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The Application of Alternating Currents of Electricity to Modern Steamship Requirements.

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READ

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CHAIRMAN: MR. J. FELL REDMAN (MEMBER OF COUNCIL).

IN introducing this subject it is not my intention to go fully into details or theory, but to lightly touch the leading points opened up by the application of alternating currents of electricity to steamship requirements.

We are all aware of the vast strides made by direct current electricity in recent years as applied to large passenger steamers, but I do not think that the possibility of applying alternating currents of electricity has ever been discussed. In my opinion there are many points in favour of the installation of alternating currents for power purposes on board ship. When we consider the large losses of energy caused through radiation, leaks and draining, in the donkey boiler and condensing plant, and the further loss of energy caused by condensation in the long lengths of steam piping required to carry the steam to the deck auxiliaries, the quantity of joints to be kept tight and glands to be packed, very often at times when the necessary labour can be ill spared, any system which can be worked at a high efficiency and with a minimum of trouble, would be a very welcome substitute.

By the adoption of a proper installation of gas-driven electric generators and motors, an installation designed with a knowledge of the conditions of work on modern steamships, I believe that the donkey boiler with its copper steam and exhaust pipes and condenser could be abolished and would soon become a thing of the past. More than this, the engine-room auxiliaries such as turning gear for the main engines, circulating pumps, feed and ballast pumps, blower and ventilating fans, ash hoists, lifting gear, fresh water and wash deck pumps, etc., which are at present operated by steam, could be more efficiently and satisfactorily operated by alternating current motors; the main boilers would then be only required for generating steam for the main engines. In addition to the above, the boat hoists, steering gear, heating and ventilating apparatus and refrigerator plant could be more satisfactorily operated by means of alternating current. We could possibly do all cooking by the aid of electricity as it is cleaner, handier and more economical than coal fires, and has been used for cooking purposes on shore for many years past.

When in cold weather there would be no trouble from frost, and the system of electric cables would be far more flexible in every way than the steam piping. The electric current would be practically always ready or at the most a few minutes only be required if the gas engines were shut down, whereas in the case of a donkey boiler several hours are required to get up steam, and as long as there is a possibility of steam being required at any time in port, steam would have to be kept up, requiring the constant attention of the donkey man. This is a very great advantage in connexion with the fire pumps alone. Alternating currents do not affect the compass, owing to the fact that in each conductor currents of opposite signs succeed each other in rapid succession. Another great point in its favour is the fact that alternating current motors are practically unaffected by weather conditions or salt water. Motors of this type are constantly working out of doors on shore under the severest weather conditions and give no trouble; this is of course a very necessary qualification for ship work.

We have of course not to overlook the fact that large quantities of copper piping at present used for the deck steam auxiliaries would not be required, being replaced by copper cables to convey the current to the various parts of the ship, the weight of the copper in the cables would be very much less than the weight of copper in the piping. This, I might mention, would be a saving in the prime cost of the installation, although it is not my intention at the present time to discuss the question of relative prime costs. Further, the extreme simplicity of the whole plant, the absence of commutators in the main generating plant and motors, the high pressure at which power can be generated, requiring very light mains for transmission as compared to the heavy copper mains required for low voltage direct current, the ease with which the voltage can be reduced at the point required by means of static transformers to suit any requirements with very little loss of energy, such as low voltage for the lighting and heating mains, and a higher voltage for the motor circuits; in fact the extreme flexibility of any alternating supply is only one of its many advantages. It is not good practice to generate direct current electricity at high voltages, as the motor transformers necessary to reduce to working pressure are far more complicated and expensive than static transformers used in connexion with alternating currents. In fact the system is altogether too expensive and complicated for consideration. Then for the efficient and economical use of electrical power on board ship we must adopt alternating electricity, with gas-driven generators, of fairly high voltage.

GENERATION.—The gas engine, working with suction gas, is, I think, the most efficient prime mover it is possible to adopt for driving generators, and as far as I can see there appears to be no insurmountable objection to the use of this kind of engine on board ship. Engines of this description up to 300 H.P. are already at work giving every satisfaction; in fact the Admiralty has already led the way in this respect, and I believe that the new cruiser *Indefatigable* will be fitted entirely with gas engines. The advantages of a suction gas plant when in port are too obvious to mention.

The most suitable type of alternator we could adopt would be the flywheel type; that is, the field windings would be built on to the rim of the fly-wheel and would revolve with it, while the armature would remain fixed, being, of course, built round the edge of the fly-wheel. This type of alternator, however, requires two small slip rings for conveying the current from the small exciter to the fields. This current does not amount to very much, being only the exciting current; these slip rings in practice give no trouble whatever.

We must now consider our power requirements. The satisfactory use of alternating currents for power purposes on board ship depends chiefly upon the polyphase motor, as this type of alternating motor is self-starting, and operates at practically constant speed from no load to heavy overloads. Conditions of work on board ship, such as winch work, fans, pumps, etc., require motors starting with maximum torque on full load, and such makeshifts as loose pulleys and in some instances friction clutches are out of the question. The fact that the polyphase induction motor can be designed with maximum torque makes them ideal motors for this kind of work. Single-phase induction motors have not the power of developing such a high starting torque, and moreover require phase-splitting devices contained in the motor to enable them to be started satisfactorily.

