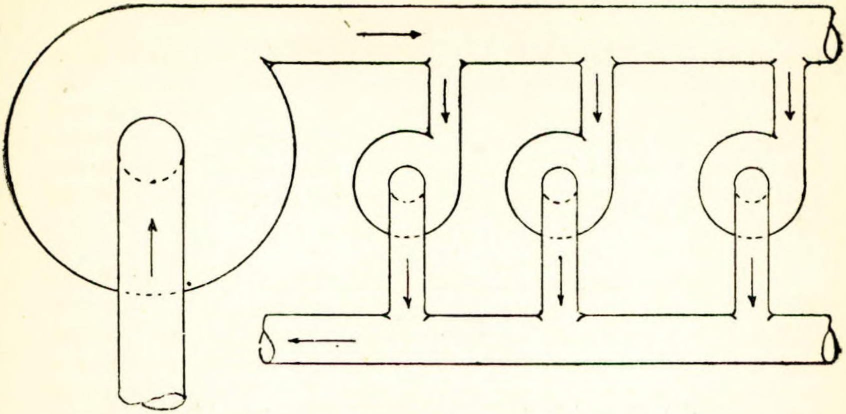
ELECTRICAL ENGINEERING.

PART I.

I BEG that you will understand that I am a working engineer like yourselves, and not a professional lecturer, and this must be my excuse for my shortcomings, as I lack that practice and experience which enables lecturers to make a difficult subject clear to their audience. At the same time, as I myself was originally a Mechanical Engineer, and subsequently added to it the study of Electrical Engineering, my case is probably very much the case of many of those whom I now address, and it may be some help to you if I preface my remarks by giving a short history of how I, who was one of the first to take up Electrical Engineering in this country, became connected with it. About 13 years ago I had designed and carried out a large foundry plant for the Stanton Iron Works Co., in the Midland Counties, and I was desirous of working this plant all night. The work was of a nature that required powerful lights, and as that same year I went with the Institution of Mechanical Engineers to see the Paris Exhibition of 1878, I heard a paper read on the subject of electric lighting, and made the acquaintance of Mr. Gramme whose dynamo machines were at that time beginning to make a stir in the electrical world, and from him bought two sets of tackle consisting of dynamos and lamps. In order to make this plant work successfully I had to study the subject, and I assure you that at that time this was no easy matter. There were no text-books on the subject of dynamo machines and arc lamps; all that existed were a few notes on the discovery of the electric arc by Sir Humphrey Davy, and of the magneto-electric machine by Faraday with its subsequent developments by Varley, Siemens, and Wild. These did not much help one to find out why sometimes the Gramme dynamos would not give any current and at other times why the arc lamps burned excessively badly. For a long time it was a case of groping in the dark and getting experience from endless trials and failures. Compared with those *dark ages* our knowledge of electrical engineering *now* is very considerable, and I propose in my two lectures to bring before you a few of the useful facts that we have learnt, more particularly those you are likely to come in contact with in your profession. The subject naturally divides itself under two distinct heads. The first being the production of electrical energy and the second, its distribution and utilization. This evening I will confine myself to the production, or, as we generally call it, the *generation of electrical energy*.

