to fit slip-ring motors to reduce the starting current, but with the smaller compressors, say up to 20 h.p., which will probably be fitted in such ships, squirrel-cage motors started directly from the mains can be used.

Centrifugal Separators.

Centrifugal separators for fuel and lubricating oil are fully efficient over about a 25 per cent. range of speed within the limit of -25% to $+10\%$ of the design speed according to type and design and size. It will therefore be possible to supply the power from the propulsion mains over a wide range of ship speed, say from 14 to 18 knots.

The discharge of the pumps driven from the separator drive will of course vary with the motor speed.

Refrigerating Installations.

It is now common practice to fit a number of small high-speed refrigerator compressors rather than one large compressor, and the varying refrigerator load can be taken care of to a certain extent by altering the number of machines in use. Further adjustments can be made, as in land installations, by arranging one or more machines to cut in or out automatically as required, to maintain the required temperatures.

Other methods, which are adopted in land installations to vary the output, depending upon the size of the machines are:—

(1) Variable clearance pockets in the compressor cylinders to give a reduction in volumetric efficiency of the compressor.
(2) Control of suction pressure to compressors.
(3) Cutting out one or more cylinders in multi-cylinder compressors by by-passing the discharge to the suction lines.

These could equally well be adopted to marine installations in which the compressors run at constant speed, if a finer adjustment than given by cutting a compressor in or out were required.

It is general, when a full refrigerated cargo is being carried, for the ship to proceed at full speed, and therefore the full output of the machines would be obtainable if the power were taken from the propulsion mains.

At reduced speeds the refrigerator load would be reduced directly proportional to the motor r.p.m.

The brine pumps can be driven by squirrel-cage motors and the output varied by adjusting the discharge valves.

The air circulation fans present a difficulty, as at least two speeds in the ratio 3 : 2 will be required, as in the *Hornby Grange.* If high speed fans are required, it will be necessary to adopt a frequency of 100 cycles and to have fitted a special circuit supplied from a motor alternator.

Electro-hydraulic Steering Gear.

Electro-hydraulic steering gears are probably the most easily converted to A.C., as they have continuously-running motors driving oil pumps which only operate under load when the rudder is moved. The essential requirement is that the motor will not stop whilst the ship is moving. If the power is being supplied by one or more auxiliary Diesel or turbo-alternator sets, the problem is little different from that of the D.C. motor. With Diesel A.C. electric propulsion machinery one engine always becomes available automatically for auxiliary duty in the event of a sudden manœuvre, but in turbo-electric propulsion it would probably be necessary to fit a standby pump driven by an air motor, or similar scheme to take care of emergency conditions, unless there is an auxiliary alternator in service continually. Fig. 21 shows the h.p. required to move the helm from hard over to hard over at various ship speeds, and the time of operation for which the classification societies allow a maximum of 30 seconds. Other forms of steering gear, some operating on the Ward Leonard system, have been developed for working with A.C.

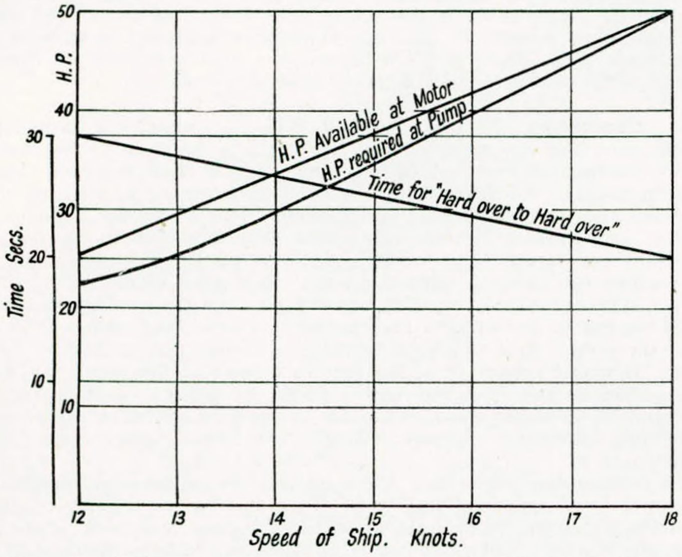

FIG. 21.—*Electro-hydraulic steering gear with A.C. motor drive.*

Winches and Windlasses.

The use of A.C. motors for winches presents a difficulty, as the normal type of such motors run at constant speed whereas a light hook speed of 4/5 times the normal lifting speed is required to deal efficiently and quickly with the cargo. It is unlikely that shipowners and stevedores would be willing to accept a standard lower than that set by the modern D.C. electric or the steam winch. Reports from Germany indicate that A.C. winches have been developed during the war years and it is understood that Continental shipbuilders are making enquiries for such winches, also that experimental work with A.C. winches having characteristics approaching those of D.C. winches, is being carried out in America.

It is possible, as in the *Wuppertal* and *Patria,* to use the main machinery exciters, which are D.C. generators driven by A.C. induction motors, to supply D.C. for this deck machinery. This necessitates a special circuit from the engine room, but no additional cost is involved for the D.C. generators.

A constant current system could also be supplied for the winches, which would give winch performances at least equal to those fitted with booster control, but this would necessitate special generators driven by A.C. motors as well as the separate circuit.

Windlasses do not present the same difficulties as the winch, as the high light hook speed is not required and it is possible to use a slip-ring motor with motor-resistance control.

Lighting and Heating.

The use of A.C. for lighting and heating has the definite advantage that any convenient voltage can be easily and cheaply obtained by means of transformers. Thus it is possible to have 110 volts for general lighting and 40/50 volts for lighting in special compartments and for supplying power for small tools, etc. in the engine room.

In large installations the circuits can be divided into sections, each with its own transformer, thus making for a cheaper and more reliable installation.

The three-phase 400-volt supply for power can be divided into three single-phase 230-volt circuits for heating. Transformers will give the 110 volts required for lighting. It may appear to be a retrograde step to revert to 110 volts for lighting soon after the change up to 220 volts on D.C., but this was mainly done to avoid the use of the three-wire system of distribution or the separate lighting circuits fed from motor generator sets. 110-volt lamps are about 25 per cent. more efficient than 220-volt lamps of corresponding output and similar life, or have longer life for the same efficiency, so that there is some advantage.

Galley equipment, water boilers, etc. and radiators generally designed for the use of D.C. can be equally well used with A.C.

Conclusion.

It will be appreciated that shipowners run their ships solely on a commercial basis; therefore changes in design do not concern them unless the performance of the ship is improved or for some equally valid reason.

A.C. can be and has been adopted for driving marine auxiliaries and the engine room arrangements found satisfactory. Modifications to some of the auxiliaries were made necessary by the conversion from steam to D.C. electric and these have now been accepted as worthwhile.

A.C. is accepted as standard for most land installations, and it is therefore to be expected that it should be considered more generally for marine work, in view of the robustness, efficiency, simplicity and easy maintenance which it will give.

Discussion.

Mr. G. O. Watson (Member), opening the discussion, said the question of A.C. for ships' auxiliaries was receiving considerable attention at the present time, and it was significant that in addition to the paper presented, a very adequate and excellent paper had also been read last month before the American Society of Naval Architects and Marine Engineers in which the whole range of A.C. in ships had been dealt with very fully and adequately.

It was difficult to decide whether or not the author was in favour of A.C. He had referred to wound rotors as being complicated and expensive, but had given no indication as to how they compared with D.C. The author had given them a sort of ***hors d'œuvres,*** with some disjointed facts which did not appear to make a continuous story which came to any conclusion.

It would be interesting to ponder a while on the origin and causes of that new phase, but the speaker suggested that the justification for a change from D.C. to A.C. had to be sought in one or more of the following :—

(1) That it was cheaper in first cost. That had not yet been demonstrated and therefore required further proof.

(2) It was cheaper to run. That also required elucidating.

(3) It was cheaper to maintain. It was alleged that the absence of commutators was in its favour but it remained to be proved that 440-volt stator windings were less prone to failure than 220-volt armatures.

(4) That it was more reliable. D.C. had given good service for sixty years and experience taught that every new method had its teething troubles. Nevertheless, land experience could be taken as a guide. It was known that A.C. motors stood up very well in coal mines and similar arduous and analogous services, although that did not mean that they were entirely trouble free. It was also known that A.C. had been adopted as standard by the United States Navy and that reliability in naval vessels was the prime consideration.

(5) It would be a factor in its favour if it showed some appreciable saving in weight.

(6) Another aspect which deserved due consideration was that of safety and potential danger of shock. It was recognized that at equal voltages A.C. was more lethal than D.C., which

> meant that great caution and more safeguards against accidental contact with live metal had to be provided. So far there had been a very clean record in the Mercantile Marine of freedom from fatality by electric shock, and that record had to be maintained. That could only be done by recognizing the dangers and safeguarding against them and by pointing out to seagoing engineers and electricians that they must not be so carefree in handling A.C. as they were with D.C.

It was now well known that the greatest and perhaps the only obstacle in the way of using A.C. was the difficulty of obtaining a variable speed efficiently and the energies of those who advocated A.C. should now be concentrated on meeting that difficulty. Winches were the chief problem.

The intention of one of the leading shipowners had been to utilize A.C. throughout in the next passenger-cargo liner, and a complete scheme had been evolved, but it had been abandoned for the sole reason that the cost of converting to D.C. for the operation of winches made the overall cost prohibitive.

It seemed a pity that the author had concentrated his examples on the characteristics of auxiliaries associated with electric drives resulting in the neglect of the more normal problem of a ship with direct drive and separately-driven generators. It was true that the aim of electrical engineers was to develop electric propulsion with auxiliaries taking power from the propulsion generators, but until electric propulsion became more popular, the more usual type of installation should be concentrated upon.

In addition to winches there were other services which required a variable speed. Variable speeds for I.D. and F.D. fans were, for instance, indispensable, but in other cases it was possible to manage with a constant speed and vary the output by either throttle or by-pass control. Variable speed A.C. motors were inefficient, and the reduced efficiency of rotor control had to be balanced against that of allowing pumps to run, perhaps wastefully, at constant speed at full output or a little less efficiently under throttle or by-pass control before deciding which method to adopt.

What was needed in the future was a concentration of effort on the exploration of new methods for the production of variable speeds efficiently and at reasonable cost. When a comparison was made with the cost of D.C., one had to be scrupulously fair to see that if constant speed were adopted to suit A.C., a comparison had to be made with constant speed D.C. Furthermore, if a higher speed to suit A.C. were adopted, then a comparison had to be made speed for speed.

One of the urges for the adoption of A.C. was, incidentally, the advent of fluorescent lighting, because if A.C. generation were not adopted it would necessitate a conversion from D.C. to A.C.

A sub-committee of the Institution of Electrical Engineers on Regulations for the Electrical Equipment of Ships had recently been considering the amplification of the rules relating to A.C., and it was probable that they might be issued in the near future. It was obviously highly desirable that when A.C. did come there should be a certain degree of standardization in such fundamental matters as voltage, phase rotation, methods of synchronizing, and so forth. Those problems, together with many others, had already received consideration. Ships' crews were continually changing, and as the synchronizing of alternators would be strange to them at first, it was important that synchronizing methods should be standardized so that the drill was the same in all ships.

In Figs. 4 and 5 in the paper 100 per cent. had been chosen for the pull-out torque with the result that full-load torque appeared at about 46 per cent. and full-load current at 19 per cent. Those curves would have been more intelligible to the uninitiated if full-load current and full-load torque had been shown as 100 per cent. In Fig. 5 the slip-ring motor starting torque was shown as twice the full-load torque, but such torques were unnecessary and could be reduced by limiting the line current during starting.

By a typographical error in the second paragraph from the bottom of page 2 there appeared the words "Wound motor" which should read "Wound rotor". The starting current of a slip-ring machine was usually full-load current, whereas in a squirrel-cage motor it might be five to six times full-load. The second sentence was, therefore, misleading. It was also not clear what was meant by "maximum torque value".

On the third page one of the chief advantages of the induction motor, namely, absence of commutator, had been omitted. It was difficult to see that the reversing of two phases to obtain reversal was a disadvantage as compared with D.C. The only motors in a ship which required reversing were the winches, windlasses, etc., in which the armature connections had to be reversed. Synchronous motors did not require an auxiliary starting device for propulsion systems as had been stated.

The starting of squirrel-cage motors involved an over-current, but not an overload of four to five times as had been stated.

The starters shown in Figs. 8 and 9 did not appear to be drip-proof and even if a packing were fitted in the door, water would still enter at the top.

The new name for the *Wuppertal* was now *Noesaniwi*.

On page 7 a voltage variation of ±5 per cent. for lighting and heating was specified. That was too wide and should be nearer ±2½ per cent. If there were any distribution transformers in the circuit for stepping down to lighting voltage they would have an inherent regulation of approximately 2 per cent. and with line drop in addition that would result in possibly −10 per cent. in some cases, which was too great.

With regard to refrigerating installations, if the intention were to take the refrigerating load from the main propulsion generators, it would still be necessary to have the auxiliary generators large enough to supply that load. A full cargo was often worth as much as the ship, and no risks could be taken. The vessel might be steaming dead slow in fog or at too low a speed to run the refrigerator motor. In that case it would be necessary to transfer it to some other source unless it happened to be a multi-engined Diesel equipment similar to the *Wuppertal* and the *Patria*.

Commander (L) J. C. Turnbull, R.N. (Associate) emphasized at the outset that any remarks he made, unless he stated otherwise, were not representative of Admiralty policy. He had however, been authorized by the Director of Electrical Engineering to say that the Admiralty were building as an experiment two destroyers fitted with A.C. auxiliaries. It was upon those experiments that the power supply for future ships would depend in the Royal Navy, namely, whether A.C. were adopted or whether they stuck to D.C.

With regard to the paper, it was a pity that the illustrations used by the author were not of marine gear. It should not be too difficult at the present time to get photographs of proper marine gear.

It would appear from the first paragraph of the paper that the question of first cost was still a factor of prime importance with regard to merchant ships, but as far as naval vessels were concerned, fighting efficiency, damage control, etc. usually outweighed the first cost.

The author stated that "the main troubles experienced with D.C. motors and equipment are burnt commutators, overheating of the winding due to the deposits of oil-laden vapour and burnt contacts in the starters. The equipment is, however, entirely satisfactory". It was difficult to agree that burnt commutators were unavoidable or necessary. Given proper maintenance burnt commutators should be unknown.

With regard to Table 1, most of the American-built A.C. ships were equipped with single-phase auxiliary power of 117 to 120 volts, using transformers to step down. In the paper, however, there was a complete blank against auxiliary power, and it was presumed that it was a U.S. Navy requirement.

On the second page the author took up the question of frequency of supply, but he did not mention why 60 cycles was so much favoured. Surely the answer was because speeds obtained with 60 cycles so nearly approximated to normal D.C. speeds that standard auxiliaries could be used with 60 cycles, but with 50 cycles considerable alteration might be necessary to the mechanical side of the gear.