In determining what number of phases it would be best to operate our machinery with, we must consider the saving in copper in transmission and the simplicity of the whole system. To arrive at the saving in copper for the different systems we must compare the equivalent weights of the combined conductors required for the same percentage loss and the same voltage. Assuming the power factor to be ·95, we express the weight of copper of the—

Direct current two-wire system as . .	100
Two-phase three-wire as . . .	89
Two-phase four-wire as . . .	105
Three-phase three-wire as . . .	79

Four, five and six-phase systems are not used in practice, and for our purpose the three-phase system would be most satisfactory in view of the fact that we have a combined power and lighting load to deal with. It will also be seen from the above tables that the three-phase three-wire system is the most economical in the saving of copper effected, at the same time it is the simplest, the voltage between and across phases being the same. In some of the alternating current systems this voltage varies, being slightly higher across the phases than between the phases, which is apt to make it rather inconvenient for installing, etc. The cost of switch gear and controlling apparatus, as well as the motors themselves, compare very favourably with that of the other alternating systems. Our main generating plant shall, therefore, consist of a suction gas equipment driving a fly-wheel type of alternator, as this type of alternator is the most suitable for our purposes. The small direct current exciter being geared directly to, or built upon, the shaft of the gas engine, the commutator of this small machine will be the only one in the whole installation. We may, therefore, say that we shall have eliminated all commutator troubles. The space occupied by this system will be far less than that occupied by any other.

We must now consider the amount of power likely to be required for operating all the auxiliary machinery. This, of course, is a very open question, and I think that I am right in saying that in the latest Cunarders the power required for this purpose is over 3,000 B.H.P. But I think that for our purpose we might say approximately 600 B.H.P. would be an average figure. This would be made up by, say, 24 winches at 10 H.P. each; windlasses 40 H.P.; engine room auxiliaries, such as pumps, steering gear, etc., 70 H.P.; ventilating fans 50 H.P., and lighting and heating 200 H.P. This load is, of course, a very variable one, and it is not likely that more than 50 per cent. of this would ever be required at the same time. As the highest efficiency of any plant can only be obtained by working it at full load, we should install our generating plant in duplicate sets of 300 H.P. each. These two sets could, if necessary, be arranged to run in parallel with each other, and I do not think that much trouble would be experienced in doing this, although the different turning moments of the gas engines might affect this operation to some extent. Our main plant would, therefore, consist of two 300 H.P. gas engines, two suction gas plants changeable with either engine, two fly-wheel alternators built on each gas engine shaft, and two exciters. I might, perhaps, mention that there are alternators of this type in use at the present day, giving every satisfaction, generating 5,000 kilowatts, being directly connected to 8,000 H.P. steam engines, the revolving field being 30 feet in diameter, so there is not much fear of our comparatively small plant not fulfilling its duties satisfactorily.

TRANSMISSION.—We must now discuss the best and most convenient method of transmitting 600 H.P. (450 K.W.) to different points of the ship for power and lighting purposes. The higher this power is transmitted the less will be the weight of copper required in the mains. We may safely say that there are no objections to transmitting this at 2,000 volts, in which case our alternators must be designed to generate 2,000 volts at about 120 revolutions per minute, at a frequency of about 50. This figure has been found more satisfactory for power purposes, although all frequencies from 16 to 160 have been tried, and some of these higher frequencies are still in use. The controlling influence in determining the frequency is the speed of our prime mover and the general nature of the load, high frequencies being best for lighting purposes. Our switch board in the engine-room must have switch-gear to operate the following changes: Change over either exciter from one alternator to the other, change over the whole of the load from one alternator to the other, synchronizers for paralleling the alternators. It must also contain the following instruments, ammeters and voltmeters and shunt resistances for each exciter, ammeters and voltmeters, also power factor meters for each alternator. Four feeder panels will also be required, having the necessary switches for four main circuits, one forward circuit, one amidship circuit, one engine-room circuit, and one aft circuit. The total current being 120 ampères, each feeder panel will control as nearly as possible one fourth of this, 30 ampères. It is also advisable to balance the load on each phase on the low tension side of the system as nearly as possible, although the phases being a little out of balance makes no practical difference to the system.

The installation of three-phase 2,000 volt cables on board ship will require the greatest care. The main cables to each transformer, carrying high tension electricity, should be of the multiple core type, made circular with packing, and the whole lead-sheathed and armoured; this solid cable could then be drawn into iron piping with water-tight joints for further protection. One of these cables would be run from the forward engine-room panel to the most convenient place forward, where a transformer would be connected to transform from 2,000 volts to, say, 200, volts for the windlass and winch motors. These motors would be three-phase squirrel type with no commutators or collecting rings of any sort. For lighting purposes in this part of the ship another transformer would be installed on the same high-tension main, transforming down to 50 or 60 volts. This lighting load would be spread over the phases on the secondary or low-tension side of the transformers. We could also use one of the phases of this transformer for a separate heating circuit if required. In the same manner the engine-room, amidship and aft cables, would feed transformers for supplying low-pressure current to the various auxiliaries, fans, pumps, etc., each in their respective parts of the ship.

On the low-tension side the whole system would be installed in exactly the same manner as the direct-current installation is carried out at the present time. The submains would run to distribution boxes, and be looped out to the same fittings and switches for the light : the mains being armoured or lead covered and fixed in position with metal cleats.

