Electric Propulsion on the Steamship Wulsty Castle

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THE Steamship *Wulsty Castle* is at present the only British electrically propelled seagoing ship in commission, and developments are being closely watched by certain prominent British shipping concerns which are keeping the electric ship propulsion proposition steadily in view.

The vessel is designed for a speed of 10 knots per hour, and for cargo carrying only, and is now trading, with other ships of Chamber's Castle Line, between

FIG. 1—THE BRITISH TURBO-ELECTRIC CARGO STEAMER *Wulsty Castle*

southern U. S. A. ports and Europe. She is capable of carrying some 6000 Imperial tons of cargo. Her length between perpendiculars is 356 ft. 3 in. (108.27 m.) beam 48 ft. 9 in. (14.86 m.) and the mean draft when fully loaded is approximately 24 ft. (7.31 m.). In the installation about to be described, two turbo alternators situated one each side of the 30 ft. by 45 ft. (9.14 m. by 13.71 m.), engine room, running in parallel, supply power to two main driving induction motors, which are situated amidships, and which in turn transmit power through double helical single reduction gearing to the single low-speed propeller shaft.

Boilers. Steam is generated in two cylindrical boilers of 13 ft. (3.96 m.) internal diameter by 11 ft. (3.35 m.) long, with 3 in. (76.2 m m.) internal diameter smoke tubes, and designed for a working pressure of 220 lb. per sq. in. The Howden's system of forced draught is used, and Schmidt type smoke tube superheaters are fitted. In addition to the standard marine mountings, "Diamond" tube blowers are installed for keeping the tubes clear.

Originally coal burning, the boilers were recently equipped with the White low pressure oil fuel system. Considerable trouble was caused, especially when burning inferior classes of oil, by heavy soot lodging on the superheater tubes inside the boiler tubes, thus obstructing the draught and materially interfering with the efficient working of the boilers. Keeping these tubes clear necessitated the frequent and liberal use of steam through the Diamond blowers. So serious did this matter become, and to such an extent did it impair the efficient running of the plant, that it was deemed advisable to remove a small percentage of the superheater tubes. This alteration was followed by good results, and by no appreciable drop in steam temperature, which approximately 550 deg. fahr. at the turbine stop valves. A feed heater is installed, through which the feed water returns to the boilers at a temperature of around 223 deg. fahr. A small donkey boiler, designed to work at 100 lb. pressure for driving cargo winches etc. in port is mounted between the two main boilers.

Turbines. In this brief article the writer does not propose to describe the Ljungström turbine[1] in detail,

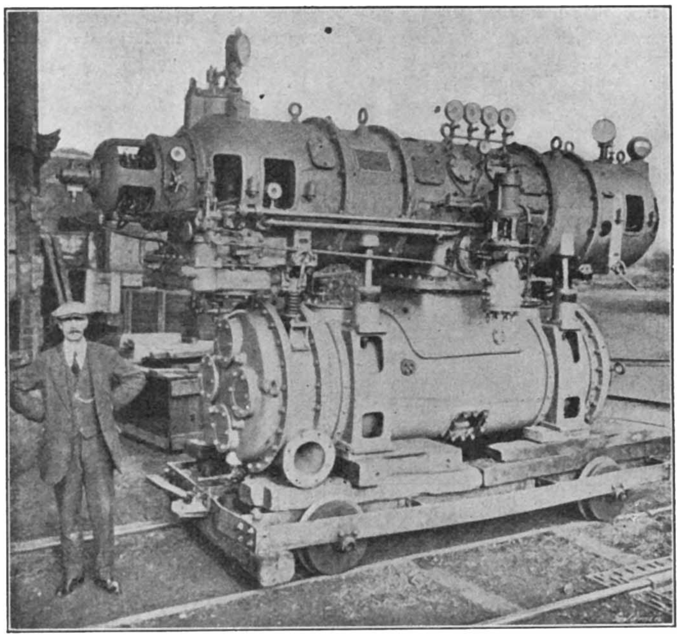

FIG. 2—LJUNGSTROM TURBO-ALTERNATOR AND CONDENSER

and will merely explain that this turbine is a radial-flow machine consisting of two disks carrying concentric intermeshing wings of reaction blading. Steam enters the blading near the center of the disks, and in passing from ring to ring outwards impells one disk in one direction and the other in the opposite direction, each disk being direct connected to an alternator shaft. Fig. 2 shows the port turbo-alternator and condenser of the *Wulsty Castle* leaving the works of the Brush

1. For detailed description of Ljungstrom turbine see *Engineering*, Vols. CV. and CVI, 1918.

Electrical Engineering Company to be placed on board. The exciter can be clearly seen on the extreme left. The condenser is of the "Contraflo" surface type and forms the bed plate of the complete turbo alternator.