On the question of starting current and starting torque, there were available squirrel-cage motors which would get down to 3·5 times full-load current with twice full-load torque at starting which would solve a lot of problems.

He did not agree that Universal motors were satisfactory on either single-phase A.C. or D.C. He took the view that they were abominable and should be used on nothing more than a Hoover vacuum cleaner!

Direct starting was quite alright, and it was agreed that "Star Delta" was a nuisance. The author had not mentioned one great advantage of the induction motor, namely, its great saving in weight.

When the author said on the third page that the cost was low, it would be interesting to know if he meant in comparison with steam, D.C. or other types of A.C. motor. Incidentally, with regard to the construction of A.C. motors used on ships, the A.C. motor had a very small air gap as compared with the D.C. motor, and he believed that the Americans had had trouble from rotors fouling the stator when the bearings became worn. Presumably to cope with that difficulty, rotors with short stout shafts should be used.

Induction motors were not at a disadvantage compared with D.C. machines when reversing was needed. A complicated starter was necessary for D.C. in order to do the same thing.

He did not think a very wide range of speed variation was required if the mechanical gear being driven were properly designed. The trouble was that so much of the mechanical gear in use had been designed for steam and had never been altered.

The author made no mention whatever of the true variable-speed A.C. motor other than the change-pole or cascade type. There were some available, one for example, being the "N.S." motor. That motor was said to be able to do anything a D.C. motor would do and a bit more. It was said to be cheaper and more efficient than the Ward-Leonard control and took up less space. He did not want to advertise a certain type of motor nor to decry other makes. What might happen was that all the other manufacturers would get together and get down to it with the result that a more efficient Ward-Leonard system would be evolved. He did not think that one would get complete control from zero to full speed with the electro-magnetic coupling for forced- and induced-draught fans. A two-speed motor would probably have to be used together with a coupling.

On the question of running D.C. deck machinery from main exciters, it would appear that there was an additional cost involved in that connection. The exciters had to be large enough to give full excitation plus any power which might be needed to shift the cargo at sea. Stand-by machines were required for when the main machinery was shut down in harbour, so it would appear that larger machines than one plain excitation machine were necessary.

Refrigeration machinery had been dealt with by Mr. Watson, but it was to be hoped that manufacturers would give them a domestic automatic refrigerator with a large enough electric motor. The refrigerators in use at the moment were designed for the ordinary house. The designers seemed to forget that the sailor was always going to the refrigerator so that the motor was required to run day and night with the result that it soon got burnt out.

He agreed with Mr. Watson that less than 5 per cent. voltage variation was necessary.

During the war a number of ships had been fitted with A.C. auxiliaries built in America, some with A.C. drive as well, and they had been very good indeed, giving very few troubles. "Across the line" type starting was used almost entirely, and, speaking personally, he had had no trouble at all except with one starter the Americans had turned out, with a 440-volt coil made with enamel-wire insulated with tissue paper. He knew of two ships in which the auxiliary compartments had been flooded—in one case ten motors had been flooded and in the other case twelve—but thanks to the absence of commutators the motors were repaired and running again 24 hours after flooding.

One trouble had been experienced with the parallel running of alternators until the engineers had been taught that that depended upon the speeds being exact.

He concluded with a plea that all encouragement should be given to the raising of the status of marine electrical engineers. The paper showed only too clearly how far they had fallen behind other nations, and he thought it was due to the fact that too many highly-placed marine engineers took the view that everything was better if it was driven by steam. The Royal Navy had not always been above criticism. However, the formation of an independent Electrical Branch of highly-qualified officers and men should enable faster progress to be made.

A scheme had now been started for entering Electrical Cadets at the age of 17 and 19 and giving them a comprehensive training in H.M. ships and Electrical Schools and at Cambridge University. At the end of their training they would have reached the rank of Lieutenant (L) and be very highly-skilled officers. Training programmes for Electrical Branch Ratings were in operation in the Naval Electrical Schools.

He personally hoped to see the Merchant Navy keeping pace with the R.N. in the development of the electrical side.

Mr. A. W. Savage, A.M.I.E.E. (Associate) said when considering the adoption of an A.C. supply, there were one of two basic principles which one had to bear in mind.

First of all, attempting to make the A.C. motor do exactly what a D.C. drive accomplished would result in complication and dissatisfaction. Secondly, in order to obtain the maximum advantage from an A.C. installation it had to be remembered that the A.C. motor was essentially a high speed machine. It was also essential that the squirrel-cage motor should be used wherever possible in preference to either the wound rotor or synchronous types.

Squirrel-cage motors with improved starting qualities which were mentioned in the paper should be considered in view of their reduced starting currents. The latter might result in overall advantages by facilitating the problem of overload and fault protection in the supply system. Such reduced starting currents would also allow the output limit permissible for squirrel-cage motors to be raised in relation the the alternator capacity. The high torque motor should not, however, be used indiscriminately with the idea of obtaining a margin of starting torque or reducing the magnitude of starting currents. When that type of motor was compared with the normal torque motor, the efficiency and power factor would be found to be less.

It would be seen from the curves in Figs. 2 and 3 that the power factor fell rapidly at reduced loads, and it was, therefore, most important that the fitting of oversize motors should be avoided. That point had not been stressed in the paper. From the previous remarks it would be apparent that closer co-operation between manufacturers of driven auxiliaries and manufacturers of motors must be obtained.

Another point which had not been mentioned in the paper was the question of enclosure of the motors which was of importance and should be in line with ship requirements.

The question of deck machinery was debatable, and from the paper one would gather that no A.C. motor was available in the country at the present time which was suitable for winches and windlasses. That was not quite correct as an investigation had shown that one or two solutions were existent which, without difficulty, could be applied if the decision to build a ship with an A.C. installation were taken. There were two broad possibilities of approach. The first was the spot conversion of A.C. into D.C. by means of a small motor generator set for each of those auxiliaries, using Ward-Leonard control for the drive. The second was the use of variable speed A.C. motors of the non-brush shifting commutator or slip ring type with special connections arranged for the purpose. Generally speaking, both groups of solution obviated the necessity of having a D.C. generating plant and distribution system on the ship.

The suitability of Ward-Leonard control for the auxiliaries in question was beyond doubt. It would appear also that whilst slip ring motor drives, even including the refinements lately developed, would entail certain compromises as to performance, and therefore would probably be restricted in their potentialities, commutator motors could be made to meet the full requirements in practically the same way as D.C. drives. From industrial experience, the reliability of such A.C. variable speed motors and their maintenance requirements seemed to be well comparable with D.C. machines.

Recent investigations had shown that the whole question of introducing A.C. for all auxiliary drives was not so much a technical problem as an economical one. At the present stage of development the most economical method for driving deck machinery was to retain the D.C. motor for that purpose and to fit D.C. generators in tandem with the port use alternators. In other words, the first costs of the whole installation had to be carefully analysed. For the larger passenger vessel the first cost would be less for an A.C. installation, for a passenger/cargo vessel costs would be approximately equal, and for the general cargo vessel the cost of an A.C. installation would be greater.

From the point of view of simplicity and maintenance of the installation, a noticeable overall advantage could be confidently expected. It could also be hoped that by careful examination of the different requirements, the capital costs of the installation as a whole would be brought down to a level which would make the A.C. system a serious competitor of the D.C. system.

It was to be regretted that the author did not include sections on distribution and protective devices, for that would have opened up a much greater field of useful discussion.

Eng. Rear-Admiral W. R. Parnall, C.B., C.B.E. (Member) said that before he had heard the remarks of the previous speakers, he had been under the impression that if it were desired to adopt A.C. motors, one had to make special provision against the lack of speed control of the A.C. motor. He had never heard of an N.S. motor until it was mentioned in the course of the discussion, so his ideas were based on the fact that if one did use A.C. one would have to find some compensating advantages to set against the disadvantages arising from this lack of control.

It was felt that the pronounced robustness and low cost to which reference had been made would be attained only by the general use of the squirrel-cage type of motor switched directly on the line. In the terms of first cost then one should compare a D.C. installation with an A.C. installation in which the alternator and the motors were sufficiently big to stand up to the four or five times current which one got at starting.

It was pleasing to note that no one had raised the question of the ghostly seventh harmonic about which so much was heard two years ago.

With regard to the various methods of handling winches, nobody had referred to the mercury-arc rectifier. It would be interesting to know if that could be used.

The author had covered in detail the use of A.C. derived from the main alternator in turbo-electric and Diesel-electric installations. Were this deemed to be good practice the principle need not be confined to electric drives for there would appear to be no reason why any turbine should not have an alternator attached to it. In either case of course, provision would have to be made for a crash stop. If one had to tune in from the auxiliary alternator to the main-engine alternator, it would take quite a bit of time. In land installations they did not always tune in. They simply cut out the existing supply, waited for a second or two, and then cut in another supply. He asked if that would mean having to provide for still heavier currents. If it did not, it would appear to be a much better way than waiting to parallel the auxiliary alternator with the main-engine alternator.

In conclusion he asked if it were considered practicable to provide the A.C. squirrel-cage type of motor throughout the ship and to switch it in and out at will and, further, if that were done would the cost still compare favourably with D.C.?

Mr. J. K. W. MacVicar (Associate) said that the utilization of A.C. supply for marine installations must obviously be given very serious consideration in the near future, and it was undoubtedly true that the electrical engineers associated with the shipping companies were well aware of the advantages and, perhaps, the disadvantages, associated with that type of supply. Any additional information and experience which could be offered to the marine world within the scope of a technical paper must be welcomed.

In linking up the question of A.C. motors driving auxiliaries with the main propulsion itself, he felt that the author had somewhat clouded the issue. The subject of auxiliary machinery alone was sufficiently large to warrant special treatment. Under the heading of methods of starting it was interesting to note the author's statement that while Star Delta switches were used for starting squirrel-cage motors, experience had shown that there was a heavy current surge between the Star and Delta positions, even up to twenty times full load current which made for worse conditions than direct starting. In Table 4, however, the author indicated that Star Delta starting should be used for the condenser circulating water pump, on the assumption that the alternator might not be large enough to permit direct on-line starting. If the surge were as great as the author had suggested, then surely some other method of starting should be used for such a large machine?

With regard to forced- and induced-draught fans which normally required a wide range of control of speed, it was common practice in large boiler installations ashore to have constant speed motors and obtain the equivalent of speed control by using adjustable inlet vanes. There was no doubt that those could also be applied to marine installation with satisfactory results.

In discussing engine-room pumps, the author referred to certain services which would require to operate at particular duties irrespective of the ship's speed. That presumably referred to where those pumps were fed direct from the main busbars. If the pumps had to be installed to give the required output at the reduced speed of, say 70 per cent. of the maximum, then presumably the motors would require to be big enough to deal with the power at maximum speed. On the assumption that the power was proportionate to the cube of the speed, the pump motors would require to be rated at approximately three times the normal duty. No doubt, however. the author would be in a position to clarify that point.

Reference was also made to refrigerating installations, and one could foresee some difficulty in driving the refrigerating compressors from the propulsion mains as the generation of heat in a particular cargo might be such that full output of the machines had to be delivered irrespective of the speed of the vessel. For the air circulation in refrigerated cargo holds there was no necessity to adopt a frequency of 100 cycles, as suitable fans could be designed to operate on frequencies of either 50 or 60 cycles, thereby avoiding any special circuit or additional motor alternator.

Mr. C. P. Harrison (Member) agreed with previous speakers that the scheme for taking A.C. supply from the main propulsion machinery should be regarded as a special case and, for comparing A.C. with D.C., it would be better to assume a constant voltage and frequency supply.

It would have been an advantage to members of the Institute if the author had given some comparative costs and weights, but this was a big problem, because the relationship would not be the same on all types of ships. He thought the author would agree that alternators of average size, that was, 200 to 600kVA., would show a saving of 10 per cent. to 15 per cent. in cost, and up to 20 per cent. in weight, compared with D.C. generators of the same speed. Squirrel-cage motors in the 10/40 h.p. range would be as low as half the cost and 70 per cent of weight of D.C. machines.

Outside the engine room there were other advantages of A.C., because some apparatus could be operated on this supply but not on D.C. For instance, there were micro-gap switches, which were completely dustproof and silent, which would be a particular boon in passenger accommodation. One could use thermostatic cutouts without the addition of contactors; cabin and ceiling fans could have induction motors, thus eliminating small commutators; and there was the ease of transforming to low voltages for inspection lamps and signalling systems, or higher voltages for electric discharge lighting in various forms.

The broad issue seemed to resolve itself into two principal considerations.

Firstly, A.C. auxiliaries were logical only if advantage were taken of the main advantages over D.C., which were the use of transformers giving simple voltage change both up and down, and the use of the squirrel-cage motor. Where the latter was departed from, the advantage of A.C. was reduced because the system then lost its ruggedness and simplicity. Therefore it would appear necessary to revise present ideas about variable speeds and think in terms of constant speeds, or at least not beyond two speeds by pole changing.

The second important consideration was standardization of of frequency. On the second page of the paper the author stated: "and it appears that three-phase 400 volts 60 cycles is being favoured for marine work". That would be a mistake, because 60 cycles was standard only in the United States of America and Canada, and the rest of the world, including South America, India and China, were all on 50 cycles, so that the majority of ports would allow a 50-cycle shore supply. Spares for 50-cycle plant would be more easily obtainable, and in some cases stock motors might be used in an emergency. Self-contained apparatus, like laundry machinery and various motor-driven appliances, could be standard industrial type. Many smaller items, such as fans, call system relays, fluorescent lighting accessories, would also be standard. To make all these things "special" for the sake of being the same as the North American continent, or in order to have motor speeds to suit existing designs of engine-room auxiliaries, would be very wrong, and would not be to the advantage of shipowners, shipbuilders or British trade.

Mr. C. J. Holyoake (Associate Member) said with regard to voltages, it was gratifying to note that classification societies were allowing 440 volts for auxiliary service as against 220 volts D.C. Everyone realized that better efficiency was obtained more cheaply by the use of high voltages. For that reason it was to be hoped that Lloyd's would, with regard to main propulsion, review the present limit of 3,500 volts, because he felt sure that designers would be able to produce switch gear and control gear, either oil-immersed or air-blast, which would meet the higher voltages.

As far as lighting and heating were concerned, it would seem to have been more reasonable to have both on the same voltage, preferably 220-230 volts; otherwise it would mean separate circuits and additional transformers. Although the author had mentioned more efficient lamps at 100 volts, it would not appear that the extra wiring, transformers, and so forth would merit that.

With regard to the question of frequency, it would be much better to standardize the frequency at the usual 50 cycles which was used throughout most of the world.

In addition to that aspect, there was also the loss of efficiency at higher frequencies to be taken into account. In connection with plant itself, most manufacturers had a wide range of design at 50 cycles which would require modification for 60 cycles.