If the installation is a very large one we should, of course, have to have more high tension mains, say one to each deck, fore and aft. This would, of course, necessitate more transformers being fixed. These transformers or sub-stations, having no moving parts and requiring practically no attention whatever, would be kept under lock and key There is no objection to having any number of these transformers in the installation. With ordinary care there would be no trouble from self-induction on the low tension sub-circuits.

Having now described an alternating current installation suitable for modern steamship work, perhaps a few remarks on the induction motors and static transformers will not be out of place.

The alternating current induction motor, sometimes known as the "squirrel-cage" motor, is undoubtedly the ideal motor for ship's use. It has no commutator or rubbing contacts. Its rotor or armature consists of an iron core, built of thin laminated iron discs, carrying copper bars short-circuited at both ends by a copper ring. Owing to the comparatively short length of these bars, and also to the fact that all the current they carry is an induced current only—that is, a current set up by induction from the current in the field or stator windings—the voltage is a very low one, requiring only very slight insulation. This rotor develops practically no faults whatever, and, of course, such faults as short circuits between the coils or commutator sections, earths on coils or commutator, brush and other troubles, etc., which the direct-current armature is subject to, are quite unknown with the induction rotor. The absence of a commutator, therefore the entire absence of all sparking, makes these motors very suitable for work in dangerous places or amongst inflammable goods. Should an induction motor be heavily overloaded to a very great extent the rotor simply stops; should this occur with a direct-current motor the armature would promptly burn out. Practically the only attention required for alternating induction motors is an occasional oiling and cleaning. In small sizes these motors can be thrown straight on to the supply without the necessity of starting resistances, etc.

The static transformer is a device used for changing or transforming the voltage and current of an alternating circuit in amount and pressure. Its essential parts are a pair of mutually inductive circuits, called the primary and secondary circuits, and interlinked with both these circuits is a magnetic circuit. This magnetic circuit is, of course, the core of the transformer. The primary and secondary coils are so arranged that their mutual induction is very great. Upon an alternating current being applied to the primary coil an alternating flux is set up in the iron core, and this flux induces a pressure in the secondary coil in direct proportion to the ratio of the number of turns of wire on the primary and secondary coils. Technically the primary coil is the coil upon which the pressure from the source of energy is impressed, and the secondary coil is the coil within which the induced pressure is generated. The core of the transformer is invariably composed of laminated iron. These transformers are built in all sizes to suit the power they are required to transform. Their efficiency is usually high, a good transformer working on full load will have an efficiency of over 98 per cent.

The efficiency of our fly-wheel alternator will be about 92 per cent. when working at full load. The motors have an efficiency of 80 per cent. for small motors to 93 per cent. for larger sizes. The efficiency of the whole system will therefore average about 85 per cent.

In conclusion, I must say that I see no reason why a voltage of 2,000 volts should not be used in connexion with large ship installations. The only place where it would be possible to get a shock would be in the engine-room, and, of course, every precaution would have to be taken to guard against this, all the high-tension switch gear being mounted in separate compartments behind the switch-board, would be operated by means of specially insulated handles projecting through the board. Winch-men and others outside the engine-room would not be in danger of receiving such a shock for the simple reason that there would be no opportunity or possibility of them being able to come in contact with the high-pressure supply, as all the machinery, etc., would be operated from the low-tension side of the transformers. Should, however, high-tension mains be debarred from leaving the engine-room, step-down transformers could be installed in the engine-room near the alternators, and low-tension mains led from the engine-room to all parts of the ship. Even if low-tension electricity was generated direct from the alternators, the many advantages of the induction motors would still be retained. As far as the engine-room equipment is concerned the usual rules for handling high-pressure alternating currents would be enforced; none but authorized and proper persons having access to the switch-board gallery or alternators, etc. Altogether I see no reason why this system of alternating electricity should not be seriously considered for application to modern steamship requirements.

Finally, I think that a few remarks on the electrical installations on board the new Cunarders, as showing the great advance made in the application of electricity, wherever possible, in these two boats, would be of interest to all marine engineers. The use of electric motors on board the *Lusitania* and her sister ship has been adopted on a greater scale than has ever before been attempted for passenger ship's work. You will observe that all the motors and lights are operated by continuous current. The *Lusitania* has eleven passenger and baggage lifts as follows: Two passenger lifts, 10 cwt. each, operated by 8 H.P. motors; two baggage lifts, 40 cwt. capacity, operated by 15 H.P. motors; two service lifts, 10 cwt. each, operated by 5 H.P. motors; three food lifts, of 2 cwt. each, operated by 1½ H.P. motors; and two ash hoists, of 2 cwt. each, operated by 3¼ H.P. motors.

The electric lighting sets consist of four generators direct coupled to Parsons' turbines, running at 1,200 R.P.M. The output of each set is 375 K.W., or 500 H.P., at 110 to 120 volts, shunt wound. In the galley electricity is largely used for driving the patent roasters; bread-making machinery, meat-slicing, potato-peeling, sandwich-making, dish-washing, cream-freezing and whisking machines, are all operated by electricity.

The refrigerating machinery, in duplicate, is operated by an electric motor, with a variable speed regulation from 40 to 110 R.P.M. The centrifugal pump for circulating the brine is driven by a small motor. The thermo tanks are also electrically operated.

The forced-draught fans for the boilers, sixteen in all, are driven by 50 H.P. motors, 100 volts at 450 revs. maximum to 185 minimum. These motors have been provided with special means of ventilation owing to the high temperature in which they have to work. The engine-room is ventilated by twelve fans driven by motors. On test the temperature rise of these and the stokehold fans was under 50°.