A Ljungstrom turbo alternator in the course of erection is shown in Fig. 3. In addition to ventilating the alternator windings, the ventilating fans, one of which can be seen near the slip rings Fig. 3, furnish the air required at the boiler furnaces. After cooling the windings, the heated air is passed along to the Howden's forced draught system where it maintains approximately 9/16 in. of draught at the furnace doors. The main lubricating oil pump and governor gear are both driven by the gear wheel on the extreme right.

these two alternators come into synchronism automatically, an ammeter joined in series with their fields (shown on the right of Fig. 2) indicating when this has occurred. Each of the two three-phase 60-cycle 650-volt, delta-connected main alternators is designed to deliver 625 kw. when running at 3600 revs. per min. The design does not materially differ from standard English practise, the rotors being solid steel forgings with milled slots, which take form-wound coils. Gun-metal wedges hold the coils in place and special caps of the same material secure the end windings from displacement by the heavy centrifugal forces. Provision has been made for exciting one or both alternators from the ship's 20-kw. 60-volt d-c. lighting dynamo,

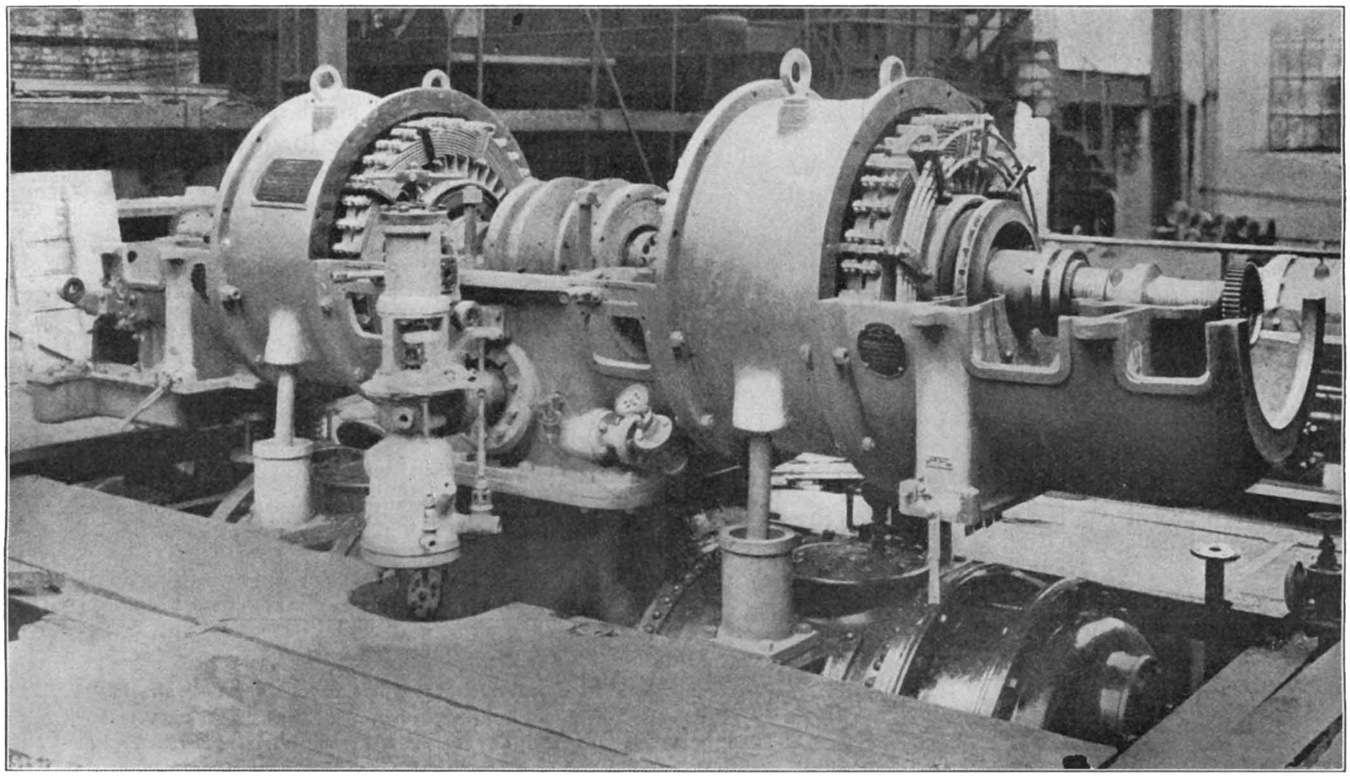

Fig. 3—Ljungstrom Turbo Alternator in Course of Erection

Fig. 4 shows the complete turbine lifted clear of the exhaust casing with the blading intermeshed and clamped in position. The special lifting gear shown allows the turbine to be rotated on one or both of two axes, thus facilitating inspection and handling. Each turbine has 39 rings of which 20 are on one disk and 19 on the other. The external diameter is 28 in. (711 mm.) and the overall length is 17½ in. (440 mm.), the total weight being only four cwt. (448 pounds). The kinetic plant is mounted near the turbo alternator and the three pumps necessary for its operation are mounted on one vertical motor-driven shaft.

Alternators. From the foregoing it will be clearly seen that each turbine runs two separate alternators. These two alternators are permanently connected in parallel, with their fields in series, and are invariably regarded as one unit. As the turbine runs up to speed should the necessity at any time arise. This dynamo is so arranged that it can be either driven by a motor at sea, or by a small De Laval turbine in port, and is capable of exciting one or both alternators, in addition to meeting the ships lighting requirements and operating the ½-kw. standard Marconi wireless plant.