Mention had been made of driving auxiliaries from the main propulsion system.

Either over-sized equipment had to be used to allow for reduced speeds, by reason of reduction in frequency, or one might be faced with occasional awkward situations, *e.g.* if there was a sudden surge down in boiler water level, it might mean that the main engine had to be speeded up in order to get water into the boiler. Such a condition could not be tolerated. Also operation at varying frequency and voltage was not conducive to high efficiency. In any case it would seem that one would need a separate supply for lighting where frequency and voltage fluctuations could not be tolerated. Therefore, the question of driving from auxiliaries might just as well be dispensed with altogether and independent generators installed for auxiliary purposes.

With regard to robustness, he could vouch for that, having had some experience with A.C. auxiliaries at sea. They did take a lot of punishment, particularly squirrel-cage motors. They would run for long periods without any attention at all.

The lack of speed control was undoubtedly the great disadvantage of A.C. as compared with D.C.

Motors having two or three fixed speeds by means of pole-changing windings could be successfully applied in some cases. *e.g.* forced-draught fans in conjunction with damper or vane control, and condenser circulating pumps. Other cases required continuously variable speeds, *e.g.* condensate extraction pumps. This could be overcome by use of a by-pass on the pump discharge back to the suction, while maintaining constant rotational speed.

The author had mentioned magnetic slip couplings, and it would be interesting to know whether they could be applied to small motors on board ship, also whether for the larger motors the possible use of hydraulic couplings could be considered.

Mention was made of parallel operation of turbo- with Diesel-driven generators. Due to the vastly different governing characteristics of these two types of prime-mover this was often very difficult in practice, although the effect of synchronizing torque in paralleled alternators might tend to better results in the case of A.C. In this direction he had met with difficulty in both A.C. and D.C. cases.

Some engineers objected to A.C. on account of the necessary synchronizing gear. His experience had been with fully-automatic synchronizing gear which had been very successful and trouble-free even under heavy bombing attacks.

With regard to the question of heavy starting current in cage motors, this was amply borne out in his experience afloat. The effect was greatly magnified in small networks, as on board ship, which did not approach in any way an infinite system as did the large power networks ashore. The starting of large squirrel-cage motors on board ship, both by auto-transformer and Star-Delta switch, had given him many uneasy moments. Double-cage rotors and/or centrifugal clutches seemed to be the answer.

The problem of power factor was to some extent bound up with that of frequency. In some cases the installation of a condenser bank for power factor correction might be justified.

Mention was made in the paper of motors operating at a frequency of 100 cycles/second and 230 volts. This seemed excessively high and suggested a very low efficiency. Surely suitable plant was available for use with motors at 50 cycles/second and, say, 400 volts?

From the point of view of safety the usual dead-front types of A.C. switchboards were a great improvement on the old open-front D.C. type. Incidentally, dead-front D.C. boards were now in use in some American-built vessels in which he had sailed.

A speaker asked about the application of mercury-arc rectifiers on shipboard for certain purposes. The speaker had heard of their use on American-built vessels, among other things, he believed, for degaussing equipment. He would be interested to hear how these performed during heavy rolling and pitching of the ship.

Mr. R. J. Welsh, Wh.Ex. (Member) said he could not help but notice the similarity between the paper under discussion and a paper which was recently read before the American Society of Naval Architects and Marine Engineers. After both papers had been read it was still difficult to decide which side the authors favoured. However, speaking personally, he was in favour of the system.

Perhaps too much time had been spent in emphasizing the disadvantages rather than the advantages in the paper, and if the whole story were one of difficulty, then the impresstion gained would naturally be unfavourable.

The advantages of the A.C. system over D.C. were undoubtedly reliability, the lack of damage by water when flooding occurred, and the lack of carbon dust from brushes which was inclined to be troublesome on D.C. machines.

As far as economy was concerned, the only comparison between A.C. and D.C. that one could make was in the case of land machinery where there were D.C. and A.C. motors, and in that event it would be found that A.C. were cheaper.

Another advantage with A.C. was that of safety. The voltage could be transformed down and there could be installed a number of independent circuits throughout the ship. Then another advantage was the light weight of the A.C. system.

Comparing the two papers once more, the American paper was more specific than the one under discussion in that it suggested clearly that one should go in more for pole-changing motors than for any other type of control. In other words, squirrel-cage motors with two speeds were favoured. For D.C. winches the use of mercury-arc rectifiers was proposed, and there was a lot to be said for that because the winch was a special thing, and most people who discussed the application of A.C. at sea had stumbled against the winch problem. One might by-pass that, however, by sticking to the winches already in use and operating them with D.C. current. It was cheaper than installing a special motor generator set for that duty.

The trouble with mercury-arc rectifiers at sea was, of course, the rolling of the ship. Winches were used, however, when the ship was tied up and the question of rolling did not arise to the same extent.

With regard to the synchronizing of A.C., that practice was becoming easier. The modern method of working was to run an incoming machine up to a speed within 2 per cent. or 3 per cent. of the right speed, and then put it on the bars unexcited. If it were not running at the correct speed then it acted as an induction motor, by virtue of its damper windings. After it was running as a motor, excitation was applied and it became a generator. This method avoided any synchronizing on black lamps or bright lamps.

On the question of commutator motors giving variable speed for winches, he was against that, because if one had to revert to commutators, and A.C. commutators at that, one would be throwing away a lot of the advantages gained through using A.C. It was better to approach the system from some other angle.

Mr. H. T. Meadows (Member) said that for a year of the last war it had been his lot to be chief engineer of a ship with a turbo-electric (A.C.) main engine, and with A.C. auxiliaries and lighting. When he and his crew joined the ship they knew very little about A.C. In fact, none of them had ever seen an A.C. motor, but at the end of that year, the ship was still running without having given any electrical trouble whatever. This was a marine engineer's tribute to A.C.

Having been used to Merchant Service practice of using D.C. with its main fuses and knife switches on the switchboard, it was disconcerting to find it necessary to dispense with the only safety devices in the form of overload switch breakers by having to keep them lashed in position. This necessity became apparent on dropping a depth charge for exercise, soon after taking over the ship from the Americans. On the depth charge exploding, the main and auxiliary machinery stopped and the lights went out. Investigation showed that, due to the underwater explosion, the auxiliary switch-breaker had opened. It then became necessary to decide which was the most important, the fighting efficiency of the ship and its reliability in action, or the general safety of machinery. The former course was chosen. Both main and auxiliary switch-breakers were lashed in position. This operation became part of the lighting-up routine, as did the unlashing of them became part of the shutting down. He had often wondered just what would have happened had an electrical fault arisen, and would have felt much safer had there been a nice fuse in each phase lead. Perhaps the author could enlighten them as to whether there was any objection to such fuses being fitted. It seemed so easy that one felt there must be some fundamental reason against the incorporation of fuses in the main and auxiliary circuits.

He suggested that they must not lose sight of the fact that the object of a merchant ship was to transport the winches from *A* to *B*. It would appear, therefore, that the first requirement would be a good reliable A.C. winch, after which the use of A.C. for the other auxiliaries could be considered.

One of the greatest advantages of A.C. current on board ship would be the ease with which shore current could be connected to the ship in most countries. One visualized the day when a ship would arrive at a home port and shore electrical current would be connected up at "Finished with Engines". This would allow the whole of the plant to be shut down. He pointed out how much this would facilitate maintenance work, and how the perspiration of junior engineers would then become unnecessary to such maintenance.

On the proposal of **Mr. A. F. C. Timpson, M.B.E.** (Member of Council) a hearty vote of thanks to the author was accorded with acclamation.

BY CORRESPONDENCE.

Mr. J. H. R. Paston-Green: Regarding synchronization of incoming alternators, the method of using bright or dark lamps was mentioned and the consequent risk involved when engineers changed ships, should these two systems be used indiscriminately. The writer would suggest that the method was very old-fashioned, and that correct synchronizing would be assured by the use of modern instruments—such as the synchroscope.

The author referred to the regulating transformers or induction regulators fitted on the *Wuppertal*. Since the supply for the auxiliaries was on some occasions taken from the main propulsion alternators, the writer would like to know whether the transformers or induction regulators were relied upon to correct variation of auxiliary voltage when the propeller load was changing continuously—as for instance in heavy seas—particularly as the voltage variation of ±5 per cent. quoted was considered as being rather large and likely to produce a perceptible variation of illumination and also appreciably reduce the life of the lamps. Any details of type of regulating tranformers used in this connection would be appreciated.

No mention is made of the transformer cooling. Could the author give any information on the use of oil-immersed transformers aboard ship and, if so, what view the classification societies took of them; had he any information relative to the use of Pyranol as a cooling medium. The writer understood that Pyranol had been used in America, its chief advantage being the elimination of fire risk, but as it was a solvent of practically all insulating material and particularly varnishes in customary use, special insulating media had to be employed.

As several speakers drew attention to the absence of any preference for or against the use of A.C. on board ship, the writer would express his opinion that marine use of A.C. would become general sooner or later, and that it would be generated by separate and individually-driven alternators capable of meeting the full electrical load excluding propulsion; in cases of electrically-propelled ships, it was suggested that provision was likely to be made for deriving auxiliary supply from the main propulsion circuit by means of transformers, but such an arrangement was to be regarded as essentially an emergency measure. The practice quoted of deriving the bulk of the auxiliary supply from the main propulsion circuit, with only a small emergency capacity available from auxiliary alternators, did not appear to be sound. It was considered that deck machinery, in particular winches, was likely to be driven by direct current from motor generator sets until such time as more development had been done and experience obtained with variable-speed A.C. commutator motors and control gear.

Mr. S. B. Jackson (Member) considered the author had performed valuable service in re-opening discussion on A.C. versus D.C. The question was not merely confined to auxiliaries, but to all forms of electrical machinery.

As A.C. generation possessed advantage over D.C. practice, more particularly as static or electronic rectification was now standard to supply all D.C. services, this would tend undoubtedly towards the gradual employment of A.C. generation with consequent economy of the electrical installation. In addition, the elimination of commutation problems, a much greater reliability of A.C. equipment, its appreciably lower maintenance cost, reduction of osmotic effects, improved intrinsic protection of circuits, inherent silence from radio aspects and greater flexibility of design of the electrical layout were factors in favour of A.C. on board ship.

Referring to Table 1, he found difficulty in appreciating the limitation of lighting to 150 volts, but this was not the fault of the author but of the classification societies. The annual cost of transformation could be easily equated against the cost of the increase (if any) of lamp renewals of the higher voltages as compared with 150 volts, but the claims of standardization seemed to be fundamental. It would be found in the long run that higher voltage was to be preferred despite all arguments to the contrary. There could be little justification for a multiplicity of voltages within the confines of a ship. In this respect he would draw attention to the fact that land single-phase voltages had been standardized at 240 and the sooner the marine industry conformed to standard land conditions the sooner would it reap its benefits.

The choice of 3,500 volts for propulsion was singularly unfortunate. It did not represent anything approaching any standard of this country. It involved excessive caution which was not justified by the facts of electrical progress. Experience indicated that standardization at 11,000 volts was quite possible. There were sufficient reasons for this. In his view there was too slavish an opinion that voltages in marine service should be different from those on land. We must follow land practice if the fullest technical economic benefits were to be obtained.

Commander Turnbull referred to "the true variable-speed A.C. motor", but compared with the electric coupling⁽¹⁾ which was being developed by his firm plus its driving motor for a given range of speed variation, the particular motor was much higher in price, weight per h.p. greater, the circuit was more complex, and it required a commutator. While the commutator was retained, the advantages of A.C. were largely lost. For winches the type concerned had considerable advantages, but for fans, pumps, air-conditioning and certain other applications, the electric coupling *ideally* matched those of the driven device.

The electric coupling consisted of two members, an outer or driving member on the driving shaft and an inner member on the driven shaft. The outer member was mounted on the shaft extension of the motor and the inner member had a shaft extension connecting to the variable-speed machine. The outer half consisted of a mild-steel ring shrouded, carried by a side plate from a hub keyed to the driving shaft. This half had cooling slots in its periphery, the inner surface being a smooth cylinder, the shrouds directing a cooling air flow through the slots to dissipate the heat generated by the eddy currents in the rim. The outer half was on the driven side so that the maximum ventilation was always obtained.

The inner half comprised a steel rim of special magnetic characteristics in the periphery of which slots were machined forming a large number of poles, carried on a side plate and hub supported on a shaft bearing. Pedestal bearings might be employed according to the load and dimensions of the coupling, the latter being fixed by the speed. The stub shaft carried a self-aligning bearing supporting the driving half. The inner half included a circumferential glass-insulated exciting coil in a recess which excited the magnetic circuit on the homopolar principle. The coil was able to withstand high temperatures without detriment. The excitation was D.C. As the driving half rotated, the reluctance of the magnetic circuit in any section of the core was varied and high-frequency eddy currents were produced. The flux changes induced eddy currents in the core which reacted to produce a torque in the driven half. These currents were generated by virtue of the field coil flux which traversed the sections of the members.

Due to the rotor slots the flux density in the gaps between the members was a maximum over a rotor tooth, and a minimum over a rotor slot. Relative movement of the two members caused a variable amplitude flux density wave to act upon the outer member as though the inner member were constructed with salient poles, the numbers of such excited poles being equal to twice the number of slots in the inner member. The cutting of the flux by the solid material in the outer member induced currents into its core which reacted to produce a torque in the inner member. The torque was a function of slip and the excitation. For a particular exciting current the torque speed curves resembled those of an induction motor having comparatively high resistance in the rotor circuit. The greater the difference in speed between the two members for a specific excitation the greater the torque exerted. The torque was proportional to the flux amplitude, and it followed that it was proportional to the excitation. As the excitation was increased the driving unit ran up to the speed determined by the load torque. With maximum excitation, full-load torque was developed with about 3·0 per cent. slip only. The excitation was about 0·3 per cent. of the power transmitted for the large sizes and about 0·5 per cent. for small capacities.

The efficiency was dependent upon the speed, being highest at maximum excitation and minimum slip. For the large sizes the efficiency was 97 per cent. and this fell to 95 per cent. for small powers. The maximum loss was 16·5 per cent of the rated input power, this occuring at approximately 66·7 per cent. speed or 48·5 per cent. maximum power. The units were most suitable for drives where the power varied with the cube of the speed and special attention to application for fans and centrifugal pumps was drawn in this connection. The minimum slip could be reduced and the efficiency increased in favourable conditions or if an oversize coupling could be employed. For forced-draught fans the losses could be absorbed in such a manner as slightly to preheat the air supply. The slip-torque relations indicated that the maximum torque and the starting torque were dependent upon the value of the excitation. Smooth and gradual increase of excitation brought the machine to the speed of minimum slip and any intermediate speed value could be obtained. Acceleration was dependent only on the inertia of the load and in decreasing speed the limiting factor was the momentum of

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(1) "Shipbuilding and Shipping Record" *Vol. LXV, No. 6, Feb. 8, 1945, p. 133*. "Marine Boiler Draught" by S. B. Jackson, (Abstracted Trans. I.Mar.E., *Vol. LVII, No. 3, April, 1945, p. 17*. If members refer to the original article more complete information will be found.

the rotating member and the rotor of the squirrel-cage motor. Means for limiting the transmitted torque could be designed for any conditions.