For boat lifting four hoists are provided capable of lifting 12 cwt. at 250 feet per minute. Each hoist is operated by 14 B.H.P. motor, 110 volts at 600 R.P.M. For deck purposes four cranes are provided, of 30 cwt. capacity each, separate motors being used for lifting and slewing. For lifting, a 15 H.P. 500 revs. motor is installed, with worm reduction gear. The slewing motor is $2\frac{1}{2}$ B.H.P at 750 R.P.M. The steam-driven auxiliaries are the circulating pumps for the main condensers, which are driven by a 358 B.H.P. engine running at 300 R.P.M. Three steam winches for cargo holds, two of which are 8×14 ins. and one 12×16 ins. There are eight steam-driven capstans, four forward and four aft, each of which is driven by a 1,000 H.P. engine. All of these steam-driven auxiliaries could very easily have been driven by electric motors.

The details of the *Mauretania* are somewhat similar as far as the auxiliaries are concerned. The galley is fitted with electric egg-boilers, grillers, hot plates and knife cleaners.

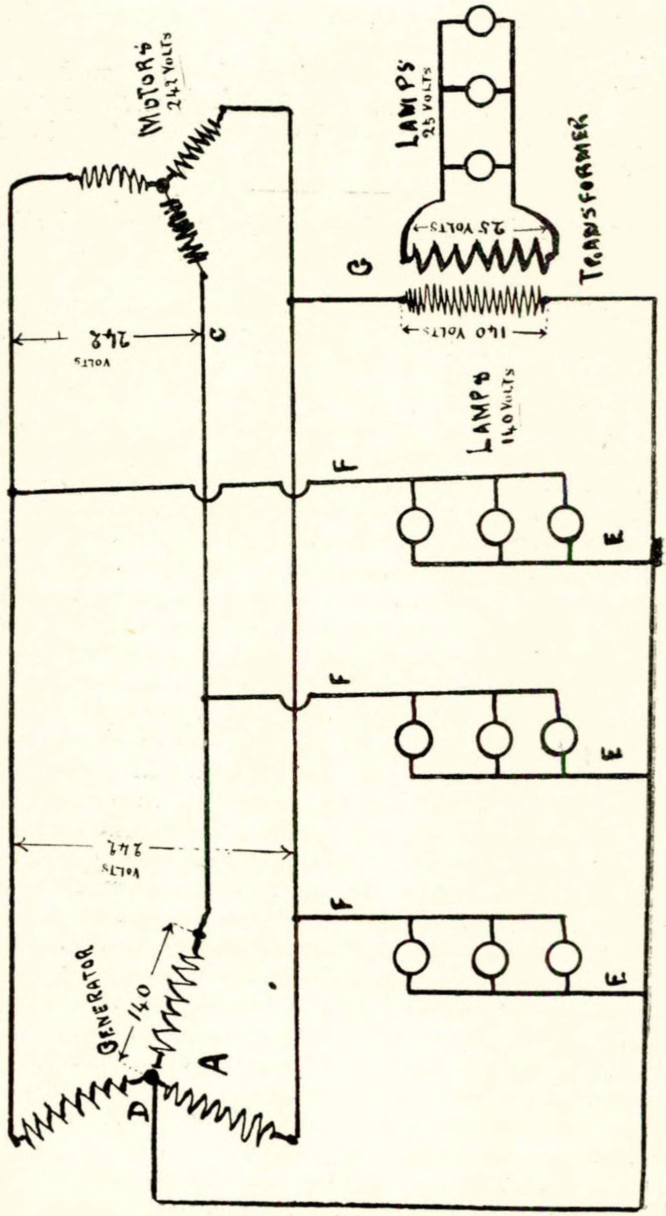
The engine-room ventilating fans consist of ten 4 H.P. fans, eight 5 H.P. fans, six 25 H.P. fans, and four 1 H.P. fans, she is specially ventilated as in her sister ship: the stokehold fans being the same as in the *Lusitania*. The 75-in. and 60-in. sluice valves are each operated by two 12 H.P. motors. A rather novel feature in these two boats is the electrically operated whistles.

The above particulars will show to what extent the advantages of electricity for operating this class of machinery have been recognised by the designers of to-day; and although in this case the direct current system has been used throughout, I feel sure that the many advantages possessed by alternating current electricity, a few of which I have endeavoured to point out in this paper, will be fully recognized in the near future.

I am indebted to Messrs. Dick, Kerr & Co., Ltd., and Messrs. Clarke, Chapman & Co., Ltd., for their courtesy in providing me with several of the lantern slides to illustrate this paper.

CHAIRMAN: Marine engineers know pretty well all that there is to be known in connexion with the steam engine, and from the paper we have heard to-night they can see what lies before them, so that the sooner they get in touch with the details the better. The application of electricity has passed the experimental stage, and soon the ships will be electrically equipped right through. We shall all be pleased if members with experience of this class of work will open the discussion.

