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Marine Electrical Installations in Service.

READ

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On *Tuesday, September, 10th, 1935, at 6 p.m.*

CHAIRMAN: Mr. A. H. MATHER (Vice-President).

Synopsis.

THE purpose of this paper is mainly to review the progress in the electrical equipment of ships' auxiliaries and to furnish records of their performance in the Mercantile Service.

A survey is made of the difficulties encountered in the earlier applications and of the experience thus gained, which has enabled designers of marine electrical plant to comply fully with the requirements on board ship.

The extent to which electrical applications have become identified with marine engineering is indicated, the electrical installation of a ship being divided into component groups and referred to for specific duties.

Comparative tests of steam and electrically driven cargo handling equipments in service are given for a number of typical ships.

The demand for electrical energy by the principal services on board ship is analysed, and graphical records of important auxiliaries fulfilling service operations are included to supplement the test data.

The auxiliary equipment of a modern ship reveals the extent to which electricity has now become identified with marine service. In every progressive stage of marine engineering there has been a simultaneous expansion of electrical services on board ship. The aim and scope of this paper is in no sense an historical review. It is an attempt to survey the many services for which electricity has been adopted in mercantile ships, with reference to operating results where available, and to indicate the latest trend in manufacture and design.

In order to convey the true perspective at the outset, a brief reference to the inception and growth of marine electrical applications may be permitted. It is approximately half a century ago since electricity for lighting purposes was introduced on board ship. One of the earliest recorded installations was fitted in the s.s. "Servia", a Cunard Company's vessel, where the public rooms, engine and boiler rooms were fitted out with Swan's electric lamps. The precise capacity of the generating plant installed is not available, but is stated as not exceeding 30 kW. It is, therefore, interesting to note that for one of the largest ships now in service the total capacity of the electric generating plant for auxiliary purposes is 13,200 kW.

The use of electricity for power purposes in connection with ships' auxiliaries followed much later, and the use of electric motors for the surface propulsion of submarines was introduced by the British Admiralty about 1904. From that time until the commencement of hostilities in 1914 there was a steady growth of electrical machinery for driving marine auxiliary plant. Thus in 1907 the "Mauretania" was fitted with sets totalling 1,500 kW. and represented the largest capacity of electric plant afloat at that time. Some seven years later, in 1914, the "Aquitania" was equipped with four 400 kW. turbo-generators giving a total of 1,600 kW. capacity.

The early history of marine electrical installations revealed breakdowns and instances of the failure of electrical plant satisfactorily to meet marine conditions. This was mainly due to lack of appreciation of marine service requirements and the absence of guidance data. In the early days of marine applications there was also a tendency to regard machinery which had given good service on industrial work as capable of performing with equal success on board ship. This reasoning proved quite sound as affecting mechanical units such as pumps and similar apparatus. The prevailing humidity of the environment on board ship, however, and arduous conditions of service necessitated a more robust mechanical design and the elimination of hygroscopic materials in connection with the insulation of electrical machines. As in most engineering problems, the remedy was simpler than the process of localising defects.

Manufacturers of electrical plant soon realised the necessity of specially designing machinery to meet the conditions prevailing in the floating and vibrating structure of a ship. In consequence, features that would enable motors to function for long periods with practically no attention and to resist exposure on a ship's deck and to breaking seas were incorporated in the general design. To-day, leading manufacturers of marine equipments, as the result of long experience, are in a position fully to meet the most exacting requirements and supply electrical plant having enduring qualities to outlast the useful life of a ship.

It is proposed to deal with marine electrical plant in association with definite services on board ship as follows :—

(1) Auxiliary Generating Plant.
(2) Motors.
(3) Deck Machinery Equipment.
(4) Control Gear for Motors.
(5) Switchboards and Electrical Power Distribution.
(6) Electric Propulsion of Ships.

The growth of electrical services throughout the entire field of industry and the increasing use of electricity for domestic purposes created an influence generally favourable for its translation to marine service. In an age of marine engineering which was solely associated with steam, there was a natural disinclination to displace the highly reliable steam driving unit for corresponding electrical plant. Confidence in the ability of electrical machinery to function with reliability grew somewhat slowly, and it is therefore in post-war tonnage that we find the wider expansion of electrical applications afloat.

The advent of the Diesel engine for ship propulsion has been the outstanding event in marine engineering during the last decade, and this new prime mover has opened up a still wider avenue of application for the driving of ships' auxiliaries by electric machinery essentially in the case of motor ships where steam is not available to the extent required.

Section 1. Electric Generating Plant.

For approximately 25 years comparatively small steam driven generating plants supplied the electrical needs of ships solely for purposes of illumination.

TABLE. I.

Total generating plant installed per ship for lighting and auxiliaries.

Year.	kW.	Prime mover.
1880	30	Reciprocating.
1910	1,500	Turbine.
1914	1,600	Turbine.
1927	2,700	Oil driven.
1934	13,200	Turbine.

The increase in plant capacity is also indicated in Fig. 1.

With the introduction of turbines for main propulsion service in 1905 there was recorded the advent of turbo-electric generators capable of supplying the electrically-driven auxiliaries, thus establishing the use of electricity for power purposes afloat. In Table I is shown the total capacity of ship's generating plant fitted in outstanding ships during the period covered, whilst an indication of the increase in individual units is afforded by the maximum continuous ratings of separate generating sets installed during the last 20 years, given in Table II.

TABLE II.

Year.	Unit capacity.	Ship.	No. of sets installed.
1914	400 kW.	"Aquitania"	4
1922	375 kW.	Cunarder	2
1927	900 kW.	"Saturnia"	3
1928	500 kW.	"Duchess of Richmond"	4
1931	750 kW.	"Strathnaver"	3
1934	1,300 kW.	"Queen Mary"	7
1934	2,200 kW.	"Normandie"	6

The choice of generating plant lies between :—

(*a*) Steam Driven Reciprocating.
(*b*) Turbo-generators.
(*c*) Oil Engine Generators.

STEAM DRIVEN RECIPROCATING SETS.

Electric generating sets driven by reciprocating engines must of necessity have a restricted field of application due to space and weight considerations.

For trawlers, coasters and general freighters propelled by triple-expansion engines, it is the general practice to fit separately driven engine generating sets of that type as shown in Fig. 2. For such applications the maximum size of generating plant installed is as follows:—

		Engine r.p.m.
Trawlers	1·5/2·5 kW.	250
Coasters	5 kW.	250/350
Freighters	10/30 kW.	250/400

This type of generating plant is an established feature on board steam propelled ships from small craft upwards to ships of the general freighter class of 8,000 tons. In many instances this plant is not duplicated on board and continuity of supply for lighting services is a vital necessity.

Open type engines running at comparatively low speeds are favoured by marine engineers, and with the routine attention given on board they have demonstrated a high degree of reliability. This type of generating plant is likely to persist, despite the disadvantage of a comparatively high steam consumption, as it is fundamentally a type suitable for continuous and arduous service. Simplicity in design has enabled this engine to be installed with complete success in hundreds of trawlers, where skilled attention is not available and where such plant is called upon to function for approximately 300 days per annum under extremely rough service conditions.

The following table indicates the space, weight and price factors for comparatively small electric generating plant of differing types. The figures represent the mean of available particulars and published information. In compiling this table every effort has been made to obtain uniformity in the basic speeds relating to the various types. For the steam driven sets a speed of 400 r.p.m. has been taken, while for the Diesel driven plant advantage has been taken of the recent developments in high speed engines, and a speed of 1,000 r.p.m. has been selected. In the case of the turbo-generator sets, the figures given relate to turbine speeds between 3,000 and 4,000 r.p.m., although it is appreciated that units operating at much higher speed can be obtained and have been installed on board ship. The generator speed is 1,500 r.p.m. throughout and even with the comparatively low speed of the prime mover, the resulting value of the weight factor is interesting for purposes of comparison.

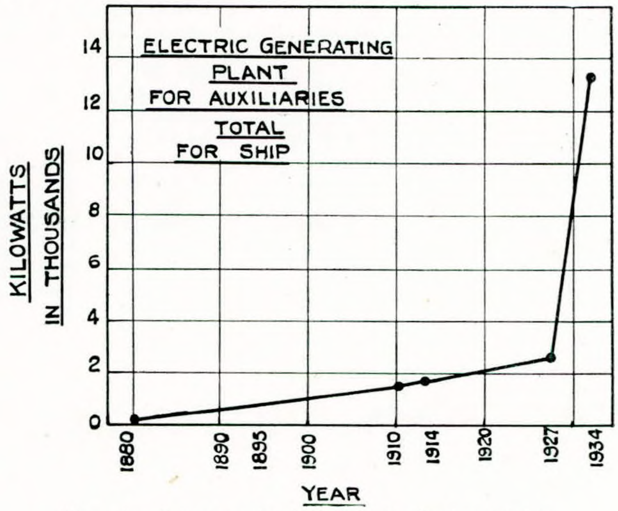


FIG. 1.—Increase in individual plant capacity.

TURBO-GENERATOR SETS.

Above 30 kW. capacity it would appear to be an economic proposition to install high speed turbo-generating plant requiring considerably less deck space and representing an appreciable reduction in weight.

The supremacy of the turbine undoubtedly led to its adoption on board ship in connection with the generation of electrical power by means of turbo-generating plant. For the propulsion of passenger liners it is still recognised as the most suitable form of prime mover compatible with considerations of space and weight. Turbo-driven generating plant can be arranged for exhausting into the ship's main or separate auxiliary con-

TABLE III.

Type of engine.	Main factors.	kW. capacity. 1·5	3	5	10	20	30	
Steam reciprocating sets 400 r.p.m.	Weight	10	15	16	26·75	46	60·5	Cwts.
	Deck space	10	10·5	11	13	17	21	Sq. ft.
	Wt. per kW. per r.p.m.	1·87	1·4	·895	·75	·644	·564	Lb.
	Cost	21·43	17·14	16·07	15·32	13·27	13·5	Pence per lb. of material.
Diesel engine sets ... 1,000 r.p.m.	Weight	13·5	14·5	16	20·5	27	40	Cwts.
	Deck space	8	9·5	10·5	11·5	18	27	Sq. ft.
	Wt. per kW. per r.p.m.	1·06	·541	·358	·229	·151	·149	Lb.
	Cost	30	28·52	26·78	27·2	27·78	30·75	Pence per lb. of material.
Turbo generating sets ... 3,000/4,000 r.p.m. ...	Weight	3·5	5	5·75	7·5	15	21·5	Cwts.
	Deck space	4	5·5	8·7	9·0	10	15	Sq. ft.
	Wt. per kW. per r.p.m.	·072	·049	·040	·035	·026	·022	Lb.
	Cost	48·46	49·7	46	46	42·9	40	Pence per lb. of material.

densers as may be preferred. During the last few years the self-contained type of turbo-generator equipment complete with its integral condenser has found much favour, and when equipped with a co-axial circulating pump this type affords distinct advantages from the point of view of rapid starting, a feature which is of considerable value in an emergency.

The following table indicates the capacity and speed of individual turbine driven generators installed during the past few years in various types of ships and is representative of current practice.

TABLE IV.

Marine turbo-generator sets.

kW.	Turbine r.p.m.	Reduction gear ratio.	Generator r.p.m.	Type of ship.
60	10,000	6·67 : 1	1,500	Cross-Channel steamer.
125	7,200	6·00 : 1	1,200	Cargo liner.
375	6,000	6·00 : 1	1,000	Intermediate passenger liner.
500	6,000	6·00 : 1	1,000	Passenger liner.
750	4,000	5·33 : 1	750	Passenger liner.
750	6,000	8·00 : 1	750	Passenger liner.
1,300	5,000	8·33 : 1	600	Passenger liner.

TABLE V.

Date.	Destination.	Full load kW.	R.p.m.	Steam. Press. lb./sq. in.	Steam. Temp. deg. F.	Steam consumption lb./kW./hr.
1884		4	18,000	60	308	200
1886	Newcastle-on-Tyne...	75	4,800	100	338	55
1900	Elberfield	1,000	1,500	150	480	18·22
1912	Chicago	20,000	750	200	588	10·42
1922	Barking	35,000	3,000	350	700	8·15
1929	New York	160,000	1,500	—	—	—
1934	Battersea	105,000	1,500	—	—	—

Turbo-generating sets having a continuous rating of 2,200 kW. are at present being manufactured and represent the largest individual generating units installed for lighting and auxiliary power services on board ship. It may be noted that the total power of such an auxiliary generating plant would be sufficient to propel the ship in which that plant was installed at a speed of approximately 11 knots.

An interesting comparison is afforded by Table V, which shows the progressive increase of individual turbine-driven generating units for industrial service over an approximately corresponding period, as recorded in the technical press.

OIL ENGINE GENERATORS.

Whilst other types of generating plant may be said to have a legitimate field associated with the particular type of engine adopted for propulsion, the oil engine has now become clearly identified with marine auxiliary generating equipment. Technical difficulties similar to those encountered by other prime movers have had to be overcome by means of research work and re-design with a view to meeting the primary requirement of reliability.

The chief claims of oil engine plant are :—

(*a*) Compact layout.

(*b*) Quick starting.

(*c*) Economy of fuel.

Difficulties associated with high piston speed and torsional oscillation have been encountered and are being gradually overcome.

For small units the present trend is in the direction of high speeds of 1,000/1,500 r.p.m. Units of this type having a capacity of 300 kW. at 900 r.p.m. are being manufactured at the present time for marine service, and their performance in service will be watched with considerable interest.

For emergency use on board ship, it is standard practice to install engine driven plant of the petrol-paraffin or analogous type. There are no indications at present that the oil engine will entirely displace steam plant for auxiliary generating service, except in the case of new ships of the Diesel-driven type.

The successful performance of generating plant of the order of 300 kW. installed in several ships where the Diesel engine speed is 500 r.p.m. indicates the progress made in Diesel engine technique and suggests that low rotational speeds may be safely discarded. In one of the large motor passenger liners built at a Continental shipyard, the main generating plant comprises three 900 kW. oil driven sets and represents the largest

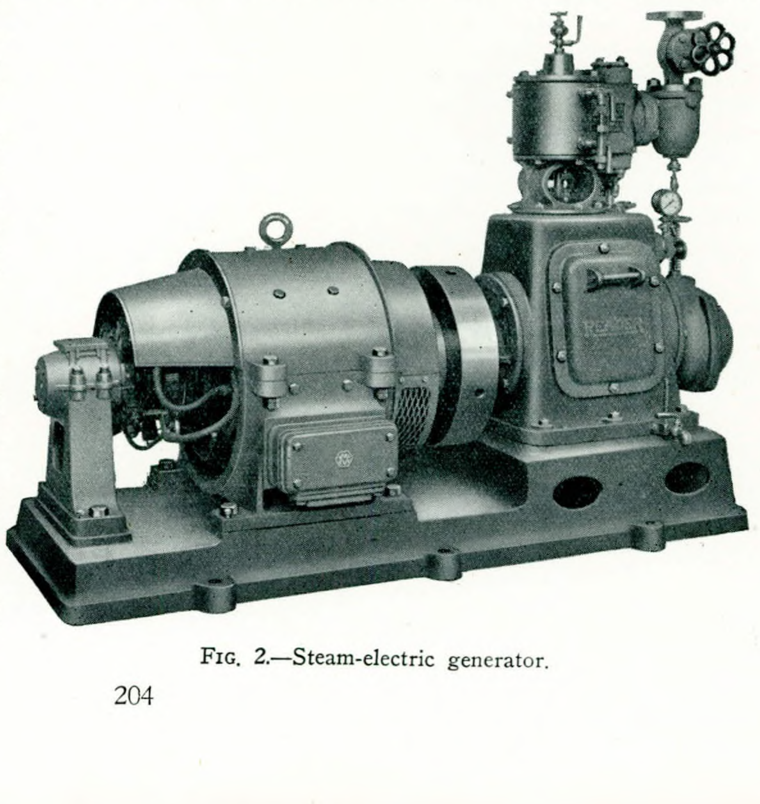


FIG. 2.—Steam-electric generator.

Diesel-driven units yet installed in any ship for this service.

Governing.

The Ship Wiring Regulations of the Institution of Electrical Engineers, in common with the require-

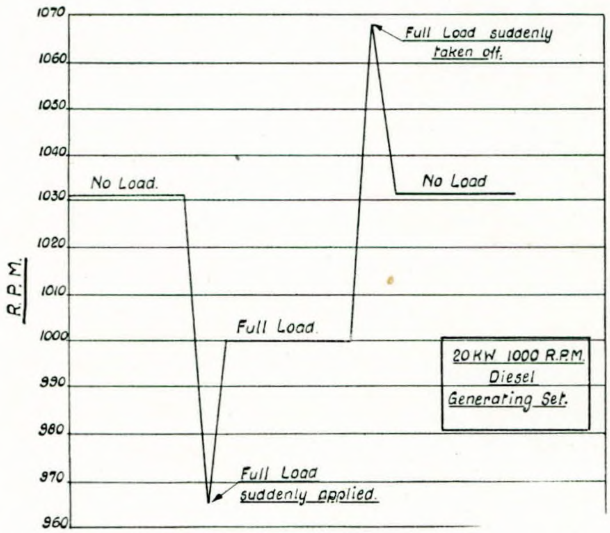


Fig. 3.—Speed governing chart—Diesel-electric generator.

ments laid down by the leading Ship Classification Societies, necessitate that each prime mover shall be equipped with satisfactory speed governing mechanism. With a fixed governor setting, maximum to minimum loading trials require the prime mover speed (in the case of oil engines) to be limited to 10 per cent. momentary and $2\frac{1}{2}$ per cent. permanent variation from steady speed conditions. Actual trial results of governor performance are depicted in Figs. 3 and 4 which refer respectively to a 20 kW. Diesel generating set and a 300 kW. turbo-generator set.

Rating of Generating Plant.

Manufacturers of electrical machinery design their plant to meet the British Standards Specification, one of the requirements being that the electrical plant shall be capable of duty with an overload of 25 per cent. for two hours. Manufacturers of the prime movers for association with such plant are not, however, required to include in the design of either steam or Diesel machinery a corresponding overload feature exceeding 10 per cent. as a standard feature.

The margin of design in the electrical plant may be regarded as a desirable feature to safeguard satisfactory commutation at heavy loads and prevent excessive heating, but it eventually reflects an unbalanced engineering design of plant. The reliability of electrical plant will doubtless be admitted, and it is suggested that uniformity in design ratings of all classes of machinery could now be adopted.

General Design Features.

The generating plant may be referred to as the heart of the ship. Special attention is drawn to the necessity of correctly balancing all rotating members. A general design of bearing, the contact area of which permits of a bearing pressure not exceeding 100lb. per sq. inch with a wiping speed of 2,000ft. per minute, has given results of satisfactory longevity. In addition, all journal bearings should be designed to maintain satisfactory lubrication under a tilting condition of 15°.

On the electrical side, conductors having a double cotton covering should be employed on field systems. Wound coils should be immersed in a special gum compound which penetrates sufficiently and also seals minute openings. Such coils so treated and finally taped and enamelled have proved completely immune from trouble.

Armature coils should be taped and insulated with mica, the complete armature being impregnated with a special hard drying and elastic compound giving a smooth and sealed external surface impervious to moisture. Mica still remains the most reliable insulating medium.

Open type generating plant has been found to give less trouble than enclosed or pipe ventilated machines, despite the high operating temperature of the average ship's engine room with its prevailing oily atmosphere of great humidity. This is due, it is claimed, to the more perfect sealing method adopted in connection with the windings and improved design of commutators with a special closure where junction between the commutator connections and the armature winding proper is effected. For Diesel engine-rooms such design features are definitely advisable owing to the penetrative influence of the heavily oil-charged atmosphere. Improvements in the general scheme of engine-room ventilation and in the design of Diesel engines have resulted in a purer atmosphere, beneficial for the

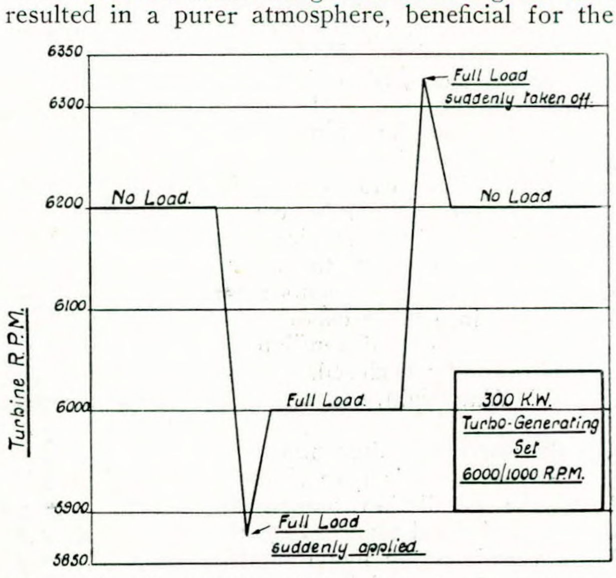


Fig. 4.—Speed governing chart—turbo-electric generator.

personnel and of considerable assistance in reducing maintenance supervision of the electrical plant.

During the past few years further increases in the total generating plant installed in passenger liners have been necessitated due to the adoption of electric galley and bakery equipments and other features classified as "hotel services".

Table VI has been prepared as an example of notable ships completed and commissioned by various countries during recent years. This list gives the leading particulars of each ship's passengers and personnel and includes the capacity in kiloWatts of the electric generating plant. It is interesting to note the increase in plant capacity with increase in the length of the ship and passenger accommodation.

With the present type of high class passenger ship equipped with all devices and arrangements corresponding to luxurious hotel services ashore it has been found that the average sea load on the auxiliary generating plant is equivalent to 1/1·25 kW. per person on board.

Section 2. Motors.

Designation of the many and varied types of motors has increased considerably during the past ten years. This has rendered identification difficult and has caused confusion in the interpretation of technical terms. Any endeavour by responsible authorities to clarify and reduce the permissible categories of marine motors would be commendable and of real service.

Broadly, motors to fulfil marine service requirements can be divided into three classes :—

(*a*) Splash-proof ventilated.
(*b*) Totally enclosed.
(*c*) Watertight.

(*a*) Splash-proof Ventilated.

Motors of this type should have the ventilation apertures on the horizontal plane spanned by a vermin-proof metal mesh and finally protected by a stout

Table VI.

Ship.	Year.	Line.	Length feet.	Breadth feet.	Depth feet.	Gross tons.	Knots.	Screws.	Passengers.	Crew.	S.h.p.	Aux. Gen'r. plant.	Total Gen'r. plant.	Aux. Gen'r. power per cent. of propulsion power.
"Mauretania"	1907	Cunard	762	88	57	30,696	29	4	—	—	—	4-375 kW.	1,500 kW.	21
M.S. "Saturnia" ...	1927	Cosulich	631	80	43	23,900	19	2	2,197	441	20,000	3-900 kW.(D.)	2,700 kW.	18
"Duchess of Richmond"	1928	C.P.S.	582	75	42	20,500	—	2	1,600	409	20,000	4-500 kW.(T.) 2-450 kW.(D.)	2,900	21·4
"Europa"	1928	N.G.L.	890	102	48	—	—	2	2,200	975	—	4-500 kW.	2,000 kW.	1·9 (steam auxiliaries)
"St. Louis"	1928	Hamburg Amer. Line.	544	72	42	16,000	16	2	1,098	300	12,600	3-400 kW. 1-220 kW.	1,420 kW.	15
"Lafayette"	1929	C.G.T.	577	78	46	25,000	17·5	4	1,079	472	18,000	3-700 kW. 2-500 kW.	3,100 kW.	23·1
"Bremen"	1929	N.G.L.	938	102	54	49,864	28	4	2,200	1,050	130,000	4-520 kW. 200 kW. (emergency)	2,080 kW.	4·4
"Viceroy of India" ...	1929	P. & O.	586	76	42	19,700	19	2	673		17,000	4-500 kW. 2-165 kW.	2,330 kW.	20·5
"Mariposa"	1931	Matson Navig. Co.	604	79	31	20,000	20·5	2	750		22,000	4-500 kW.	2,000 kW.	12·1
"Britannic"	1930	White Star	684	82	49	26,940	16/17	2	1,550		20,000	4-500 kW.	2,000 kW.	13·4
"Rangatira"	1931	Union S.S. Co., N.Z.	406	58	26	—	21·5	2	936	112	13,000	3-350 kW.	1,050 kW.	10
"Strathnaver"	1931	P. & O.	630	80	38	22,547	22	2	1,166	476	28,000	3-750 kW. 1-400 kW.	2,650 kW.	12·7
"Empress of Britain"...	1931	C.P.S.	730	98	56	42,348	24	4	1,153		62,000	4-450 kW. 2-800 kW. (Port)	3,400 kW.	7·3
"Monarch of Bermuda"	1931	Furness Withy	550	77	42	22,424	19¼	4	831	456	19,000	4-750 kW.	3,000 kW.	21
"Conte di Savoia" ...	1931	N.G.I.	814	96	49	48,502	27	4	2,280	720	120,000	6-850 kW.	5,100 kW.	5·7
"Victoria"	1931	Lloyd Triestino	541	70	31	13,500	20·5	4	524	254	17,000	4-660 kW.	2,640 kW.	20·8
"President Coolidge" ...	1931	Dollar	615	81	52	22,000	20·5	2	988	323	26,500	4-500 kW.	2,000 kW.	10
"Neptunia"	1932	Cosulich	590	76	46	19,475	19	4	1,540	260	18,000	4-650 kW.	2,600 kW.	21·9
"Normandie"	1935	C.G.T.	1,027	118	91	75,000	30	4	2,170	1,340	160,000	6-2,200 kW.	13,200 k W.	8·25
"Queen Mary"	1935	Cunard	1,018	115	—	73,000	30	4	—	—	—	7-1,300 kW.	9,100 kW.	6

splash-proof cowl. Removable vertical side doors of sufficient size to permit of access to the brushgear and for inspection purposes should be fitted, the joints being complete with resilient packing. Such machines are now being installed and are designed to prevent admission of water up to the centre line of the motor whilst resisting water resulting from any leakage or defect in overhead pipe lines.

The features indicated could be representative of a ventilated type of motor with a suggested classification type—Marine Standard Ventilated (M.S.V.). It is submitted that motors of this type would be quite suitable for engine-room auxiliaries, steering gear, ventilation, refrigeration and other 'tween deck services which are in operation continuously or for protracted periods.

(*b*) Totally Enclosed Motors.

Motors of this type are desirable for certain selected and intermittently loaded services below deck, i.e. engine turning equipments, laundry services, etc., or where the environment necessitates a motor of the totally enclosed type. All such machines should have specially tight joints, and removable doors fitted with inspection windows, while the completed motor should be capable of withstanding water at a pressure of 1lb. per sq. inch. This latter feature might with advantage be adopted as a standard for motors of this type.