The coupling had only two working parts, was entirely self-contained; no fluid was required. Speed change was extremely flexible and obtained without shock or stress. Disconnection of the motor from the load could be instantaneous, this facility lending itself to a variety of protective arrangements depending upon the nature of the protection required. The motor could be started against no load. Owing to the low value of excitation required, automatic electronic control was possible. It was simple to provide remote control any convenient distance from the controlled units, and the control panels of several couplings could be arranged together at one place. The control could include any type of visual speed, load or other control indications.

Electronic control by the use of Thyratrons secured maximum flexibility as Thyratrons not only acted as rectifiers of the A.C. supply, but permitted infinitely variable control of the mean energy of the excitation from zero to maximum, combining in one unit the rectification and control functions. Thyratron control was very efficient, frictionless, inertialess, introduced no error and its instantaneous response permitted high operational rapidity. Heat losses were not dissipated as with rheostats. In conjunction with oil-burning equipment, suitable control could also be provided to permit adjustment of the correct fuel-air ratio, thus securing the highest operational economy. Further oil or flame failure devices were easily applicable.

He held the view that the electric coupling had a future in marine service and it would provide in a neater, more elegant form most of the speed control functions required for marine work.

G. M. Sellar (Member): In Tables 1 and 2 the author detailed the requirements of the various classification societies in respect of voltage permitted for A.C. installations, but refrained from commenting on the limitations thereby imposed on makers of electrical plant. It would be of interest to learn his views on this question and whether these requirements were found to be restrictive on the design and arrangements of A.C. equipment for shipboard use. British plant in general was more conservatively rated than American, but the latter so far as could be judged from surveys of ships classed with the American Bureau of Shipping was satisfactory in service.

Regarding the use on tankers of A.C. supply for lighting and heating, the British Corporation Register would give favourable consideration to sound proposals for such installations, but would recommend the adoption of a lower voltage for general lighting than that used in cargo ships.

It was not clear why the frequency of supply of 60 cycles, as stated in the paper, was the standard favoured for auxiliary A.C. equipment. As 50 cycles was the British Standard for land service, presumably the greatest manufacturing advantages would result if this were also adopted for marine service.

When describing the types and characteristics of motors available for use in A.C. installations, it would not be out of place in a paper for marine engineers who were not generally familiar with A.C. equipment, to enlarge on the superlative robustness and simplicity of the squirrel-cage motor. Notwithstanding its limitations of constant speed and low starting torque, it could almost be said that the squirrel-cage motor was the principal reason for considering A.C. supply for shipboard auxiliary services.

While A.C. motors and starters presented economies in weight and cost over their D.C. equivalents, it should be emphasized that individual A.C. motors should have ratings closely allied to their maximum continuous duties and that over-sized motors should not be fitted except in special circumstances; otherwise starting currents, which might be four to six times those at normal full load, would have adverse effects on the characteristics of the installation or entail the fitting of generating plant which was over-powered and uneconomic. Individual motor efficiencies and power factor would also suffer at loads below designed full load.

Details of voltage regulators for the alternators which would maintain the system voltage within, say $\pm 2\frac{1}{2}$ per cent. of normal could usefully be added to the paper.

Regarding the existing installations described which took a supply through transformers from high voltage propulsion units, it would appear that the frequency range of the order of 36 to 50 cycles thereby applicable to the auxiliary circuits was undesirably wide. In such cases it would be necessary for an auxiliary alternator to be kept idling and ready for transference at short notice in the event of any emergency speed reduction or reversal being demanded from the propulsion unit.

A.C. commutator motors were not mentioned in the paper. While these had the disadvantages accompanying commutators, they had the advantage of providing excellent speed variation and control which was what was wanted for auxiliaries such as forced-draught fans and refrigerating compressors.

While the advantages of using A.C. supply in the engine room were many, it would appear probable that D.C. supply would be retained in cargo ships until such time as reliable A.C. winches were developed.

W. S. Steel (Associate Member): The author's paper came at an opportune time when shipowners were faced with high costs for their new tonnage replacing war-time losses, and any means which held out prospects of lower operating expenses warranted careful study. Also it was likely that in many cases the capital cost of a ship with A.C. auxiliaries would be less than one with D.C., but a different approach to the whole question of generation, distribution, and individual method of auxiliary drive might be necessary to achieve lower first cost. The author made some reference to this last point under "Refrigeration Installations" and cited the special arrangements on certain Diesel-electrically propelled vessels with mainly A.C. auxiliaries. But perhaps undue emphasis had been placed on taking auxiliary power from the main engines which was, of course, only feasible on ships with electrical propelling machinery.

It was felt that it should be possible to make a good case for A.C. auxiliaries whatever the main propulsion method on certain classes of ships. For instance, on a large passenger liner where there was a substantial hotel load in addition to accommodation ventilation and possible air conditioning, or a large refrigerated vessel where reduced maintenance and losses were particularly attractive. The use of fluorescent lighting with A.C. should reduce fire risks and ease the task of the naval architect by providing relatively "cold light" in accommodation spaces.

Shipowners might be disappointed that more was not said about deck machinery drives on a ship with A.C. auxiliaries in this paper. Having regard to the time lost in loading and discharging cargo, anything which slowed up these operations would not find favour with those whose living depended on efficient ship operation. It must be admitted that no entirely satisfactory solution of the problem of driving cargo winches with A.C. motors was in sight. On the other hand D.C. winch equipments had reached a high degree of development, and unless an entirely new technique of loading cargo could be developed it was difficult to see how the D.C. winch could be improved upon if A.C. auxiliary power was justified for other purposes.

For small amounts of cargo-handling equipment A.C./D.C. converters for each winch or group of winches might be satisfactory, but for more comprehensive installations separate A.C. and D.C. distribution systems represented a better arrangement. The most efficient method was to employ tandem A.C and D.C. generators driven by the auxiliary prime movers, and the D.C. generators could, with considerable advantage, be made to feed a constant current ring main, including the winches and anchor windlass, as was done on the cable-layer H.M.T.S. *Monarch*. Thus every "constant current" winch would have the best type of performance normally associated with a Ward-Leonard set, or a converter for each individual winch motor which was necessary even on a vessel with D.C. auxiliaries throughout. The capital cost and efficiency of this arrangement should be appreciably better, and if more than one constant current generator was installed the reliability was superior also.

A secondary advantage of having A.C. generators arranged to run in parallel was the ability to have one of them driven by "back-pressure" auxiliary turbine where high initial steam conditions existed and a supply of low-pressure steam was required for heating, cooking or evaporation purposes. The alternator so driven was allowed to float on the A.C. busbars delivering electrical power in proportion to the demand for low-pressure steam. Instead of the usual speed governor the back-pressure turbine was provided with a pressure governor arranged to regulate the admission of high-pressure steam to keep the low-pressure steam system within predetermined pressure limits. This resulted in electrical power being generated with a very low nett heat consumption rate per kilowatt and, moreover, the alternator when running light when there was very little demand for low-pressure steam served to correct the power-factor of other parallel-connected alternators carrying the bulk of the electrical load.

In conclusion one was struck by the range of A.C. frequencies quoted in the paper. No doubt existing installations had good justification for adopting non-standard frequencies, but it was to be hoped that auxiliary A.C. systems in future British ships would use the standard frequency of 50 cycles adopted for land installations over the greater part of the world.

The Author's Reply to the Discussion.

The author, in reply to Mr. Watson, stated that it was interesting to note the comparison of this paper and that read before the American Society of Naval Architects and Marine Engineers and also the conclusion that the author had not made it clear whether or not he was in favour of A.C. It must, then, be assumed that the facts had been presented fairly and it was left to the individual to decide if A.C. were suitable for the particular case under review. It would generally be conceded that A.C. had many advantages for some ships, whereas for others D.C. would still be preferred. It was hoped that the paper, together with the discussion and reply, would make a complete story and present the facts in an impartial way.

The relative costs and weights of A.C. and D.C. motors were shown in Figs. 22 and 23, which indicated that A.C. slip-ring and squirrel-cage motors were cheaper and lighter than D.C. motors of similar speed and temperature rise. Commutator motors were a good deal more expensive.

The relative maintenance costs could only be obtained by actual comparison of ships, one with A.C. and the other with D.C. motor-driven auxiliaries, running under similar voyage conditions. A good deal of trouble had been experienced with commutators in some ships, and it would be expected that A.C. motors would generally give better service than D.C. motors under engine-room conditions. Most A.C. motors would be fitted with roller or ball bearings. Whereas many preferred journal bearings in horizontal motors, ball bearings were accepted more readily now than previously.

The point made regarding the freedom from electric shock on board ship was important, but the earlier ships fitted with electric lighting and power used 65 to 110 volts and it was only fairly recently that 220 volts was adopted for lighting. Special low-voltage circuits which could be cheaply arranged for inspection lamps and special tools in the engine rooms would prevent electric shocks to a great extent.

The point on the auxiliary generators required for the refrigerating load was generally fully appreciated, but if the load could be carried by the main engines for most of the time at sea, it did give the engineers a more reasonable chance to keep the auxiliary engines in a good state of repair. This had been found to be more and more difficult as the time spent in port and particularly in one port was reduced. It was the auxiliary engines which suffered first, when the time available for overhauls was limited.

It was interesting to note from Commander Turnbull's remarks that the Admiralty were building two destroyers and fitting them with A.C.-driven auxiliaries. It was hoped that the information obtained from the performance of these vessels would enable the Admiralty, and of course the manufacturers of the auxiliaries, motors and control gear, to decide if A.C. gave a performance equal to, or better than, D.C.-driven auxiliaries, but some considerable time must elapse before this information could be obtained.

The comments on illustrations obviously not intended for marine use, but merely to show the general method of construction, brought to the fore the special marine requirements of making the motors, alternators and control gear drip-proof or watertight. This would, no doubt, prove useful.

The statement regarding the use of D.C. motors was misinterpreted. All systems had their troubles and those particularly associated with D.C. systems were enumerated. The concensus of opinion was that D.C. motors and equipment were satisfactory, but this was no reason why the possibilities of an alternative system should not be put forward. A sound conclusion could not be formed if the issue were clouded by condemning the D.C. system.

It was generally agreed that first cost of all merchant ship machinery was of importance next to reliability, but it was not regarded so seriously to-day as in more normal times. It was also sometimes partially disregarded, as in the Royal Navy, if greater efficiency was obtained for the extra capital expenditure.

It was scarcely true to say that much of the mechanical gear on merchant ships had not been redesigned since it was originally introduced for steam. The vertical centrifugal pumps, high-speed multi-cylinder air compressors and refrigerators had in general been redesigned to suit the electric-motor drive. Winches and electro-hydraulic gears likewise bore little similarity to the original steam-driven types.

There was no doubt that many of the auxiliaries worked satisfactorily at constant speed, as was generally necessary on land power stations using A.C.

A.C. motors had smaller air gaps than D.C. motors of similar power and r.p.m., and in general this led to ball or roller bearings being used instead of journal bearings. Short stiff shafts would also help.

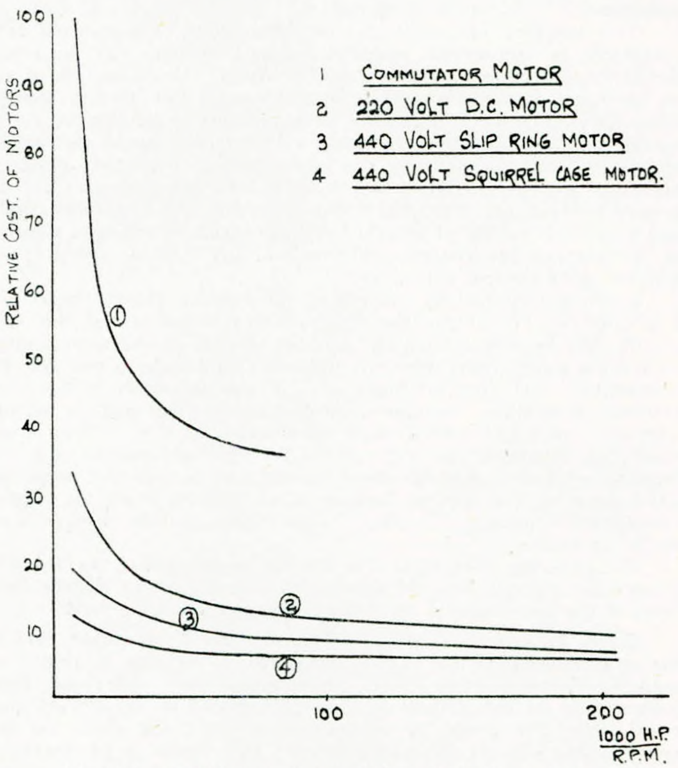

FIG. 22.—*Relative costs of A.C. and D.C. motors.*

Commutator motors were not mentioned, principally because of the high cost as shown in Fig. 22. Some designs had been developed which eliminated all or most of the brush and commutator trouble, and these could, no doubt, be used in special circumstances, where a

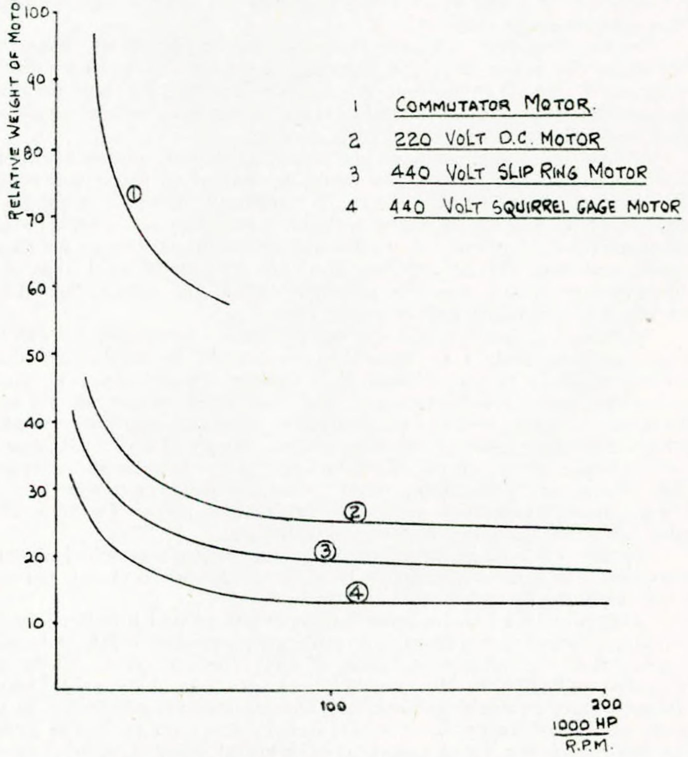

FIG. 23.—*Relative weights of A.C. and D.C. motors.*

large speed variation was required. They were, however, heavier and took up more space.