Mr. W. P. DURTNALL: We must all thank Mr. McLaren for the very interesting paper he has given us. My opinion on this subject agrees with his, that the electrical driving of auxiliaries has a future in view of the possibilities of reducing expenditure, not only in operation, but in first cost. I was under the contrary impression until about two months ago, when I went closely into the question, and found that the cost, as given to me for the purpose of comparison, works out cheaper by quite 20 per cent. with the system of alternating current than with that of steam-equipped winches and steering connexions. Mr. McLaren refers to the adoption of three-phase currents. I think I am perfectly in accord with him in that direction, because so many things can be done on board ship with the three-phase current that could not be done so satisfactorily otherwise. I do not know that so very high a voltage as 2,000 volts would be necessary, although I notice the author mentions later that there would be no danger in this, as unqualified persons would have no occasion to come in close proximity to the engine room. Of course it depends entirely upon the owners of the ship. In a long ship the cost of cables would be considerable if a low voltage were adopted. In reference to the lighting question, I have recently drawn up for a small town a system for lighting the town with alternating three-phase current, and for supplying the motors in that case the current will be distributed about 242 volts, that is between the phases.


MOTORS
242 VOLTS
LAMPS
25 VOLTS
TRANSFORMER
25 VOLTS
G
140 VOLTS
B
242
VOLTS
C
LAMPS
140 VOLTS
F
E
F
E
242
VOLTS
F
E
GENERATOR
140
A
D

We will say that A is what is generally termed the star-connected winding of the alternator ; when I say the voltage for the motors I mean the voltage from B to C. That is for power work ; there is very little power. I do not suppose there is more than 150 horse-power in the whole town. But from the neutral point, D, the voltage to any of these outers will be 140 volts from this centre. This can be a bare copper conductor, earthed, or, if necessary, it could have a very light covering, and between any of these points we can balance the lighting circuits at 140 volts. E and F would be the service into the houses, shops, etc., so as to take advantage of this arrangement, which cannot be done in any other method than the alternating current one. You have to balance the distribution of the current also, especially suitable for long distances, in which case you may transform up to a certain high voltage to transmit it. Further, if you take that current at 140 volts into the houses, you can put in each house a little auto-transformer, G, and you can bring connexions off and supply the lights at lower voltages, or you can come down to, say, 25-volt lamps. I might say that the ordinary carbon filament lamp which has been used for many years now uses about $3\frac{1}{2}$ watts per candle-power, and will light for about $35\frac{3}{4}$ hours one 8 candle-power lamp per B.T. unit. By having an alternating current system with metallic filament lamps, 25-volt lamps giving 24 candle-power, and using 1 watt per candle-power, it would make a saving of two-thirds the current. You could not do that so conveniently and efficiently when supplying both light and power on the continuous current system. If that were adopted on marine installations it would come out at 200 to 250 volts, which is the maximum for marine lighting purposes, and the new improved metallic filament lamps could be only used in very large candle-powers. I think for lighting on board ship advantage might be taken of this star-connected machine, with the power at high voltage, and the lighting at low voltage ; taking advantage of small copper mains for the motors and low voltage, and therefore strong metallic filament lamps that would then be possible. It would be an interesting consideration in a ship with alternating current, light and power supply. I do not know whether it would pay for cooking, although it is found very convenient to cook by electricity. I remember when the City of London Electric Light Company started the supply for a large hotel, I was asked to investigate the matter, for supplying electricity to cook a dinner of thirteen courses for about two hundred people. I figured it out on behalf of the proprietors, who were interested in the financial success of it, and contemplated adopting it on a large scale if it proved to be more economical than their existing methods. The price of the current then, for cooking, was 2*d.* per unit; it can now be obtained for heating purposes for 1*d.* in many large towns, and $1\frac{1}{2}d.$ or 2*d.* per unit around London. In the case quoted the cost worked out at 2*d.* per head, while the French chef said he could do it at $\frac{1}{2}d.$ per head using coal direct. Mr. McLaren refers to the exciting current as very small; in a 100 kilowatt set where the pressure is constant a good strong exciting current is required, but it varies from 1 to 3 per cent. of the total output. The speed of one particular gas engine is cited at 120 revs. per minute; I think a higher speed than that might well be assumed, as these alternators would probably have to be at work at sea, and any reduction in dead weight is an advantage. Mr. Shackleton mentioned in his paper recently that gas engines are now made for speeds up to 400 revs. per minute, working constantly in central electricity stations; the engines I am proposing in the above case I have sketched are oil engines of 50 h.p. each, made by a first-class firm, one engine at each end of the alternator, and the speed is 350 revs. per minute. Mr. McLaren's paper is of very great interest, and it is interesting to see the amount of attention marine engineers are taking in furthering the use of electricity at sea.

Mr. F. M. Timpson: I quite agree that there is a large field for the application of electricity in marine work, and no doubt a great saving would be effected by its use for auxiliaries. I believe it had to be tried in the earlier stages when not sufficiently well known to get the good results, and that has hindered its adoption; but this is only a matter of time, and it will help to cut down heavy expenses, thus giving a chance of making ships more remunerative.