(*c*) Watertight Motors.

For deck equipments, including winches, capstans, anchor gear and ventilation units installed in exposed positions, motors of the watertight type are essential. Experience has indicated that deck mounting motors should be of the totally enclosed watertight type, capable of completely resisting water at a pressure of 10lb. per sq. inch. This is necessary satisfactorily to withstand conditions associated with deck services and to resist breaking seas in heavy weather.

Bearings.

For marine applications bearings of the journal or sleeve type require special design features to withstand the effects of rolling and pitching during adverse weather conditions and to maintain satisfactory lubrication when the motor is inclined 15°. The author suggests that the consensus of marine opinion would affirm that only minor and infrequent troubles have been experienced with this reliable type of bearing. Motors fitted with journal or sleeve bearings are, however, heavier and occupy more space than motors equipped with ball or roller bearings.

The increasing adoption of vertical type pumping equipments has led to a wider use of ball and roller bearings for the driving motors of such units. Manufacturers of electrical machinery have devoted considerable attention to the design of suitable assemblies of ball and roller bearing arrangements intended particularly for marine service. This has resulted in the satisfactory performance of motors so equipped and supplied for marine applications.

In connection with over 1,000 marine motors equipped with ball and roller bearings, reports from the ships concerned indicate that minor troubles had been experienced with eight machines. Of this number four motors had required electrical adjustments whilst the remaining four had developed defects in the ball bearings. Investigation of this matter finally revealed that on two machines wear of the lower half ball race had occurred due to a pendulum action generated by hull vibrations, the motors being in reserve for long periods. In the remaining two machines a lubricant which was unsuitable for operating conditions had been used.

Totally enclosed motors are inefficient for continuous operation, as the motor becomes a form of "electric heater" if there is no air movement over the motor yoke, and above 60 h.p. the totally enclosed motor becomes impracticable. It is undesirable to fit such machines on board ship for continuously loaded services, and for certain special applications where total enclosure is deemed neces-

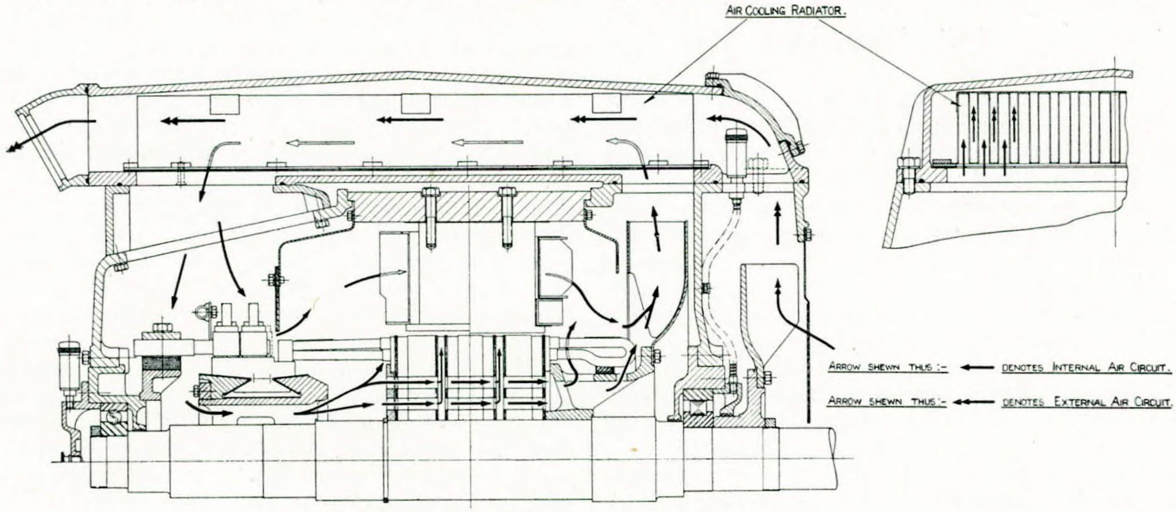


Fig. 5.—Totally enclosed fan cooled motor.

sary fan cooled motors are preferable. In one design this type of machine is fitted with air cooling radiators mounted above and below the yoke and external fans for forcing the cooling air over them. The sectional arrangement of this type of motor, including the external and internal cooling circuits, is shown in Fig. 5.

Special Services.

With the increase of engineering devices and additional equipments installed on ships there has been a considerable increase in the volume of noise under voyage conditions. In the case of passenger liners it is necessary in the interests and for the comfort of passengers to restrict this noise wherever possible.

In connection with the ship's ventilation plant for passenger accommodation there has been evolved a special design of motor in which the various noise-producing elements have been so modified that the motor is almost noiseless in operation. This has been achieved as a result of scientific investigation and research into the cause of noise generated by the various components of a standard motor. In these experiments, by means of a specially designed scientific apparatus the pitch and intensity of each component of the sound emitted were isolated and separately measured. Subsequent experiments enabled each of the sound producing components to be restricted or eliminated, thus reducing the total noise to a negligible value under all conditions of load.

Such motors when associated with ventilation trunking ensure a quiet supply of ventilating air to passenger cabins owing to the almost complete absence of noise at the source, i.e. the driving motor. In achieving the silent running of this type of motor the most difficult problem was to deal effectively with the magnetic hum, which is fundamental in origin and penetrative in influence. By continuous and progressive research this magnetic hum has now been completely eliminated.

Section 3. Electrically-driven Deck Machinery.

General Notes.

The electric drive for deck machinery, introduced over 20 years ago, has steadily increased and is now a recognised part of the equipment of passenger liners and motor ships. Such equipment completes the scheme of rendering ships self-contained and independent of power supplies from the shore for cargo handling purposes. Instances of ships on cargo service making varying calls show that cargo equipment may be in service for periods of from 30 to 100 days per year.

Attention has been drawn from time to time to the long periods of inactivity of cargo appliances, which applies in a similar degree to the essential anchor and warping machinery. Alternative suggestions have been made that portable electric cargo winches might be fitted to pre-arranged deck seatings for use only in port when the vessel has docked, or that cargo handling should be effected by harbour cranes specially fitted for this purpose by the appropriate shore authority. The adoption of such proposals would result in the transfer of capital expenditure from the shipowner to the Harbour Board, but would make for clear decks and reduction in maintenance of ships' equipments. There are many real difficulties to be overcome before such schemes could usefully materialise. In many parts of the world sufficient power facilities are not yet available, nor is suitable equipment installed for cargo work, while instances of cargo transference from ship to lighters alongside, necessitating ship equipment to deal with this operation, have also to be considered.

It would appear that the present practice of completing ships with all necessary deck machinery will continue owing to the responsibility of the shipowner for the safe and speedy transport of merchandise. The commercial aspect is of extreme importance to the shipowner, as any delay or interruption of power supply to shore equipments would result in heavy demurrage and dock charges.

When the issue is narrowed to a choice between steam and electrically-driven deck machinery, the final decision usually turns upon the question of initial capital expenditure. Electrically driven deck machinery costs considerably more and may be taken as being approximately twice the cost of corresponding steam machinery. The cost of attendant steam pipe lines may be taken as being equivalent to that of the cable work and electrical distribution, although it is in fact more expensive. In addition, the necessary generating plant on board for the winch supply has to be considered.

Regarding economy in operation, it has been definitely established that the fuel cost in connection with steam winches is from 7 to 10 times more than with electric winches per ton of cargo handled, without any reference to routine maintenance charges.

Taking the case of a cargo ship equipped throughout with steam reciprocating machinery and auxiliaries, it has frequently been stated that to install electrical deck machinery together with electrical generating plant solely for deck services during port duties is not a sufficiently attractive proposition to the shipowner. This is due to the additional capital expenditure involved and the intermittency factor of operation. To extend such a scheme, however, to embody the electrification of the engine room services on board cargo ships would enable owners to reap the benefit not only of reduced fuel costs but of lower maintenance charges, which on steam driven units are admittedly a fairly heavy item. Specific cases have been taken for review and in each instance it has been shown that the extra cost of electric winch equipments could be equated to the saving in fuel accomplished in a period of approximately seven years.

In these days when so much thought and

experiment is being devoted to economy in propulsion of ships, there is a tendency to overlook the substantial savings that can be so readily achieved by substituting electrically-driven auxiliaries for the corresponding and wasteful steam equipments.

ELECTRICALLY-DRIVEN WINCHES.

Dealing solely with the question of operation, it will be found that the winch of the present day design is capable of handling heavy lifts at a sufficiently slow speed, and of returning the light hook as speedily as possible in order to reduce the idle part of the load cycle. Thus a 3-ton winch capable of handling the full load on the hook at a speed of 100ft. per minute is also arranged to give creeping speeds or inching movements to meet stowage conditions.

In recent years there has been a tendency to increase the light hook speed to five or six times the speed of normal full load duty. There would not appear to be any appreciable gain in a light hook speed exceeding 300ft. per minute, as the rate of working cargo depends solely upon the ability of the stevedores either to stow or break out cargo as required.

For general utility purposes the present standard design of silent running worm geared winch fulfils general requirements for cargo operations. An alternative form of winch which has found some favour in recent years is an adaptation of the standard winch operated as a modification on the well-known Ward Leonard system of control. Such winches have a high-speed motor generator set, usually enclosed in the baseplate of the winch. The chief claims for this equipment are that it can effect a more graduated range of speed control than can be obtained by the standard winch. The speed of the winch depends upon the voltage applied to the driving motor, and this is controlled from the motor generator set directly instead of through the usual resistance bank. By this arrangement a starting resistance is omitted and the control gear, whilst not being completely eliminated, is reduced to a starting and reversing contactor. On the other hand such equipments are more expensive and there are three electrical machines in operation as compared with only one motor on the standard winch.

The present day worm-geared winch is a reliable piece of apparatus, and the self-contained type embodies sound design to fulfil the requirements of

(*a*) essential speed control from creeping to maximum light hook speed,

(*b*) ability to withstand the roughest usage by untrained or native operators,

(*c*) capability of resisting weather or breaking seas and permanent exposure on a ship's deck, and

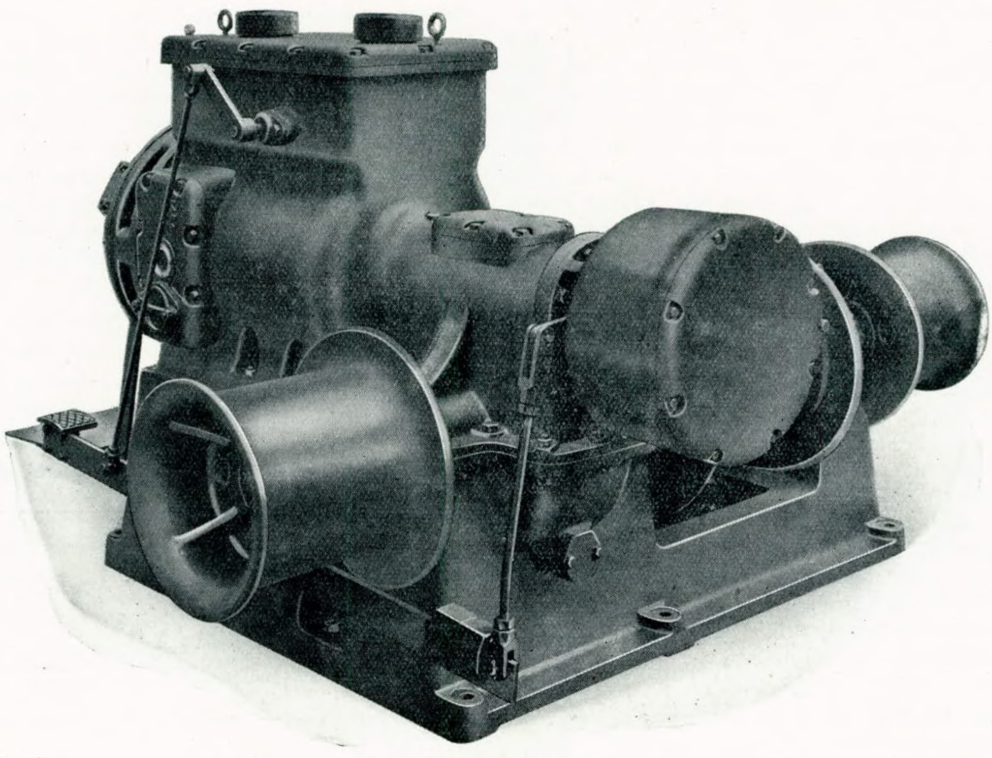


FIG. 6—Three-ton winch.

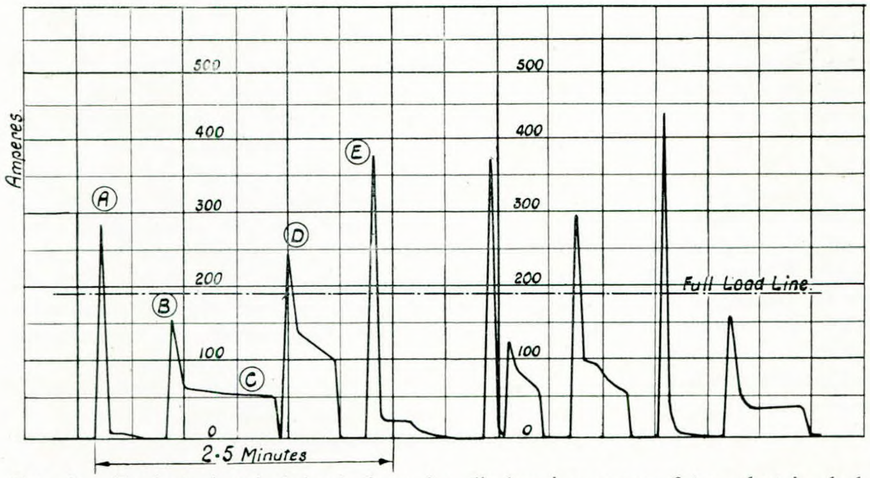


FIG. 6A.—Typical electrical load chart for discharging cargo—3-ton electric deck winch: (A) lowering light hook; (B) picking up load; (C) hoisting—steady; (D) lowering load; (E) returning light hook.

(*d*) facilities for rapid inspection and overhaul.

There is a growing opinion in favour of the silent worm geared winch which, when completed by the manufacturer, only requires connection to the main cables to be ready for service. Such winches are equipped with contactors for accelerating and controlling the motor and have the resistance housed in a compartment integral with the winch. This arrangement can be varied where it is desired to house the contactor gear separately in specially constructed compartments, usually forming part of a deck house. Such compartments then contain the control gear and resistances, and this arrangement is sometimes preferred as affording protection for overhaul or inspection in bad weather.

In Fig. 6 is shown a recent design of a 3-ton silent worm geared cargo winch, equipped with contactor control gear and with the master controller incorporated with the motor casing. A magnetic brake of the disc type is fitted at the outboard end, designed to hold safely the full load on the hook in the event of failure of the ship's supply, whilst an overspeed brake of the centrifugal type is also included to limit the motor speed to a safe maximum when lowering at full speed. In addition a foot brake lever is fitted for additional control or for checking the winch speed as desired by the operator. The peak loads imposed upon the winch motor during cargo discharging operations are shown in Fig. 6A.

Turning to the question of operating cost only, the author has made special investigations owing to the discrepancy in results recorded during tests by independent observers. The results are given in Table VII, which relates to six ships running on normal trans-ocean cargo schedule, three of the ships being equipped with steam winches and the remaining three with electrically-driven winches. The economy consequent upon the adoption of the electric winch is revealed and confirms previous statements that the steam winch is an expensive item as far as fuel is concerned.

Actually the author has reason to believe that in practice ships equipped with electrical deck machinery and generating plant have revealed to owners a definite saving in from five to six years' normal service, despite the heavier initial cost of the equipment.

WINDLASS AND CAPSTAN EQUIPMENTS.

Turning to the heavier side of deck machinery, marine engineers have looked to the electrical engineering industry to provide them with a scheme of control which will enable the equipment to give the same load characteristic as a steam engine. Smooth acceleration and an even graduation of speed are essential features of control in connection with warping or anchor duties, and the wide speed range given by the motor generator form of electric control is extremely desirable for such operations.

For small equipments of 20/50 h.p. a satisfactory scheme of resistance control to meet requirements has been devised. For large ships where equipments of 100 h.p. are required the motor generator form of control is definitely the most suitable type to install.

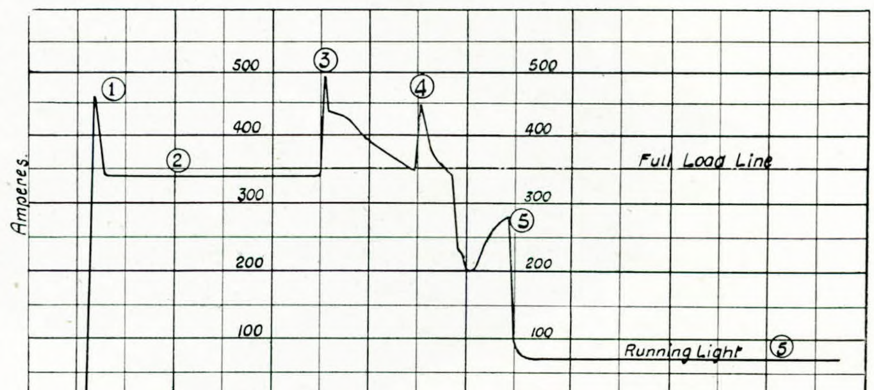


FIG. 7.—Cross-Channel mail steamer. Electrical load chart for warping ship alongside quay by electric deck capstan; motor particulars 44 h.p., 110v. (NOTE.—Figs. 1 to 5 indicated the load on respective controller notches).

As a matter of general interest, in connection with a cross-channel steamer a graphical record of the electrical load during the operation of warping the ship alongside the quay is shown in Fig. 7. Instantaneous and responsive control of speed is imperative for warping ship in heavy weather.

For anchor duty the electric control should admit of paying out and hauling in slack cable at a fairly fast rate, with the ability to give a very slow rate of working the cable when stowing the anchor in the hawse pipe. For capstan work it is essential that electric control should be perfectly smooth to avoid anything of the nature of rope surging. A characteristic load curve of a windlass equipment is shown in Fig. 8, where the effort at corresponding speeds is given for the various controller notches during anchor operations.

As an approximate and ready guide to the motor h.p. required in connection with windlass and capstan equipments the chart shown in Fig. 9 has been prepared. This has been based upon the average efficiency of the range of electrical equipments covered, with a view to obtaining a close estimate of the power required to be exerted by the electric driving motor.

SAFETY DEVICES.

In addition to the customary protective device fitted to the electrical equipment, it is quite general practice to fit some form of mechanical device, generally a slipping clutch, which should function to disengage the electrical gear in the event of a sudden and dangerous load being encountered in service. It is usual to set such clutches to slip at a load equivalent to 1·33 times full load torque, a value below the usual setting at which the electrical protective device is arranged to trip. In practice it is found that slipping clutches cannot be relied upon to retain an adjustment corresponding to a definite torque value, and it is unfortunate that reliability in this direction has not yet been obtained. In many instances this has resulted in the ship's personnel permanently locking slipping clutches in position to prevent disengagement.

A long felt want would be met by the advent of a slipping clutch that would operate with integrity against definite values of torque and would retain its initial setting.

STEERING GEAR.

Steam steering gear has one advantage, namely

TABLE VII.

Cargo operations—service performance data and costs.

	A. 250′ steam coaster.	B. 450′ cargo steam ship.	C. 420′ cargo steam ship.	D. 400′ cargo motor ship.	E. 400′ cargo motor ship.	F. 350′ cargo motor ship.
Built	1920	1922	1929	1926	1930	1930
Winch equipment ...	Steam	Steam	Steam	Electrical	Electrical	Electrical
No. and size of winches	6-7″×10″	12-7″×12″	14-7″×12″	6-3 ton	8-4 ton	8-3 ton
No. of hatches	2	4	4	2	2	2
Average load	16 cwts.	15 cwts.	20 cwts.	25 cwts.	20 cwts.	15 cwts.
Height of lift	25ft.	40ft.	40ft.	35ft.	35ft.	30ft.
Duty	Discharging	Loading	Loading	Discharging.	Loading and unloading	Loading
Cargo lifted per 8 hour day	615 tons	1,167 tons	1,200 tons	982 tons	960 tons	1,000 tons
Cargo lifted per hatch per 8 hour day ...	307·5 tons	266 tons	300 tons	491 tons	480 tons	500 tons
Cargo lifted per winch per 8 hour day ...	102·5 tons	88·7 tons	85·7 tons	164 tons	120 tons	125 tons
Cargo lifted per winch per hour	12·8 tons	11·09 tons	10·7 tons	20·5 tons	15 tons	15·6 tons
No. of lifts per hour ...	16	12	12	16	16	20
Fuel	Coal	Coal	Coal	Oil	Oil	Oil
Winch fuel consumption —per day	3 tons	5·41 tons	6·4 tons	0·229 tons	0·165 tons	0·212 tons
Total cargo handled ...	1,000 tons	7,000 tons	6,000 tons	8,600 tons	39,633* tons	2,000 tons
Total fuel used ...	5 tons	32·5 tons	32 tons	2 tons	6·82 tons	0·425 tons
Fuel per ton of cargo ...	10·75lb.	10·4lb.	11·94lb.	0·52lb.	0·387lb.	0·476lb.
Fuel cost per ton of cargo—pence	0·864	0·835	0·960	0·192	0·143	0·176
Total elec. energy kW./hrs.					15,135	
Elec. energy per ton kW./hrs.					0·383	

*Denotes 10 round voyages, during which records were taken.

Summary of results.

	Steam winches coal.	Elec. winches Diesel gen.	
Mean fuel consumption per ton of cargo handled	11·03lb.	0·461lb. oil	Coal taken at 15s. per ton
Mean cost per ton of cargo handled	0·883 pence	0·170 pence	Oil taken at 70s. per ton
Cargo handled per penny	1·32 tons	5·88 tons	

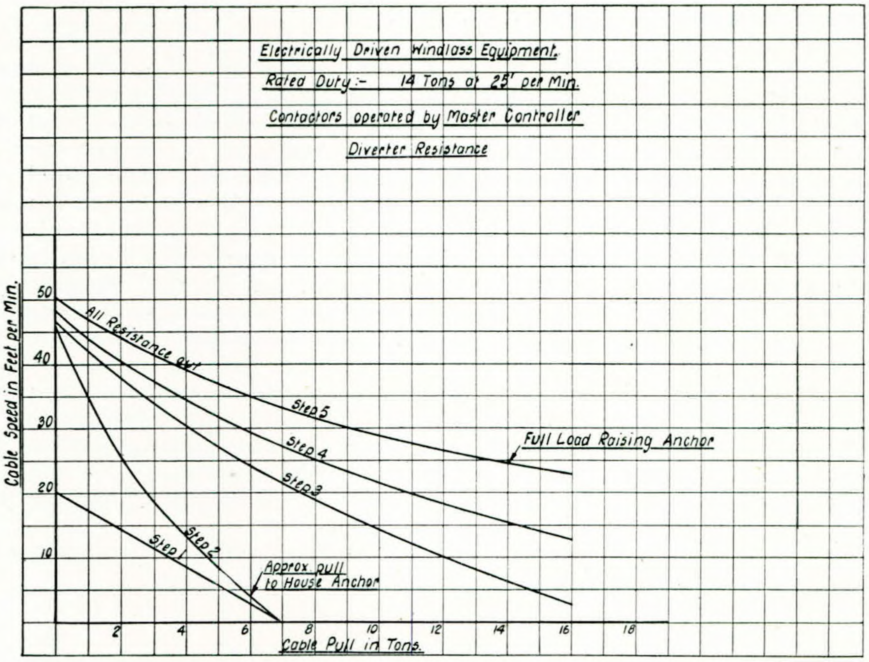


FIG. 8.—Characteristic curve of a windlass.

that of low initial cost, which is generally admitted, but in operation it is a very expensive item as far as fuel is concerned. With the best design steam consumption is admittedly very high and is constantly taking place even under conditions of zero helm. This is because there is a lag in the transmission scheme and failure of the valves to close definitely and fully. In such conditions a continuous and by no means inappreciable amount of steam is consumed. The lack of synchronism between the helm position and the steering engine and consequently the actual position of the rudder, can be improved by the provision of a rudder indicator. Such a device operated from the rudder post gives a reading on a large scale instrument in the wheel-house, affording the helmsman a definite indication of the rudder position. Thus if the steering engine valves do not close completely when the wheel is put amidships there may be a small rudder angle still held. The rudder indicator does afford some means of correction because rudder angle means steam consumption. Such a device, therefore, tends to reduce the consumption of the steering engine, but the inevitable loss due to condensation in long steam lines still continues, even if economiser valves or general improvements in the design of the steering engine are introduced. It is probably because of the difficulty in determining accurately this wastage in connection with steam steering equipments that this source of loss has not received the attention which is of primary importance in the interests of economy. Water rates taken on a general cargo ship of 3,000 s.h.p. revealed that the steering engine was responsible for 7 per cent. of the total fuel consumption.

In motor ships and passenger liners steering gear of the electro-hydraulic or analogous type is now recognised as standard practice because of the overall economy and convenience. The electro-hydraulic variable delivery type of steering equipment as fitted in larger ships is driven by an electric motor which runs continuously in

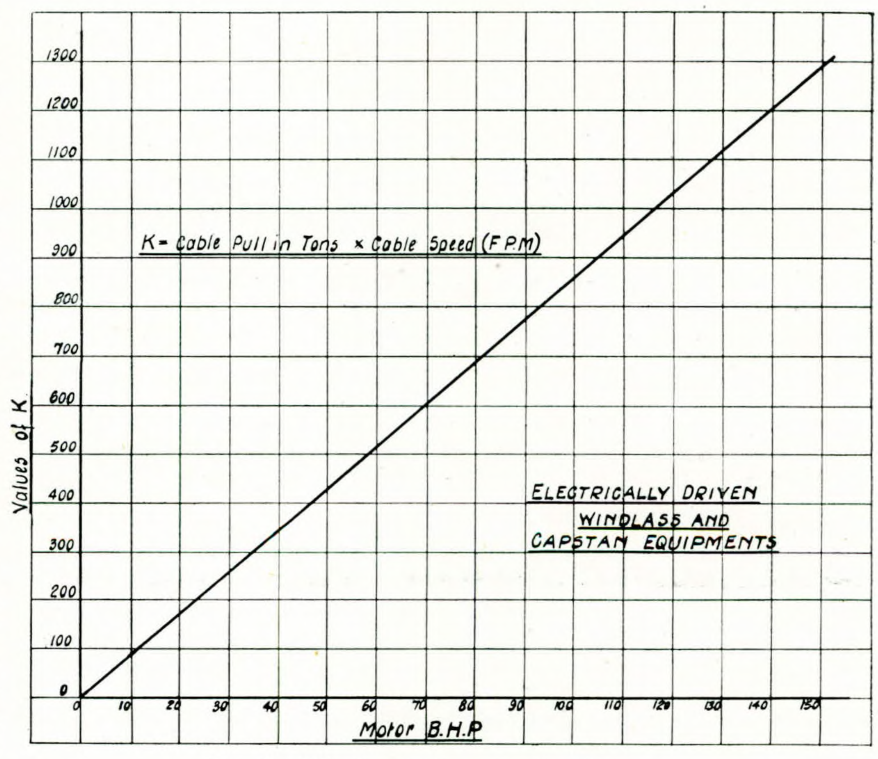


FIG. 9.—Windlass and capstan h.p chart.

one direction and at practically the same speed throughout the load range. Under these conditions the motor is not subjected to any heavy stresses consequent upon starting, sudden imposition of load, or reversal.