The size of exciters for electric propulsion machinery if they had to deal also with deck machinery, was an interesting point. This system had been used in some ships satisfactorily, but it would be expected that the standby machines would be used to supply power for the winches, etc. at sea, if these were required.

In reply to Mr. Savage, it was agreed that in many cases the A.C. commutator motors would give the variable-speed characteristics required, but Fig. 22 illustrating the relative costs of such motors, together with the statement that the introduction of A.C. auxiliary drives was more of an economic than technical matter, explained to a certain extent why this type of motor was not mentioned in the paper.

The supply of A.C. power for deck machinery would be difficult until A.C. motors suitable for use on deck had been developed and tried out. Ward Leonard control of winches and windlasses, which could be adopted for A.C., made for better but more costly machines. The approximate relative costs of the different types of winches were :—

D.C. contactor controlled	100%
D.C. booster controlled	130%
A.C./D.C. Ward Leonard controlled :—	
(*a*) motor generators below deck or in deck house	150%
(*b*) Self-contained Ward Leonard controlled	170%

An A.C. winch was being developed in this country for ship use and should make for the more easy adoption of A.C. generally. It was understood that the cost of such winches would probably be somewhat less than the Ward Leonard controlled winch, but this would depend upon the demand for such winches compared with the demand for D.C. winches.

The scheme suggested of coupling a D.C. generator to the port use alternators to supply the power to the deck auxiliaries would probably be the simplest and cheapest solution at the present time, as it would permit the normal contactor-controlled type of D.C. winch to be used.

In reply to Admiral Parnall, it was generally felt that, if A.C. was to be successfully applied, then the squirrel-cage motor should be used for as many drives as possible, because of its robust construction and relative low cost. Other motors, of which the N.S. motor was one, were being developed, which would give a speed variation as great as could be obtained with a D.C. motor and series control. Such motors were expensive as already shown, were more complicated and would therefore be used for special duties only.

It had been suggested in America that the mercury-arc rectifier should be used for supplying D.C. to normal type winches.

As explained previously, the chief advantage in the Merchant Navy of using the main engines to supply the auxiliary power requirements at sea was that the auxiliary engines could then be overhauled during the voyage, and again it might be possible to reduce the number of auxiliary generators/alternators fitted in the ship. This might not be so apparent in the Royal Navy as in the Merchant Navy, where there had been a tendency in some ships to economise in auxiliary machinery, with the result that the auxiliary generators were overloaded and ran for long periods without overhaul.

The author agreed with Mr. MacVicar that forced- and induced-draught fans could be run at constant speed if provided with adjustable inlet vanes as in land practice, but it was felt that the standard type of fans would be preferred, since variable-speed fans were more efficient than constant-speed fans with damper or vane control. This could be arranged if the drive was from a slip-ring motor or a squirrel-cage motor and an electro-magnetic coupling.

Generally, a vessel proceeded at full speed when fully loaded with a refrigerated cargo, but there were sure to be exceptions. In such case, the power supply would need to be taken from the auxiliary alternator supply for so long as the full output of the compressors was required, which varied from three to seven days depending upon the nature of the cargo and its condition when loaded.

It was agreed that there was no need to adopt a frequency of 100 cycles for refrigerator cargo hold fans provided the fan speed suited both the frequency and the fan design.

For example, in the case of a large refrigerated ship such as the *Hornby Grange*, in which the frequency was 100 cycles, motors were fitted to give the following speeds :—

	High.	*Low.*
Small fans	2,930 r.p.m.	1,950 r.p.m.
Large fans	1,950 r.p.m.	1,450 r.p.m.

The corresponding speeds for a frequency of 50 cycles would have been 1,450 and 950 for all sizes, which would have necessitated much larger fans. Whether or not the separate circuit with the higher frequency was justified, depended on the relative cost.

It was agreed with Mr. Holyoake that some oversize auxiliaries were required if the power was taken from the main propulsion system. This worked satisfactorily on the two Diesel-electric propelled vessels *Wuppertal* and *Patria*, and it was assumed that the extra cost of the larger pumps, etc. was more than compensated for by the omission of separate auxiliary engines for use at sea.

The lighting and heating circuits were taken directly from the propulsion mains in both vessels, and the chief engineer of the *Wuppertal* reported that the system worked satisfactorily under all weather conditions. This vessel was laid up in the tropics for a considerable time during the war, with only a watchman on board; engineers and electricians were sent from Holland and had the machinery working in one week, which confirmed the robustness of A.C. motors and switchgear.

Magnetic slip couplings could be used for coupling induction motors to fans to give speed variation fairly efficiently; forced- and induced-draught fans which required a wide range of speed control could conveniently be driven this way.

Hydraulic couplings, similarly, could be used for auxiliaries if required, but the introduction of any type of coupling necessarily increased the cost of the complete unit. It was for this reason that constant-speed or, if necessary, two-speed induction motors should be used whenever possible.

In reply to Mr. Welsh, it was better if possible to use only the single-speed induction motor, as this was the cheapest and most reliable type. Generally, two-speed motors were most suitable for ventilating and circulating fans when speeds fairly well apart were required. It was appreciated that the Americans were developing A.C. winches with multi-speed squirrel-cage motors whereas, it was understood, the A.C. winch being developed in this country utilized a commutator motor. It would be interesting to compare the performance of these two types when the particulars were released.

It was understood that there were no difficulties in the way of synchronizing normally, with the use of a synchronoscope of some description. The method described would necessitate the alternator being pulled into synchronism, with a surge on the mains.

During the war years, when the ventilation in many ships was restricted due to black-out regulations, oily vapour, carbon, dirt, and general engine room dirt were drawn into the motors, etc., sometimes to such an extent that the ventilating spaces of the machines were greatly restricted, with the result that the motors gave trouble. The bulk of the deposits was such that it could not be carbon dust only. It was as well to make this point clear, as A.C. motors were also liable to overheating if the ventilating ducts were choked.

One of the advantages of A.C. motors, alternators, etc., was that there were no commutator risers which had given trouble in D.C. generators under similar circumstances, due to the deposition of carbon dust and oil on them causing shorts.

Mr. Meadows was thanked for his interesting contribution. It was understood that overload breakers and contactors for naval ships had been redesigned and could now withstand a shock of 1,000g. without coming out. The difficulty with fuses was the time taken to replace them when an electrical fault occurred.

The point made about the winches was a very real one. A cargo ship was in effect a large warehouse used to transport cargo from *A* to *B*, and the cargo-handling gear was a very important part. It was useless to fit more powerful propulsion machinery to speed the ship from *A* to *B*, if more time would be spent at *A* and *B* loading and discharging the cargo. In many instances, stevedores insisted that the steam winch handled cargo more quickly and efficiently than D.C. electric winches; it would therefore be useless proposing an A.C. winch less efficient than the existing type of D.C. winches.

The author agreed generally with Mr. Paston-Green and particularly that it would be advantageous to arrange for similar types of synchronizing and control gear to be fitted in ships with A.C. auxiliaries. Mr. G. O. Watson of Lloyd's Register of Shipping had stated that a sub-committee of the Institution of Electrical Engineers had recently been considering the amplification of rules relating to A.C., and that fundamental matters such as voltage, and method of synchronizing would probably be subject to a certain degree of standardization.

It was generally felt that it would be better to use air-cooled rather than oil-cooled transformers on board ship. Pyranol had been used both in America and in this country during the war for small step-up transformers for marine use. The advantage was the elimination of fire risk. The difficulty of the solvent action on insulating material and varnishes was overcome by the use of special material as stated. A further difficulty was in handling, as it was liable to cause dermatitis. It was understood that Pyranol was not obtainable in this country at the present time, and it was not favoured.

It was confirmed that the regulating transformers or induction regulators in the *Wuppertal* and *Patria* were relied upon to supply a reasonably constant voltage during rough weather.

In reply to Mr. Sellar, tables 1 and 2 were given to illustrate that A.C. was given as favourable consideration for auxiliary purposes as D.C. by the classification societies. No comment was really necessary, as designers and probably shipowners would not wish to go beyond 440 volts for auxiliary power at the present time, except for special units, which no doubt, would be given consideration.

It had been felt by some that 220 volts D.C. was too high for lighting on board ship, but it was generally adopted to save the complication of the three-wire system of distribution, or the use of special circuits with motor generator sets. It was therefore probable that 110 volts A.C. would be accepted by many shipowners without comment, as it could be more readily obtained.

The squirrel-cage motor was the real advantage of A.C. systems, and unless full use was made of these machines in every possible auxiliary then A.C. was not so attractive.

It would appear that the range of frequency 50/36 cycles used in *Wuppertal* and determined by the speed range required of the ship must have been the extreme limit, as the next Diesel-electric vessel *Patria* for the same owners was arranged for a frequency range of 50/42 cycles. In both vessels, one of the main Diesel alternators was transferred from the main busbars to the auxiliary busbars in the event of an emergency speed reduction of the vessel.

The high cost, weight, size and complication of A.C. commutator motors at the present time, was such that it would not be economical to use them except for special duties. The suggestion to use them for refrigerating compressors was interesting, but these were not found necessary on land installations where the variation of output was obtained in the compressors themselves, or by the use of a number of compressors.

Forced- and induced-draught fans, in which the h.p. varied approximately as the R.P.M.^{3} could conveniently be driven by slip-ring motors with a limit of 15 per cent. loss of input energy at 65 per cent. of speed, and most of this loss occurred in the rotor resistance. Similar efficiencies were given by a squirrel-cage motor and electro-magnetic coupling.

To be really satisfactory, it would be necessary to adopt a standard frequency for all marine work. Some work was at present in hand for which a frequency of 60 cycles was adopted, but if the speeds available with 50 cycles were suitable for all the machinery, there was no reason why the Merchant Marine should depart from it.

The author agreed with Mr. Jackson that the electro-magnetic slip coupling, together with a squirrel-cage induction motor, made quite a suitable drive for fans, centrifugal pumps, etc., where the load varied approximately as the R.P.M.^{3}, or the coupling was used for heavy starting torque conditions only as a clutch. The disadvantage, of course, was the extra cost of the slip couplings. If the pumps could be arranged to work at constant speed for all outputs, it would generally make for a better arrangement.

The couplings were very suitable for forced- and induced-draught fans where a large speed regulation was required, and it was probable that the total cost of an induction motor and slip coupling would not be much greater than a D.C. motor with shunt and series speed control. A less expensive drive, which might take up more space, was a slip-ring motor with rotor speed control, as mentioned in the paper.

In reply to Mr. Steel, the general adoption of A.C. for ships' auxiliaries was bound up to a very great extent with the solution of the deck machinery problems. The change-over from the cheap steam winches to the relatively expensive D.C. winches was accepted readily by the shipowner, because of the saving in fuel. Unfortunately, there was no such saving in the change from D.C. to A.C. winches, although as shown in the reply to Mr. Savage, the increased cost of the latter was very appreciable. This extra cost would have to be borne by the saving on the remainder of the installation, or alternatively offset by the advantages gained from the A.C. system in general.

If A.C. was to be adopted to any extent for marine work, it would be advisable to decide, as soon as possible, on a standard voltage and frequency; this was being considered by the Institution of Electrical Engineers.

Hydrogen Peroxide for Propulsive Power*

Production and Use by the Germans During World War II.

By Capt. LOGAN MCKEE, U.S.N.

The use of hydrogen peroxide for propulsion purposes has been referred to from time to time in the public press. Certain details of the applications have of necessity been restricted, and similar restrictions still apply to some phases of the subject. However, there are features of the use of this material for power production, particularly by the Germans during the last war for V-bombs and for propelling airplanes and submarines, which are not restricted, and which it is felt would be of engineering interest.

Chemistry Involved.

The formula for hydrogen peroxide is H_2O_2, and the material we will deal with is further defined by giving the per cent. concentration, i.e., it is normally manufactured at about 27 per cent. concentration. If a higher concentration is required, it is distilled under low absolute pressure, starting at about 50 mm. Hg. and decreasing the pressure to about 30 mm. as the concentration is increased to 85 per cent. When used as a disinfectant the concentration is about 3 per cent., the remaining 97 per cent. being water.

The Germans used a concentration of 80 to 85 per cent. for 26 different war weapons and had it in an experimental stage for 40-odd others. They gave it a cover name of "Ingolin". Professor Walter, who was the foremost proponent of its use in Germany, named it after his eldest son, Ingol. It is also known there as "T-stoff".

It was sometimes used as a monofuel or primary fuel, i.e., using only the heat of dissociation of the H_2O_2 into H_2O plus O_2. The heat of dissociation for 80 per cent. concentration is roughly 1,000 B.T.U. per lb. The mixture, in that case, would be 80 per cent. H_2O vapour (superheated steam) and 20 per cent. O_2 by volume (63 per cent. H_2O and 37 per cent. O_2 by weight), and the mixture would be at 500 C. (932 F.), assuming that the liquid was supplied at 70 F. It was, however, used more often as a secondary fuel, i.e., all or nearly all of the free oxygen was further burned with a fuel, such as decalene (which is similar to Diesel oil) or methyl alcohol. The reaction would, in some applications, take place all in one step by the use of a liquid catalyst and fuel combined. The Germans named the liquid catalyst and fuel mixture they used "Helmann" after Walter's second son. Their mixture was hydrazine hydrate and methyl alcohol. The reasons for using the material as a secondary fuel are to take advantage of the larger heat release per pound of mixture and also because the dollars and cents cost per B.T.U. obtained from fuel is much less for that than from H_2O_2.

It will be noted from the foregoing that the heat of dissociation of H_2O_2 per pound is about 1/19 of that of the heat of combustion of a pound of oil. The value of H_2O_2 is therefore its ability to furnish free O_2 when and where you want it. It has advantages over liquid or gaseous oxygen in that it is more easily contained and it produces a lower flame temperature.

Production of H_2O_2 in the United States.

Prior to and during this war, H_2O_2 in this country was not concentrated for commercial or military purposes at greater than 50 per cent., although some laboratory tests had taken it higher. The reason it had not been taken to higher concentrations is that, unless certain rules are known and carefully observed, it is violently unstable and, naturally, the danger increases with the concentration. It follows that the Germans were far more advanced in the subject than any other country. We have been interested in it in this country for years, but did not reach the point of taking advantage of its characteristics in the higher concentrations. We now can and do concentrate it commercially to a higher percentage than the Germans ever did and to a greater degree of purity. For example, the Buffalo Electro-Chemical Company will supply it at 90 per cent. concentration with only 5 parts per million impurities. Du Pont can do about the same. The Germans usually had much greater amounts of impurities, some of them not very harmful.

The foregoing will give an idea of the order of the concentrations used.