Mr. A. H. Mather: This subject is quite a novel one to marine engineers, certainly the subject of alternating current for use on shipboard has not been previously brought before the Institute of Marine Engineers, and it is a point in its favour that it is a pioneer one in that direction. Mr. McLaren refers to the generation of alternating current on board ship at very high voltages: he gives the figure of 2,000 volts. Unless there is a very good reason for generating at that extremely high voltage, it seems to me it is almost unnecessary, if it is going to be transformed down immediately it leaves the generator. If it is going to be taken some distance as in the *Mauretania* or *Lusitania*, there is some excuse, because the losses in transmission would be so very much less relatively. If however it it a question of the cost or weight of the generating plant and a high voltage would be a benefit, then, of course, it will be an advantage. If Mr. McLaren would give us some points in that direction it would be of assistance to us. Another point crossed my mind while Mr. Durtnall was giving his illustration upon the board. Direct currents of electricity seem to be fairly simple to understand, although the average engineer turning over to electricity finds it somewhat confusing. He knows what his steam is, superheated, saturated and dry steam, but he does not know what electricity is. With a direct current machine, however, he can understand the diagrams illustrating the action going on in a dynamo, but when an alternating current diagram is put before him, showing the combination of phases in the three phase system, a diagram like the one shown on the board, it would be more confusing still, and he would ask to be shown how economies could be effected without having to wade through a text-book to understand it. On the whole, it seems to me that the use of electrical appliances on board ship will be extensively adopted in the near future, and in view of the commencing paragraphs of the paper, where reference is made to the great losses incurred in a steam plant, and knowing the amount of that loss, if the prime cost is within anything like a reasonable amount as compared with that of the steam plant, there is no doubt the running charges will be very much less, and it would be of advantage to the shipowner to have these matters placed well before him.

Mr. J. Clark: I think we are very much indebted to Mr. McLaren for giving us this interesting paper. As he states at the beginning, one does not often come across papers on alternating current for use on shipboard. I rather regret to see him depreciating our old friend the continuous current motor; it has many advantages that the three phase motor has not, and although I hold no brief for either the continuous or the alternating current motor, it does not do to shut our eyes to the advantages which either of these types may possess. It is certainly news to me that motors either of the induction type or continuous current motors will stand being left out of doors under the severest weather conditions without being exceedingly well protected; the insulation will not stand unlimited abuse in that respect. With regard to the simplicity of alternating current motors, it is a fact that they are not adopted as they might be on shipboard. Every one knows the disadvantages of hydraulic plants, especially in winter time, and I feel that if electrical plants were as simple and as trustworthy as they are said to be, hydraulic plant would be unknown; but still it holds its own. Of course there are conditions where the induction motor is an ideal one to be put down, but I do not quite agree with the statement as to its simplicity and its freedom from breakdowns; in fact I believe there are more burnt-out effects with the squirrel cage rotors than with armatures of the direct current machine. I believe, as the author says, there are a good many burnt-out armatures, but there are ways of avoiding that. With regard to the cables, it is a moot point whether the cables would not cost as much as copper pipes for the same work, as it is not like a land installation where there are large areas to be covered. The author gives the weight of copper for the three-phase three-wire system as 79 per cent. These, of course, are paper figures and are not found in practice. We have to allow a power factor of at least ·7 per cent., which gives 40 per cent. more copper for the same voltage. Although several points in favour of the three phase system are good, we must not run down the direct-current motor in order to score with the three phase system. In connexion with the starting difficulties, a squirrel cage motor of large size starting under full load torque will draw so heavily from the generator that the other motors working at the same time will be affected adversely. I think for small powers it would be quite suitable, but not for large powers. Even with the auto-transformer the arrangement is not quite satisfactory, as the working of these motors is often entirely in the hands of men who are not supposed to be electricians. In connexion with the efficiency of the whole system—85 per cent.—this is a very high efficiency indeed, because it is well known that motors do not operate at anything like their full load continuously, and especially on shipboard, where at one time it may be running idle and at another it may be running overloaded. Everybody wants a variable speed in induction motors. There are devices for changing the poles and other methods, but one wants to see the variable speed induction motor in actual work, but there are none, so far as I know, in practical use. The broad fact stands out that in these two Cunard boats both, I take it, are fitted with direct current; why? I should think the case of alternating current was carefully considered in connexion with those boats. As I remarked before, there may be points where the induction motor scores, but there are a great number of other points that want clearing up.

Mr. W. Watson: I think that an installation such as is proposed would be perfectly successful provided it were put down of the very best material. There is no business in this country that has suffered more from the ill effects of shoddy materials than the electrical business, and I have no doubt that if proper materials were used the scheme would be perfectly successful. Another point that is often taken unfair advantage of is the capability of the three phase motor to stand overload. It is not fair to the motor. When it breaks down, as it may, the maker is blamed for cutting his price and so on. Although a number of us may call ourselves electrical engineers, we ought not to overlook the fact that primarily we are steam engineers, and as such we feel rather conservative when it is suggested that feed pumps, and steering gear, should be driven electrically. I think the present way of getting the water into the boiler is the best one, particularly with the type of feed pumps now on the market, and I think the same remark applies to steering gear. I would suggest making the electrical installation even simpler than Mr. McLaren outlines; such as a three phase voltage of 200 volts, a star wound job, giving a voltage between the neutral and any phase of 115, which is eminently suitable for metallic filament lamps, thus saving the cost of transformers. Mr. Durtnall mentioned about the current taken up by the exciter. I know machines where it is even less than 1 per cent.; I think even in a 500 kilowatt job it will be well under 1·5 per cent., that is working on a ·9 power factor. I think Mr. McLaren might have made that a little lower; I am afraid he will never get a power factor of ·9 on a three phase motor—it will be nearer ·85. I must congratulate him on having adhered to the 50 cycles. That of course is the standard frequency for combined power and lighting jobs, and I think there is no doubt it is the most suitable. I agree with him entirely when he states that there will be very little danger. There is no doubt whatever the whole system may be made absolutely "fool-proof." I congratulate Mr. McLaren on having broken new ground with this paper, and am sure would be delighted to see a ship so equipped.