Main Motors. The two main induction motors are of the wound-rotor type and are fitted with the usual design of brush lifting and short-circuiting gear. Each is designed for a speed of 714 revs. per min. and rated at 785 h.p. Trial tests indicate an efficiency of 95 per cent and a power factor of 0.875 at full load. These motors run in pedestal-type bearings with split spherical bushings. They are arranged for forced lubrication, and each is ventilated by its own fan mounted on the rotor spider. The stator windings are arranged with a single bar per slot and insulated with seamless mica tube, the end connections being heavy copper strips. The rotor windings are of the cylindrical barrel type as shown in Fig. 5.

Gearing. The gearing is illustrated in Figs. 7 and 8. The pinions are 9.2 in. (233 mm.) in diameter at the pitch line and have 23 teeth. The large wheel with which they gear is 86 in. (2.18 m.) in diameter and the reduction ratio is 9.4 to 1. The total effective width of face is 22 in. (558.8 mm.). The thrust block is of the Mitchell type and is incorporated in the gear case. Two gear-driven oil pumps are mounted at the ends of the pinion shafts, and supply all the bearings including those of the main motors.

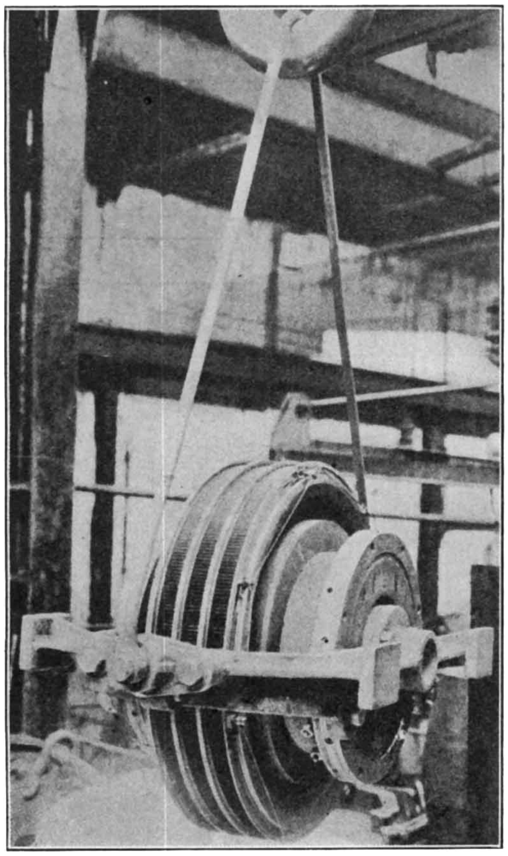

Fig. 4—Complete Turbine Lifted Clear of Casing

Switchboard. The switchboard represents standard shore practise. An ammeter, and a hand-operated oil switch, fitted with the usual overload and time-lag arrangements are provided for each alternator and main motor. The wattmeters, exciter voltmeters and field regulators, synchronizing gear, etc. are all of the usual commercial types. The reverse current relay shown in Fig. 10 has been removed.

Control. The turbines are never throttled for the purpose of reducing the speed of the ship. Speed is controlled by manipulating variable resistances in the main motor rotor circuits, a small control hand wheel being used for this purpose.

Reversal is effected by reversing two phases in the main motor stator circuits by means of the control wheel and an automatic reversing oil switch. Orders from the bridge are transmitted by means of the engine room telegraph which is mounted at the control position in the forward end of the engine room. The electrodes used in the main motor rotor circuits are cone-shaped nickel castings, while the electrolyte is a solution of K O H. Two small circulating pumps circulate the electrolyte through specially constructed coolers. The cones are raised or lowered by means of the control wheel, to which they are geared. When the control wheel is in the stop position the tips of the cones are raised clear of the liquid thus breaking the rotor circuits of the main motors. A safety arrangement prevents the closing of the main motor switches until the control wheel is in the stop position, and also prevents the main motors being short-circuited unless the control wheel is in either the full speed ahead, or full speed astern, position.

Operation. Referring to Fig. 10, it will be observed that the first motion of the control wheel from the stop position in either direction closes the reversing switch for ahead or astern running as the case may be. The necessary direct current for operating the automatic reversing switch, it will be seen, is supplied, through a change-over switch, from either exciter. Further motion of the hand wheel (a) cuts out the operating coil of the reversing switch and closes the economy coil circuit (b) lowers the tips of the cones into the electrolyte and starts up the main motors (c) adjusts the shunt regulators of the alternator exciters to meet the changing load conditions (d) locks the main motor switches to prevent them being reclosed should they open with an overload, and finally (e) in the full speed position unlocks the main motor short-circuiting hand lever. The speed then, varies as the angle through which the control wheel has been turned from the stop position, 120 deg. representing full speed. From about 15 revs. per min. any speed can be obtained up to 76, a special locking arrangement enables the control wheel to be clamped in any desired position. A suitably adjusted counterbalance weight allows the control wheel to be turned freely. The time required to reverse the propeller from full speed ahead, to full speed astern or vice versa, is merely the time required to turn the hand wheel from one extreme position to the other, and is approximately 10 seconds. Considerable difficulty was at first experienced in bringing the motors up near enough to synchronous speed, to enable them to be safely short-circuited. To surmount this difficulty, a hand-operated non-inductive grid-type buffer resistance can be placed in parallel and operated in conjunction with the liquid controller when short-circuiting the rotor windings.