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Characteristics of Hydrogen Peroxide.

In the concentration used by the Germans, the specific gravity is 1·37 at 32 F. It is colourless or slightly yellow and has a distinctive, but not unpleasant, odour. The 100 per cent. concentration freezes at 20 F., and boils at 306 F. at atmospheric pressure, and its specific gravity at 32 F. is 1·46 plus. A peculiar thing is that 80 per cent. H_2O_2 freezes at 11 F. and, of course, 1 per cent. at just under 32 F.; 60 per cent. solution freezes at —70 F. The boiling point at atmospheric pressure has to be obtained by extrapolation as the material detonates before reaching the boiling point. Concentration is determined usually by taking its specific gravity, although titration gives a more accurate check. Impurity in the form of sulphuric acid throws off the determination of concentration by observations of the specific gravity and this gave the Germans so much trouble that they learned to eliminate the H_2SO_4.

After a stabilizer (or stabilizers) is added, (the Germans used oxyquinoline or phosphoric acid) it can be left in an open container without too rapid a loss in concentration. Concentration drops off rapidly at first and becomes progressively slower as time goes on, provided no unusual conditions are encountered, and provided further that the heat of decomposition is allowed to dissipate. The drop during the first month in storage is about equal to the drop to be expected for the remainder of the year. It is roughly 1½ per cent. the first month and 3 per cent. the first year and very little thereafter, but may be much less.

Provided one's hands are clean, they can be put into a high concentration of H_2O_2 without any immediate sensation except a slight prickling. In less than one hour, however, the hands will look as though whitewash had dried on them. When that coating wears off, the skin will be bleached white. All except a few materials act as catalysts for H_2O_2 so if there is dirt under the fingernails or on the hands, a burn will result. The antidote is water, and the way it acts is to reduce the concentration quickly.

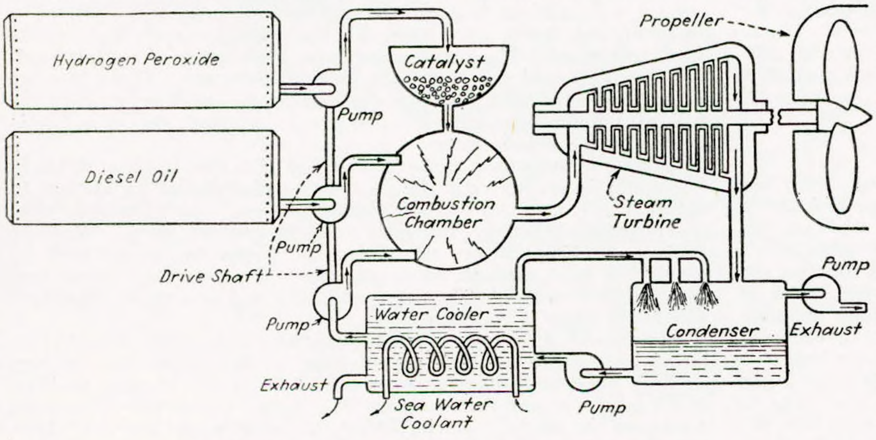

FIG. 1 DIAGRAM OF COMPLETE-CYCLE ENGINE USING HYDROGEN PEROXIDE

With regard to materials used for handling and storage, iron and copper must be carefully avoided as they are catalysts. Stainless steel, 99·6 per cent. pure aluminium, glass, ceramics, and certain synthetics can be used; the most widely used synthetic in Germany being polyvinyl chloride, which looks like rubber in its usual form, although it is also available as a cloth. It is used as a packing material for valve stems and for gaskets but it has one serious deficiency in that it shrinks and hardens with age. It is therefore difficult to keep the systems tight when using it. It is understood that du Pont has a much superior synthetic for the purpose.

Precautions in Handling H_2O_2.

When the Germans first started handling and storing concentrated H_2O_2, they used many precautions which they later determined from experience to be unnecessary. The requirements which are essential are carefully observed. They have no more fear of handling it than they have for handling gasoline, for example.

In storage the first indication of instability of H_2O_2 is a rise in temperature. If something isn't done about it, the condition becomes progressively worse, finally reaching the danger point when the temperature registers 140 F. At that time, the H_2O_2 is dumped into water. In the early storages, there were cooling coils in the tanks and a sprinkling system above them, but experience showed that they were unnecessary. On noting a rise in temperature, more stabilizer is added.

By far the most fundamental rule in handling concentrated H_2O_2 is to have fresh water instantly available for diluting any spilled H_2O_2. Almost without exception, when concentrated H_2O_2 is spilled, a fire starts. All that is needed to put it out is to reduce the concentration below 78 per cent., provided, of course, that no large amounts of cumbustibles are in the area. The reason that the fire starts so readily is that there are usually some small amounts of combustibles present, such as grease, paint, wood, or cloth on which the H_2O_2 spills; the dirt on the combustible materials acts as a catalyst; heat of dissociation of the H_2O_2 raises the temperature of the combustibles to their ignition point, and the free O_2 is available to maintain the combustion. A little dilution of the H_2O_2 keeps the heat of dissociation below the auto-ignition temperature of the combustibles. The Germans kept water in the bilges of the engine rooms of their H_2O_2-driven submarines to reduce the concentration of any spilled H_2O_2.

The men who handle concentrated H_2O_2 wear scrupulously clean polyvinyl-chloride coveralls (which don't look much different from any other kind of coveralls), boots and gloves of the same material, except that the latter are in the form of synthetic rubber.

Laboratory demonstrations of the properties of concentrated H_2O_2 are quite impressive, two in particular. In the first, a clean piece of wood has one end submerged in an open container of H_2O_2. No reaction takes place when it is withdrawn. Another piece of similar wood is rolled on the floor and then dipped in the H_2O_2. It catches fire upon being withdrawn. The dirt it picks up from the floor contains materials which are catalytic. In the other demonstration, a small amount of liquid catalyst (hydrazine hydrate) is put in a large flat pan. Then the chemist stands off as far as possible and throws about 2oz. of H_2O_2 from a beaker into the pan. Only a small part of it actually gets in the pan, but what actually arrives reacts with a loud noise and eruption of sparks. In other words, the decomposition of H_2O_2 in the presence of a catalyst is very violent. In fact, it is a more powerful explosive than TNT, if properly combined with catalyst and fuel; that is, it contains more releasable energy per pound. The material mixes in all proportions with alcohol and with glycerine. It is many times more dangerous to have around than dynamite or TNT, as it is much more unstable.

Hydrogen-peroxide Manufacture.

The usual method of manufacturing H_2O_2 is the hydrolysis of persulphuric acid, but it can be manufactured by any one of several chemical methods. Quite a lot of electrical power and expensive facilities are required for the hydrolysis method so the product is expensive. The cost will come down considerably but it will probably remain high as compared to fuels or gaseous or liquid O_2. Towards the end of the war, Germany had a capacity for manufacturing about 3,000 tons a month which was not nearly the amount she wanted. It required the services of about 3,000 men to do the manufacturing. Their largest plant was well hidden in the Harz Mountains and was not located by our Intelligence until after the war.

The utmost care is used in the manufacture and cleaning of storage tanks. They are gas-welded and great pains are taken to leave no possibility of H_2O_2 seeping into crevices or under the edges where plates are lapped. Welding rods are carefully selected in order to obtain alloys free of copper. An oxidizing flux is used. After welding the interior of the tank is cleaned and polished, treated with 10 per cent. nitric acid, washed, painted (or filled) with 20 per cent. solution of caustic soda, washed, treated with 10 per cent. nitric-acid solution, washed, then the inside coated with wax.

The wax is composed of paraffin, beeswax, and a synthetic prepared by I.G. Farben. The principal purpose of the wax is to fill any small holes or crevices which may exist. The outside of the tank is heated to melt the wax being applied to the inside. The reason for taking such precautions to fill crevices is that several explosions were attributed to H_2O_2 becoming trapped between plates where they overlapped.

The shape of the tank is influenced by trying to get as small a surface-volume ratio as possible. After the tanks are ready, H_2O_2 is put in and carefully watched for 2 weeks. If undue decomposition is noted, the tank is emptied and the interior again treated. About 10 per cent. of the interior is left empty, as a gas space. All piping and valves used for transferring H_2O_2 must be completely flushed with fresh water after each use.

German Uses for Hydrogen Peroxide.

The Germans used H_2O_2 to launch V-1 bombs, to drive fuel pumps in the V-2 bombs, to drive torpedoes, ME163 and 262 airplanes, and submarines.

For the V-1 and V-2 bombs only the heat of dissociation was used. It was a rather expensive use of energy but was so positive in action that its simplicity and reliability were worth the cost.

Airplanes. The performance of the airplane was astounding. The thrust from the rocket engine corresponded to that of a 3,700-h.p. conventional-type engine, and it weighed about 250lb. It was not subject to the explosion danger to nearly the extent of the torpedo engine, although the same principle of H_2O_2 in combination with a catalyst and fuel was used. The working fluid was not put through a turbine in this case, however, so power was obtained entirely by jet action. It could be cut on and off instantly.

It was related to the author by a German that a woman made the first test flight in the plane. The fuel supply lasted only a very few minutes but thrust was so great that the plane could not be flown in level flight, with the engine on, for more than a few seconds. It very quickly approached the speed of sound. It could climb to 30,000ft. in 2 min., which made it extremely valuable as an intercepter plane. The first planes, the ones which saw war service, had only a main jet so the engine was either full-out or dead. A later design incorporated a cruising jet, in addition to the main, which increased the time that the engine could be kept on about twentyfold. Its rate of climb and speed in level flight, under cruising jet conditions, were not much better than that of an orthodox gasoline-engined fighter plane, and its radius of action much less; but, until the fuel was exhausted, it had a tremendous reserve of power.

Torpedo Drive. The torpedo drive was somewhat similar to the submarine drive. In the former, a liquid catalyst and fuel combined (Helmann) were used. After 2 or 3 sec., decalene was admitted and the Helmann shut off. Decomposition of H_2O_2 was then accomplished by heat. Temperature in the combustion chamber must remain above 1,800 F. The catalyst chamber and combustion chamber were combined. That resulted in a rather dangerous situation, as the arrival of the three liquids had to be accurately co-ordinated. If any was off-time a serious explosion resulted, and our information indicates that about one out of each 100 torpedoes was wrecked that way. The performance characteristics were much superior to those of any other torpedo and they were essentially wakeless.

Submarine Propulsive Power.

In 1943 the Germans realized that our anti-submarine forces had won against the type 7C submarine which they had depended on up to that time. The 7C was fundamentally much like the ones we used in characteristics, except that it was considerably smaller so its speed and endurance were less. It displaced about 700 tons on the surface, had a surface speed of 17 knots and a submerged speed of about 7·5 knots. The Germans were able to change their thinking radically in regard to submarines. They realized that, in order to cope with our anti-submarine forces, they would have to go to a true submarine, instead of a surface ship which could be submerged, and that, to make an attack and then escape, it would be necessary to have high underwater speed. Their first and most important development was the underwater breathing tube or "Schnorchel". They used this against us effectively. It permitted them to make a war patrol without once coming to the surface. It was essentially a pipe, which extended 18in. or so above the surface, through which they obtained air for the Diesel engines and for ventilation.

Then, in the summer of 1943, they conscripted a group of eminent designers and technicians and assembled them in a little town in the Harz Mountains. They produced the much discussed type 21 boat. It was a completely different submarine. It would have been very effective against us had the Germans not made one fatal error in their design, as they have done so often. Their hydraulic system was so complicated that they couldn't get it to work before the war ended, although they had built about 120 of these boats by that time. Type 21 had a surface displacement of 1,600 tons, a surface speed of 15·5 knots and a submerged speed of 16·5 knots for one hour. It obtained its high underwater speed by the use of a large battery power and a battery with very thin grids, 0·160in. thick.

At this time Walter, at Kiel, was able to speed up the acceptance of his hydrogen-peroxide submarine. He had experimented on the use of hydrogen peroxide since 1935 and had built and operated an 80-ton experimental H_2O_2 submarine before the war. It performed in accordance with his design and realized some 25 to 26 knots submerged speed. During the war, he supervised the design of four school boats, the first of which went into operation in the fall of 1943. They were known as type 17 and performed in accordance with expectations. They were followed by five operational boats, type 17B. These were 380-ton-surface-displacement vessels, surface speed 8·5 knots, submerged speed 25 knots, and had two bow torpedo tubes and two spare torpedoes. They never had a war patrol because there was never enough hydrogen peroxide to permit them to so operate.

The last word in submarine design was to have been the type 26 Walter boat. It was under construction when the war ended. It was to have been of 900 tons surface displacement, 11 knots surface speed, and 24 knots submerged speed. It had 10 torpedo tubes but no spare torpedoes. The hydrogen-peroxide engine (it had only one shaft) was rated at 7,500 h.p. Our bombing force never permitted the Germans to get the engine assembled.

However, the author collected together all the parts for one engine in the summer of 1945 and shipped them to England, where the engine now is. A schematic diagram of this engine is shown in Fig. 1.

Details of Submarine H_2O_2 Power Plant.

There is a so-called triple-feed pump which pumps H_2O_2, Diesel oil, and water. The Ingolin pump parts, piping, and catalyst chamber are stainless steel. The first position on the starting wheel allows only Ingolin to be pumped. Ingolin reaches the catalyst chamber where it sprays on porous porcelain stones on which are fixed calcium, potassium, or sodium permanganate. As mentioned before, the Ingolin breaks up into steam and O_2; 80 per cent. steam by volume, at a temperature of about 930 F. From that point on, materials are simple alloy steels. The steam and O_2 mixture go to the combustion chamber. Soon after it reaches that point, the cooling water is allowed to circulate. The water makes two passes through the combustion-chamber water jacket and then sprays into the turbine working fluid. Soon after the cooling water is admitted, decalene is allowed to spray into the combustion chamber.

The temperature in the combustion chamber is above the auto-ignition point, but an automobile spark plug in the combustion chamber is energized to assure ignition. Danger of explosion exists in the event ignition fails. A proportioning device admits water, Ingolin, and decalene in a ratio of approximately 12 to 9 to 1. The proportioning device gave more trouble than any other item in the machinery plant. The earlier ones were installed on the triple-feed-pump suctions and the later ones on the discharges. There is more hazard connected with those on the discharge side because when the flow of Ingolin is restrained a pressure is imposed upon it and it is churned in the Ingolin pump.

Flame temperature in the combustion chamber is about 4,000 F. The water is sprayed into the combustion chamber in an amount to reduce the temperature to the desired degree. The Germans used approximately 1,020 F. for their turbine working fluid. Working fluid is now about 94 per cent. steam by volume and 85 per cent. by weight. It goes through what amounts to a conventional steam turbine, operating at 14,000 r.p.m., and into a contact-type condenser where the steam is condensed.