Mr. E. Shackleton : Mr. McLaren's paper is most admirable, and covers a ground the principles of which Mr. Durtnall is so enthusiastic about, and which I myself endorse. I see the question of adopting a gas engine has again cropped up. It is rather hard on the steam engineer, especially as Mr. Durtnall is more or less assisting at its funeral by proposing turbo-electric propulsion. In this case it is apparent that to carry out the electrical business for auxiliary work, it would not be done at anything like a reasonable prime cost. I see Mr. McLaren mentions about the new cruiser being fitted with gas engines. I am afraid there is no hope that such a step will be taken. Personally I hope they do not take it. It is from those who are engaged more in the commercial and engineering conduct of steamers and prospective gas-boats that such advances must first come. The author refers to gas engines running in parallel; they would do that quite easily on electrical work. The gas engine, of course, is far more delicate on the question of governing than the steam engine; in fact if we see them used for main propulsion at sea we shall obtain what we have not yet been able to get, direct and immediate governing. The point has been raised regarding the speed. I think that 200 to 250 would be about the speed of the engines mentioned by Mr. McLaren, although of course he has not mentioned what type he would suggest. There is no reason that I can see why a horizontal engine or two horizontal engines should not make up the power in a case like this. I barely touched on this in my paper, and I think the saving that could be effected by having electrical winches and for general power supply outside the main boilers would be enormous. The author has not mentioned what kind of fuel he proposes to have for the gas plant, bituminous, anthracite or coke. However, there need be no difficulty about that, as I think if his plans were designed for coke, with a little exercise on the part of the stokers by regulating the engine you might have it for both, and there would always be sufficient fuel in cases of emergency from the main boiler coal. I am sure Mr. McLaren has dealt with the subject in a very able manner, and we must congratulate him on the painstaking way he has gone into the whole subject.

Mr. W. E. Farenden (Member). Mr. McLaren has referred to the possibility of doing away with the donkey or auxiliary boiler altogether, and adopting a gas driven electric generator to do its work. The donkey boiler is used for many purposes at present, viz. : for pumping out the ballast tanks, bilges, for refrigeration, winches and capstan, and many other things, and to talk of doing away with the donkey or auxiliary boiler means a big undertaking, and one with which we are not yet familiar. It means that a ship would be in harbour without having any steam on whatever. Of course, steam is used in case of fire for the fire pipes, steam heating, cooking, and other things besides the driving of auxiliary machinery, and Mr. McLaren is suggesting a big thing in saying that the ship in port should be without steam altogether.

I think we should have to consider the matter very carefully before adopting high voltage alternating current in place of the direct current. Then with regard to the generating plant, so far as electric-lighting stations are concerned, the most efficient engine has been found to be the steam-driven turbine. Would not Mr. McLaren advocate having a plant driven by a turbine engine, because from the figures which have been submitted to us on previous occasions the turbine driven plant appears to have a very high efficiency.

Alternating current is harmless to the compass as mentioned by the author, but so is direct current, properly installed, especially if double wiring is used ; but even on the single wiring system compass troubles are quite a minor source of difficulty. With regard to commutators in main generating plants, the upkeep for repairs to them is very little.

Mr. McLaren claims extreme simplicity of the whole plant, but I fail to see how this can be with mains of 2,000 volts, and mains at 50 or 60 volts, all mixed together, or set out in rows along the bulkheads, or otherwise disposed of ; then we have transformers at different places about the ship ; of course copper wire might be saved, due to the high transmission of power, but the cables from the low voltage will require to be larger than those now generally used, and the additional cost of the transformers must be added to the price of the mains, so that it is questionable whether the great saving mentioned by the author actually exists. It is a big jump from the 105 volts used at the present time to the 2,000 volts now suggested, and, like Mr. Mather, I cannot see where the saving comes in with this high voltage, if it is to be transformed down to 110, and then again down to 50.

With regard to the burning out of the direct current motor due to overload, if an overload cut out is fitted, as it is, or should be, with the direct current motor, the same result is achieved, viz. : the overload automatically cuts out the motor, and the armature does not burn out.

Mr. McLaren speaks also of running lead sheathed mains in iron pipes at sea. I am afraid this would not answer, for electrolysis would soon be set up, and within a year or two the lead would entirely disappear, being converted into white oxide.

The only place where one could get a shock under the author's proposal would be in the engine-room. That would be quite sufficient, and really one place would be as good as another if one is to have 2,000 volts. This installation of 2,000 volts would require the greatest care.

I think Mr. Clarke raised the question as to the installation in the *Mauretania* and *Lusitania*. Continuous current is used in these ships, and no doubt the question was gone into at the time, and the difference between the alternating current and continuous current considered, yet the owners of these ships decided to put in the continuous current.

Mr. J. H. Ferguson : The large flywheel that would be necessary for the gas driven generator would be a serious drawback, especially in view of the gyroscopic action that would be set up. If it is a question of steam driven or gas engines, I think the preference should be given to steam. It is an interesting point whether the greater insulation required would more than cover the cost of the copper saved. It would need to be very efficient insulation to withstand the sea water, and 2,000 volts seems rather high for damp shipwork.