Load. In still water the load depends on the draught of the ship, and ranges from approximately 30 per cent when the ship is light to full load value when the ship is fully laden. At sea, the load depends on the position of the propeller in the water, and in bad weather, continually fluctuates from approximately 25 per cent to

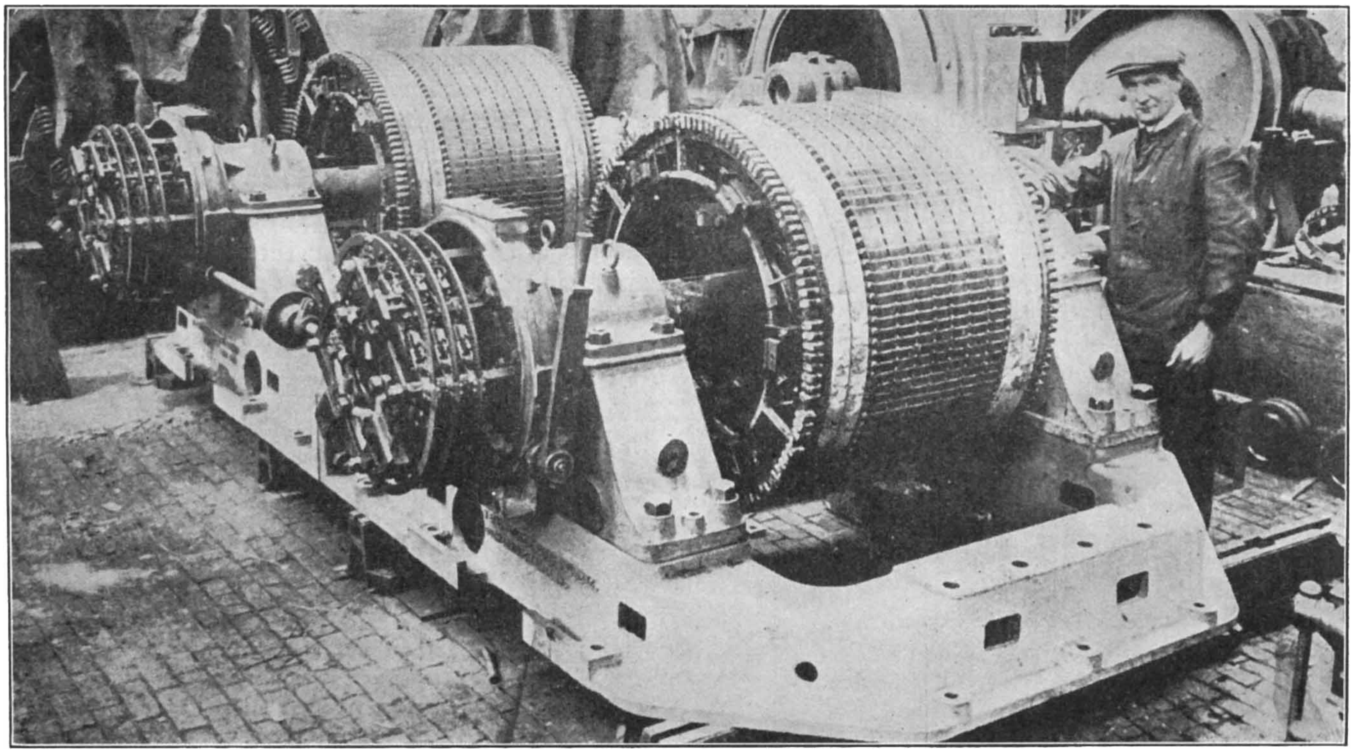

Fig. 5—Rotors of the Main Induction Motors

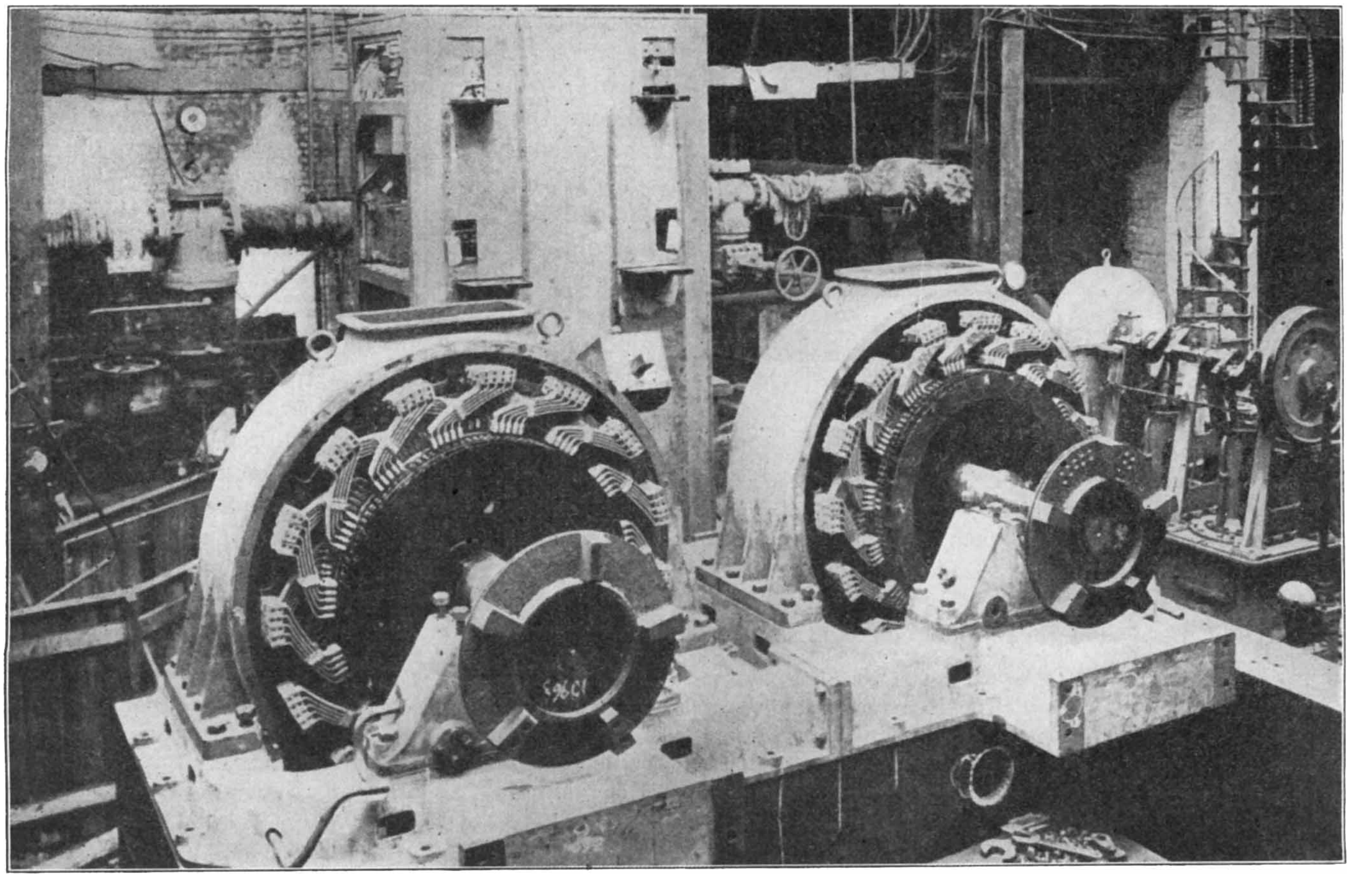

Fig. 6—Main Motors in Course of Erection

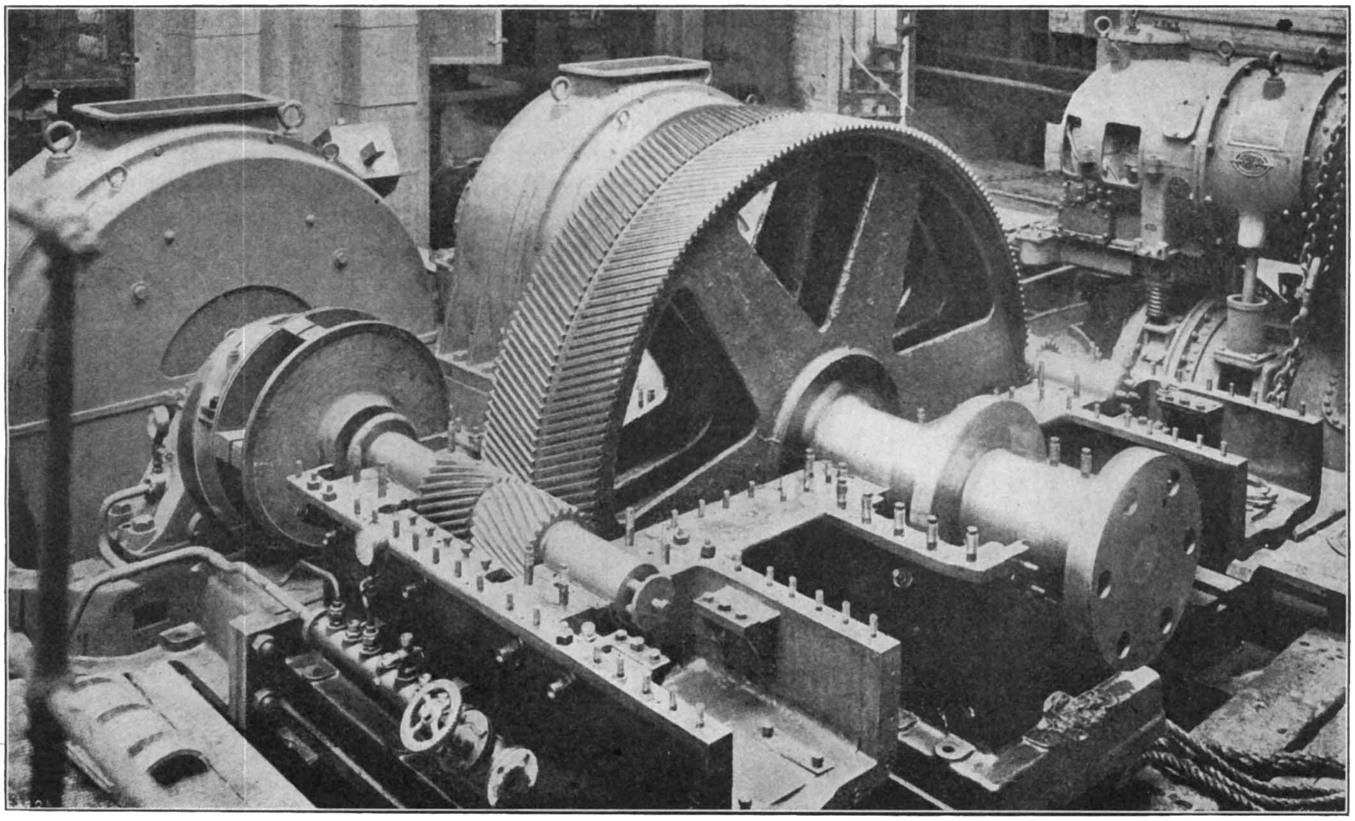