There is a definite preference in marine service for continuously running motors in connection with power steering equipments. Any slight delay in starting up a steering motor in equipments where the motor is not continuously rotating is obviated where electro-hydraulic or telemotor systems are installed.

With such units the mean power required under normal voyage conditions is a fairly low proportion of full load, and does not exceed 30 per cent. of the normal full load rating of the motor. Due to the intermittent nature of the loading, motors for steering duties are usually rated for continuous excitation of the field windings and one hour at full load on the armature.

The following table giving the h.p. of electric motors in connection with steering gear units installed in typical ships will probably be of interest.

TABLE VIII.

Steering unit for cross-channel steamer.

Ship.		Length, feet.	Gross tonnage.	Speed in knots.	Steering motors.
Cross-channel	...	350	3,600	21	10 h.p.
Cargo ship ...	...	415	5,000	12	15 h.p.
Passenger liner	...	600	14,000	16	35 h.p.
Passenger liner	...	600	22,000	19	42 h.p.

The chart shown in Fig. 10 relates to steering gear trials carried out at sea in connection with a telemotor control equipment.

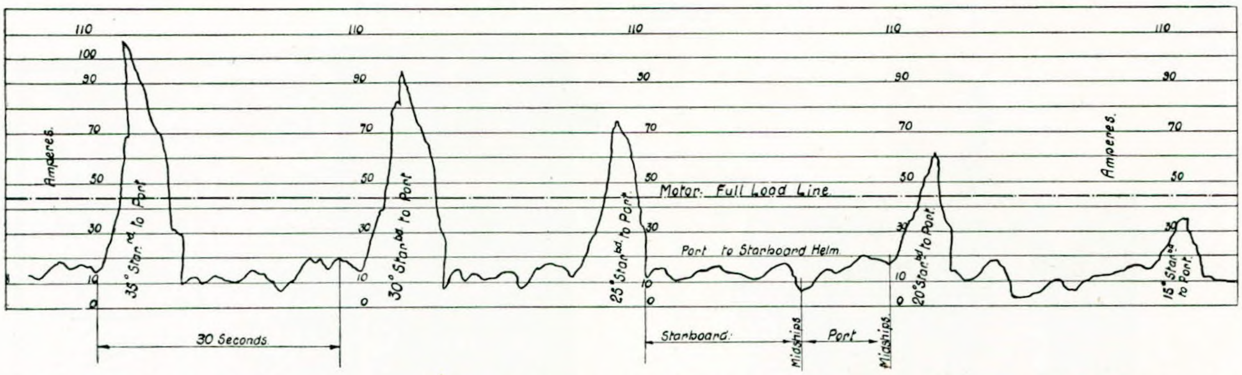


FIG. 10.—Steering gear trials—motor load chart during manœuvring test at 14 knots; 2,000-ton Diesel-electric ship, steering gear—electrical telemotor control. (NOTE.—Steering motor 10 h.p., 220v., 600 r.p.m.).

The increasing load peaks on the motor when reversing helm hard over from varying degrees of rudder angle under full power steaming conditions indicate the ability of the steering motor to deal with sudden and heavy overloads.

Tests carried out on a steering motor on board a 450ft. motorship under smooth sea conditions are depicted on the curve given in Fig. 11. The graph, which is the result of observed readings, is of interest as indicating the shape of the motor load curve when helm is steadily applied and increased to "hard over".

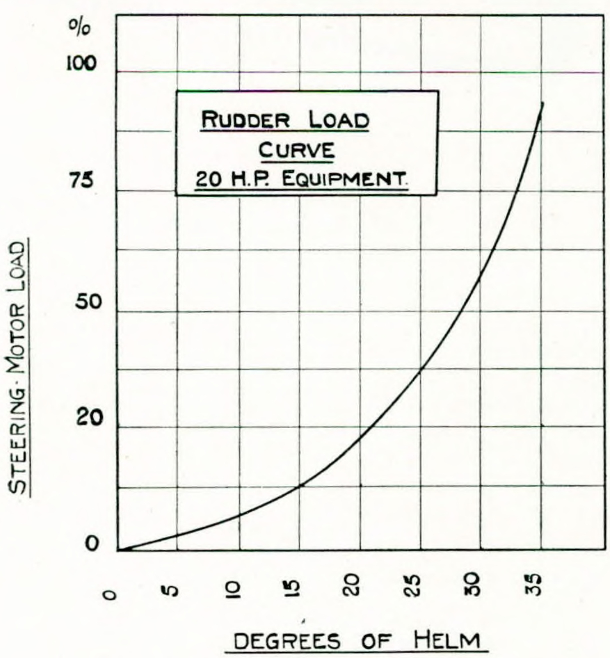


FIG. 11.—Steering motor load test.

Section 4. Control Gear for Motors.

Control gear for the purpose of starting and regulating the speed of motors in marine service should fulfil the following essential requirements:

(1) Reliability in operation.
(2) Robustness of construction.
(3) Simplicity of design.

For manual operation starters of the drum type have proved satisfactory and capable of breaking full load without subsequent damage to contacts. The last break should always be transferred from the drum contacts to a contactor incorporated in the starter design for that purpose.

Every motor starter should be completed with a no-volt release, a feature affording protection by returning the starter to the "Off" position in the event of failure of the ship's supply. As regards the question of protection in the case of an overload occurring in connection with the driven member, the Classification Societies do not insist upon the inclusion of such a feature. In support of this it may be said that certain equipments may normally be subjected to overloads of a temporary nature but still within the capabilities of the electrical equipment and without resulting in any damage. To include an overload protection device in such cases may result in a dislocation of important services in the engine room, with serious results. Taking the specific instance of steering gear equipment it is undesirable to fit any feature which will cause an interruption in this highly important circuit.

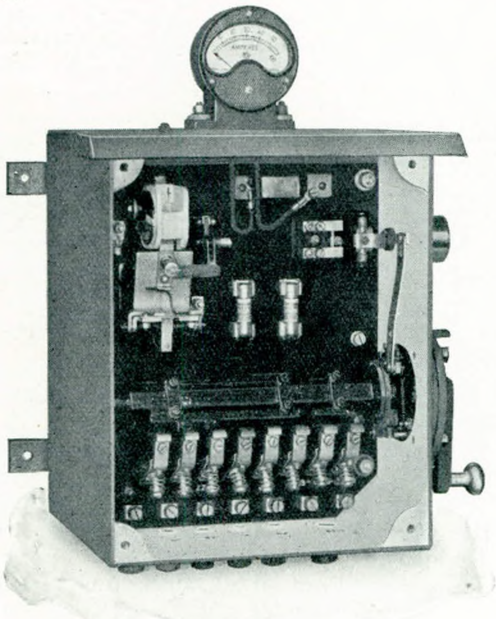


FIG. 12.—Steering gear starter.

A typical starter for steering gear duty is shown in Fig. 12.

In this apparatus special contacts are usually fitted which close an alarm bell circuit should the supply to the starter be interrupted, thus providing an audible warning on the bridge.

All control gear on board ship should be provided with means for completely isolating the starter when in the "Off" position, to enable the ship's personnel to effect inspection or adjustment without attendant danger from shock.

In the design of details consideration of the actual service conditions and difficulty in effecting repairs or renewals on board necessitate the elimination of small screws and flimsy contacts.

Complete accessibility of all working parts is essential, and all bars and rods carrying contacts should be insulated with mica fitted under pressure, subsequently wrapped with silk tape and finally varnished before assembly of details.

In connection with coils the use of fine gauge wire has proved definitely unreliable and the use of wires above 30 S.W.G. (·0124in.) is advocated.

An illuminated signal light embodied in the starter to indicate when a starter is in actual operation has proved of service to the engine room staff and is a most useful feature.

Cases enclosing control gear should be perfectly drip- or splash-proof, and if not exposed should be designed for safe ventilation.

Where totally enclosed starting gear is deemed necessary the internal details and heat producing elements should be designed to meet that particular service in order to prevent overheating. In order to ensure a satisfactory heat dissipation factor the area of the enclosure must be sufficiently great.

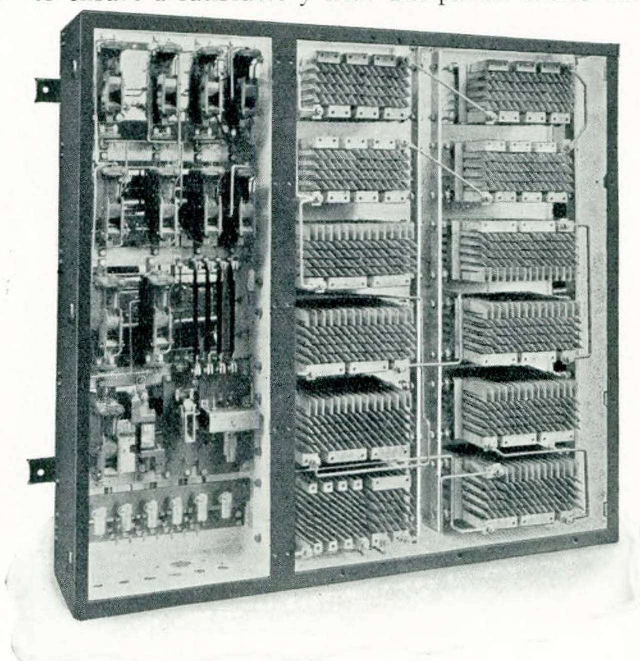


FIG. 13.—Windlass contactor panel.

In Fig. 13 is illustrated a totally enclosed control gear equipment for anchor duty where the resistance elements are designed for continuous operation. In this particular instance the rated full load duty is 56 h.p. and the cubic content of the control gear case is 400 cubic feet. In general, control gear of the manually operated type for power ratings up to 50 h.p. on a 220 volt circuit has proved satisfactory for marine service conditions. Above such a rating of 50 h.p. control gear of the automatic contactor type is preferable as affording instantaneous arc suppressing qualities when breaking circuit under full load conditions.

Section 5. Switchgear and Distribution.

The main switchboard installation may be termed the electrical centre of gravity, furnishing the link between the generation and distribution of electrical energy throughout the ship. For all the auxiliary services it is conventional practice to employ open type switchboards, either of the block panel or skeleton type, i.e. insulated bars mounted on a framework, as is customary for naval work. The principal detail is the generator circuit breaker, which should be designed to resist concussion during heavy weather and continuous vibration of the ship's structure.

All links and tripping mechanism should be designed to resist pitching and rolling conditions of the ship.

The main busbars and circuit breaker connections should be supported in a very robust manner, and all rear connections where joints are made should be tinned and riveted together.

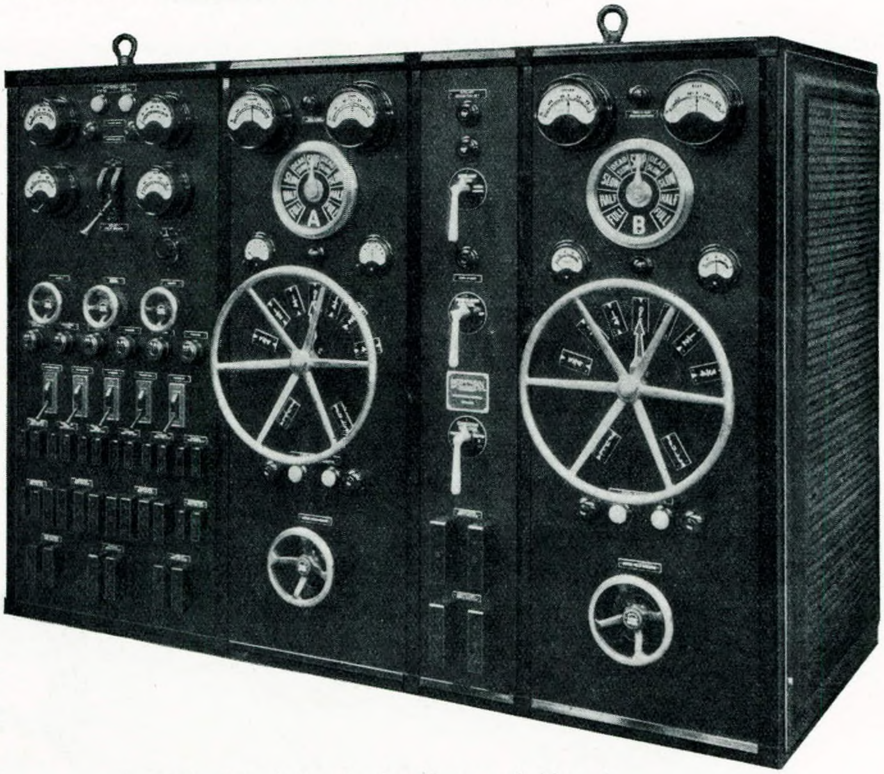


FIG. 15.—Diesel-electric ferryboat switchboard.

All bolts and rear stud connections should be definitely locked by means of double nuts to ensure tight contact permanently.

Overheating of contacts and jointed connections is generally traced to imperfect "facing" of surfaces or insufficient pressure of contact rather than electrical overloading.

The increase in the electrical drive of auxiliaries and hotel services has correspondingly extended the dimensions of main controlling switchboards and as the total generating plant capacity will vary from 10 per cent. to 15 per cent. of the main propulsion power a modern passenger liner of, say, 20,000 s.h.p. will require a main switchboard approximately 30ft. in length, thus controlling 80 h.p. per foot. In some instances it has been found necessary, due to space limitations, to sub-divide the switchboard into two or three sections when arrangements for electrically coupling the sections by means of busbars carried in overhead trunking are necessary. The

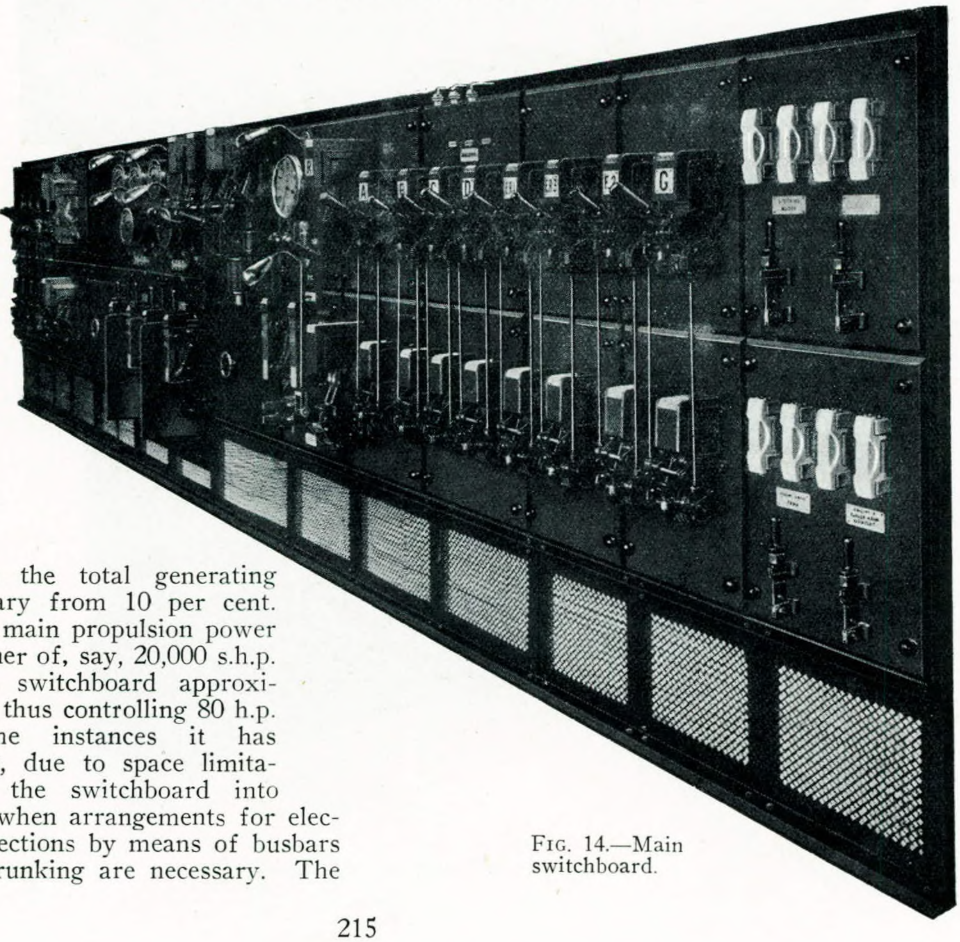


FIG. 14.—Main switchboard.

location of the switchboard is usually on a platform in the engine room, athwartships and adjacent to the generating plant or, alternatively, the switchboard is self-contained with generators in a separate dynamo room.

A typical open type switchboard as fitted in a large passenger liner is shown in Fig. 14.

The increasing size of marine switchboards suggests that consideration might with advantage be given to some alternative design with a view to reducing size and weight. In this connection the more general introduction of sheet steel cubicles of the dead front type is advocated.

The enclosure of all live contacts is not only in the direction of increased safety but is in accordance with the latest electrical practice in industry, and is a further safeguard against the risk of fire spreading.

Fig. 15 illustrates a complete and self-contained switchgear unit of this type fitted in a Diesel-electric ferry boat in this country for the control of the main propulsion units. Such dead front switchboards or cubicles are being increasingly used for all the auxiliary services in American and Continental owned ships, but in this country their use so far has been restricted to electrically propelled ships, where due to the high voltage of the generating units complete enclosure of all live parts is essential.

A further recent and most useful development in connection with sheet steel cubicle switchgear is indicated in Fig. 16, which represents a master control board installed in a large modern factory.

Superimposed on the panel there is a mimic diagram, which is virtually an illuminated diagram of connections and is actuated as the various switches and apparatus function, thus establishing a visual review of the complete electrical installation for the guidance of the operating engineer.

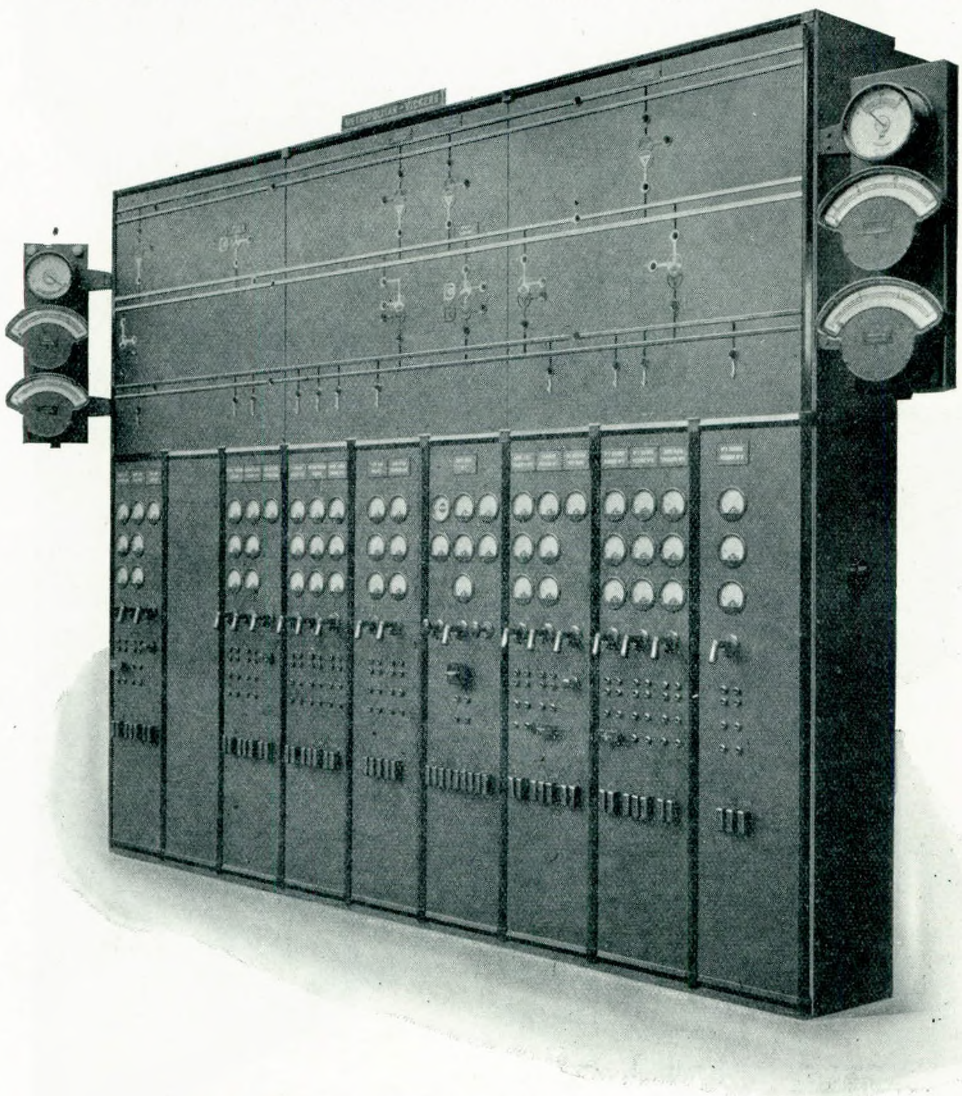


FIG. 16.—Industrial dead front board.

Modern systems of communication and the many types of signalling arrangements, together with the steady performance of turbines and other prime movers render it permissible to remove the point of electrical control from close proximity to the machines, and to institute remote electrical control.

The increase in switchgear capacity for controlling the individual generating units has reached a stage where, due to the physical effort required to close heavy current circuit breakers, attention might be usefully directed to the question of electrically operated breakers and switches. This in turn may eventually result in a redistribution and re-grouping of the main distributing points, electrically controlled throughout the ship from a central main control board. This follows the lines now generally adopted by Municipal Authorities and large industrial undertakings as the safest and most efficient method of control.

ELECTRICAL LOAD ANALYSIS.

It is both interesting and instructive to analyse the electrical load or "make-up" as demanded by the various services throughout the ship from the electric generating plant.

In the case of a present day trans-ocean liner the electrical load may be divided under the following main headings with the approximate power demand equated in terms of specific requirements as follows :—

Engine room and hull services ...	0·20 kW. per person
Heating and cooking	0·20 „ „ „
Ventilation	0·20 „ „ „
Refrigeration	0·15 „ „ „
Lighting, etc.	0·25 „ „ „

Thus under average voyage conditions the load totals approximately 1 kW. per person on board.

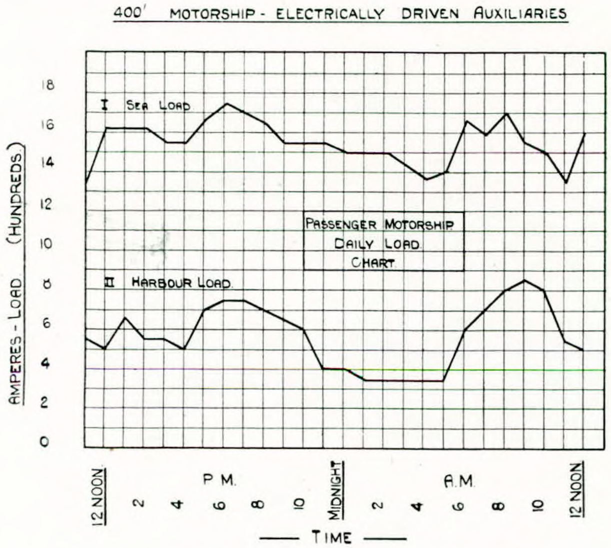


FIG. 17.—Daily load chart from 400ft. ship. (Voyage data: passengers 250, personnel 140, total 390; maximum load 385 kW.; average load 340 kW.; minimum load 297 kW.).

DAILY LOAD CHART.

In connection with a 400ft. motor liner curves of voyage and harbour loads for 24 hour periods were carefully logged, and the mean results of these are given in Fig. 17, whilst in Fig. 18 is shown the graphical record of the current demand over 24 hours as determined from readings recorded in a 20,000 ton liner during a regular passage on the North Atlantic service.

ELECTRIC COOKING LOAD.

The increasing adoption of electric cooking on

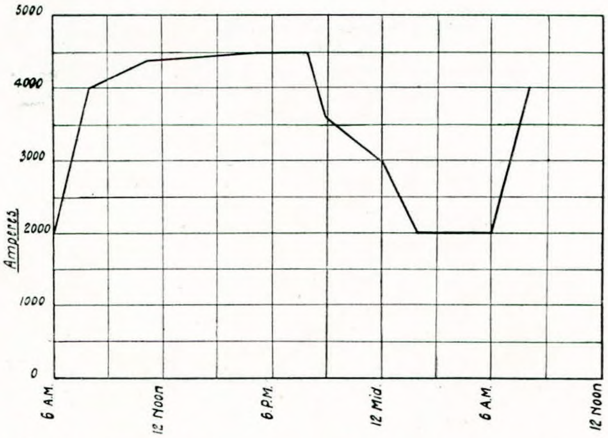


FIG. 18.—Typical load curve for auxiliaries and hotel services of an Atlantic liner.

board has necessitated a substantial increase in the power supplied for galley services, and power records taken in various ships and translated into terms of individual demand are shown in the curve in Fig. 19. This affords a useful indication of the total consumption of electrical energy for cooking requirements for ships carrying between 200 and 2,000 passengers.

ELECTRICAL LOAD DIAGRAMS.