Mr. McLaren : I was very pleased to hear Mr. Durtnall open this discussion ; I know he has made a great study of the question of the use of alternating currents, and it is a pleasure to be favoured with his remarks. In the beginning of my paper I said I only intended touching upon the leading points. I have made the paper as simple as possible for the mere sake of trying to raise a discussion. I think it is a thing that has never been seriously considered for ship work, and it is only of recent years that it has been used to any extent for land work. But every large power station now has alternating current, and the higher the voltage the better. As far as 2,000 volts is concerned, it is not too high from an economical point of view : the higher the voltage the more economy is obtained. With reference to Mr. Durtnall's diagram on the blackboard, I may say I had this idea of the neutral wire at one time to put before you, but I gave the paper simply to raise discussion. I am glad the point has been raised. The high voltage seems to be the point which frightens most people—they think the high voltage means death to every one who goes near—but my experience is that there are more accidents with the lower voltages, because with the high voltage the necessary care is taken to see that no accident can happen. Mr. Mather spoke of making it easy to understand. As far as alternating current is concerned it takes very little study to really understand the system. I suppose most engineers understand continuous current simply because they are used to it. To put a small alternator on board ship for lighting a ship with 100 lights is out of the question, but consider the number of tramp ships with small continuous current sets. That is why the engineers get to know more about continuous current. One of the great reasons why I have brought forward this subject is the number of breakdowns that take place on the continuous current motor on board ship, and I am of opinion that if we can do away with commutators and brush gear it would be a great step towards the successful application of electricity on board ship. It was mentioned that the continuous current sets had done good work, and that this fact should not be lost sight of. In past years I had a good deal of experience with continuous current, and no doubt great advances have been made, but in the future, unless these motors are greatly improved upon, the expenses of upkeep will be enormous. I saw in one case the figure of about £65,000 mentioned for an electrical installation. I think if alternating current were used this figure would be very much reduced. Mr. Clark spoke of finding fault with the continuous current motor. I do not want to find fault with it, I believe it does good work, but it will not stand the economy test. My first experience with alternating current motors was when in America, and I have seen a winch working when covered with snow and in damp weather, working with no trouble whatever, under conditions where the continuous current motor would not work. Within the last twenty years I suppose the continuous current has advanced more than the alternators, but that is because it was the first and the simplest introduced, and I believe that in time the alternator or squirrel cage motor will take its place. It is a similar case to that of the low pressure and high pressure steam boiler. Nowadays we have 200 lb. pressure and think nothing of it, whereas once we thought 100 lb. a high pressure. Engineers will soon be educated up to it and it will gradually be adopted. I quite agree with Mr. Watson in his remarks as to the material. Alternating current motors are often supplied of very bad material, and in other ways advantage is taken of the buyer. I know it from experience. You buy what you expect is a 10 H.P. motor and you get a 7 H.P.—that is known to have been done—and when the motor is started it means you are going to give it a lot of wear and tear. You could not start a continuous current motor under the same conditions. Mr. Shackleton goes on to speak of the gas engine. When I mentioned the gas engine it was really only to start discussion. As I said I do not want to go into the figures as yet, but I may go more fully into that subject at some future time to consider whether it would be better to apply the gas engine or the turbine, both of which have their advantages. Mr. Farenden referred to doing away with the donkey boiler. My idea was certainly to make the alternators and gas plant take the place of the donkey boiler. The efficiency of the donkey boiler installation on a large ship is very low; I do not suppose that the efficiency on some of the donkey boilers, winches, etc., is 25 per cent. when working, if the amount of steam used when working, the getting up steam, stopping, running and leakages are taken into consideration. I have not seen a proper test, but particulars in relation to this are well worth obtaining. It is quite true, as Mr. Farenden says, that the question of adopting the turbine engine would be worth going into. With regard to transforming the voltage, in the Charing Cross station there is a very high voltage. It is stepped down before leaving the engine room. Of course this is only a suggestion, but I really think it is possible to obtain a big saving in alternating current by stepping down in the engine room. At some future time it is my intention to get a few figures together and to go into this matter thoroughly, and in Mr. Durtnall's paper we have sufficient data to enable us to make comparisons as to the relative cost. Of course he refers to prime movers, and I only refer to auxiliaries, my attention being particularly directed to them through observing the very great losses which take place through the use of the donkey boiler for driving winches, etc. In small ships it is not so bad, but when one gets 2,000 to 3,000 H.P. absorbed in auxiliaries, the time has come when we have to effect a saving upon them. There is nothing more abused than the ship's winch. With reference to steering gear I believe there is a steering gear electrically worked fitted on Sir George Newnes' yacht, and I do not think there have been any breakdowns. With good workmanship and good material I do not see why there should be. As Mr. Watson says, electrical work suffers very much from the use of shoddy material, but I do not see why a good, well-fitted job should break down, although, of course, we have even the best steam engines breaking down—it is one of the greatest troubles we find at sea. I thank you all for the attention with which you have listened to my paper.

A hearty vote of thanks was accorded to Mr. McLaren on the proposal of Mr. Durtnall, seconded by Mr. Mather.

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VOL. XXI.

PAPER OF TRANSACTIONS NO. CLIV.

SOME DETAILS OF A CARGO STEAMER,

BY MR. W. VEYSEY LANG (MEMBER),

READ

Monday, February 15, 1909.

CHAIRMAN: MR. JOHN LANG, R.N.R. (MEMBER OF COUNCIL).

ADJOURNED DISCUSSION

Monday, March 29, 1909.

CHAIRMAN: MR. F. M. TIMPSON (MEMBER).

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