FIG. 7—GEARING WITH COVER REMOVED

150 per cent of full load normal value. Even in the heaviest seaway, with this drive, absolutely steady running is at all times assured, and "racing," which imposes very severe strains on other types of marine engines, is here quite unknown.

Auxiliary Motors. Practically all of the auxiliary machinery in this plant is motor-driven, three-phase squirrel cage motors of substantial construction being used. Two small switchboards, for the control of these motors, are mounted on the engineroom after bulkhead. Most of these motors are not equipped with starting devices, and are therefore usually run up with the alternators, in preference to switching them directly across full line voltage. Two 17-h.p. motors drive the main circulating pumps for the condensers at 1730 revs. per min. while two 14-h.p motors operate the combined kinetic, head and pressure pumps at the same speed. The 20-h.p. boiler feed pump motor runs at

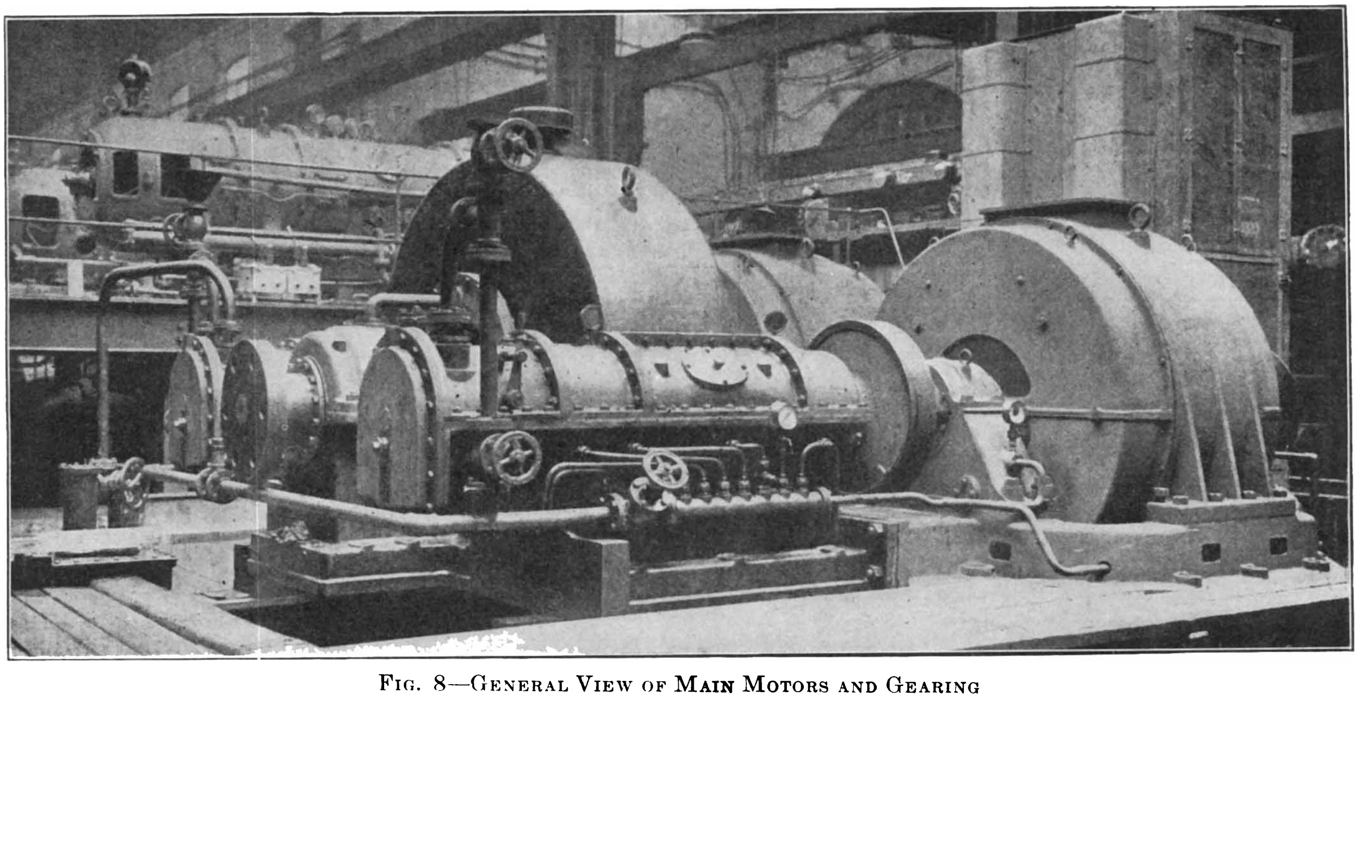

FIG. 8—GENERAL VIEW OF MAIN MOTORS AND GEARING

3515 revs. and is equipped with a star-delta starting device.