To analyse the electrical loading of the ship's

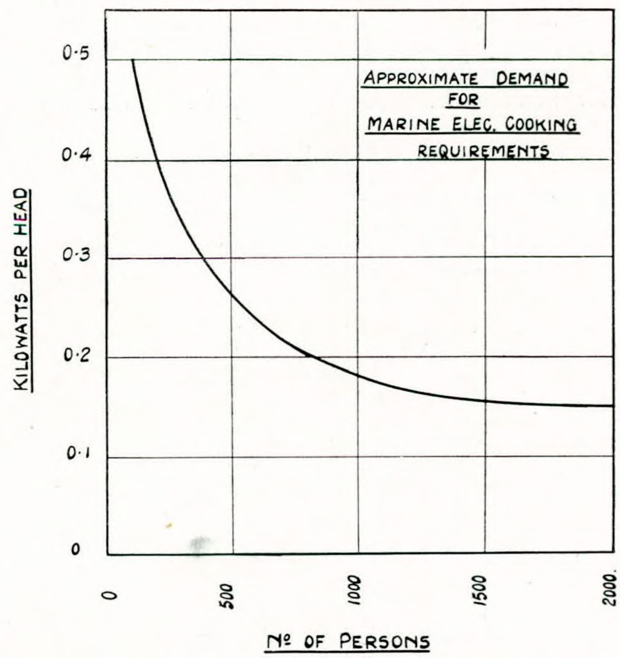


FIG. 19.—Galley service.—Electric cooking demand.

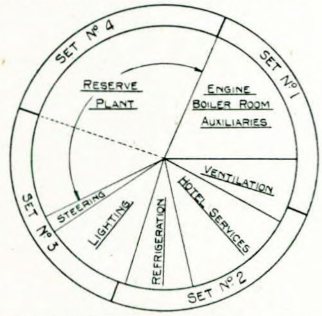
services in detail, records obtained in two typical ships have been collated :—

(*a*) 600ft. Turbo-electric Liner.

(*b*) 485ft. Cargo Motor Ship.

600' TURBO-ELECTRIC LINER
TWIN-SCREW
TOTAL AUXILIARY GENERATING PLANT 4 x 500 KW = 2000 KW.
ELECTRICALLY DRIVEN AUXILIARIES
TOTAL B.H.P. OF MOTOR INSTALLED = 3000

ELECTRICAL LOAD DISTRIBUTION ON VOYAGE



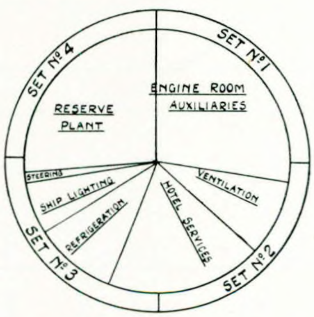
ANALYSIS OF SEA LOAD							
	STEERING	LIGHTING	REFRIGERATION	HOTEL SERVICES	VENTILATION	ENGINE & BOILER ROOM	TOTAL
KW	30	200	250	250	150	350	1230

DETAILS OF ELECTRIC MACHINERY								
	DECK MACHINERY	REFRIGERATION	VENTILATION	ENGINE & BOILER ROOMS	WORK SHOP	GALLEY & HEATERS	STEERING	VARIOUS.
MOTOR H.P.	935	400	300	900	100	300	70	250

FIG. 20.

The auxiliary plant installed in the electrically propelled ship is of roughly twice the aggregate power of that fitted in the cargo liner. The load diagrams relating to these ships, typical of each type, give the normal voyage load demands and also indicate the amount of reserve plant available after meeting average requirements. These load diagrams are given in graphical form in Figs. 20 and 21.

485' CARGO MOTOR SHIP
TWIN SCREW 8000 TONS.
TOTAL AUXILIARY GENERATING PLANT. 4 x 270 K.W. SETS = 1080 K.W.
ELECTRICALLY DRIVEN AUXILIARIES
TOTAL B.H.P. OF MOTORS 700 H.P. VARYING FROM 0.5 TO 150 H.P.
TOTAL Nº OF LIGHTING POINTS = 1500



ELECTRICAL LOAD DISTRIBUTION - CARGO MOTOR SHIP

ANALYSIS OF SEA LOAD							
	SHIP LIGHTING	STEERING	REFRIGERATION	HEATING, COOKING & LAUNDRING (HOTEL)	ENGINE ROOM	VENTILATION	TOTAL
K.W.	75	15	100	200	300	100	780

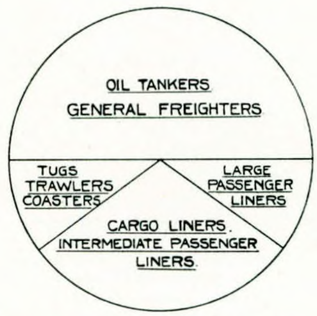
FIG. 21.

Electrical requirements vary considerably with the type of ship and nature of the propulsion unit. Thus a steam propelled ship of 8,000 tons may require electrical plant of 50 kW. capacity only, whilst a motor ship of similar size equipped with electrically driven auxiliaries may require from 500 kW. to 700 kW. electrical generating plant.

Generally speaking the electrical requirements of a ship increase steadily above propulsion powers of 3,000 h.p., and the major interest of the electrical industry is confined to approximately 40 per cent. of classified tonnage.

During the past three years the advent of motor coasters, which are superseding large numbers of small steamers engaged in coastal services has further extended the adoption of electrical plant in marine service. This, it is suggested, is another indication of the reliability of electrical equipments in general.

CLASSIFICATION OF TONNAGE
REGISTERED IN U.K. 1933



TOTAL H.P.	CLASS OF VESSEL	% OF TOTAL
100-800 H.P.	TUGS, TRAWLERS & COASTERS	10 " "
800-3,000 H.P.	GENERAL FREIGHTERS & TANKERS	50 " "
3,000-10,000 H.P.	CARGO-LINERS & CROSS CHANNEL STEAMERS	30 " "
10,000 H.P. & ABOVE	PASSENGER LINERS	10 " "

FIG. 22.

Fig. 22 represents the average classification ratio of tonnage in the United Kingdom, and is given as a matter of general interest. It should be observed that in all tonnage represented therein there is electrical plant, if only for lighting services, even on board the smaller craft. Although 50 years have elapsed since the introduction of electric lighting on board ship it is worthy of note that there is as yet no reliable alternative to this form of illumination.

Section 6. Electric Propulsion of Ships.

Since the War there have been intensive research and experiments in connection with the many variations and forms of marine propulsion.

Exhaustive reviews of all existing methods of propulsion and progressive ideas regarding the latest developments over the entire region of applied science have occupied the serious attention of all who are associated or identified with marine engineering. Within this area of thought all devices for the establishment of economy and efficiency have been considered and assessed. In no period of the history of marine engineering have there been such fundamental change and striking results as recent years have yielded, necessitated by economic factors and the poverty of shipbuilding activities.

The electric propulsion of ships, though associated with the consideration of marine electric applications, is a subject too wide for analytical treatment in this paper. Much has been written and many discussions have taken place before various institutions concerning the possible advantages to be obtained by the adoption of electric propulsion for specific and definite service.

During the past few years alone there have been actual and notable applications of electric propulsion in a number of ships, which will, within the next few years, afford testimony based upon operating experience with this drive.

Electric propulsion of ships, the reclamation of energy from waste heat in steam reciprocating and Diesel engine plants, and the utilisation of higher steam pressures and higher temperatures have necessitated and received mature consideration. Electric propulsion in this country has now reached a stage of practical consideration as distinct from academic interest.

From the trend of the latest practice in marine engineering it would be idle to claim that the electric ship offers a simple solution of all problems identified with sea transport services. Electric propulsion is an innovation, and as such will be subjected to careful investigation and experiment by marine engineers.

The close of the first century of mechanical propulsion of ships presents to the shipowner a difficult problem regarding final choice of the form of propulsion to be adopted in new tonnage.

From the complexity of the many types of propulsion with attendant variations in hull form, propellers, and additive components, decision can only be effected by the process of elimination, not infrequently resulting in compromise. The best ship and drive for the projected service is not, however, solely a question of engineering and of the maximum economy in fuel consumption. The merits of each type of propulsion can only be determined in each individual case by consideration of :—

Initial cost.
Schedule of service.
Nature of trade considerations to meet the shipowner's requirements.

Close co-ordination between shipowners, shipbuilders and engineers generally results, however, in the best ship for the particular service being decided upon in each case.

The chief claims for the electrically propelled ship are :—

(*a*) Maximum flexibility of control.
(*b*) Reduction in noise and vibration.
(*c*) Clean engine room layout.
(*d*) Correct and continuous power recording.

Special services offer definite opportunities for the grouping of electrical machinery to obtain maximum economy, and these are most valuable considerations, especially in luxury liners or high class passenger ships.

The year 1932 produced a notable succession of electrically propelled ships and reached the highest mark yet recorded in any year for British shipbuilding with this form of drive.

The latest application of the turbo-electric drive in a quadruple screw ship, the first of its type in the mercantile marine, is an outstanding event in marine engineering. The history of marine engineering and naval architecture in this country

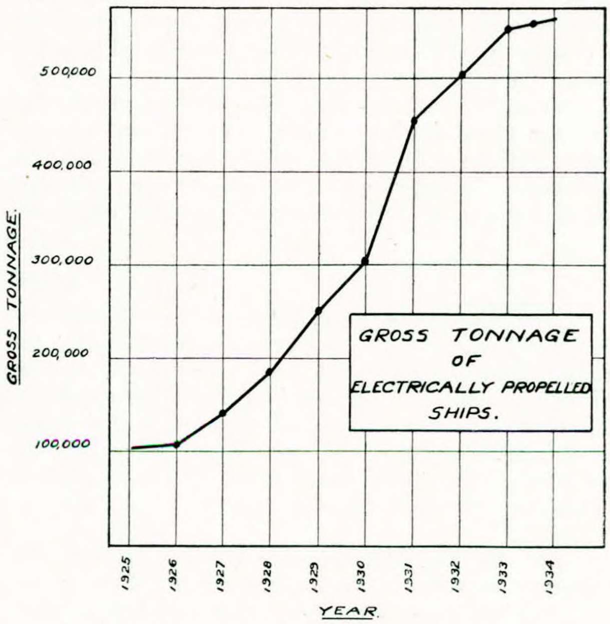


Fig. 23.—Electrical propulsion tonnage.

has, however, effectively demonstrated that whilst being somewhat reluctant to accept changes, shipowners will eventually adopt any scheme of proved merit.

It is impossible to arrive at rigid conclusions regarding any form of drive, and each individual case must be decided according to the type of vessel and the specific service to be met. The progress of electric propulsion in this country, while slower than that recorded by America, is definite, and a comparison of electrically driven tonnage completed during the last ten years, compiled from published information, is as follows :—

U.S.A.	140 ships.	Approx.	350,000 s.h.p.
U.K.	26 „	„	162,000 „

The growth of electric propulsion during the last ten years as recorded by Lloyd's Register of Shipping is shown in Fig. 23, which includes ships equipped with turbo-electric and Diesel-electric drives for main propulsion purposes only.

The author wishes to thank the Metropolitan-Vickers Electrical Co., Ltd., for the loan of blocks and illustrations, and for the facilities afforded in connection with the preparation of this paper.

The author prefaced the reading of the foregoing paper with the following remarks:—

It was now over 50 years since electricity was first introduced on board ships, and then only for a restricted scheme of illumination. Electric lighting at sea was then on trial.

That period, which had been of tremendous historical and engineering significance, had seen the introduction of the turbine (which opened the way to increased powering of ships), a new prime mover for marine service in the Diesel engine, and also the introduction and full development of electricity in marine applications as represented by the electrically-propelled passenger liner.

Planning the electrical installation for a large passenger liner to-day was a project demanding considerable thought and ingenuity, and represented a distinct phase of marine engineering. The standard of electrical apparatus manufactured for ship service in this country was comparatively high, and this was to be attributed to the uniform and unvarying standards adopted by the British Admiralty in past years. This precedent had wisely been followed by the shipping authorities and marine engineers of this country, thereby maintaining for the Mercantile Marine correspondingly high-grade apparatus.

Progress in steam generation and plant on ships had been steady, and during the last ten years distinctive and rapid. Greater knowledge of the structure and behaviour of metals and the employment of increased temperatures had created a high standard of marine engineering technique and new values of economical efficiency. To that achievement the electrical industry had made a definite contribution by:—

(*a*) Developing and producing apparatus for the safer navigation of ships and the safeguarding of human life;

(*b*) Improving the performance and efficiency of ships' equipments by the electric drive of the auxiliaries;

(*c*) Producing electrical apparatus representing the most accurate method for the measurement of energy;

(*d*) Assisting in the improved standard of accommodation and services on board ship.

Discussion.

The Chairman complimented the Author on the excellence of the paper and referred to the added interest it would have for those of the Members who were present at the recent visit to the Works of the Author's Company, where many of the units illustrated in the paper were actually on view. He then invited Mr. G. O. Watson (Member) to open the discussion.

Mr. G. O. Watson (Member) said that The Institute was to be congratulated on their policy of including papers on electrical subjects in their programme, in view of the important and essential services to which electricity to-day was universally applied. The author was likewise to be congratulated on the manner in which the subject was presented. The graphs and schedules were of the kind which assisted progress and were helpful in the creation of new standards and specifications.

With regard to the early application of electric lighting to ships the author mentioned the s.s. "Servia", but he did not give the exact date. So far as the speaker's own investigations had gone the earliest applications in merchant ships which he had traced were the Pacific Steam Navigation Co.'s s.s. "Mendoza" and the Inman Line's s.s. "City of Berlin", both of which were fitted with electric lighting at the end of 1879.

It seemed a pity from the practical point of view that the author had included the "Normandie" figures in Table 1 and Fig. 1. Much as one admired the foresight and enterprise of her owners in installing such a large electrical plant, it was a mistake to quote the figures as typical of 1934 practice. It was rather like saying that in 1933 mothers in Canada produced five children at one birth as though it were quite the usual thing. Table VI gave a truer picture and it might be said that anything over 3,000 kW. was the exception rather than the rule. An interesting addition to the latter table would be the case of the cross-Channel motorship "Prince Baudouin" completed last year. The particulars of this vessel were:—

Length	354ft.
Breadth	46ft.
Depth	25ft.
Gross tons	2,750
Knots...	$23\frac{1}{2}$
Screws	2
S.h.p.	17,000
Aux. gen.	4×480 kW.
Total gen.	1,920 kW.
Aug. gen. per cent. of prop. power	11·3 per cent.

On the question of oil engine governing, $2\frac{1}{2}$ per cent. permanent variation was mentioned. He doubted if this was ever achieved in practice. The

B.S.I. requirement was 3½ per cent. and this was borne out by Fig. 3.

With regard to the consumption of electricity per person on board it would be interesting to know the figure for hotel service alone, neglecting engine room auxiliaries; also the extent to which it varied with the complement of passengers. That was to say, how would it vary between say full complement and half or quarter of full complement?

He agreed with the Author's suggestion as to the classification of enclosures for motors, but with regard to the water pressure test, he thought it would be more practical to specify immersion under water and the application of an internal air pressure of predetermined amount.

With regard to winches a good deal remained to be done in the direction of settling the rating of cables for supplying them and it was hoped the discussion would result in something practical forthcoming. The factors were these. Consider the chart shown in Fig. 6A and observe the wide fluctuations in amperes. From the point of view of the motor it had become fairly well established that a half-hour rated motor was satisfactory for the general run of winch service. Actually in practice the full load rating of the winch was not hoisted with every lift, and, as stated by the Author, there was a limit to the rate at which the stevedores could either stow or break out cargo. Three main factors entered into the rating of a winch motor, viz., maximum load, speed and foot-tons per hour. In practice a small load per lift with a continuous succession of long lifts could be a more severe trial on a motor than a few lifts at maximum load. With so many variable and indefinite factors it was somewhat difficult to arrive at a logical basis for the rating of the supply cables. It did not follow that because the motor was half-hour rated the cables should also be half-hour rated. The correct method of arriving at the rating was to take a continuously rated cable equivalent to the root mean square or R.M.S. value of the load. This presupposed that the exact values of load in relation to time for the worst conditions were known, which unfortunately was not the case. The problem was somewhat akin to that of the tramp who remarked, "If we 'ad some 'am we could 'ave some 'am and eggs, if we 'ad any eggs".

The question of cable ratings therefore, at the moment, boiled down to an arbitrary basis which might or might not be the best for a particular case. Superintendents and owners could therefore be of great assistance by disclosing the results of their experience. Were failures of winch cables frequent and if so were they due to their being overloaded? The problem was really divided into two sections, viz., the cables to individual winches and cables supplying a group of winches. In the latter case the number of winches, method of working, arrangement of hatches and nature of the cargo entered into the problem.

There were many other problems arising from this paper which time did not permit being entered into at this juncture, but there was one which could not be left out. As he had remarked at another Institution on a recent occasion there was the important question of the status and qualifications of the men whose daily job it was to keep the electrical plant in running order. How did the superintendent who was engaging electricians know whether they knew their job? In his humble opinion the time had arrived when "tickets" should be awarded to ships' electricians. By this he did not mean that owners should be compelled to employ such men, but that the men should have the opportunity of acquiring a hallmark of proficiency.

Mr. W. J. Belsey (British Thomson-Houston Co., Ltd.) said that generally speaking he was in entire agreement with the views expressed by the Author, and there were only one or two minor points to which he would like to draw attention.

On page 204 the Author stated that it was standard practice to install for emergency use engine-driven generators of the petrol-paraffin or analogous type. At present it appeared to the speaker that there was a decided tendency to fit full Diesel engine-driven generators for emergency purposes, with the elimination of fire risk from petrol.

On page 205 the Author stated "Conductors having double cotton covering should be employed field coils" and presumably on armatures for small motors. He would submit that a much more satisfactory form of insulation was enamelled wire with single cotton covering, the enamel giving the dielectric strength, and the cotton covering the the mechanical protection. With double cotton covering and perfectly impregnated, the dielectric strength was 300 to 400 volts between adjacent wires, but with enamelled wire and single cotton covering the dielectric strength was just over 3,000 volts, thus greatly improving the insulation between turns, and on small motors where the armatures were wire wound preventing internal short circuit.

Regarding the Author's remarks about trawlers being the hardest-worked vessels, he thought that tankers were equally hard worked, as some tankers to his knowledge were only 3 to 4 hours in port, and were at sea from 320 to 330 days in the year.

In his remarks on switchgear the author did not mention what was now fairly common practice on large ships, viz., selective tripping; that was to say, that if one of the generators failed and an overload was thrust on the generators remaining on the busbars, the non-essential services were tripped out, leaving the essential services running. Whilst on the subject of switchboards he would put in a plea for the use of a smaller type of instruments than was generally used at present. The small scale instruments were quite as accurate as the large scale instruments and occupied considerably less space, and having lighter and smaller moving parts were less liable to damage.

Mr. C. P. Harrison (Associate) said that he was very pleased to note that the Author had drawn attention to the necessity for classifying various types of marine motors, but he did not think the three classes suggested would be the most suitable. The speaker thought that there should be four classes as follows:—

(1) Enclosed ventilated drip-proof motors which had both ventilation on upper and lower halves of the end shield and not restricted to the upper half as suggested by the Author. The maximum ventilation would assist in keeping down weight, space and cost. Such motors must, however, have drip-proof cowls over these ventilation openings. The expression "drip-proof" appeared to be more descriptive than "splash-proof", since the latter term usually implied splashing upwards as from deck washing, and such conditions would not be present for engine-room motors. It was understood that the E.V.D.P. motors would be suitable only for engine rooms or deckhouses where full protection from the weather was given and there was no washing down with hose pipes.

(2) Totally-enclosed motors for engine room or similar below-deck services where full enclosure might be necessary because of oil and damp atmospheres.

(3) Totally-enclosed weatherproof motors which would be suitable for exposed deck services and capable of withstanding heavy seas or a bosun's hose. With these machines it would be necessary to take more care with joints than with the totally-enclosed motor for engine room use.

(4) Totally-enclosed watertight motor. This was virtually a submersible motor and very rarely required.

The watertight motor was a very difficult proposition from a manufacturing point of view and he did not think that any such motors made to withstand 10lb. per sq. in. water pressure would meet the requirements of a truly watertight motor. In any case it was almost as impossible to make a watertight motor as a gas-tight motor, and the weatherproof machine might reasonably be compared with the flame-proof motor which did not necessarily prevent gas getting in but prevented any effects of explosion getting out. It was almost impossible to prevent a totally-enclosed motor breathing, and as a result of experience with troubles of this nature the practice had been adopted of drilling a ¼in. drain hole in the bottoms of totally-enclosed motors (even for deck services), as it was far better to make provision for any small amount of moisture to get away than that the motor should be completely enclosed and trap such leakage.

The experience with ball and roller bearings was of interest and he could say that similar trouble had been experienced on steering gear motors which were in bad positions from the point of view of hull vibration and where a standby motor was installed and sometimes left standing for long periods. Instructions to change over the steering gear motors more frequently had reduced the complaints.

On the subject of electrically-driven winches the Author mentioned the essential requirements, the last of which were facilities for rapid inspection and overhaul. There was no doubt that the winch with its contactor control gear separately mounted in deckhouses had every advantage from this point of view.

The Author had drawn attention to the preference for open-type steam engines on small generating sets, because what was visible to the eye received attention and correct maintenance. This argument surely applied very strongly to contactor control gear for winches. Such control gear locked away in a winch bedplate with a watertight joint and many nuts and bolts to remove was liable to comparative neglect.

With some 150 sets of identical winch control gear mounted in deckhouses the replacements had been negligible and the complaints nil, whereas with a very much smaller number of similar equipments mounted in the bedplates, considerable trouble had been experienced. This contrast was undoubtedly due to the fact that the visible gear was correctly routine inspected and such slight adjustments in contacts, etc., as were necessary, had been made.

Under the heading of "Safety Devices" the Author referred to the difficulty of getting satisfactory slipping clutches, but the speaker did not quite understand why he referred to the mechanical slip being set at a figure below the electrical protective device. Surely it was common practice with winches and windlasses to set the stalling relay (which would work accurately at any figure) to trip out all running contactors except the first, thus putting all resistances in circuit. This resistance would carry full load current continuously, and the winch or windlass could therefore be stalled quite safely. An additional overload relay would trip if due to any electrical fault there was a still more excessive current.

The Author stated that all control gear must be provided with means for completely isolating the *starter,* in other words, an isolating switch, although the illustration in the paper did not appear to show such switch. He believed the classification societies were quite satisfied providing the *motor* was isolated when the starter was in the "off" position, but should any attention to the starter be necessary it could be isolated in any case from the distribution board, and a separate circuit to each motor must be provided to comply with classification rules. It was essential, however, that when the engineers saw the starter in the "stop" position, or when they pressed the "stop" push button, they should be safe in assuming the motor was isolated.

The dead-front type of switchboard suggested as being probable future practice for ship work was, he thought, subject to the same criticism as the winch bedplate-mounted contactor gear, namely, that the open-type board was far more suitable because it was very accessible and with the comparatively simple distribution circuits used on board ship, the operator could easily see which circuits were closed and which open. This simplicity really disposed of the necessity for any illuminated diagram. Under present conditions head room was already drastically limited, and any addition of a diagram on the lines of the illustration in the paper would be impossible.

Mr. J. A. Jaffrey, M.Sc. (Lloyd's Register of Shipping) said that the problem of torsional oscillation had come into prominence since the advent of the Diesel engine. It might not be generally known that torsional oscillation did not reveal itself by the presence of vibration. A Diesel generator set might appear to be running satisfactorily and quite free from vibration, but still suffer from the dangers arising from torsional oscillation. The results might show up after a few months in service, but generally speaking the troubles that had arisen were after a period of years. Fundamentally, the torque from the Diesel engine was not constant and it was the variation in torque which gave rise to the trouble. It was well known that a complex form of wave shape might be resolved into a number of sine waves of different frequencies, and the complete unit of Diesel engine and dynamo must be such that the natural frequency of torsional oscillation did not synchronise with any of the sine waves which went to make up the complex wave of the torque or turning effort of the Diesel engine. In simple language, the speed at which the armature, crank shaft and pistons, etc., were moving during the course of one revolution was at some instants greater and at other instants less than the mean speed of one revolution. It was an actual fact that if the combined unit had not been checked for torsional oscillation, the torque might be as high as eight times the normal full load torque on various parts of the combined unit. The Diesel engine was the fundamental cause of the trouble, and in any case the calculations were usually made for a Diesel engine in a new and balanced condition. After having been in service certain cylinders might not be functioning properly, so that the actual torque diagram of the Diesel engine would be different. In spite of calculations and design, it was not commercially possible to obtain a constant torque from the normal Diesel engine, and so the torque on certain parts of the unit would always be greater than the mean torque. The chief weakness in the dynamo armature was the drive of the laminations. It had been the normal practice in manufacturing firms to work to limits. This simply meant that a tolerance of a few thousandths of an inch was allowed on the diameter of a hole, and similarly the portion which fitted the hole also had a tolerance of a few thousandths of an inch. It would often be found as a result that the hole was on the large size and the shaft on the small size, which resulted in a poor fit. Normally, however, even with this state of affairs, the hub or spider was sufficiently well driven, as it was an interference fit on the shaft, and the key was provided in addition. In the case of the core, however, a different case arose; the laminations were built up and an interference fit could not be used. The evils of limits were very obvious. The keyway in the spider for the key driving the laminations was cut to limits; the key was afterwards fitted by hand to the keyway in the spider; the laminations were then built up on the key, and if no other precautions were taken it would be found that there was a clearance between the key and the sides of the keyway in the laminations. It was a particular fault in engineering practice that keys were incorrectly fitted, especially blind keys; it often happened that the key was fitted to the keyway in the shaft, and the half coupling, spider, or whatever it might be was pressed on without any reference to the fit that would be obtained with the key, as fitted to the blind keyway in the shaft, and the keyway in the member which was pressed on to the shaft. In the case of reversing drives, the manufacturers themselves went to the trouble of fitting folding or taper keys, often broaching the keyways of the two members concerned before the keys were fitted. From this point of view, the keyways in the spider should be broached together with the keyways in the laminations before the fitting of the keys.

In any case a torsiograph record should be taken of every Diesel generating set when in operation. No matter how carefully the calculations were made, certain factors had to be assumed, and a very definite check of actual operation was given by the torsiograph record.

The end plates clamping the laminations were usually of considerable weight, and strangely enough a positive drive was not always provided. These end clamping plates should be positively driven either by dowels or a fitted key.

From the practical aspect of the generator, the presence of torsional oscillation resulted in the relative movement of the parts comprising the rotating members. Generally, it was the laminations which moved relative to the spider, or it might be that the commutator risers fractured. These were the two more general troubles, although occasions had arisen when the arms of the spiders themselves had cracked. The movement of the laminations could very often be discovered by the cracking of the paint against the spider arms, or even by the presence of ferric oxide. The commutator risers usually cracked near the point where they were sweated into the commutator segments, and the beginning of the trouble might often be seen by scraping the risers at this point and the use of an ordinary magnifying glass. It must be understood that these troubles were not instantaneous; they gradually developed over a period of time, and if discovered early on by the use of the torsiograph, further development of the trouble could be prevented.