In the earlier engines, the non-condensing gases were forced overboard by the turbine back pressure but in the engine for the type 26 boat, they were pumped overboard by a Lysholm-type positive-displacement rotary compressor. The spray water for the contact condenser is cooled by circulation through a surface-type heat-transfer unit located outside the pressure hull; sea water is forced through the heat-transfer unit by scoop action.

The machinery installation is not quite as simple as the sketch indicates. The turbine has the same problem of shaft-gland sealing as any other steam turbine. It is water-sealed with a gland leak-off and leak-off condenser. There are three auxiliary lubricating-oil pumps which are used for starting only. When running, lubrication is accomplished by pumps driven from the gears. There is a Diesel engine for surface and schnorchel operation; a main motor and a creeping motor for submerged battery drive. The main motor also serves as a generator while the boat is being driven by Diesel engine or Walter engine. It furnishes power for auxiliaries and for charging batteries. The creeping motor is a high-speed low-power affair which drives the main shaft through multiple V-belts. The main turbine drives through a conventional single-reduction double-helical gear and then through a planetary gear. The Diesel and main motor are on the same shaft and drive only through the planetary gear. The single-reduction gear and turbine can be disconnected by a clutch. The main motor and Diesel or just the Diesel are connected or disconnected by clutches. The main motor, however, always operates, either as a motor or a generator, except when the creeping motor is in use. All gears are disconnected when using the creeping motor.

Germans Complicated H_2O_2 Machinery Unnecessarily.

The machinery was subject to many breakdowns, the principal reason being that in Germany a design error, or what might be interpreted by the courts as a design error, was a civil offence. That caused the designers to guard against all damaging casualties to machinery, instead of accepting some hazards for the sake of simplicity. For example, there were five shut-down devices installed to guard the turbine. That resulted in complications which led to frequent malfunctioning of safety devices. The machinery compartment was sealed off when machinery was running but the crew would go in with little hesitation when casualties occurred.

Submarine propulsion was the ideal application for H_2O_2, its value resulting from the fact that using H_2O_2 is a good way to obtain O_2 for combustion when operating submerged. By "a good way" is meant that it had many advantages. It was carried in collapsible polyvinyl-chloride bags outside the pressure hull. The hydrostatic pressure outside kept a positive pressure on the Ingolin pump. Ingolin used from inside the bags was displaced by sea water outside the bags, which compensated for about three-quarters of the weight of Ingolin used, the difference being the difference in the specific gravity of the two liquids. Fresh water obtained by condensing the H_2O in the turbine working fluid could compensate for the difference, in order to maintain neutral buoyancy. Actually it was not done that way but was accomplished by admitting sea water into a compensating tank. Excess fresh water was forced overboard with the CO_2 and other non-condensing gases.

The one big disadvantage to the use of Ingolin is its cost. As indicated before, about 9 times more of it is used than Diesel fuel, and it costs 60 or 80 times as much per pound. Multiply 60 or 80 by 9 and the result is high. As a matter of fact, its cost is near enough to a thousand times greater than fuel oil to use that figure as a rough comparison of costs when using H_2O_2 and oil for producing power.

CORRESPONDENCE.

To: *The Editor of the* TRANSACTIONS.

The abstracts "Improvements in the Detail Design of Surface Condensers" and "Diesel-engine Crankcase Ventilation" which appeared respectively on pages 118 and 122 of the December, 1946 issue of the TRANSACTIONS, have prompted the writer to submit the following notes on these subjects:—

Improvements in the Detail Design of Surface Condensers.

In the abstract which appeared in the TRANSACTIONS it is stated that a moulded bakelite tube insert is fitted to eliminate defects caused by the mechanical attrition of the circulating water.

During an overhaul and survey carried out in New York in 1943 to the C.P.R. ship *Empress of Scotland*, a routine inspection was made of the condensers, in the course of which various tubes were removed for examination. The contents of the sea-water side, apart from the usual sludge and small fish, showed pebbles of a sufficient size to prevent their being drawn through the tubes, and of such a weight as to lead one to imagine that a definite hammer action could be set up across the tube plate. It will be argued that a bakelite mould would crack under these conditions.

The tubes in the case of the *Empress of Scotland* were secured by the usual "stepped" ferrule at the outlet side and a plain at the inlet, with packing in both ends. In the inlet side was fitted a lead sleeve similar in shape to the bakelite mould. It was expanded into position and protected the ferrule; it also answered the purposes claimed for the bakelite mould. The fitting of the sleeve took a matter of seconds, a tool designed for the purpose being provided (see Fig. 1).

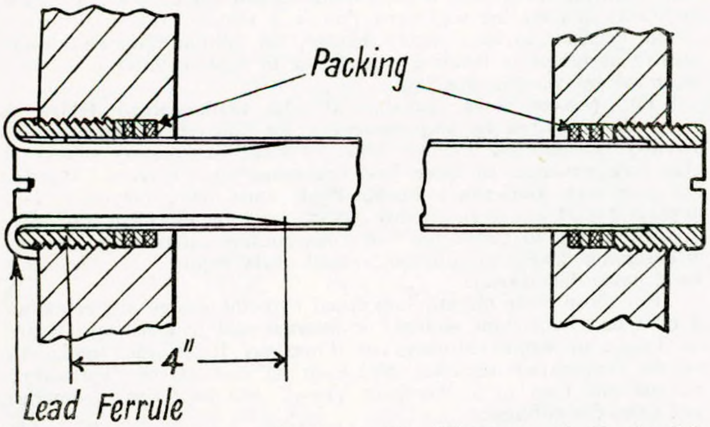

FIG. 1.—*Lead sleeve as fitted to the "Empress of Scotland's" condenser tube inlet.*

Diesel-engine Crankcase Ventilation.

The system adopted in the Blue Star Lines' *Australia Star* incorporates an extraction fan for each engine. In each end of the crankcase, at the highest possible point, and also at a point on the camshaft chain case, trunkways of approximately one square foot in area are connected. The trunks are led to a common chest to which are connected a sump and drain. The main trunk is then led vertically to the extraction fan, which in turn discharges through a trunk terminating in goose necks in the funnel top.

The air in this vessel's engine room is particularly free from contamination. Further, the reduction of pressure in the crankcase is such as to prevent the leaks of lubricating oil which, before the system was fitted, constituted a source of extreme annoyance.

Yours, etc. C. F. JONES (Member).

JUNIOR LECTURES.

BELFAST COLLEGE OF TECHNOLOGY.

A lecture on "The Launching of Ships" was delivered at the Belfast College of Technology on Tuesday, January 14th at 7.30 p.m., by Mr. Denis Rebbeck, M.A., M.Sc., B.Litt., (Member). The audience, numbering some 130, was largely composed of students and apprentices.

The Principal of the College, Mr. D. H. Alexander, O.B.E., M.Sc. (Member), occupied the Chair, and in the course of his introductory remarks referred to the purpose of the lecture and the objects of the Institute in organizing such meetings. The Council was officially represented at the meeting by Mr. W. E. McConnell (Vice-President) and Mr. C. C. Pounder (Vice-President designate) for the Belfast area. Mr. Pounder took the opportunity of inviting all who wished to approach him in his future capacity as a Vice-President of the Institute to do so with the assurance of co-operation and assistance in the furtherance of their careers.

Mr. Rebbeck then delivered his lecture, which was illustrated by an admirable series of lantern slides giving a great deal of detailed information. The slides included many photographs of launching ways and apparatus, and some very interesting graphs showing the nature of the calculations involved in the preparation of a launch. A film of the building and launching of an actual ship completed the lecture. Further remarks by senior members of the shipyard staff of Messrs. Harland & Wolff, Ltd. added much valuable information. This included a detailed account of the nature, treatment and testing of the lubricant on the ways, an item which, instead of being taken for granted, was shown to be one requiring very skilled attention, in the absence of which the most carefully designed launching arrangements might fail.

A hearty vote of thanks to the author, proposed by Mr. McMaster, was accorded with enthusiasm, and the meeting then terminated.

UNIVERSITY OF LONDON, KING'S COLLEGE.

A lecture on "Gas Turbines and Their Prospects" was delivered by Professor S. J. Davies, D.Sc., Ph.D. at University of London, King's College, on Monday, 20th January, 1947 at 6 p.m. The audience including visiting members and students, numbered over 100.

Dr. S. F. Dorey, C.B.E. (Vice-President), who officially represented the Council at the meeting, occupied the Chair.

Professor Davies presented even the most difficult parts of his subject matter with an exemplary clarity and fluency. With the aid of a large and interesting series of slides, he traced the development of the gas turbine from the first patent of John Barber's in 1791 to the modern gas turbine fitted in the latest types of aircraft. During the course of his lecture, Professor Davies also dealt with the various combinations of the simple combustion turbine and additional components to improve efficiency which were possible in aeroplanes, power stations, ships, locomotives and the chemical industry, and reviewed the possible future applications in these fields.

At the conclusion of the lecture, Dr. Dorey supplemented the lecturer's remarks on the present state of development in the marine field, and the audience took advantage of his invitation to ply Professor Davies with a number of questions to which the lecturer replied.

A vote of thanks, proposed by the Chairman, was accorded with enthusiasm to Professor Davies, thus terminating a most instructive and enjoyable meeting.

SUNDERLAND TECHNICAL COLLEGE.

On Monday, 3rd February, 1947 at 4 p.m. a lecture on "Combustion Turbines" was delivered by Mr. J. Calderwood, M.Sc. (Member of Council) to a large audience of students at Sunderland Technical College.

Dr. A. H. Langley, Head of the Electrical Engineering Department of the College, occupied the chair, and in introducing the lecturer thanked him for undertaking the long journey from London in such inclement weather.

The lecturer first dealt with the early development of the combustion turbine and described how the difficulty of obtaining suitable material to withstand the high temperatures which were necessary for efficient working, had been one of the principal obstacles to overcome.

By means of a series of excellent slides he illustrated the various cycles of operation and expressed the view that the combustion turbine was a prime mover which would have a place in the future of marine engineering.

Keen interest in the lecture was evinced by the members of the audience who prolonged the meeting by asking many questions to which Mr. Calderwood replied at length.

On the proposal of Mr. D. A. Wrangham, M.Sc., the Principal of the College, a hearty vote of thanks to Mr. Calderwood for his interesting and instructive discourse was carried with acclamation. Mr. W. H. Fraser (Vice-President), who was representing the Council at the meeting, then briefly described the intention of the Institute to arrange further lectures of this character for the benefit of technical students, a purpose of which the audience signified their enthusiastic approval.

On Mr. Fraser's proposal a vote of thanks was accorded to the Chairman for his able handling of the proceedings and for the arrangements which he had made for the lecture. In reply, the Chairman expressed his pleasure in being able to further the work of the Institute and thanked the Council for providing such an excellent lecture.

ADDITIONS TO THE LIBRARY.

Presented by the Publishers.

B. S. 1340-43: 1946—Drawing Papers (Tracing, Detail and Cartridge). 10pp., 2s. net, post free from British Standards Institution, 28 Victoria Street, London, S.W.1.

Tide and Speed Tables, 1947. Marine Instruments Limited, 107, Fenchurch Street, London, E.C.3. 158pp. Obtainable free on application to Marine Instruments Ltd.

Fuel, Power and Heat Costing. Fuel Efficiency Bulletin No. 48, January, 1947. Prepared by the Fuel Efficiency Committee of the Ministry of Fuel and Power. 38pp., illus. This bulletin can be obtained free on application to the Ministry of Fuel and Power, Queen Anne's Chambers, Dean Farrar Street, Westminster, or from the Ministry's Regional Offices.

Munro's Engineers' Annual, 1947. Completely revised. James Munro & Company, Ltd., 16, Carrick Street, Glasgow, C.2. 144pp., illus., 3s. 6d. net.

The Journal of Commerce Annual Review of Shipping, Shipbuilding, Marine Engineering and Equipment, 1947. Published by Charles Birchall & Sons, Ltd., 17 James Street, Liverpool 2. January, 1947. 368pp., profusely illus., 2s. 6d.

CONTENTS.

Introductory Survey.
Initiative and Enterprise in Commerce, by the Hon. Sir Joseph P. Maclay, K.B.E.
Qualified conditions of Free Enterprise, by M. Arnet Robinson.
Appraisal of the Shipping Scene in America, by Frank O. Braynard.
Developments at British Ports, by Brysson Cunningham, D.Sc., B.E., F.R.S.E., M.Inst.C.E.
Marine Insurance Markets Recuperative Powers, by D. King-Page.
Radio and Electronic Aids to Navigation, by Capt. R. W. Ravenhill, C.B.E., D.S.C., R.N.
Remarkable Developments in Whaling Industry, by Frank C. Bowen.
Foundation Laid of Post-War Standard in Decoration, by W. A. Gibson Martin, F.R.G.S.
Shipbuilding Costs a Matter of Serious Concern, by H. E. Hancock.
Some of the Outstanding Ships of 1946.
Pre-Fabricated Welding in British Shipyards.
News of Developments in Metallurgy.
Plastics have many Shipboard Applications.
Marine Propelling Machinery—STEAM or GAS TURBINES?
Marked Activity in Electric Propulsion.
Oil Engine Approaching Zenith of its Power? by A. C. Hardy, B.Sc., M.Inst.N.A.
Progress in British Aircraft Construction, by A. James Payne, A.R.Ae.S.
New Construction in Hand or on Order.
Output of British Shipyards and Engine Works in 1946.

Sea Hazard (1939-1945). A record of the engagements between enemy submarines, aircraft, etc., and the ships under the management of Houlder Brothers & Co., Ltd., 53, Leadenhall Street, London, E.C.3. Published by the Company for private circulation. 1947. 105pp., 21 photographs.

During the war years Messrs. Houlder Bros. lost fifteen ships with a total tonnage of 120,028 tons gross register. Nine were torpedoed, two mined, one sunk by a surface raider, one bombed and sunk, one captured and eventually sunk, and one bombed and beached. In addition to these the m.v. *Imperial Transport* was twice torpedoed, and repaired on each occasion. As the narrative later describes, half of this ship was lost in the first instance; the remaining portion was brought safely home, and rebuilt into a new ship, only to be torpedoed again.

There have been many eloquent expressions of appreciation of the action by men of the Merchant Navy in which we join, but there is one point which the Company feel has rarely been mentioned. That is, so many of these men who valued their silver Merchant Navy badge above battledress and uniforms were men who had years ago experienced similar horrors of the tragedy of war at sea. They knew that this one-sided form of warfare was to be a fight to the death, and, with the knowledge and experience of the past clear in their memory, they willingly wrote yet another page in our history. Facing unknown danger calls for courage, but fighting known peril merits the description of heroism.

The Company suffered very heavy losses to its fleet primarily because this was a battle of foodlines, and the refrigerator vessel was, to the enemy, a valuable target to sink. But the Company, engaged in rebuilding and replacement programmes, is determined, with the aid of its ships and seamen, to take its full share in assisting Britain to regain her position of supremacy as a maritime nation.