Two small motors of 1½ h.p. each, circulate the

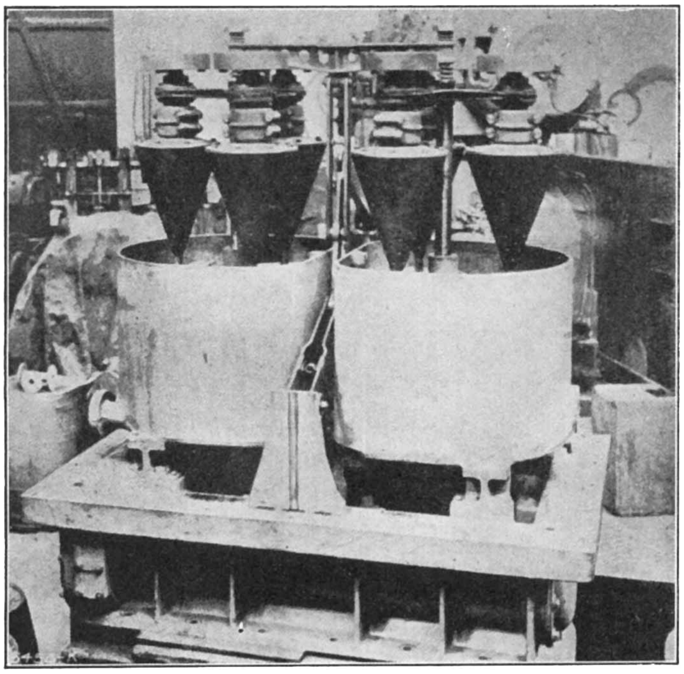

FIG. 9—VARIABLE LIQUID RESISTANCE FOR CONTROLLER

electrolyte of the main motor controllers, through coolers of special design, and run at 1100 revs. A 33-h.p. motor, speed 1720 revs. and fitted with an auto-starter, drives the ship's lighting dynamo while at sea, and a 700-rev. per min. 12-h.p. motor, fitted with a star-delta starter operates the ships steering gear. This last motor normally runs light, and is only loaded when the steering wheel on the bridge is moved, this movement being transmitted to the steering compartment by means of telemotor gear. Although the above motors have often been called upon to operate under most unfavorable conditions, they have always furnished excellent continuous service at sea, and have conclusively demonstrated, that for this class of marine work, the squirrel cage motor of reliable make, requiring as it does the minimum of attention, and occupying a very small amount of space,—both important factors in a ship's engineroom—is eminently suitable.

General. Unfortunately no data of a reliable nature are available regarding the economical end, but the writer, judging from previous marine experience with other types of drive, is of the opinion that this is entirely satisfactory. Notwithstanding the severe operating conditions, practically no trouble has been experienced with the electrical end at sea, with the exception of that caused by the deterioration of rubber insulation due to excessive heat while in tropical latitudes. One breakdown, which necessitated the ship being run at reduced speed and efficiency by one alternator while the necessary repair was being affected, was occasioned by a badly sweated alternator rotor slip ring connection generating sufficient heat to loose its solder leaving a loose connection held together by a

GENERAL PARTICULARS OF SIX HOURS FULL POWER TRIAL WITH SHIP MOORED AT QUAY, AT SUNDERLAND, ENG.

WEDNESDAY, JULY 3RD, 1918.

Time p.m.	Revs. per min.		Volts.	Port turbine.				Starboard turbine.				Temp. of sea	Kilowatts.		
					Before valve.		Vacuum by		Before valve.		Vacuum by				
	Turbine.	Propeller shaft.		Amperes	Pressure.	Temp. deg. F.	Kenoto-meter.	Amperes	Pressure.	Temp. deg. F.	Kenoto-meter.	Deg. F.	Port.	Star-board.	Total.
1.30	Synchronized both turbines.														
2.0	3,600	75	660	700	190	555	28.9	600	190	560	28.7	58	696	595	1,291
3.0	3,600	75	660	700	190	582	28.9	600	190	590	28.7	58	696	595	1,291
4.0	3,600	74	650	700	190	578	28.9	600	210	590	28.7	58	687	589	1,276
5.0	3,550	75	630	680	210	579	28.9	670	210	580	28.7	58	645	638	1,283
6.0	3,550	74	630	630	200	581	28.9	700	200	574	28.7	58	600	660	1,266
7.0	3,550	74	650	650	195	589	28.9	680	200	580	28.7	58	646	665	1,311
8.0	3,525	75	630	630	195	588	28.9	685	195	585	28.7	58	600	652	1,252
9.30	Shut down.														
Means	3,568	74.5	644	670	195	579	28.9	648	199	580	28.7	58	653	628	1,281

Designed normal full load output of both turbines		1,250 kw.
Actual output of both turbines on trial		1,281 "
Power used by auxiliaries as measured on trial:		
Two circulating pumps	27.4 kw.	
Two air or kinetic pumps	27.0 "	
One boiler feed pump	15.2 "	
Electrical steering gear	6.2 "	
Lighting circuits	4.2 "	
Total for auxiliaries	80.0 kw.	80 "
		1,201 kw.
Less energy absorbed in motors of 95 per cent efficiency	60.0 kw.	
Less energy absorbed in gearing of 98 per cent efficiency	24.0 "	
	84.0 kw.	84 "
Balance or net power on propeller shaft		1,117 kw.