With regard to the rating of generating plant, a point that did not seem very obvious was the question of cost relative to rating. The cost of an electrical machine was determined by:—

(*a*) the lowest speed at which it had to run;

(*b*) the highest voltage it had to give; and

(*c*) the largest current it had to carry.

For instance, a motor rated 100/200 h.p. 220 volts 500/1,000 r.p.m. was a 200 h.p. motor at 500 r.p.m. The point was that the amount of speed variation necessary should be kept as small as possible. A simple way of remembering the fact was that the armature had to have a sufficient number of conductors on it to give the voltage at the lowest speed, and these same conductors had to be capable of carrying the current required for the largest output. It was little or no advantage to the manufacturer to know that the machine had to give half power at half speed; in certain exceptional cases an advantage did accrue from the increased cooling due to windage at the higher speed.

It should be particularly emphasized that at the lowest speed in the case of variable speed motors, and in the case of all other constant speed d.c. machines, the shunt field was on full load continuously. The armature might be on a very light load, but the shunt field was always on full load in the conditions given above. Generally, it was easy enough to insulate a shunt field spool from earth. The trouble was between turns. Double cotton-covered impregnated coils gave the best results. The trouble usually occurred at the four corners, as might be expected. The radius at the corners was fairly sharp and, during the winding, the double cotton covering would appear to give a better cushioning and centring effect than any other form of insulation. As in so many other cases of insulation, it was not a question of the breakdown strength of the insulation but of the physical deterioration that occurred during the manufacture of the finished article. In the case of the shunt field spool it was more a question of mechanical thickness of separation at the corners rather than of the dielectric strength of the insulation.

Bearing all these points in mind, it was obvious that shunt field windings worked under the worst conditions, and the final criterion was that of the maximum temperature at which the cotton would operate without deleterious effects. It was not so much a question of temperature rise as of the maximum total temperature to which the cotton was subjected, and as a rough guide the internal highest temperature of the coil was about 20° C. higher than that recorded by a thermometer on the surface. Moreover, cotton was very hygroscopic and it was essential that the impregnation be very thorough.

As a very obvious example of the above remarks, there was the case of steering gear motors. These machines were usually working on a load the temperature effects of which were very much below those of the full load rating of the machines, but, and a very important but, the shunt fields were on full load continuously.

Small motors were much more difficult to design from a purely electrical point of view than larger machines. The percentage of insulation relative to size of conductor was obviously much higher, and it was usually a case of finding sufficient room, quite apart from the consideration of making the motor as compact as possible. Physically, it was not possible to get inside a large number of small machines to clean them. Again a large number were equipped with fans at the back end. These fans drew all the dirt and the carbon dust from the brushes through the machine as a general rule. The present general practice was to make small machines with ring frames, i.e., not split on the centre line. All these things resulted in the great problem of inaccessibility. There was no doubt that if the smaller machines were more accessible, fewer troubles would be experienced. There was one type of fan now coming into use wherein the motor and fan were mounted as a unit in the ventilating trunking. The writer knew of one particular example where no inspection covers were provided, and in order to look at the motor four hours' work were necessary to pull the whole trunking down complete with motor and fan. This was perhaps an exceptional case, but it was an actual case, and had bearing on the question of accessibility.

This led to a consideration of great importance which appeared to be overlooked, especially in the smaller type of machines used in marine work. Long, extra long, creepage surfaces should always be provided; much greater than was normal practice on machines used on land. Machines were inaccessible and should therefore have longer creepage surfaces. The thickness of insulation might be such as would withstand kilovolts, but the creepage, i.e., the surface, was such that 220 volts or 110 volts would cause trouble. Dirt, salt, oil, all sorts of impurities, became deposited on the surface, forming a conducting path; an arc took place and insulation was destroyed.

It might not be generally realised that the cable used for the wiring on board ship would withstand a breakdown voltage of the neighbourhood of 20,000, but it was not probable that when an installation was made on a vessel that anything approaching 5,000 volts could be applied. Now one cause of this was again that of creepage surfaces. Consequently, no matter what the apparatus was, whether it be a simple lampholder or a main propulsion motor, the point to be borne in mind was that of creepage surfaces. All the controversy of enclosing and not enclosing and the fact that open type machines appeared most satisfactory, were probably due to the fact that the operating staff could keep clean the creepage surfaces of the open type machines.

With reference to ball and roller bearings, one of the chief causes of the trouble was pinching due to incorrect alignment; this was especially true of roller bearings. Most of these troubles might be cured by the use of bearings with self-aligning features. The other major cause was corrosion, and the chief preventative was the provision of a film of oil or grease to protect the working parts. An unsuitable form of grease was one cause of trouble; the grease was squeezed out from between the rollers or balls and gradually hardened into a solid mass, and the actual working surfaces were not protected. If an attempt were made to inject more grease, none would enter and it was concluded that the bearing was full. It was good practice to inject a small quantity of oil occasionally to soften the grease if the bearing could not be dismantled and thoroughly cleaned. Alternatively, during hot weather, especially with deck machinery, the grease might run and escape. It would be an excellent thing if the inspection of the bearings could more easily be made, and it was suggested that manufacturers should provide means for easily exposing the whole of the bearing, in addition to the normal greasing plug. It was possible to obtain bearings made from stainless steel.

Sleeve bearings should be provided with oil level gauges as well as overflows. Moreover, in single bearing machines, especially where the back-end half coupling was bolted to a flywheel, the bearing should be provided with spherical self-aligning features.

Mr. A. F. C. Timpson, M.B.E. (Member) pointed out that although he quite realised that robust designs of electric generators were installed in trawlers it was perhaps very much overstating the case to maintain that these were functioning 300 days per annum, as it was improbable that the electric light would be available during a considerable portion of the voyage. On the question of safety devices for windlasses and capstans, he would draw the Author's attention to the possibilities of epicyclic gearing, introduced between the motor coupling and the gearing for the windlass or capstan proper. Gearing of this type was formerly fitted on a well-known make of motor car and provided excellent slipping facilities which were practically stalling features. The bands holding the drums were easily adjustable and comparatively cheap to renew. Investigation along these lines might provide the type of slipping clutch which the author required. The Author mentioned electric hydraulic steering gears. For smaller powers of up to, say, 30ft.-tons torque a simple type of gear with right and left hand plate clutches running in oil and a standard design of hunting gear had already proved itself in service, and was much less costly to install. With larger steering gears, difficulties were experienced with this design owing to the heat generated in the clutches and the difficulty of dissipating this heat. He agreed with the Author that with either design it was desirable to fit a continuously running motor. The Author in his paper dealt exclusively with direct current supplies. In a recent paper read before The Institute it was stated that within the next few years it was probable that most vessels would be fitted with alternating-current motors, and that motors of the squirrel-cage type were likely to prove the most reliable in service, and the lowest in first cost. Presumably, with this design there would be difficulty in supplying types other than constant speed motors, and there would also be difficulties in arranging quick reversal, so that with the prospect of alternating current it would seem desirable to introduce mechanical features rather than electrical features for the control of winches, windlasses, capstans and steering gears, and for controlling the output of engine-room auxiliaries.

Mr. F. M. Jones, B.Sc. (Member), said that the paper was very comprehensive, covering practically the whole range of electrical applications to marine work, and as these had enormously increased during recent years it was obviously impossible to expect the Author to go into much detail. It would appear that the time had now come when papers on this subject should be limited to one, or at the most two sections, which would enable the author to deal with them in a full and detailed manner.

Mention had already been made of the small engine-driven dynamo sets for trawlers and coasters. Referring to the particulars on page 203, the r.p.m. of the small-sized sets was lower than that of the larger sizes, in contrast to the general rule that the r.p.m. went down as the size went up. They had been told that the open type was very much in favour for this class of work. This had been the case until about four years ago (he was referring more particularly to the smaller class of steam propelled coasters and cargo boats, where 10 - 15 kW. was installed), but now the tendency was to install the enclosed, forced lubrication engine. The open type engine was going out of favour and its place was being taken by the enclosed type, which was just as reliable, required no attention, and was cheaper to maintain.

With regard to Fig. 1 showing the increase in individual plant capacity, he assumed that when plotting the curve the author took the maximum size in each year. It was not an average?

In reference to the rating of generating plant and the 25 per cent. overload, for many years those who were responsible for drawing up specifications had retained this clause covering a 25 per cent. overload on dynamos, and it often led to some confusion as to whether the prime mover also had to be capable of the overload. Complete generating sets were often referred to as "the dynamo"; in particular the emergency set was often called "the emergency dynamo", and when stipulating an overload of 25 per cent. for two hours, this was intended to refer to the dynamo only, and not the engine. When the prime mover was a steam turbine there was usually no difficulty in giving the overload required on the dynamo, but in the case of Diesels, nearly every manufacturer only allowed for 10 per cent. Shipbuilders and manufacturers were sometimes confused as to what the prime mover had to develop, and it would be helpful if specifications laid down what overload, if any, was required of the complete set.

Regarding the statement on page 217 that "Under average voyage conditions the load totals approximately 1 kW. per person on board", this could hardly be taken as an average, because every ship differed in this respect, and the installations varied according to a very large number of divergent requirements. Table VI indicated that. If the statement were correct there would be 13,000 people on the "Normandie" and 9,100 on the "Queen Mary", and so on throughout the list. There was hardly an instance in that list where the number of kiloWatts installed was the same as the number of persons on board.

On the proposal of the **Chairman,** seconded by **Mr. F. J. Mayor** (Member), a very cordial vote of thanks was accorded to the Author, who suitably replied.

By Correspondence.

Mr. F. A. Pudney (Member) approved of the Author having confined his paper to certain aspects of the use of electricity aboard ship, other than for main propulsion. Opinion seemed to be divided regarding the commercial success of its application as a main propelling force, however efficient the system might be from the technical point of view. For other duties aboard ship under modern conditions, electricity was unsurpassed.

Under the heading "General Design Features" exception might be taken to the Author's suggestion that Diesel engine-room conditions were unsatisfactory. While it was true that there were certain well-known motor vessels of earlier type afloat in which the conditions in the engine-room were bad, modern installations were operating under reasonably hygienic conditions.

He agreed with the Author in emphasising that electrical machines must be specially designed to suit marine conditions. He had once inspected a fruit ship in Genoa which had a main propelling motor operating under vile conditions, in a sort of lumber hatch which had been flooded; consequently the unit broke down and the whole system had to be replaced. The motor was of the open type, and was so placed that the field coils were far too near the bilges. Dampness was a real source of danger to electrical plant, but troubles also arose through the painting of leads in positions where they took time to dry out.

There appeared to be considerable variations in the load factor on marine electrical plant during the twenty-four hours, and it would be of interest if the Author could illustrate this by any available data.

He asked what were the real differences between a watertight motor and a totally-enclosed one? Also was the term "submergible" a play on words, or had the makers of electrical plant evolved these various types?

Traction motors operated under very bad conditions, but seemed to stand up to their work very well. He wondered whether they were assisted in any way by the motor suspension bar "spring" feature, which appeared to have an elastic effect not always noticed in connection with deck machinery. Would not the adoption of this feature in marine units prevent a certain amount of "stalling"?

As illustrating an example of totally-enclosed motors which were operating satisfactorily under the difficult conditions of continuous service, he offered the accompanying photograph.

In connection with the Author's desire for simplification of control gear, which he fully supported, the illustration also indicated what was being done by the Italian Navy in having continuously running motors for various services, such as ammunition hoists and armament control, all operated if required from remote positions, as well as with "close up" control. The interesting feature of the assembly was that an "all steel" friction gear was employed, close coupled to constant running motors having the simplest of control gear suitably housed, and with the friction "variatore" supplying power over a varying range of speed (without gears or steps).

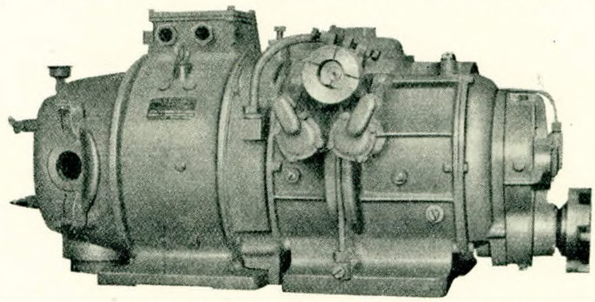


FIG. 24.—"Motovariatore" of 8 h.p. with reduction gear giving a speed of 300 r.p.m. on the outboard shaft; oil servo-motor, remote control.

The combined "motovariatore" was of patented design, and allowed of motors running at, say, 1,400 r.p.m. delivering power at 600 r.p.m. in the ahead position to 600 r.p.m. in the astern position, gradually and continuously passing through a neutral position. The whole of this movement was obtained by operating a single control arm through an arc of approximately 75°, and without any switching of motor controls. Could the Author say whether this scheme appeared to offer advantages over the switch control arrangements for certain deck and shipboard machinery at present in use in our own Mercantile Marine?

"Motovariatore" of sizes up to 50 b.h.p. on the motor side were being constructed and installed for naval purposes, the "all steel" friction gear having an efficiency of 95/97 per cent.

In conclusion, though somewhat beyond the scope of the paper, the writer desired to put forward the following suggestion, which had occurred to him as the result of many cross-Channel flights in the dusk during the past summer, namely that co-operation between air liners and merchant vessels would be very helpful by the latter supplying a strong upward beam of light from their upper deck housing. Some such scheme of moving and controllable "lighthouses" would often prove of service, and provided the electrical industry could supply suitable plant for this duty, he suggested that the idea be submitted to the Air Ministry for consideration.

The Author's Reply to the Discussion.

The Author, in reply, said that he would like to thank the Chairman and the various speakers for their appreciative and helpful remarks.

Mr. Watson had asked for further information regarding the earliest application of electric lighting on ships. Available records indicated that the Admiralty were trying out electric searchlights on board destroyers about 1875 and in 1879 electric lighting was installed on the "Servia", whilst in the same year similar installations were fitted in several liners by various owners. Patents for the commercial form of glow lamps were actually taken out in 1879.

The reasons for including the "Normandie" in Table I was to record that for the first time in marine service individual auxiliary generating sets had passed the 1,000kW. rating in any ship.

Regarding the question of oil engine governing, Mr. Watson doubted that requirements were being uniformly met. This view was shared by the Author, and the charts shown in Figs. 3 and 4 would probably afford information for further consideration by the various classification societies with a view to adopting the present B.S.I. requirements of 3½ per cent.

Mr. Watson had also asked for further information concerning the load variation for the hotel services on board. From records taken the following graph (Fig. 25) had been prepared which would indicate that the electrical cooking load was not strictly proportional to the complement on board. The following records relating to a modern passenger liner with a full complement of 1,500 persons might perhaps be of some interest to Mr. Watson.

General lighting	...	150kW.
Galley cooking	...	350kW.
Cabin heating	...	140kW.
Cabin ventilation	...	160kW.

The above represented maximum steady readings observed.

In regard to the rating of winch cables Mr. Watson had raised a number of important points. This matter had been receiving consideration by certain authorities for some time and Mr. Watson's suggestion that superintendents and owners could assist was fully supported, as the actual temperature records of cables under working conditions and in various latitudes would be invaluable. The three main considerations in the determination of winch cable ratings were:

(*a*) Intermittency factor of separate winch cables.

(*b*) Diversity factor of group winch feeder cables.

(*c*) Temperature of environment.

(*a*) The R.M.S. loading for winches was generally found to lie between 70 per cent. and 80 per cent. of full motor load value, as winches were mainly dealing with lifts equivalent to one-third of designed load on the hook.

(*b*) The diversity factor for winch equipments was of the order of 0·5 and tests on ships revealed that the average steady load might be taken as the full electrical load of 50 per cent. of the total equipments at any instant.

(*c*) The temperature of the environment determined by the latitudes through which the ship was operating had an important bearing upon the safe working temperature of the winch cables.

American marine cable practice was to allow

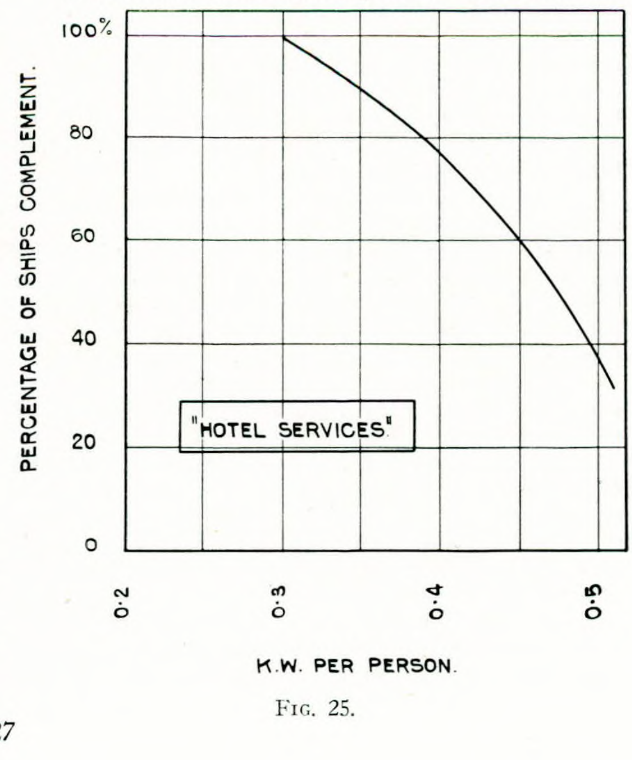


FIG. 25.

an increased current carrying capacity of $33\frac{1}{3}$ per cent. (approximately) for intermittent services. Standard British marine practice allowed from 18 to 26 per cent. for similar duty. Mr. Watson's view that to rate cables similarly to motors for half or one hour ratings was unsatisfactory was also shared by the Author.

Mr. Belsey had referred to the use of enamelled wire with a single cotton covering and the figure given for the di-electric strength of such completed wires was very interesting. One of the chief difficulties in connection with motors was to include design features not only to comply fully with service conditions but to withstand dampness and rough conditions on board ship months before launching. The additional mechanical protection offered by double cotton covering should not be overlooked.

The plural starting type of switchboard with selective tripping of non-essential circuits as required and as fitted on several ships of the liner class was not included by the Author, who had attempted to cover the average ship.

Mr. Belsey had said that tankers were worked as hard as trawlers, being at sea for 330 days of the year during which time the generating plant was in service. Tankers were equipped with duplicate generating sets, the routine arrangement being for each set to give equal periods of running. The majority of trawlers were only equipped with a single generating set.

Mr. Timpson had also referred to generating plant in trawlers. It was now standard practice for East Coast trawlers regularly to complete round voyages of 3,000 miles, during which time the generating plant was continuously in service.

Reference to the use of epicyclic gearing for windlass and capstan equipments had also been made by Mr. Timpson in connection with trouble experienced with slipping clutches. The renewable bands on the drums suggested might, in the Author's opinion, be the cause of trouble due to the variation between the friction surfaces.

Regarding the use of alternating current motors, the Company with which the Author was associated equipped a fleet of tankers some 15 years ago with alternating current machinery, the voltage being 110. These equipments, mainly of the constant speed type, had given very satisfactory performance, very little maintenance being involved.

In the interests of safety the classification societies restricted the voltage to 110 in the case of tankers.

Mr. Pudney had drawn attention to the load variation on electrical generating plant. Certain equipments were switched on load as conveniently as possible which prevented unnecessary overloading. This could be explained more clearly by reference to Fig. 17 showing the curve of sea load. The general shape of that curve was followed by the harbour load curve to the extent that maximum and minimum readings occurred near the same time on both curves. This explained that certain routine conditions obtained, and that peak loads were due to the demands of hotel services. It would be seen that the sea load increased steadily before noon, remaining uniform until the conclusion of lunch at 2 p.m. Peak load occurred at 6 p.m. due to galley preparations for the evening meal, passengers cabin load also being increased concurrently. The load fell away consistently until 2 a.m., which was the time of minimum load on board. The sharp rise in load at 4 a.m. was due to pastry and baking ovens being switched in circuit until 6 a.m. followed by increasing load at 7 a.m. due to galley preparations for breakfast. The latter equipment was on reduced load due to the switching out of sections as cooking was completed, being cut out at 9 a.m., and with increasing daylight the ship's load was gradually reduced until 11 a.m., when galley equipment was again put into service to meet the luncheon requirements at 1 p.m.

Mr. Pudney had also asked for the real difference between totally-enclosed and watertight motors. The former, while having no openings, would have all covers securely finished and made dust-tight and splash-proof. A watertight motor would have heavier covers with a wide face on apertures and increased bolting points on machined joints to enable the motor to resist breaking seas as in the case of deck mounting equipments.

The information given by Mr. Pudney in connection with the "motovariatore" as used by the Italian Navy was very interesting, and for such an equipment the control need only take the form of a light duty starter. In this country analogous types of equipment had taken the form of a high-speed motor fitted with a speed reducing gear having a ratio of 2·5 : 1 and direct coupled to an electro-hydraulic unit. A simple form of starter was employed for running up the motor and then all speed control of the driven member was effected by a handwheel on the fluid system. This latter type of equipment was installed on a number of passenger liners for controlling the cargo winches several years ago and worked satisfactorily, but the initial cost was considerably greater than the usual electric geared type of winch. The Italian scheme referred to had definite possibilities for deck machinery with a speed range of 6 : 1 instead of 2·5 : 1, and, if competitive in price, with equipments performing similar duties.

In reply to Mr. Harrison, it was helpful to have his support in favour of simplifying the types of motors for marine service. When deliberating this matter, consideration should be given to conditions on board during the building stages as indicated in reply to a previous speaker. For example, prevailing conditions in the engine room and 'tween decks during construction of the ship would be more severe than in actual service. When testing out pipe lines for the different services, incipient leaks, sometimes of a generous character, could be resisted by motors of the splash-proof type.

Mr. Harrison had suggested a totally-enclosed weather-proof motor for deck mounting. Such machines were built to withstand an external pressure of water at 1·5lb. per sq. in. This was equivalent to immersion in slightly over 3ft. of water, and a doubtful proposition for deck mounting. Deck equipments in exposed positions might be subjected, under heavy weather conditions, to breaking seas equal to a weight of 20 tons. In addition, experience had generated a respect for the accuracy and faithfulness with which deck hands "hosed-down" equipments—an operation which watertight motors could withstand.

The drain hole referred to by Mr. Harrison for deck mounting motors was standard practice and was usually fitted at the lowest point of the motor yoke.

The location of control gear for deck winches referred to by Mr. Harrison was not in the hands of the manufacturer. It was a point determined by the design of deck fitments and accommodation. If it was desired to house control gear in deck houses adjacent to winch groups, provision was obviously necessary in the initial ship design stages.

Regarding Mr. Harrison's reference to the fitting of safety devices in connection with deck machinery, the difficulty lay in the friction faces failing to maintain a uniform value for the coefficient of friction required. The result was that even slight adjustments had allowed excessive current to flow sufficiently to open the line circuit of the motor.

Referring to control gear, Mr. Harrison had also commented upon the illustration Fig. 12. This referred to a steering gear starter in support of the remarks on page 214, probably overlooked by Mr. Harrison, wherein it was stated that "it is undesirable to fit any feature which will cause an interruption in this highly important circuit".

Mr. Jaffery had made a very interesting contribution in his remarks concerning torsional oscillations inherently generated by Diesel engines. From the Author's experience the Diesel engine manufacturers were to be congratulated upon the manner in which they had grappled with this problem. Co-operation between Diesel engine makers and the manufacturers of electrical plant had resulted in an improved engineering technique. The problem in connection with Diesel-electric plant was mainly two-fold.

(1) To restrict the nature and extent of the engine oscillations.

(2) To prevent their communication to the generator.

The standard practice on the part of certain manufacturers to incorporate a form of cushioning device with the Diesel engine had yielded good results in damping oscillations. Regarding electrical machinery, manufacturers had also carefully studied this difficulty and certain features in the design and construction of generating plant had been embodied to meet this racking service. In this connection careful fitting, during assembly, and the use of specially designed keys had contributed to successful performance in service.

Mr. Jaffery referred to the use of ball and roller bearings. It could be emphasized that with precision in fitting and the careful design of bearing housings very little trouble had been experienced, providing that a suitable type of grease to meet environment conditions was utilized.

Mr. Jones had drawn attention to the running speed of low power generating plant. The figures given on page 203 indicated the revolutions generally found acceptable to superintendent engineers and for trawler service there was a disinclination to go to higher speeds.

Regarding the question of open or enclosed type of reciprocating sets for small generating plant, the enclosed forced lubrication design had been greatly improved in recent years. On steam freighters and similar ships where high grade engineering personnel was available, engines of the enclosed type had been introduced and accepted. In the case of trawlers and drifters, however, there was still a preference for open-type machinery with visibility of moving parts.

The figures given for generating plant in Fig. 1 were maximum ratings.

Mr. Jones did not appear to be quite clear regarding the statement made on page 217 in regard to the electrical loading referred to. The statement "average voyage conditions" covered winter and summer schedules, varying latitudes and regular sailings and cruising itineraries. The figure of 1kW. per person represented the maximum steady electric loading of all auxiliary services which occurred several times per day.

The electrical load analysis given on page 217 referred, of course, to ships equipped throughout with electrical-driven auxiliaries, including electric galley equipment. Reference to Fig. 17 relating to a round trip of six weeks showed that the maximum load was only 13 per cent. above average load.

The electrical energy required per person aboard was determined mainly by the extent to which the hotel service equipment was fitted and which included heating, cooking and ventilation.

During the last five years the demand for electrical energy on ships of the liner class had definitely increased. This could be attributed to new tonnage being designed to meet cruising requirements when desired, and also to the installation of additional electrical equipments on existing ships to enable the fulfilment of alternative cruising schedules.

Instances had occurred on ships when on cruising service, though not originally designed for such duty, where heavy and persistent overloads on the electric generators had necessitated shutting down large plant such as the refrigerating equipment.

The present tendency to increase the length of the average passenger liner would in turn increase electrical requirements chiefly for the hotel service load.

In his reference to Table VI Mr. Jones had assumed a set of conditions that would be very pleasant to shipowners, viz., that ships always sailed with a full complement on board. This was not the case. In addition, the whole of the electric generating plant was not always on full load which Mr. Jones had probably inferred from the publication of Table VI. There must be provision for standby sets in reserve, and it would doubtless be correct to say that on ships fitted with three generating sets, one of these would generally be in reserve. Precise figures relating to the average number of passengers per voyage and the corresponding number of crew were not available, but could be assessed at between 60 per cent. and 70 per cent. of a ship's full complement.

STUDENT EXAMINATION PAPERS, 1935.