Naval Architect's, Shipbuilder's and Marine Engineer's Pocket Book. (Fourteenth Edition Revised Second Impression). By Clement Mackrow & Lloyd Woollard, M.A. The Technical Press Ltd., London. 1946. 718pp. illus., 30s. net.

The fourteenth edition of Mackrow's Pocket-Book presents few new features, but the work is such an old and valued friend to naval architects and marine engineers, that it is not surprising that there should continue to be a steady demand for edition after edition—to present as prizes to budding experts, or to replace tattered volumes worn out by constant handling.

The present issue contains all the mathematical tables so constantly required by ship designers for theoretical strength and stability calculations, together with sufficient explanatory matter to give sure guidance to those just beginning their careers. (During the late war Mackrow's Pocket-Book must have played a very important part in assisting many old stagers to re-establish confidence in their ability to tackle the numerous routine calculations involved in designing dozens of different special craft required for our wide-flung naval operations).

For those more directly concerned with the design and construction of merchant ships sections on international requirements, Board of Trade, or rather Ministry of Transport Rules, the regulations of the registration societies, and even on methods of "Estimating Weight and Cost of a Merchant Vessel" will be found of interest and value for reference.

Conveniently associated with the specialist information noted above are the usual tables of data common to most engineers' handbooks, as well as information about tides, drydocks, anchors and cables, chains and wires, timber and a dozen and one other items of particular service only to naval architects.

It is a pity that the theoretical part of the book has been curtailed a little, stability having been cut somewhat. For preference, aerodynamics might well have been omitted—aeronautics has already gone—and more space have been devoted to modern trends in the use of light metals, plywoods, plastics, ships' plumbing, and conditioning of accommodation and cargo spaces.

Incidentally, it was curious to find information re the "Strength of Submarines" and "Viscosity" mixed up with tables of chain rigging and belaying cleats.

However, Mr. Woollard—joint author with the late Clement Mackrow—has done an excellent job, and this new edition will no doubt be quite as welcome as its numerous predecessors have been.

The British Navies in the Second World War. By Admiral Sir W. M. James, G.C.B. Longmans, Green & Co. London. 1946. 246pp., with 22 plans, 21s. net.

Official histories of naval or military campaigns often overwhelm the general reader by their lengthy reports and intenseness of detail. After a very short time they are apt to be relegated to the library shelf where they remain merely as reference books unless perhaps occasionally disturbed by an enthusiastic student of naval and military warfare. Admiral James's book is unlikely to suffer in this way. In the first place it is not an official history, though the details are based on authorized pronouncements and personal experiences. Also it is not intended for students of naval warfare, most of whom, nevertheless, will probably read it, but for the general reader who will find it as accurate an account as he is likely to desire.

The story quickly develops into a correlated series of moral events from September, 1939 onwards. The Fleet takes up war stations—Expeditionary Force landed in France—German submarine offensive opens—Battle of River Plate, and so the story unfolds right up to the Japanese surrender.

The book is illustrated with 22 charts, which by the judicious use of colours and broken lines show clearly the disposition and track of the ships taking part in nearly all the major naval campaigns. They provide a wealth of detail which would be difficult to describe adequately in any other manner. It is probably these charts which have increased the cost of production to a figure which is more than the "general reader" is usually prepared to pay. He may rest assured, however, that here is an excellent story of the British Navies' contribution during the second world war.

English for Engineers. (Fourth Edition Third Impression). By S. A. Harbarger, Anne B. Whitmer and Robert Price. McGraw-Hill Book Company, Inc. New York and London. 1943. 218pp. 10s.

A teacher of writing, whatever the rank or skill of his student, must accept the degree of facility previously developed and can only help it to grow towards increasing usefulness during the period of work together. All experience, said Ulysses, "is an arch where through gleams that untravelled world whose margin fades forever and forever" as we move. The composition teacher's aim seems to be largely that of keeping the horizon constantly advancing.

English for Engineers is intended peculiarly for students with well-developed interests in specialized technical fields. To readers of this book, therefore, we wish to point out certain features intended to meet the needs of such students, but based firmly upon the assumption stated above:

A group of inventorying chapters (II-VIII) surveys specific skills which the technical student brings into any course in composition, with emphasis upon those that will be basic to his professional writing.

Once the groundwork in general composition has been tested, chapters IX-XIX develop the problems peculiar to various specialized writing situations—communications, reports, publishable forms, etc.

The appendix, "Suggestions for Practice Writing", provides a variety of practical situations wherein the student may apply his mastery of fundamentals to typical problems in his field of interest.

The special bibliographies accompanying each chapter suggests sources of further material (*1*) to remove any inadequacies in fundamental skills, (*2*) to expand a knowledge of specialized types of applied writing, and (*3*) to keep the whole problem of writing within the scope of human living.

The object of this fourth edition has been to discuss the topics of the previous editions in the light of shifting emphases in outlook and engineering practice. Despite resultant changes, however, the spirit and the philosophy of the first edition are as much in demand today as they were twenty years ago: to create an interest in English as an integral part of engineering training and of professional activities; to suggest methods of study which technical students can use to develop skill in written English; and to indicate methods of proceeding under their own power when an instructor is no longer available.

As a result, the aim of this edition has been to stimulate the upperclassman and the young graduate engineer to begin to identify for themselves the applications of writing principles to their individual activities.

Just as technical students in their junior and senior years are required to adapt scientific principles to the use and convenience of man, and to direct the human element concerned therewith, so in the advanced course in English, students can be made aware that the application of the basic principles of writing is in the same category.

Modern Petrol Engines. By Arthur W. Judge. Chapman & Hall, Ltd., London. 1946. 496pp., 304 figs., 36s. net.

The book under review is well up to the high standard set by the author in his earlier works, and the text is amply illustrated by a considerable number of photographs and diagrams. As it deals exclusively with petrol engines for automobile, aircraft, marine and high-speed stationary purposes, the subject is covered in much greater detail than in most text books where internal-combustion engines of all types, oil, gas and petrol, are dealt with in one volume.

Chapters I, II and III give a history of early engines, the combustion process and fuels, and the thermodynamics of the petrol engine. These chapters together with chapters IV and V, running to 196 pages, dealing with petrol engine performance, containing maximum output and supercharging, cover in an excellent manner the theoretical principles applicable to the engine itself and to the problems of combustion of the various fuels available. Further chapters cover the cooling of engines, carburation and fuel injection, ignition, lubrication, and describe various petrol engine types including the single sleeve-valve engine, the two-stroke engine and the internal-combustion turbine. As well as dealing with theoretical considerations, the book quotes many results of experimental tests and gives data obtained from engines in production at the present time.

In all, the book runs to 509 pages (including index) and, whilst most aspects of the subject are dealt with fairly fully for a work of this nature, in addition an extremely valuable list of technical references is given, enabling the reader to pursue further any particular aspect in greater detail. An index is also provided enabling rapid reference to be made to any part of the subject.

The chapter dealing with combustion turbines is rather brief, covering only the elementary theory, owing to the censorship of information of this character which existed at the time this book was written. It may be expected that this will be supplemented in future editions.

Patents of Invention—Origin and Growth of the Patent System in Britain. By Allan Gomme, late librarian of the Patent Office. Published for The British Council by Longmans Green & Co. 1946. 48pp., illus., 1s. 6d. net.

The Patent Office is to-day one of the most important British Government departments. To it inventors of new machines and processes of all kinds apply as a matter of course for legal rights to safeguard the use and manufacture of their inventions. The law of patents is based in an essentially economic conception—the encouragement and protection of industry; it developed as an integral part of British law, and has directly influenced the formation of similar systems elsewhere.

Mr. Allan Gomme, who has written this brief survey of the origin of patents, was librarian to the Patent Office until 1944, having been for forty years a member of the Patent Office staff. He is an authority on the historical aspects of patent law and practice and is the author of papers on this subject, published in the Transactions of the Newcomen Society.

The Steam Turbine and other Inventions of Sir Charles Parsons, O.M. By R. H. Parsons. Published for The British Council by Longmans Green & Co. 1946. 32pp., illus., 1s. 6d. net.

At a time when pessimists discuss the imminent collapse of this country a booklet of this description acts like a tonic. It is not technical in the accepted sense, but it does show how much the whole world has benefited from the wisdom and energy of that great engineer, Sir Charles Parsons. His name is, of course, a household word, but his genius is not always appreciated even by engineers.

Some information is given concerning the many interests he had outside turbines and gearing, and even with some previous knowledge the reader must be astounded at the amazing versatility of this man. From searchlight reflectors to the amplification of musical and vocal sounds—what a range, and what an amazing brain he possessed to impress upon all this a permanent mark of his interest. One cannot call it a passing interest, either, for to everything he touched Charles Parsons added something tangible for those who came after him.

This is a short book, and much has had of necessity to be left out. The reader will feel a vague regret at this fact, and nowhere so much as when reading the short section on "Parsons' Life and Character". The stories concerning this amazing man are legion, particularly on the Tyne, and it is a pity more has not been made of this part of the book; however, one always feels this when reading of Charles Parsons.

Published for the British Council, this booklet should reach a wide public and it is to be hoped this will be the case. The world should be told more of British brains and courage, and Parsons had more than his share of courage. Within its limitations, this well written booklet, now in its third edition, is wholly worthy of the subject.

Presented by Lloyd's Register of Shipping.

Rules and Regulations, 1946-47.

Purchased.

The Examination of Arc Welds in the Shipyard. (M4). Recommendations by the Admiralty Ship Welding Committee for the guidance of shipbuilders, designers, inspectors and foremen engaged in the fabrication of ships' structures by welding. H.M.S.O. 1946. 29pp., 23 figs., 1s. net.

Shipbuilding. Notes on visits to Blohm und Voss, Deutsche Werft, Germania Werft and Deschimag. British Intelligence Objectives Sub-Committee. (B.I.O.S. Final Report No. 822. Item Nos. 12 and 29). H.M.S.O. 1946. 28pp., illus., 2s. 6d. net.

Investigation of the B.M.W. 003 Turbine and Compressor Blading. British Intelligence Objectives Sub-Committee. (F.I.A.T. Final Report No. 441). H.M.S.O. 1945. 9pp., 2 figs., 1s. net.

Small Vertical Steam Engines for Driving Generators, etc. Bohn & Kahler A.G., Kiel, Germany. British Intelligence Objectives Sub-Committee. (F.I.A.T. Final Report No. 378). H.M.S.O. 1945. 8pp., 4 illus., 1s. net.

Electronic Principles as Applied in Germany to the Testing of Materials. British Intelligence Objectives Sub-Committee. (B.I.O.S. Final Report No. 724. Item Nos. 1, 7 and 9). H.M.S.O. 1946. 194pp., illus., 16s. 6d. net.

Quadrant Type Electric Steering Gear for the German 5,000-ton and 9,000-ton Hansa Ship Program; also other Electric Steering Gear. British Intelligence Objectives Sub-Committee. (F.I.A.T. Final Report No. 376). H.M.S.O. 1945. 16pp., 12 illus., 1s. 6d. net.

New Radial Flow Turbine Design. British Intelligence Objectives Sub-Committee. (F.I.A.T. Final Report No. 102). H.M.S.O. 1945. 7pp., 2 illus., 1s. net.

Mechanical Foam Liquid and Equipment. British Intelligence Objectives Sub-Committee. (B.I.O.S. Final Report No. 704. Item Nos. 30 and 31). H.M.S.O. 1945. 13pp., 1s. 6d. net.

Foundries. Notes on German Iron and Steel Foundries including Centrifugal Casting. British Intelligence Objectives Sub-Committee. (B.I.O.S. Final Report No. 818. Item No. 31). H.M.S.O. 1946. 36pp., illus., 3s. 6d. net.

Investigation of German Researches on Fine Structure of Metals with Especial Reference to X-ray Diffraction Techniques. British Intelligence Objectives Sub-Committee. (B.I.O.S. Final Report No. 826. Item No. 21). H.M.S.O. 1945. 18pp., 2s. net.

MEMBERSHIP ELECTIONS.

Date of Election, 4th February, 1947.

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Transfer from Associate to Associate Member.

Ernest Harold Duncan.

Transfer from Student to Associate.

Devender Chander Chopra.
Henry Thomas Morrison.
Peter Alan Lennox Watson, Lieut.(E), R.N.

Transfer from Student to Graduate.

David Bryce Stables.

PERSONAL.

(When notifying changes of employment, members are requested to state whether they are agreeable to the information being published in this column).

T. Dickerson (Associate) has been appointed an engineer surveyor to Lloyd's Register of Shipping.

F. B. Gill (Member), of Lloyd's Register of Shipping, is now stationed at Hong Kong.

D. Griffiths (Associate Member), senior assistant to the Admiralty engineer overseer, London District, has been appointed in charge of the recently-formed A.E.O. sub-office at Bedford to deal with Admiralty contracts in Bedfordshire, Huntingdonshire, Cambridgeshire and Hertfordshire.

A. W. Hildrew, B.Sc. (Member) has been appointed to the principalship of the North Gloucestershire Technical College at Cheltenham and will be taking up his duties there in April or May.

D. G. Hogan (Member) is proceeding to India as service engineer for Messrs. Babcock & Wilcox, Ltd.

A. M. Keith (Member) has been elected a Member of the Institute of Fuel.

F. Mack (Associate), having been released from H.M. Forces, has been appointed assistant maintenance engineer at the hospital of British Legion Industries, Maidstone.

G. A Nicol (Member) has been promoted to district superintendent by Insurance Engineers, Ltd., and has been transferred to the Edinburgh area.

A. J. Pover (Associate) has been appointed engineer-in-charge of the Union Cold Storage Company's plants in the Glasgow area.

Com.(E) F. H. Pugh, O.B.E., R.N. (Member) has been released from the Royal Navy and has reverted to the retired list.

E. K. Riple (Member), who has been in charge of the technical department of the Norwegian Shipping and Trade Mission since it was established in 1940, has retired from this post and is returning to his old firm of Messrs. Arnesen, Christensen & Smith. R. Morton (Member) who is senior superintendent engineer of the technical department of the Mission, succeeds Mr. Riple.

J. H. Skinner (Member) has been appointed to the staff of the Ministry of Works.

R. N. F. Smit (Member) has been released from the S.A.N.F. and has returned to his civilian employment.

J. Spray (Member) has been awarded the D.S.C. He is now released from the Royal Navy and has returned to his former employment as senior engineer of the Birmingham branch of The Vacuum Oil Co., Ltd.

W. A. Walker (Member) has retired from active service with Messrs. Sprostons, Ltd., and has resigned as managing director of the company. He remains, however, a director and is also retaining his directorships of Demerara Banate Co., Ltd., and Chaguaramas Terminals, Ltd.

Kenneth Drummond Thomas (Member) has been awarded the M.B.E. for courage in facing Japanese action during service as chief engineer of a merchant ship.