1,117 kw. equals 1,117 ÷ 0.746 or 1,496 S.H.P.

single rivet; the consequent arcing at this point ultimately opening the circuit.

The electric ship propulsion porposition has much to recommend it, and this phase of electrical advancement undoubtedly offers a wide field for future investigation and development.

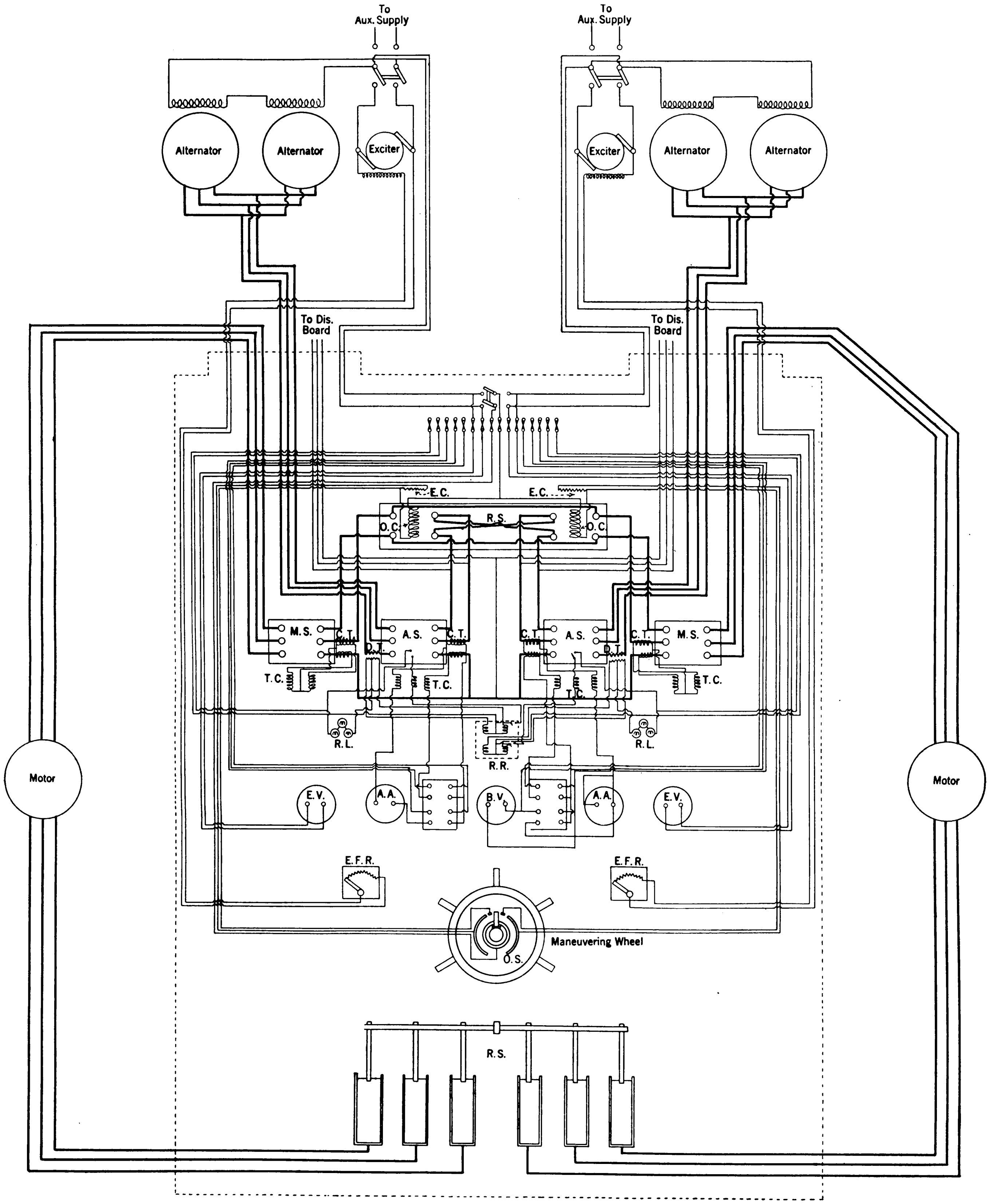

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Fig. 10—Diagrammatic Sketch of Electrical Connections

A. S. Alternator Oil Switch
M. S. Main Motor Switch
R. S. Reversing Switch, Elec. Operated
O. C. Operating Coil for Switch
E. C. Economy Resistance(inserted when core is up)
C. T. Current Transformer
T. C. Oil Switch Trip Coils
D. T. Transformer for Reverse Gear
R. R. Reverse Relay
R. L. Lamps (Pilot Lights) used as Resistance in Reverse
B. V. Bus Bar Voltmeter
E. V. Exciter Voltmeter
A. A. Alternator Ammeter
O. S. Operating Switch for Main Rev [illegible]
E. F. R. Exciter Field Regulator
R. S. Liquid Rotor Starter
I. W. Integrating Wattmeter