The following are the Papers set for the recent Student Examination:

ENGLISH AND GENERAL KNOWLEDGE.

Monday, May 27th, 1935. 7 to 10 p.m.

SECTION I.

Write an essay not exceeding 700 words in length on one of the following subjects :—

(*a*) Progress in Engineering.
(*b*) Pride.
(*c*) The Norman Conquest.
(*d*) First impressions of some place of historic interest that you have visited.
(*e*) India.
(*f*) The influence of the Cinema on modern life and habits.
(*g*) From sail to steam.

SECTION II.

Six questions to be answered.

1. With what advance in science do you associate the following: Joule, Watt, Faraday, Napier?

2. From what countries do we obtain the following raw materials: tin, rubber, cotton, wool, nickel?

3. Name two classic and two modern authors and mention a character that each has made famous.

4. Describe briefly the solar system and mention the principal planets.

5. Describe briefly one of the following characters: Scrooge, Alan Breck, Jess Oakroyd, Abraham Lincoln, Prospero, Rob Roy.

6. State briefly either (*a*) the changes brought about by the Norman Conquest or (*b*) the causes leading to the formation of the First Parliament or (*c*) the reasons for England's prosperity in the reign of Elizabeth.

7. What is the atomic theory and how does it differ from modern ideas of the structure of matter?

8. What are the principal navigable rivers of Europe and to which important cities do they give access?

9. State the advantages of the gyro-compass over the magnetic compass; why is the latter valueless for use near the poles?

10. Give the reason for the historical importance of two of the following: King John, Cromwell, Clive, Wolfe, Luther, Robespierre.

ELECTRICAL ENGINEERING.

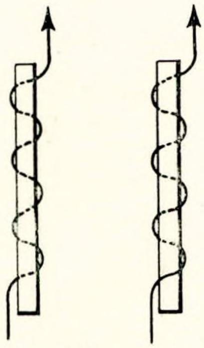
Tuesday, May 28th, 1935. 7 to 10 p.m.

Seven questions only to be answered.

1. (i) What is meant by (*a*) a primary cell and (*b*) a secondary cell or accumulator?
(ii) For what purposes are each of these types used, and why?

2. A battery has a discharging E.M.F. of 2·05 volts per cell. If the internal resistance of each cell is 0·0005 ohm, and the resistance of the leads from the battery to the lamps 0·011 ohm, how many cells must be used to supply current to 500 lamps, each 60 watts—220 volts?

3. (i) State Faraday's Laws of Electro-magnetic Induction.



(ii) Two soft iron bars, each enclosed in a coil of wire through which a current passes are placed as shown. If the direction of the current is indicated by the arrows, illustrate the lines of force in the magnetic field.

(iii) Describe an easy method of ascertaining the direction of the lines of force.

4. Two resistances of 5 and 12 ohms are connected in parallel, and this group is then connected in series with two other resistances of 2 and 7 ohms, these latter being in series. If the pressure of supply is 220 volts, find what total current will flow; and also what will be the current in each of the parallel resistances.

5. What is the purpose of the commutator of a dynamo? Make a simple sketch of a commutator or part of a commutator showing the armature windings connected to it.

6. Make a diagrammatic sketch of either a double-wire or three-wire distribution system for house lighting. What are the particular merits of the system shown?

7. A steam trawler is fitted with one dynamo connected to a main switchboard and providing current for three outgoing lighting circuits. Show by a sketch how the main switch, the distribution switches, the fuses, the ammeter and the voltmeter are wired to the switchboard.

8. A group of 40 lamps, each 60 watts—220 volts, is supplied with current from a dynamo 50 yards away. If the drop in voltage is 2·5 volts, and the resistance of an inch cube of copper is 0·66 microhm, what must be the cross section of the cable in square inches?

9. Compare the advantages and disadvantages of (i) a carbon filament lamp, (ii) a metal filament lamp and (iii) a gas-filled lamp.

10. Describe the uses of the following types of electric motor: (i) open type, (ii) screen protected, (iii) totally enclosed and (iv) water-tight. How is the cooling of the various parts of the motor dealt with in the above types?

11. Describe with a sketch the construction of a voltmeter or ammeter.

Explain how the instrument can be adapted for use either as a voltmeter or ammeter.

12. (i) Describe the make up of an electric cable composed of a conductor of 7 wires insulated with rubber and sheathed with lead; and show a cross section of the cable.

(ii) What is the advantage of having a number of wires stranded rather than a single wire?

(iii) How is a cable protected that is laid in a place where it is liable to damage?

MATHEMATICS.

Thursday, May 30th, 1935. 7 p.m. to 10 p.m.

Full marks can only be obtained by correct answers to *twelve* questions. Not more than *three* questions in any one section may be attempted. To obtain a pass, marks *must* be obtained in each of the sections A, B, C and D.

Section A.

1. There are four numbers in Arithmetical Progression. The sum of the two extremes is 8, and the product of the means is 15. Find these numbers.

2. Find the values of x that satisfy the following equations:—

(*a*) $$\frac{243+324\sqrt{3x}}{16x-3} = (4\sqrt{x}-\sqrt{3})^2$$

(*b*) $$x^2-\frac{2}{3x} = 1\tfrac{4}{9}$$

3. Solve the following equations:—

(*a*) $$\left.\begin{aligned} \tfrac{1}{4}x + \tfrac{1}{7}y &= 20 \\ 7y + 4x &= 584 \end{aligned}\right\}$$

(*b*)
$$\left.\begin{aligned} y + \frac{x}{2} &= 41 \\ x + \frac{z}{4} &= 20\tfrac{1}{2} \\ y + \frac{z}{5} &= 34 \end{aligned}\right\}$$

(*c*) Simplify $\sqrt[10]{(4a^2-12a+9)^5}$

4. There are two vessels A and B each containing a mixture of wine and water. In A the wine : water : : 2 : 3, and in B : : 3 : 7. What proportions of each mixture must be taken to form a third mixture in which the wine : water : : 5 : 11?

5. Solve the two following equations :—

(*a*) $x-1=2+\frac{2}{\sqrt{x}}$

(*b*) $\frac{a+x+\sqrt{2ax+x^2}}{a+x-\sqrt{2ax+x^2}} = b^2$

6. In comparing the rates of a watch and a clock, it was noted that the watch time was 11hr. 59min. 49sec. when the clock was 12 hours (noon). Two mornings later when it was 9 hours (a.m.) by the clock, the watch time was 8hr. 59min. 58sec. The clock is known to gain 0·1sec. in 24 hours, find the rate of the watch.

SECTION B.

7. Given that $\pi = 3{\cdot}141592653589793$.............., prove that the circular measure of $10''=$ 0·00004848136811..............

8. Show that $\sin 75^\circ = 0{\cdot}9659$
$\sin 15^\circ = 0{\cdot}2588$
$\tan 15^\circ = 0{\cdot}2679$

Prove the truth of any formula you may employ.

9. What do you understand to be the meaning of $\sin^{-1}\frac{1}{2}$? Draw this angle to scale.

Also explain why $\sin^{-1}\frac{1}{2} = \cos^{-1}\frac{\sqrt{3}}{2}$

is not an identity. Illustrate your answer geometrically.

10. A and B are two consecutive milestones on a straight road and C is a chimney visible from both A and B. The angles CAB and CBA are observed to be 36° 18′ and 120° 27′ respectively. What is the distance between C and B?

11. Show that "three times the height in feet of the place of observation above sea level is equal to twice the square of the distance of the horizon in miles".

12. Show that $\sin 3A = 3\sin A - 4\sin^3 A$.

SECTION C.

13. Give the definition of a Logarithm. What is meant by the statement that a system of logarithms has been calculated to the base 10? Illustrate your answer by examples.

14. Having given that

$\log_{10} 2 = 0{\cdot}3010300$
$\log_{10} 3 = 0{\cdot}4771213$
$\log_{10} 7 = 0{\cdot}8450980$

find the values of $\log_{10} 6$, $\log_{10} 16$ and $\log_{10} 63$ to seven significant figures. What is the value of $\log_{10} 1$? Can you prove the truth of your answer?

15. How may logarithms calculated to a base *a* be converted to another base *b*? Having given that $\log_{10} 2 = 0{\cdot}3010300$, find $\log_2 10$.

16. Having given that $\log_{10} 30 = 1{\cdot}4771213$, find the value of $\log_{10} 0{\cdot}03$, also $\log_{10} (0{\cdot}03)^{\frac{1}{4}}$; hence what is the value of $\sqrt[4]{\frac{3}{100}}$?

SECTION D.

17. The sides of a triangle ABC are trisected, the side AB at X and Y, the side BC at P and Q, and the side CA at R and S; show that the area of the figure PQRSXY is equal to $\frac{2}{3}$ of the area ABC.

18. Prove that if the vertical angle of a triangle is bisected internally or externally by a straight line which cuts the base or base produced, it divides the base internally or externally in the ratio of the other sides of the triangle.

19. Given a triangle ABC, show how to draw a line DE parallel to BC, so that the triangle ABC = twice the triangle ADE.

20. Construct a triangle ABC, having given one side, such that the base angles ABC and ACB are each double the angle BAC at the vertex.

21. Show how to divide a quadrilateral into any number of equal parts by a line through one vertex.

22. Prove that if two chords of a circle (produced if necessary) cut one another, the rectangle contained by the segments of the one is equal to the rectangle contained by the segments of the other.

SECTION E.

23. Give a full explanation of the meaning of the symbol $\frac{ds}{dt}$

If s is the symbol denoting space, and t time, what then does $\frac{ds}{dt}$ denote?

24. If $s=ut+\frac{1}{2}gt^2$, find the value of $\frac{ds}{dt}$ from first principles, that is without the use of any rules. Note that u and g are constants.

25. If $y=A \sin (B\theta+C)$, find the value of $\frac{dy}{d\theta}$ A, B, and C being constants.

If $\theta=\omega t$, where ω=angular velocity in radians per sec. and t=time in seconds, can you give any mechanical example illustrating the use of $\frac{dy}{d\theta}$?

26. State the full meaning of

$$\int_{t1}^{t2} (v+gt)dt$$

Explain and illustrate your answer as fully as you can.

APPLIED MECHANICS.

Friday, May 31st, 1935. 7 to 10 p.m.

Answer not more than *six* questions.

1. A stone is thrown vertically upwards with a velocity of 50ft. per second from the top of a tower 100ft. high. Find the time to reach the ground and the velocity when it strikes the ground.

2. A piece of clay weighing 8lb. travelling at 15ft. per second strikes a piece of iron weighing 12lb. travelling in the same direction at 9ft. per second. If the clay adheres to the iron, find the velocity after impact and the loss of kinetic energy.

3. A train weighing 400 tons is travelling at 30 miles per hour on the level when the rear portion of the train, weighing 50 tons, becomes detached by the breaking of a coupling. The resistance to traction is 10lb. per ton. What would be the speed of the engine portion of the train three minutes after the breaking of the coupling, if the pull exerted by the engine remained unaltered?

4. Describe a laboratory experiment to find the value of "g", the acceleration of a body due to gravity. Make a sketch of the apparatus used.

5. A hemisphere of radius R rests on a plane which is inclined at 10° to the horizontal. If the roughness of the plane is sufficient to prevent sliding, find the angle which the flat surface of the hemisphere makes with the horizontal.

NOTE.—The centre of gravity of a hemisphere is on the symmetrical axis at a distance of $\frac{3}{8}$R from the centre of the sphere.

6. What is meant by the "total pressure" on a surface immersed in a liquid, and what is meant by "centre of pressure"? A rectangular bulkhead in a ship is 50ft. wide. Sea water, weighing 64lb. per cubic foot, rises to a depth of 18ft. on one side of the bulkhead. What is the total pressure in tons on the bulkhead, and what is the position of the centre of pressure?

7. A weight of 10 cwts. is being dragged along the floor of a workshop by block and tackle having three sheaves in the top block and two sheaves in the bottom block. The top block is fastened to a wall, and at a certain instant the ropes between the blocks are inclined at 30° to the horizontal. If the coefficient of friction between the weight and the floor is 0·4, and the efficiency of the tackle is 90 per cent., find the pull on the free end of the rope.

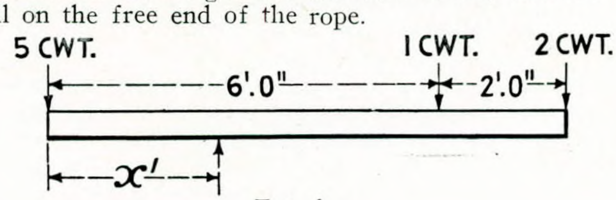


FIG. 1.

8. A beam 8ft. long, 3in. wide, and 5in. deep rests on a single support and is loaded as

shown in Fig. 1. Find the position of the support and the maximum stress in the beam at the support. Neglect the weight of the beam.

9. A solid round shaft is designed to transmit 2,500 h.p. at 120 r.p.m. If the maximum working shear stress allowed is 9,000lb. per sq. in., find the diameter of the shaft.

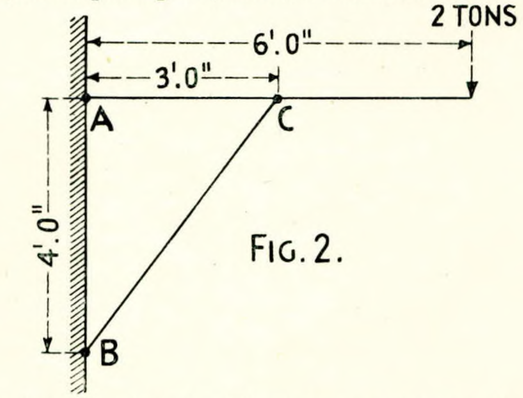


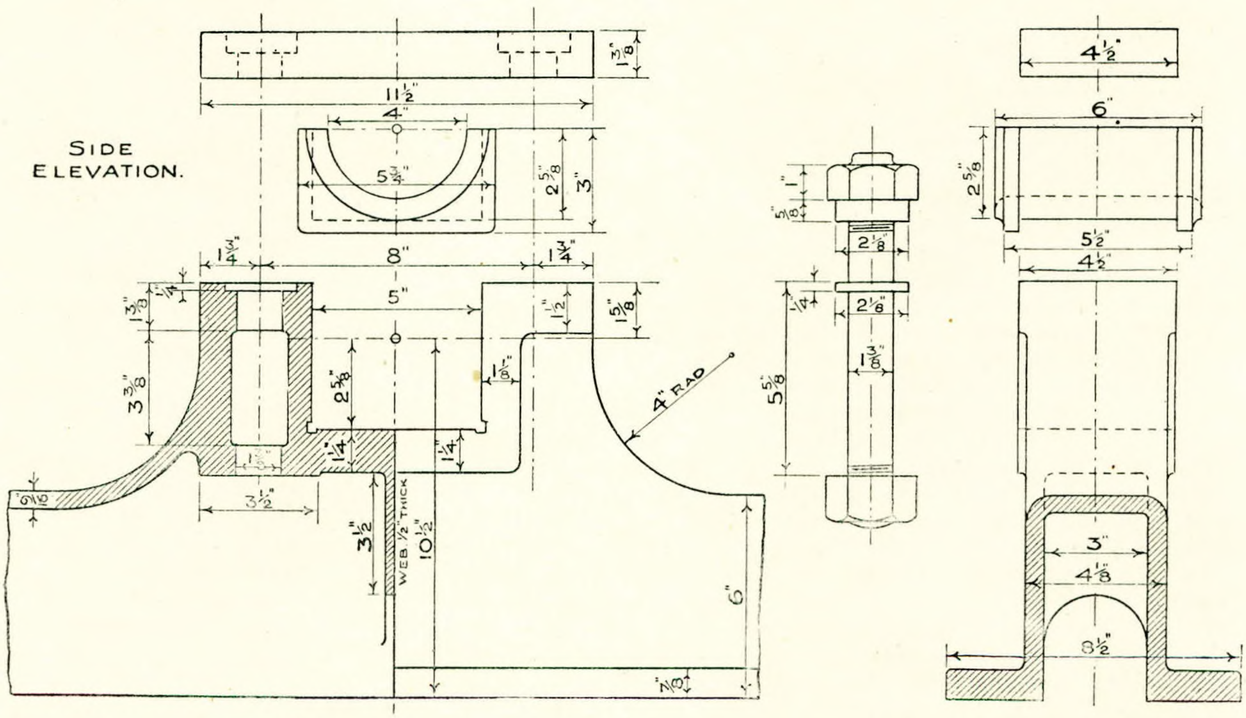
FIG. 2.

10. A wall crane is as shown in Fig. 2. The beam is pin-jointed to the wall at A, and the strut BC is pin-jointed at B and C. Find graphically the magnitude and direction of the reactions at the wall at A and B. Neglect the weight of the beam and strut.

MACHINE DRAWING.

Monday, June 3rd, 1935. 7 to 10 p.m.

ENGINE MAIN BEARING.



Draw to a scale half full size the following views of the bearing shown in the accompanying sketches :

(*a*) A side elevation of the completed bearing with the left half in section.

(*b*) A front elevation, projected from (*a*), with the left half in section.

(*c*) A plan projected from (*a*).

NOTE.—Arrangements for locking the nuts and for the lubrication of the bearing should be shown.

Questions.

1. Name the material you would employ in the construction of (*a*) a piston rod, (*b*) a boiler superheater tube, (*c*) a condenser tube, (*d*) a bedplate for a reciprocating engine. State briefly the reasons for their use.

2. (*a*) State briefly in what circumstances studs are used instead of bolts.

(*b*) If a nut is locked by a thin check nut, which nut should be put on first? State the reason for your answer.

3. Distinguish between a key and a cotter, sketching an example of each, and state the purposes for which each may be used.

HEAT ENGINES.

Tuesday, June 4th, 1935. 7 to 10 p.m.

Answer not more than *six* questions. Candidates are allowed to use Callendar's Steam Tables which are supplied herewith.

1. Four cubic feet of air at atmospheric pressure (14·7lb. per sq. in., absolute) and at 40° C. are compressed to twelve atmospheres. Find the volume and temperature at the end of compression, when the process is (*a*) isothermal, (*b*) adiabatic [$\gamma = 1{\cdot}4$], and (*c*) according to the law $PV^{1\cdot3} = $ a constant. Illustrate your answer with a PV diagram.

2. The equation to Willans line for a certain steam engine is W=13·9 (I.H.P.)+345, W being in lb./hr. Steam is supplied to the engine at 200lb. per sq. in. absolute with a dryness fraction 0·93, and exhaust takes place at 3lb. per sq. in. absolute. Find (*a*) the steam consumption in lb. per hr., and (*b*) the indicated thermal efficiency, when the engine develops 82 B.H.P. with a mechanical efficiency of 76 per cent.

3. A slide valve cuts off steam at 62 per cent. of the stroke of the piston. The valve travel is 3in., the exhaust lap ⅛in., and the lead ⅛in. Draw the valve diagram to a scale of twice full size, and from it determine (i) the angle of advance, (ii) the steam lap, (iii) the maximum openings of the port to steam and exhaust, and (iv) the percentages of stroke at which release and compression take place.

4. What do you understand by brake m.e.p.? Carefully explain how you would determine the brake m.e.p. for a single cylinder internal combustion engine which is not fitted with an indicator cock.

5. Describe, with the aid of neatly drawn diagrammatic sketches, the operation of a two-stage air compressor.

6. A ship is fitted with two single-acting, four-stroke oil engines. Each engine has six cylinders of 51in. stroke and 24in. bore. On trials the following data was obtained:—

	r.p.m.	m.e.p.	Oil consumption lb/hr.
Port engine	131	110	432·5
Starboard engine	127	108	423·7

Determine the I.H.P. of each engine. If the calorific value of the fuel oil is 19,100 B.Th.U. per lb. determine the indicated thermal efficiency of each engine.

7. Explain the essential differences between an impulse and a reaction steam turbine. Make a neat sketch of *either* a section through the wheel and blades of the first pressure stage of an impulse turbine fitted with two velocity rows, *or* a pair of reaction blades arranged with Parsons' end-tightening. In each case the attachment of the blades to the rotor and the casing should be clearly indicated.

8. Explain *six* of the following terms used in connection with internal combustion engines: (i) spill valve, (ii) draw card, (iii) air injection, (iv) scavenging, (v) supercharging, (vi) volumetric efficiency, (vii) mechanical injection, (viii) waste heat recovery, and (ix) piston cooling.

9. The following readings were obtained in an experiment on the determination of the calorific value of a sample of coal: weight of coal, 1grm.; weight of water in calorimeter, 1,020grm.; water equivalent of calorimeter, 170grm.; initial temperature of the water, 15·9° C.; final temperature of water 22·65° C. Determine the calorific value of the coal in C.H.U. and B.Th.U. per lb.

This coal is used on a boiler and 18·2lb. of air is supplied per lb. of coal. The coal contains 8 per cent. of ash, the stokehold temperature is 70° F., and the temperature of the gases at the base of the funnel is 504° F. Find what proportion of the heat available in the coal leaves in the gases. Take the specific heat of the gases as 0·24.

10. A two cylinder double-acting steam engine has to develop 280 I.H.P. at a speed of 160 r.p.m. The admission pressure is 180lb. per sq. in. absolute, the back pressure is 2lb. per sq. in. absolute and cut off occurs at ⅜ stroke. Assuming hyperbolic expansion and no clearance volume, find the cylinder bore. Take a diagram factor of 0·75 and a stroke bore ratio of 1·5.

INSTITUTE NOTES.

THE SECOND ANNUAL AUTUMN GOLF MEETING.

The Second Annual Autumn Golf Meeting was held on Monday, September 23rd, 1935, at Shirley Park, East Croydon, by kind permission of the Shirley Park Golf Club Committee.

The weather conditions were perfect, and the programme, as on the similar occasion last year, consisted of a Medal Competition in the morning and a Four Ball Greensome in the afternoon. Twenty-two members competed in the two events, with the following results :—

Medal Competition.—The first prize, a silver salver presented by Major W. H. Dick, was won by Mr. O. H. Moseley with a net score of 70. The second prize, a silver tankard presented by Mr. A. F. C. Timpson, M.B.E., was won by Mr. H. S. Humphreys with a net score of 73. The third prize, a silver sherry set presented by Mr. A. Robertson, C.C., was won by Engineer Rear-Admiral J. Hope Harrison with a net score of 77. A prize for the best scratch score, one dozen Dunlop golf balls presented by Mr. Walter C. Jones, was won by Mr. T. C. Riddell.

Four Ball Greensome.—The first prizes, two cases of silver ash trays and match box holders presented by The Hon. J. Kenneth Weir, were won by Mr. D. M. Denholm and Engineer Rear-Admiral J. Hope Harrison, who finished 3 up. The second prizes, two pairs of silver mounted decanters presented by Messrs. Ernest A. and W. Robert Beldam, were won by Messrs. R. B. Pinkney and J. A. Rhynas. The third prizes, two cut glass vases presented by Mr. T. A. Crompton, were won by Messrs. F. M. Burgis and T. C. Riddell. The two last-named pairs tied by finishing 1 up, the issue being decided on the better score in the second half.

The prizes were distributed at the close of play by Mr. A. Robertson, C.C., Convener of the Social Events Committee. On his proposal, cordial votes of thanks were accorded to the donors of the handsome prizes, and to the Committee and Secretary of the Shirley Park Golf Club for their courtesy in affording such excellent facilities for the Meeting. The thanks of the assembly were also expressed, on the proposal of Mr. R. Rainie, M.C., to Mr. Robertson and the Secretary for their successful arrangement of the details of the programme.

The following members participated in the proceedings :—Messrs. E. F. J. Baugh, F. M. Burgis, T. A. Crompton, B. C. Curling, D. M. Denholm, J. G. Edmiston, R. M. Gillies, J. A. Goddard, S. G. Gordon, Engineer Rear-Admiral J. Hope Harrison, H. S. Humphreys, E. B. Irwin, W. C. Jones, R. Julyan, A. R. Langton, L. J. Le Mesurier, E. E. Mees, O. H. Moseley, R. B. Pinkney, R. Rainie, J. A. Rhynas, T. C. Riddell, A. Robertson, J. Robinson and A. Walker.

EDUCATION GROUP.

The second meeting of the Education Group was held at the Institute on Thursday, October 3rd, 1935, at 6.0 p.m. Mr. T. A. Bennett, Chairman, presided and the following members of the Executive Committee and of the Group were present : — Messrs. R. F. Thompson (Vice-Chairman, Executive Committee), J. Carnaghan, K. G. Cooch, J. H. Currie, F. S. Gander, W. S. Ibbetson, S. B. Jackson, T. W. Longmuir, R. C. Moyle, G. Patchin, F. H. Reid, H. Scott, H. R. Tyrrell, A. C. West, Engineer Rear-Admiral W. M. Whayman and B. C. Curling (Secretary). The Chairman read messages of regret for their unavoidable absence from Messrs. W. E. Dommett, C. J. M. Flood, J. B. Harvey, G. F. O'Riordan, F. R. Rogers, J. W. M. Sothern, G. J. Wells and J. Paley Yorke.

The minutes of the inaugural meeting of the 10th May, 1935, were confirmed and signed, and the Chairman then called upon the Secretary to read a report on the work of the Executive Committee since its formation.

The report stated that the Council having decided to co-opt in an advisory capacity representatives of the Board of Education, the London County Council, and of recognised associations representing the technical colleges and engineering and shipbuilding employers, the following co-opted members had been appointed to date :—

- Dr. A. Morley—Board of Education.
- Mr. J. H. Currie—The London County Council, Education Department.
- Principal J. Paley Yorke—Association of Principals in Technical Institutions.
- Mr. G. Thompson—Association of Teachers in Technical Institutions.
- Mr. R. H. Green—The Shipbuilding Employers' Federation.
- Principal G. Patchin—The Association of Technical Institutions.

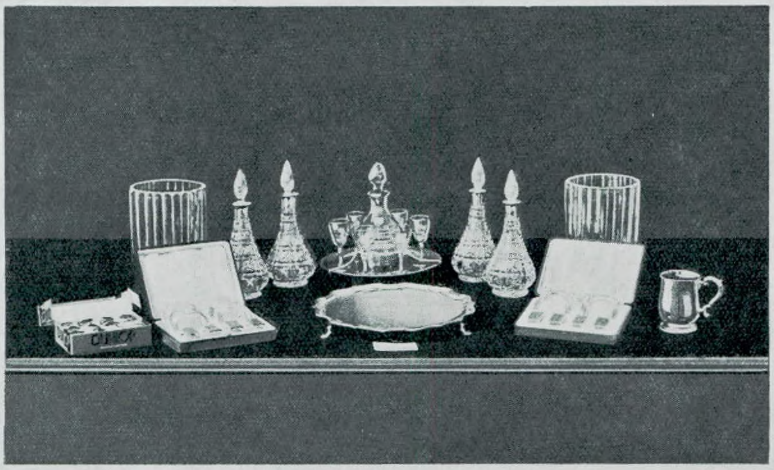
The Executive Committee's activities had been mainly concerned with the drafting of

(*a*) the Objects and Regulations of the Group,
(*b*) a circular notice regarding the admission of Associate Members, and
(*c*) the Association Membership Examination Syllabus.

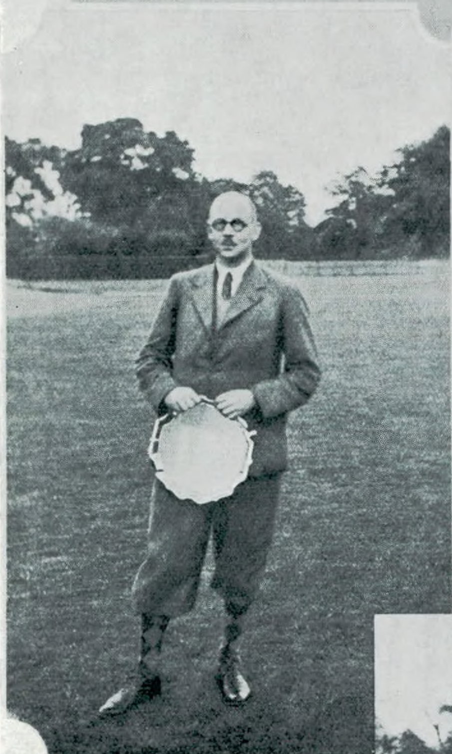
Copies of these drafts had been issued to all members of the Group prior to the meeting, and after discussion and a minor amendment of the circular notice, these drafts were passed for recommendation to the Council, by whom they have since been approved and adopted at the Council Meeting of October 7th.

The Objects and Regulations of the Group are as follows :—

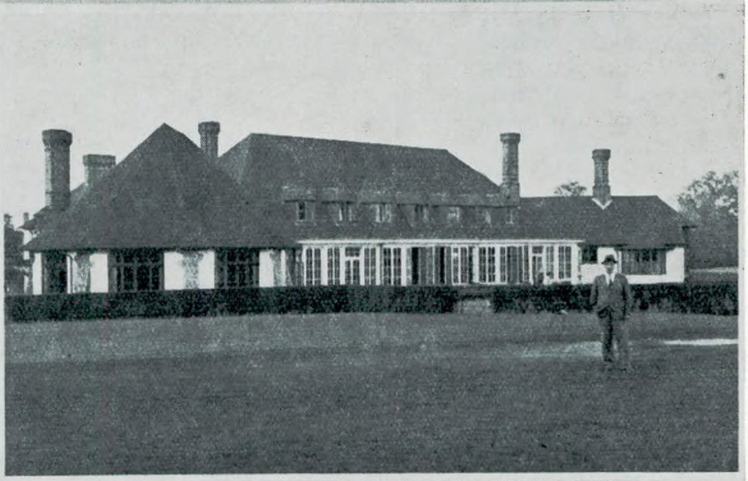
1. The object of the Group shall be to discuss any matter of educational interest and



THE PRIZES



O.H.MOSELEY.
WINNER OF THE
MEDAL COMPETITION



THE CLUBHOUSE

SOME OF THE COMPETITORS

THE SECOND ANNUAL AUTUMN GOLF MEETING.

and if a decision on the subject at issue results from the discussion, to report to and advise the Council thereon. The advice tendered to the Council shall be as decided at a meeting of the Group.

2. All members of The Institute shall be allowed to attend the meetings of the Group, but only those who have registered as members of the Group prior to the Meeting shall be entitled to vote.

3. The members of the Group shall elect a Chairman and a Vice-Chairman. A further seven registered Members and a Secretary shall be elected, who with the Chairman and Vice-Chairman shall form a Committee. The Committee shall include not less than two nor more than four Members of Council. At the end of each year the Chairman shall retire from that office, but shall remain a Member of the Committee ex officio for the ensuing year, and the Vice-Chairman shall succeed to the Chair. The Vice-Chairman shall be elected annually. Only those Members who have served for at least one year on the Committee shall be eligible for election as Vice-Chairman.

4. Three Members of the Committee who have been in office for three years shall retire and the vacancies thus caused shall be filled by the election of three new Members at an Annual Meeting to be held in May. The retiring Members shall not be eligible for re-election until the expiration of one year, with the exception that when necessary the Vice-Chairman shall be allowed to remain for his year of office as Chairman, in which case only two Members of the Committee shall retire.

5. The Group shall hold at least two meetings in every year, including the Annual Meeting in May for the election of a Vice-Chairman and Members of the Committee to succeed those retired.

6. The Committee shall have power to co-opt.

7. The Committee shall have power to invite any person to attend a Committee Meeting, but such person shall not be entitled to vote.

An important step was taken by the Council at their meeting on 9th September, when it was decided to appoint an Examinations Board to deal with all examinations which come within the purview of the Institute. This Board will be appointed by the Council and will consist of six Members, of whom at least one will be a Member of Council and four will be nominated by the Executive Committee of the Education Group. The first Board has been constituted as follows:—Messrs. T. A. Bennett, J. Carnaghan, C. J. M. Flood, F. H. Reid, H. Scott and R. F. Thompson. The Examinations Board will be responsible to the Council for the nomination of examiners for, and for the regulation and conduct of, all Institute examinations.

The circular notice regarding the admission of Associate Members and the Associate Membership Examination Syllabus are being issued separately within the next few weeks.

The Chairman, in conclusion, thanked the members present for their attendance, and announced that the next meeting of the Group would take the form of a lecture entitled "The History of Technical Education" to be given by Principal J. Paley Yorke, M.Sc., on Thursday, January 30th, 1936, in the Lecture Hall of the Institute.

ELECTION OF MEMBERS.

List of those elected at Council Meeting held on Monday, October 7th, 1935.

Members.

Walter Bernard Stewart Angel, 28, South Park Crescent, Ilford.

Andrew James Brown, Harbour View, Harwich, Essex.

Frederick John Chenery, c/o I.P.C., Box 309, Haifa, Palestine.

Eric George Maconachie Hunt, Sunny Side, Low Street, West Tilbury.

Edmund Harding, St. Tudno, Wimpson Lane, Southampton.

Daniel Shaw Holt-Wilson, Lieut.-Com'r. (E.), R.N., Wootton House, Westernway, Alverstoke, Hants.

Rice Parry Jones, Overdale, Colman Hill, Cradley, Staffs.

Ronald Alexander Macdonald, Sherwood, 175, Hadleigh Road, Leigh-on-Sea, Essex.

James Henry McGregor, Messrs. Huddart, Parker, Ltd., 466, Collins Street, Melbourne, Australia.

Walter Alexander Morrison, 2nd Engineer, China Navigation Co., Ltd., c/o Messrs. Butterfield & Swire, Hong Kong, China.

Douglas Robb, 9, Atherton Drive, Upton, B'head.

William N. Roscoe, 60, Jenner Road, Barry.

Archibald Jardine Scott, 167, Dumbarton Road, Clydebank.

Ferdinand Joseph van Hecke, Mortselschesteenweg, Hove, near Antwerp, Belgium.

William Waddle, Bansberia Mills, Bansberia, Hooghli, Bengal, India.

Edgar Watson, Iona, Winchester Road, Half-way Tree, St. Andrew, Jamaica, B.W.I.

Cedric Swanton Waugh, Messrs. Huddart Parker, Ltd., 466, Collins Street, Melbourne, Australia.

Charles Thomas Way, 9, Woodside Mansions, St. Georges, E.1.

George Hulford Whale, 30, Bradleigh Avenue, Grays, Essex.

John Kilpatrick Whitelock, 89, Radnor Park Gardens, Clydebank, Glasgow.

Joseph James Bertram Williams, 19, Vanguard Villas, Devonport, Plymouth.

Harold Hughes Winch, 46, Cambridge Road, Colchester.

Associate Members.

Stanley Edgar Ashworth, Bonveno, Eccleshill, Bradford.

Joseph Clare London, 105, Egerton Road, Manchester, 16.

Robert William Miller, Beechcroft, Lakewood Road, Chandlers Ford, Southampton.

Alfred Douglas Smith, 35, Midfield Avenue, Barnehurst, Kent.

Associates.

John Graham Edmiston, 24, Blackheath Park, S.E.3.

George Nelson, The Mount, Causey Way, Hexham, Northumberland.

Students.

George H. Carson, Seafield, Portwilliam, Wigtonshire.

Herbert Hugh Courtenay, 205, Westcombe Hill, Blackheath, S.E.3.

Robert Burton Wight, Elm Drive House, Leatherhead, Surrey.

Transferred from Associate Member to Member.

William Hunter Barr, 51, Lorne Street, Leith.

William Redvers Gurney, 48, Middlesex Road, Bootle, Liverpool 20.

Henry Taylor, 2, Overtoun Terrace, Dumbarton.

Transferred from Associate to Associate Member.

Edward Louie Parry, 41, Lampton Avenue, Hounslow, Middlesex.

Transferred from Student to Associate Member.

Maurice James Barrett, Sarnia, Jotman's Lane, South Benfleet, Essex.

Henry Freeman, 128, Stanhope Road, South Shields.

Arthur Douglas Timpson, 4, Coventry Road, Ilford, Essex.

ADDITIONS TO THE LIBRARY.

Presented by The National Physical Laboratory.

Report of the Advisory Committee for the William Froude Laboratory for the year ended December 31st, 1934.

"Ship Wave-Resistance. Progress since 1930". Paper read before the Institution of Naval Architects by W. C. S. Wigley, M.A.

"Resistance Experiments in Smooth and Rough Water made with Models of High-Speed Ships". Paper read before the Institution of Naval Architects by J. L. Kent and R. S. Cutland.

Presented by the Publishers.

"Instructions to Surveyors—Special Passenger Certificates (St. 6) for Launches and Motor Boats". H.M. Stationery Office, 2d. net.

British Engine Boiler and Electrical Insurance Co., Ltd.'s Technical Report for 1933-34.

The British Electrical and Allied Industries Research Association: Sub-Committee J/E: Joint Committee: Steels for High Temperatures. Progress Report from the National Physical Laboratory, September, 1935.

Transactions of The Institution of Naval Architects, Volume LXXVII, containing the following papers:—

"Launch of the Quadruple-screw Turbine Steamer 'Queen Mary'," by McNeill.
"Transport of Refrigerated Cargoes under Modern Marine Practice", by Woods.
"Channel Train Ferry Steamers for the Southern Railway", by Abell.
"Resistance Experiments in Smooth and Rough Water made with Models of High-speed Ships", by Kent and Cutland.
"A Simplified Form of Direct Flooding Calculations", by Scott.
"Steamships with Main Boilers on Deck", by Meldahl.
"The Evolution of the Modern Steam Trawler with Superheating", by Nicholas.
"The Corrosion Problems of the Naval Architect", by Hatfield.
"An Experimental Investigation of Cracking in Mild Steel Plates and Welded Seams", by Coker and Haigh.
"A Standard of Stability for Ships", by Pierrottet.
"Ship Wave-resistance—Progress since 1930", by Wigley.

Transactions of the North East Coast Institution of Engineers and Shipbuilders, Vol. LI, containing the following papers:—

"The Reduced-speed Running of Merchant Ships", by Telfer.
"The Trend of Destroyer Design", by Champness.
"Progress in Naval Construction", by Johns.
"Thermocouples", by Pratt.
"Production in Engineering Works", by Green.
"Heavy Weather Damage", by King.
"The Relation of Fatigue to Modern Engine Design", by MacGregor, Burn and Bacon.
"Fuel Consumption and Maintenance Costs of Steam- and Diesel-Engined Vessels", by Le Mesurier and Humphreys.
"Ship Vibration: Simple Methods of Estimating Critical Frequencies", by Burrill.
"Flying Boats and their Possible Developments", by Gouge.
"Wake", by Baker.
"Ocean Transportation of Petroleum in Bulk", by Hand.
"Ship Collisions", by Camps.
"Liner Development during the past Fifty Years", by Denham Christie.
"Cargo-Ship and Tanker Development during the past Fifty Years", by McGovern.
"Coaster Development during the past Fifty Years", by Dugdale.
"Marine Steam Turbine Development during the past Fifty Years", by Walker.
"Reciprocating Marine Steam Engine Development during the past Fifty Years", by Summers Hunter, Jnr.
"Marine Boiler Development during the past Fifty Years" by McPherson.
"Marine Heavy-Oil Engine Development during the past Fifty Years" by Keller.
"Recent Progress in Electrical and General Engineering", by Swallow.

"Engineering Drawing", by Harvey H. Jordan, B.S., and Randolph P. Hoelscher, M.S., C.E. Third revised edition. Chapman & Hall, Ltd. 528pp., copiously illus. 15s. net.

This new textbook on engineering drawing puts before the public a work upon which the authors have spent more than twelve years. They have embodied in it the approved American standards in drawing, the study of present practices in the technique of descriptive geometry and many new illustrations of a practical nature.

One advantage of a book of this type is the extensive scope it offers as a reference work. It contains twenty-five chapters, each one complete in itself and dealing exclusively with its own subject. Thus, an easy and methodical way is presented to the beginner of grasping the basic principles of drawing and, as the Authors put it, of learning the "Graphical Language".

The book appeals to the reviewer in many respects. Apart from its thoroughness in detail, it offers in its text the elementary fundamentals of lettering; use of instruments; all types of projections, intersections and developments; working drawings; sketching; and also the more advanced principles of the higher graphical methods. It would be difficult to pick out any outstanding subject for special attention, but it should be noted that, with regard to the projection of the various views, the Americans and British differ in the way they show front, right and left hand elevations.

Apart from this, the book has many outstanding merits, not the least of which is the terse and clear style in which it is written, and the Authors can be complimented on preparing this elaborate revised third edition.

It can be thoroughly recommended to *draughtsmen,* teachers and all others interested in the graphical methods of reproducing one's ideas on paper.

"Marine Diesel Oil Engines—A Manual of Marine Oil Engine Practice", by J. W. M. Sothern. 4th edition. The Technical Press, Ltd., 1090pp., 800 illus., 45s. net.

It is hardly necessary to remind Members that this book, now long recognised as a standard work, contains exhaustive notes and sketches descriptive of the principle, construction and running of large marine oil engines, of the faults which occur, and of the cause and remedy of these faults.

This new (fourth) edition has been carefully revised and corrected, and a number of entirely new sections, descriptive and illustrative of various details and fittings representing recent developments, have been incorporated. The book, of course, is arranged as a textbook for the Board of Trade Examinations for Motor Certificates and Endorsements, and prospective purchasers of the volume for this purpose will be interested to know that the "Engineering Knowledge" section has been greatly augmented, the latest questions given at the Board of Trade Examinations being included, together with answers.

The weight and size of the volume have been kept down to reasonable limits by the omission of the drawings at the end of the book. The index has also been carefully revised, corrected, and brought up to date to facilitate the location of any item required in the text without loss of time or trouble.

"Marine Engines—History and Development", by G. L. Overton, A.R.C.S. (Science Museum Handbook). H.M. Stationery Office, 96pp., illus., 2s. net.

This handbook is intended to serve as an introduction to the study of the history and development of marine engineering with special reference to the Collections relating to marine engines, boilers and propellers in the Science Museum.

The contents are a record of experimental and early marine steam propulsion, the history of the paddle engine, followed by synoptical accounts of the introduction and development of reciprocating steam screw engines, marine steam turbines, marine internal combustion engines, marine steam boilers and marine propellers. A full index and useful list of references are appended.

The book is well illustrated with photographs of some of the interesting exhibits to be seen at the Museum, and apart from its strictly technical value will afford every marine engineer interest and pleasure far in excess of what could be expected for the modest price at which it is published. We commend it specially to those of our Members who, for geographical reasons, have not found it possible to make a personal inspection of the Museum Collections.

"The Principles of Motor Fuel Preparation and Application", by Alfred W. Nash, M.Sc., and Donald A. Howes, B.Sc., Ph.D. (Vol. II). Chapman & Hall, Ltd., 523pp., illus., 30s. net.

The second volume of this extensive work deals mainly with the properties of motor fuels. A large chapter gives details of the analysis of the factors involved. Knock rating occupies a prominent position, as would be expected in consideration of this most important quality of motor fuel. The various theories of detonation which have been put forward are explained and methods of knock rating tests and the engine units used for these tests are described, as is also the method of road test correlation. In this section the metallic dopes for suppressing detonation are dealt with, the chief being tetra ethyl lead, which is treated fully.

The chapter on internal-combustion engines commences with the theoretical heat cycle and follows with a description of the studies made by various investigators on the phenomena of combustion processes which set practical limitations to the achievement of the ideal cycle. This chapter concludes with brief references to automobile and motor cycle engines and gives descriptions of various types of proprietary aero engines.

The chapter on motor fuel specifications outlines the history of the development of specifications and a separate chapter is devoted to aviation fuel requirements, which includes a brief survey of the aero Diesel engine.

Other chapters concern the formation of gum in motor fuels and the effect of fuel volatility characteristics on engine performance.

The last chapter is devoted to the automobile Diesel engine and its fuel requirements. Various combustion chamber designs are described but the criticism of the directed spray type in an open combustion chamber is apt to be misleading considering the excellent efficiency and service given by one famous design of this type.

Altogether a comprehensive survey of motor fuel characteristics and their application to the internal combustion engine, not the least useful features being the extensive references to the work of well-known investigators on the various subjects and the subject index at the back of the volume. It is a book that should be read by all those to whom the subject is of interest.

ABSTRACTS.

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

The Orient Liner "Orion".

A Twin-screw Turbine-driven Steamship for the Mail, Passenger and Cargo Service to Australia.

"The Shipbuilder and Marine Engine-builder", October, 1935.

General Considerations.

One of the major problems which confronts the marine engine-builder is the disposition of the main engines, boilers and auxiliary machinery, as not only must these units be accommodated in the minimum space, but adequate room must be allowed for maintenance and overhaul. The layout adopted for the "Orion" will be apparent from Figs. 1 and 2.

Six Babcock & Wilcox boilers are accommodated in a single boiler-room, the four larger boilers forward and the two smaller aft. Storage, overflow and wing settling tanks are arranged to both port and starboard of the boiler-room.

The turbines in each main propulsion set are arranged abreast, the high-pressure turbine inboard, the intermediate-pressure ahead and high-pressure astern in the centre, and the low-pressure ahead and astern unit outboard. The manœuvring gear of each turbine set is at the forward end, the forced-lubrication pumps being outboard of each station. The feed-heaters are mounted on the starboard side of the engine-room bulkhead; and the main and auxiliary feed pumps, together with the make-up feed evaporators, are situated abaft this bulkhead. The turbo-generator room is a flat fitted at the forward end of the engine-room, just below the level of *G* deck. The fresh-water plant and lubricating-oil tanks are accommodated on a flat aft, and immediately above, on *G* deck, is the engineers' workshop. The direct-contact feed-heater for port duty and the lubricating-oil gravity tank are fitted in the engine-room casing.

Main Turbines and Gearing.

The main propelling machinery consists of two sets of Parsons turbines. Each set comprises one high-pressure, one intermediate-pressure and one low-pressure turbine working in series and driving separate pinions which engage with the main gear wheel. The total power developed is 24,000 s.h.p. at a propeller speed of 112 r.p.m., corresponding to a ship speed of 21 knots.

The high-pressure turbine is of the impulse-reaction type, the first stage being two-stage velocity-compounded, with both rows of blades mounted on the same impulse wheel; while the following six stages are fitted with reaction blading mounted on a hollow drum of forged steel. Special stainless steel has been used for the impulse blading and nozzle-vane material. The intermediate-pressure turbine is of the reaction type, and comprises seven stages of blading mounted on a hollow forged-steel drum. The low-pressure section of each main propelling set is single flow, and comprises 16 stages of reaction blading attached to forged-steel disc wheels. Seventy per cent. of the full ahead power is available for astern driving, the power being developed in high-pressure and low-pressure astern turbines working in series. The high-pressure astern turbine is incorporated in the intermediate-pressure cylinder, and comprises one three-stage velocity-compounded impulse wheel. The low-pressure astern turbine is housed in the low-pressure casing, and consists of one two-stage velocity-compounded wheel, followed by five stages of reaction blading.

Both labyrinth and carbon packing have been utilised for all the rotor shafts of the turbines. The adjusting blocks fitted are of the Michell pivoted type.

The gearing is of the double-helical single-reduction type with patent enveloping teeth. The gear ratio is such that all the turbines run at 1,715 r.p.m., which corresponds to a propeller speed of 112 r.p.m. The gear wheels have cast-iron centres with forged-steel rims shrunk on; while nickel steel has been adopted for the pinions, which are connected to the turbine rotors by flexible couplings. Central bearings are fitted to the pinion shafts.

The governing of the main turbines is effected by means of an Aspinall governor. This governor, through forced-lubrication control, operates a bulkhead emergency valve. Lubricating oil is used as the transmitting medium between the governor and the emergency self-closing valve. Hence, in this system, the following dangers are guarded against:

(*a*) Overspeeding of the turbine is controlled by a governor of the centrifugal type having the usual springs and pawls. On the turbine revolutions attaining a predetermined and readily adjustable value, an oil-escape opening, controlled by the main springs, is opened, and the lubricating-oil pressure falls, causing the stop valve to shut off the steam supply.

(*b*) In the event of the lubricating-oil pressure falling, say, due to pump failure or the emptying of the gravity tanks, the bulkhead emergency stop valve is again caused to shut off steam.

(*c*) Excessive back pressure in the condenser also causes closing of the valve.

A feature of this governing system is that the governor action operates merely on the oil pressure, and is not required to move spindles, levers, etc.

Boiler Installation.

The boilers are arranged in one boiler-room, the set comprising four large boilers at the forward end, and two small boilers aft. Each boiler is

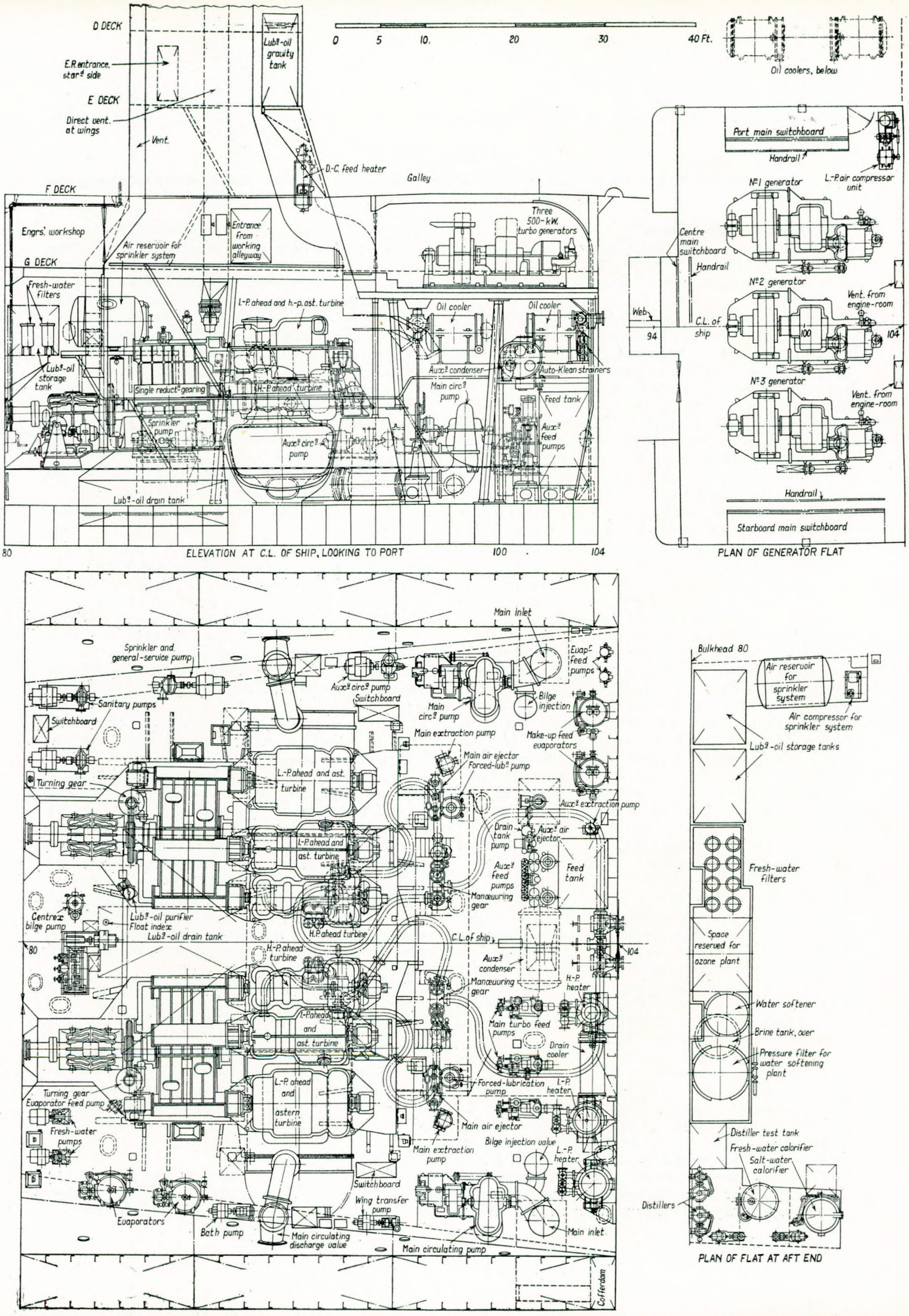


FIG. 1.—General arrangement of the engine-room of the twin-screw turbine-driven mail, passenger and cargo liner "Orion".

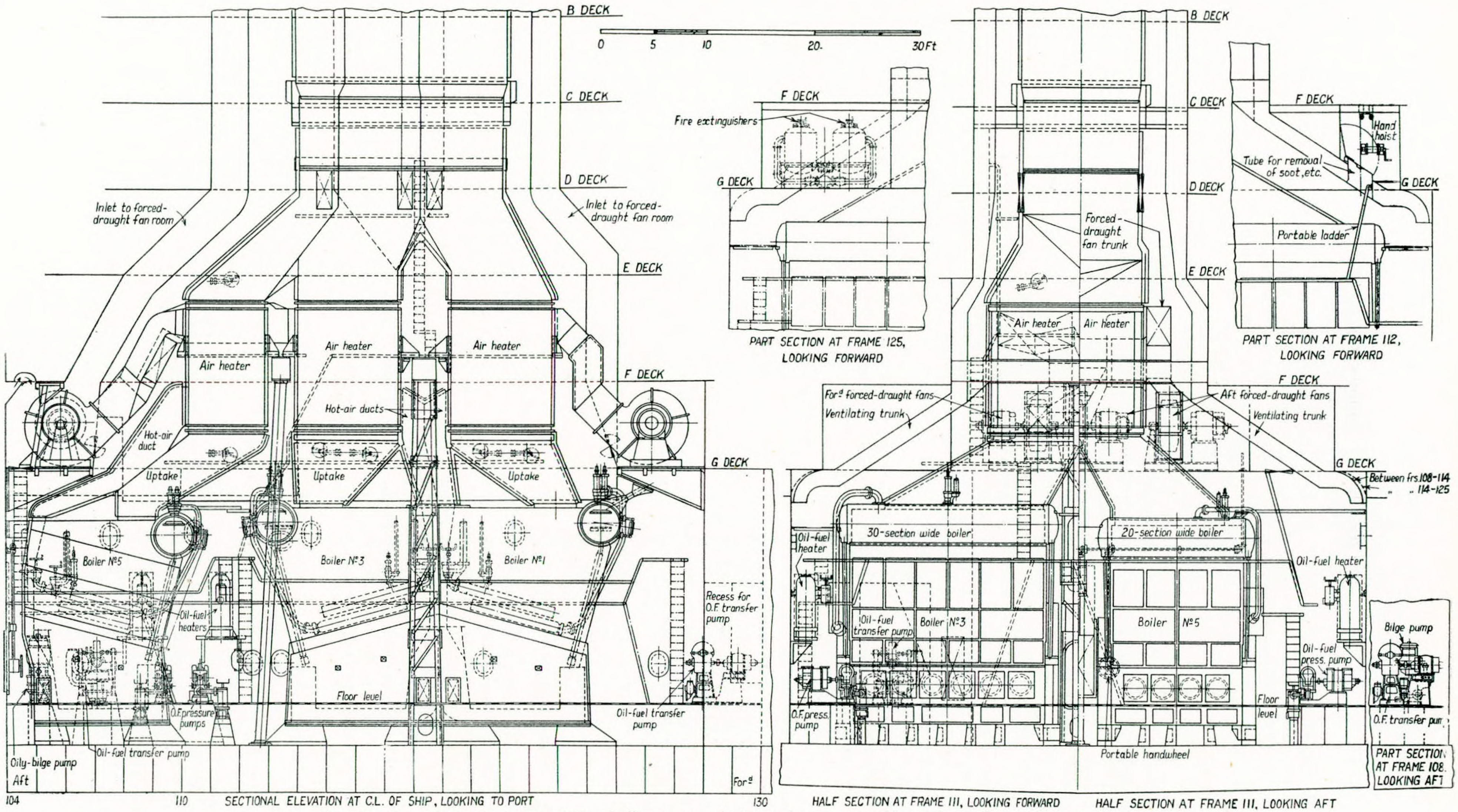


FIG. 2.—General arrangement of the boiler-room of the twin-screw turbine-driven liner "Orion".

fitted with superheaters and tubular air-heaters. The principal heating surfaces are as follows :—

(*a*) *Generating surface.*—Each large boiler, 7,465 sq. ft.; each small boiler, 3,585 sq. ft.; total generating surface of six units, 37,030 sq. ft.

(*b*) *Superheating surface.*—Each large boiler, 1,004 sq. ft.; each small boiler, 717 sq. ft.; total superheating surface of six units, 5,450 sq. ft.

(*c*) *Air-heating surface.*—Each air-heater for each large boiler, 8,000 sq. ft.; each air-heater for each small boiler, 4,000 sq. ft.; total heating surface of six air-heaters, 40,000 sq. ft.

The final conditions of the steam are 425lb. per sq. in. at the engine-room bulkhead valves and 725° F.—about 275° F. superheat.

The boilers, which are oil-fired and equipped with Wallsend-Howden burners, operate under conditions of forced draught on the closed air-duct system with open stokeholds. Air is supplied by five double-inlet electrically-driven fans. Each fan is driven by a 20-h.p. motor. They are mounted in two groups on flats in the boiler-room at the level of *G* deck; three fans are situated athwartships on the flat at the after end of the boiler-room, and two on the forward flat. The fans are 57in. in diameter, and are capable of discharging 18,000 cu. ft. of air per minute at a head of 4in. of water at the fan outlet.

The oil-fuel installation consists of four units (one pair working and one pair stand-by), each unit comprising an electrically-driven pump and one heater. Each pump handles 16,200lb. of oil fuel per hour. Strainers have been fitted on the suction side of the oil-fuel pumps, and also in the discharge line from the oil-heaters to the burners.

Two fuel-oil transfer pumps of the electrically-driven two-throw type, and each of a capacity of 60 tons per hour, are provided for transferring oil from the settling tanks, which are fitted both port and starboard.

Diamond soot-blowers are used, modern boiler efficiencies demanding that tubes must be kept clean, especially the bottom rows, and the old cleaning system by means of a hand lance has given way to more reliable mechanical methods. Care has been taken to ensure easy and simple operation, ready overhaul and maintenance, and the economical use of steam by adopting the most efficient jets from well-designed nozzles and careful disposition of the elements.

Condensing and Boiler-feed Appliances.

That high overall efficiencies of modern high-pressure boiler installations are largely dependent on the careful design and arrangement of the condensing and feed-heating appliances is incontrovertible. It is with the object of eliminating thermal losses and the conservation of heat that a closed-feed system has been adopted for both the main and auxiliary circuits.

The main condensers are of the regenerative type and are underslung from the low-pressure turbines, spring supports being fitted to relieve the load on the turbine casings. The cooling surface in each condenser is about 12,500 sq. ft., a vacuum of about 29in. of mercury being maintained with a barometer height of 30in. and with a sea-water inlet temperature of 86° F. The tube alloy has the important characteristic of forming a natural vitreous scale when immersed in sea-water; and this scale, which possesses strong adherent properties, heals quickly and firmly in the event of a broken condenser tube. Each main condenser is fitted with a closed-feed controller, comprising a supplementary feed-valve and overflow valve operated by a single float.

Two main circulating pumps are driven by a steam turbine which is rated at 130 b.h.p. and runs at 4,250 r.p.m. The pumps are driven through 10 to 1 reduction gear, and are each capable of delivering 16,000 gallons of sea-water per minute against a head of 21ft. at 425 r.p.m.

Two vertical-spindle motor-driven extraction pumps have been supplied, each capable of a normal output of 99,500lb. of condensate per hour and an emergency output of 150,000lb. per hour when drawing from 29in. mercury vacuum and discharging against 25lb. per sq. in. gauge. The pumps are of the two-stage type, and the casing, which is of gun-metal, can be split on the vertical centre-line.

Two sets of steam-jet air ejectors maintain the vacuum in the condensers. These ejectors are of the three-stage vertical inter-condenser type, the circulating water being the main condensate.

A drain cooler of an area of 400 sq. ft. is provided and is capable of raising 210,000lb. of feed water per hour from 106 to 122° F.

Three turbo-driven centrifugal feed pumps have been fitted—two working and one stand-by. Each pump is of the two-stage pattern, capable of a normal output of 160,000lb. per hour and an overload discharge of 200,000lb. per hour against a discharge pressure of 550lb. per sq. in. The turbines take live boiler steam at 425lb. per sq. in. and 725° F.

Two single-cylinder direct-acting vertical pumps have been supplied for auxiliary feed-pump duty.

Three-stage feed-heating has been adopted, the system being as follows :—

(*a*) The low-pressure heater utilises the turbo-generator exhaust steam, together with the drains from the intermediate-pressure heater and evaporator, and is capable of raising the temperature of 226,000lb. of feed per hour from 120 to 215° F. The heating surface is 650 sq. ft.

(*b*) The intermediate-pressure heater increases the feed temperature of 226,000lb. of feed per hour from 215 to 296° F., and is supplied with bled steam and the drains from the high-pressure heater.

(*c*) Steam bled at 140lb. per sq. in. is the medium adopted in the high-pressure stage, and the heater is capable of handling 226,000lb. of feed per hour, the temperature change being from 296 to 336° F.

For port duty, a direct-contact feed-heater is employed which utilises exhaust steam as a heating medium and is capable of handling 20,000lb. of feed per hour.

The make-up feed is supplied by two vertical evaporators. Each handles 40 tons of water per 24 hours when supplied with steam at 75lb. per sq. in. absolute. The associated feed pumps are of the two-throw type, 2¼in. diameter by 2½in. stroke, and electrically driven.

Electrical Equipment.

The main generating sets comprise three Allen turbo-generators.

The turbines run at 5,000 r.p.m., and are designed for steam at 425lb. per sq. in. pressure and 725° F. temperature. The turbine exhaust is used at sea for feed-heating (low-pressure stage), and by-passed to the auxiliary condenser when in port. Provision has also been made for bleeding a suitable quantity of steam from these turbines in order to heat the condensate. The generators are compound-wound machines, and have a rated output of 500 kW. at 220 volts. These dynamos are driven through double-helical gearing at 500 r.p.m. They are designed for a maximum temperature rise of 55° F., and are capable of running at 25 per cent. overload (625 kW. output) for two hours.

The emergency generator set is a Diesel-driven unit accommodated on *D* deck. The motor is a vertical, four-stroke cycle, airless-injection, six-cylinder Diesel engine running at 500 r.p.m. It is directly coupled to a 220-volt compound-wound generator of a normal rated capacity of 90 kW., and is designed for a permissible overload of 10 per cent. (99 kW. output) for one hour.

Messrs. G. Kent, Ltd., of Luton, supplied two steam meters. One meter is for measuring the auxiliary steam supplied to the pumps, and is designed for a maximum flow of 48,000lb. of steam per hour, the steam conditions being 425lb. per sq. in. and 725° F. total temperature. A static pressure recorder, with a pressure range of 318 to 500lb. per sq. in., is attached to the meter. The other meter supplied is for measuring the turbine consumption, and measures the steam flow to each turbine in turn by means of a two-way switching arrangement. Here the maximum flow is 90,000lb. of steam per hour, the steam conditions being as before.

The P. & O. Liner "Strathmore".

A Twin-screw Turbine-driven Steamship for the Mail, Passenger and Cargo Service to India.

"The Shipbuilder and Marine Engine-Builder", October, 1935.

The principal dimensions and other salient characteristics of the design to which the "Strathmore" has been built are given in the accompanying table, where, for purposes of comparison, the corresponding data for the "Orion" are also given.

LEADING PARTICULARS OF THE "STRATHMORE" AND "ORION".

	"Strathmore".	"Orion".
Length overall	665ft.	665ft.
Length B.P.	630ft.	630ft.
Breadth overall	84ft.	84ft.
Breadth moulded	82ft.	82ft.
Depth moulded to *F* deck ...	38ft.	38ft.
Depth moulded to *E* deck ...	47ft. 6in.	47ft. 6in.
Draught	30ft.	30ft.
Displacement, tons	28,400	28,400
Gross tonnage	23,428	23,371
Passengers—		
First-class	445	486
Tourist-class	665	653
Total	1,110	1,139
Crew	515	466
Total complement ...	1,625	1,605
Shaft horse-power	24,000	24,000
Speed, knots	21	21

Propelling and Auxiliary Machinery.

The "Strathmore" is propelled by two screws, each driven by a set of Parsons turbines through single-reduction gearing. Each set comprises one high-pressure, one intermediate-pressure and one low-pressure turbine working in series and driving separate pinions which engage with the main gear-wheel. The details of these turbines and their blading are identical with those of the main propelling units installed in the Orient Line's latest mail, passenger and cargo steamship "Orion". The similarity between these vessels also extends to the boiler installation, engine-room auxiliaries and general machinery layout. The main gearing in this vessel only differs from that installed in the "Orion" in that central bearings are not fitted to the pinion shafting. This arrangement results in a shorter overall length of machinery. Michell thrust blocks have been fitted to the lines of shafting, and the adjusting blocks on the turbines are of the Michell pivoted type.

Forced lubrication is supplied to the shaft bearings, gearing and main thrust blocks, and this service also provides the transmission medium for the turbine-governing apparatus. A Vickcen oil purifier, capable of handling 225 gallons of turbine oil per hour, is incorporated in the forced-lubrication circuit.

The steam-generating installation consists of six Babcock & Wilcox high-pressure marine-type boilers. There are four large and two small boilers, and all are fitted with superheaters and tubular air-heaters. The pressure is 450lb. per sq. in., steam temperature 725° F. The total generating surface of the four large boilers is 29,860 sq. ft., with a total superheating surface of 4,280 sq. ft.; while the total generating surface of the two small boilers is 7,170 sq. ft., with a total superheating surface of 1,434 sq. ft. The total air-heating surfaces for the large and small boilers are 32,000 and 8,000 sq. ft. respectively.

The boilers are oil-fired on the forced-draught closed-air duct system. The motors are arranged for a wide speed variation, and the pressure of the oil discharge to the burners can be adjusted to a fine degree by a regulating relief valve. The burners and air directors are of the latest pattern, and are designed to give a short flame and a high combustion efficiency. Special heat-resisting steel has been adopted for the air directors to withstand the intense radiation from the flame and furnace brickwork. Two air directors on each boiler are hinged to give easy access to the furnace.

Both the main and auxiliary feed systems are of the improved closed-feed type, comprising the following items:—

Two Weir regenerative condensers underslung from the low-pressure turbine casings. The closed-feed controllers are bolted direct to wells on the main condensers.

Two vertical-spindle motor-driven condensate-extraction pumps.

Two three-stage air-ejectors.

One surface drain-cooler.

Two turbo-driven feed pumps.

Two turbo-driven centrifugal circulating pumps.

Low, intermediate and high-pressure feed-heaters, using auxiliary exhaust steam and steam bled at suitable stages from the main turbines.

Make-up feed is provided by two high-pressure evaporators, each having a capacity of 40 tons per 24 hours.

The ship's service fresh-water plant includes two 50 tons per day high-pressure evaporators, two distilling condensers, and a two-throw evaporator feed pump of 3 tons per hour capacity. In connection with the ship's hotel and catering services, the soft-water supply is ensured principally by a Basex water-softening installation manufactured by the Paterson Engineering Co., Ltd., of London.

Electric-generating Installation.

The "Strathmore" differs in several respects from the "Orion" in regard to electrical equipment.

The main generating machinery consists of three steam turbo-driven, direct-current, compound-wound dynamos, these machines being housed in an auxiliary-machinery compartment at the forward end of the engine-room. The steam turbines, which run at 5,000 r.p.m., are designed for a steam pressure of 400lb. per sq. in. and a temperature of 720° F., but they are capable of withstanding the full boiler pressure of 450lb. per sq. in. They are of the standard impulse type, and have stainless-steel blading. The generators are driven through single-reduction double-helical gears at a speed of 500 r.p.m., and have an output of 500 to 550 kW. at 220 volts.

The emergency generating plant consists of a 110-kW. set comprising a six-cylinder Diesel engine developing 165 h.p. at 600 r.p.m., directly coupled to a 220-volt generator of the single-pedestal type.

In the "Strathmore", vital equipment such as the steering gear and engine-room auxiliaries are electrically-driven, and the system of control and distribution of the electric power adopted is such as to ensure continuous supply to these units under the most abnormal conditions. The main switchboard is fitted in the dynamo room and is split into three separate boards, each of which is fed from the corresponding generator through a 2,500-ampere triple-pole circuit-breaker. The port and starboard bus-bars are connected to the centre bus-bars through two 3,500-ampere double-pole switches fitted on the centre switchboard.

The main dynamo breakers have the usual overload device with time lag and reverse current releases. The positive and equaliser poles are mechanically coupled for hand control, the negative poles being electrically operated by a solenoid and controlled by a switch conveniently placed for paralleling. Special instant-action emergency trip relays are fitted, which operate at a pre-determined load to trip out certain selected feeder circuits of secondary importance, and thus, in the event of abnormal conditions, allow the maintenance of the essential supply by relieving the generators of part of their load. This arrangement is desirable for dealing with the case of a generator shutting down involuntarily when running in parallel, as in this event the generators still remaining on the bus-bars will not have their circuit-breakers tripped. It also provides a safeguard against running machines becoming loaded beyond their normal working capacity.

The main switchboards distribute current to 13 auxiliary switchboards fitted in convenient positions throughout the ship, and to the important power and lighting services, through double-pole circuit-breakers or double-pole switches and fuses, as required.

Refrigerating Machinery.

Refrigerating machinery is installed on the tank top in a special compartment forward of the midship oil-fuel tanks. The plant comprises four of the latest type of electrically-driven horizontal refrigerating machines of the twin-compressor type similar to those supplied for a number of recently completed meat-carrying vessels, the cooling medium being CO_2. In normal circumstances, two of the machines will deal with the insulated-cargo spaces and the provision rooms, and one will be employed in connection with the air-conditioning installation associated with the ventilation of the first-class dining saloon. The fourth machine is held in reserve and is available for any of the duties. Each machine has a pair of CO_2 compressors driven by a variable-speed electric motor of 125 b.h.p. coupled directly to the crankshaft. The working parts are enclosed, and all the principal bearing surfaces have forced lubrication. There are four sets of CO_2 condenser coils of copper tube, each enclosed in a circular casing of cast iron. In a separate insulated compartment are the four sets of steel-tube evaporator coils, each coil being housed in a circular steel casing. Circulation of sea-water is effected by two centrifugal pumps, while the circulation of brine through the grids is catered for by means of five centrifugal pumps. The brine arrangements have been planned to permit the simultaneous circulation of brine at several different temperatures.

To provide the strict measure of temperature control necessary for the safety of the produce carried in the various refrigerated and insulated compartments, a comprehensive equipment of electrical distance thermometers is installed.

Trials and Delivery.

After leaving her builders' yard at Barrow runs were made at 14, 16, 18 and 20 knots and at full speed, and steering trials were also carried out. The weather was unfavourable and a strong S.S.W. wind was blowing, but in spite of the weather conditions the mean of the two runs at full power was 21·910 knots, the highest speed being 22·277 knots. The almost complete absence of vibration at full power was marked.

The Effect of Soot on Heat Transmission in Small Boilers.

"Engineering", 16th August, 1935.

The rate at which heat can be transmitted through metallic walls depends upon the properties of the metal and the actual temperature gradient within it. Any extraneous condition that prevents high temperatures on the inflow side reduces the amount of heat that passes through, and the rate of evaporation, if a boiler is in question, on the other side. A layer of soot acts in this way, and must be removed if efficiency is to be maintained. Usually large boilers, and frequently those of medium size, are equipped with soot blowers, and fuel savings have resulted from their application, amounting sometimes to 8 per cent., but commonly to 4 per cent. or 5 per cent. Very little information has, however, been available regarding the losses incurred with small boilers, where the deposits are usually thicker, because they are more rarely removed, and for that reason some interest attaches to the publication, by the United States Bureau of Mines, of a report on investigations conducted on the "Effect of Soot on Heat Transmission in Small Boilers" at the Pittsburg Experiment Station, by Messrs. P. Nicholls and C. E. Augustine.

The work referred to was restricted to the action upon heat transfer of soot deposits. It was conducted with two cylindrical cast-iron sectional boilers, with 20in. and 24in. diameter fireboxes. The tests did not directly cover the waste of fuel under service conditions due to the decrease in the available draught caused by the clogging of passages or flues, which commonly accompanies poor or incomplete combustion. Very little definite information is available on the thermal conductivity of soot, and deposits vary so much in density and composition that heat transmission tests of samples would prove of small practical value. Such deposits invariably contain ash, and sometimes are largely of that nature.

The actual heat resistance from hot gas to water is a summation of the resistances of the soot and film of hot gases, the actual resistance of the metal, and the surface resistance on the water side. There is much information already available on all these factors, with the exception of soot itself, and the tests of heat transfer were therefore conducted by duplicating, as far as possible, actual service conditions. Hot gases of a definite weight per hour and a definite temperature, were passed through the boiler, the heat transmission being determined from the heat delivered and from the temperature of the gases leaving the boiler. This was accomplished by burning high-temperature coke, supplying a definite weight of air per hour, and constantly adjusting the rates of primary and secondary air so that the carbon dioxide content of the flue gases was kept constant for five hours, and was the same in the successive tests. For the first test, all heating surfaces were thoroughly cleaned, and then sooting was accomplished, as an independent operation, by burning coal in the normal manner with natural draught. After light sooting, the second test was made, after which the procedure was continued until no further increase in soot was possible. Finally, the boiler was again cleaned and re-tested.

Dealing first with the 20in. diameter boiler and taking the initial clean condition as the standard, slight sooting, referred to as $\frac{1}{8}$in., though the thicknesses were not uniform over any one area and decreased along the path of the gases, caused a heat loss of 3 per cent. Further sooting, classed as medium, and referred to as $\frac{1}{4}$in. with the same reservation, increased the loss to 4·9 per cent. Smaller increases in the magnitude of the loss occurred as sooting continued, and a maximum of 6·6 per cent. was ultimately reached. The repetition test for the clean condition, after removing all deposit, confirmed the first. Generally speaking, the results with the 24in. diameter boiler showed corresponding changes, but their magnitude was less, which was to be anticipated, because the ratio of the area of the surface to the cross-section of the gas stream decreased with an increase in diameter. The greatest loss in this case, with heavy sooting, was found to be 5·3 per cent. The loss with the first sooting layer was proportionately greater than with the further increases. As a possible explanation of this, it was suggested that the surfaces being initially clean received a deposit of tar, which may have decreased their ability to absorb radiation from the fuel bed. The maximum losses were obtained with heavier layers of soot than would be tolerated in service.

The value of these tests, conducted under arbitrarily fixed conditions, may, of course, be questioned from the standpoint of the average conditions under which such boilers are operated. The carbon dioxide content in the flue gases was higher than is usual in service, reaching 14·1 per cent. in the case of the larger boiler, and the tests did not include a period after a firing when the surface of the bed was dull and there was little radiation. To cover all such questions fully would, of course, require very extensive experimental investigation. It was nevertheless found that the heat absorbed by the secondary heating surface, where the action was by convection, was roughly proportional to the product of the weight of the gases passing and the difference in temperature between them and the surface. This product tended to remain constant for a given rate of heat liberation, being independent of the quantity of excess air. The rates of burning used, namely, 2½lb. and 3lb. per square foot per hour, were selected as fair average values for all conditions during the use of such boilers in the heating season.

To assess the loss in terms of the heat available in the coal burned, some assumed value would have to be given to the loss of fuel in the ash; this was placed at 4 per cent. Similarly, allowance had to be made for the loss of combustible in the flue gases; this varied rather widely, but was taken as an average at 8 per cent., making a total loss of 12 per cent. Thus the loss of efficiency on the basis of heat contents of the fuel would be 88 per cent. of 6·6 per cent. for the maximum case, or 5·7 per cent.

The main practical objection to soot is that it clogs the passages and the lack of adequate draught results in waste of fuel, in addition to the loss from the insulating effect of the layer of soot. A secondary result of insufficient draught is the fuel lost to the ash pit through the necessity for shaking the grate.

BOARD OF TRADE EXAMINATIONS.

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

For week ended 12th September, 1935:—

Name.	Grade.	Port of Examination.
Thompson, Joseph E. ...	2.C.M.	Newcastle
Crombie, Thomas	2.C.	Glasgow
Dick, James	2.C.	„
Peters, Robert A.	2.C.	„
Souter, James L.	2.C.	„
Summers, Benjamin G. ...	2.C.	„
Barnett, Samuel R.	2.C.M.	„
McLennan, Alexander ...	2.C.M.	„
Malcolm, Thomas	2.C.M.	„
Evans, Ernest W. ...	2.C.	Cardiff
Ashworth, Stanley E. ...	2.C.	Liverpool
Camden, Stanley	2.C.	„
Clark, Royston H.	2.C.	„
Manson, George	2.C.	„
Pollard, John G.	2.C.M.	„
Barrett, Maurice J.	2.C.	London
Robertson, Arthur J. ...	2.C.M.	„
Arthur, Laurence K. B. ...	2.C.	Newcastle
Clark, George H.	2.C.	„
Coulson, Richard C. C. ...	2.C.	„
Fox, James G.	2.C.	„
Ross, William	2.C.	„
Armstrong, Leslie	2.C.M.	„
Bell, John W.	2.C.M.	„
Bright, Henry W.	2.C.M.	„

For week ended 19th September, 1935:—

Name.	Grade.	Port of Examination.
Burrows, Henry J.	1.C.	Cardiff
Williams, Joseph J. B. ...	1.C.	„
Ford, James D.	1.C.	Glasgow
Galbraith, Alexander B. ...	1.C.	„
Matthews, John A.	1.C.	„
Maver, John W.	1.C.	„
Robertson, James R. B. ...	1.C.	„
Taylor, Henry	1.C.	„
Whyte, Ian G.	1.C.	„
Clark, William	1.C.M.	„
Forrest, Hamilton	1.C.M.	„
Hitchmough, William ...	1.C.	Liverpool
Murphy, Norman G. ...	1.C.	„
Tector, James W.	1.C.	„
Way, Charles T.	1.C.	London
Dickie, James G.	1.C.	Newcastle
Fernie, John	1.C.	„
Seymour, William W. ...	1.C.	„
Wase, Philip H.	1.C.	„
Wright, Robert	1.C.	„
Harrison, John	1.C.S.E.	„
Oliver, Thomas V.	1.C.M.E.	„
Stuart, Norman	1.C.M.E.	„
Haggitt, Walter	1.C.M.E.	Liverpool
Wills, Alfred J.	1.C.M.E.	London
Macfarlane, Robert G. ...	1.C.M.E.	Glasgow
Hodges, Donald A. ...	1.C.M.E.	Cardiff
McNeish, James M.... ...	2.C.S.E.	Glasgow

For week ended 26th September, 1935:—

Name.	Grade.	Port of Examination.
Fairbairn, George E. ...	2.C.	Newcastle
Kelly, Albert	2.C.	„
Morgan, John H.	2.C.	„
Robson, George P.	2.C.	„
Wilson, John	2.C.	„
Carverhill, David	2.C.M.	„
Laws, Roy	2.C.M.	„
Sharp, Norman	2.C.M.	„
Willis, Arthur L.	2.C.M.	„
Costain, Arthur	2.C.	Liverpool
Kermode, Eric M.	2.C.	„
Smith, David	2.C.	„
Young, Stewart	2.C.	„
Elder, Gerald G.	2.C.M.	„
Jones, Richard	2.C.M.	„
Cubitt, James C.	2.C.	Glasgow
Forrest, William G. ...	2.C.	„
Chalmers, John	2.C.M.	„
Leitch, Charles W.	2.C.	Dublin
Ellis, Harold	2.C.	London
Lee, John S.	2.C.	„
Plastow, Edwin C.	2.C.	„
Caskie, John S.	2.C.M.E.	„