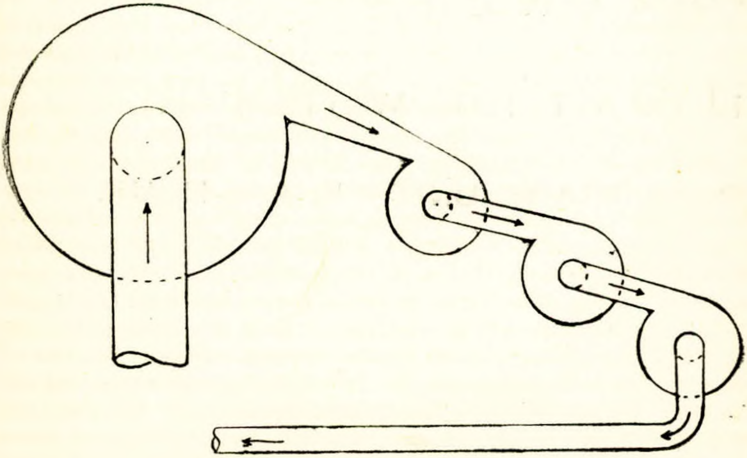
We used sometimes to talk of electricity as an electric fluid. We do so no longer, because we are by no means certain that it is a *fluid*, in fact we do not know what electricity is, but we do know that there are certain phenomena which act on our senses in a peculiar way and which we call electrical phenomena, and know that by employing certain apparatus in a certain manner, we can reproduce these phenomena, and, among others, we can reproduce a force which we call electro-motive force, which for brevity's sake I will hereafter call E.M.F. E.M.F., like any other unbalanced force, produces what we believe to be motion of the particles acted on by it. We do not know anything of the nature of this motion, but we give it the name of an Electrical Current. The law which governs the flow of electrical currents is well understood. It was discovered by Ohm, of Munich, and it is to this effect that the current varies as the E.M.F. which causes it, and the resistance to its passage through the conductors along which it flows. In other words, the Current equals the E.M.F., divided by the Resistance, or the E.M.F. is equal to the Current multiplied by the Resistance. Electrical energy or power is the product of the Current multiplied by the E.M.F. The whole of our electrical engineering is connected with the generation and utilization of this electrical energy. Although, as I have said, we prefer *not* to speak of the electric *fluid* yet what has been called the hydraulic analogy, has been very generally employed by lecturers who, like myself, are desirous of explaining to an audience of Engineers the main features of the generation and distribution of Electrical Energy. Although this hydraulic analogy is not perfect, yet it is sufficiently so for our purpose this evening. I want you therefore to consider the electrical current as if it were the flow of a fluid through pipes, the speed of the flow being in proportion to the head or pressure produced by the generating machinery, which, of course, in the case of hydraulic machinery, would be some form of pumping machinery. I have on the wall a diagram, No. 1, which illustrates this analogy. The kind of pump which is the nearest approach to the electrical pump or dynamo is the centrifugal pump, and my diagram shows a centrifugal pump circulating water through a system of pipes. The diagram shows the upper pipe, which may be called the pressure pipe, and the lower one the return, or the exhaust pipe.

FIG. 1.



Parallel System.

FIG. 1A.



Series System.

FIG. 2.

E=ELECTROMOTIVE FORCE IN VOLTS.

C=CURRENT IN AMPERES.

R=RESISTANCE IN OHMS.

W=ENERGY IN WATTS.

OHM'S LAW $C=\frac{E}{R}$

KILOWATT=1000 WATTS=$1\frac{1}{3}$ HP.

B. OF TRADE UNIT=I.K. PER HOUR.

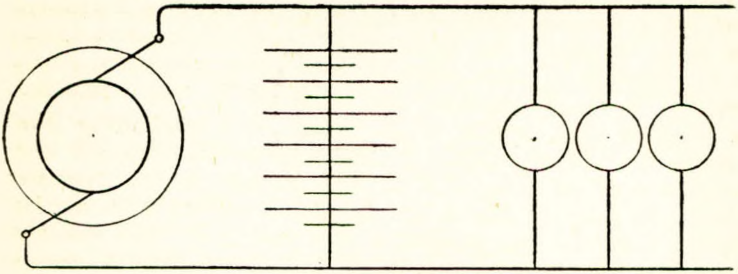
This last delivers into a well from which the centrifugal pump forces it into the pressure pipe, whence it returns by the various channels I have shown. These channels take the form of Centrifugal pumps reversed, in other words, Turbines. In this way the energy which was communicated to the water by this Centrifugal pump, and which takes the form of pressure in the pressure pipe, is partly reproduced in the form of mechanical energy at the spindles of the turbines. Of course there are many other ways in which the energy of the water may be utilised. Now, if we substitute for the Water what we call Electricity, and for the Centrifugal pump the Dynamo machine or Electric pump producing E.M.F. or electrical pressure in the pressure main, and substitute for the pressure and exhaust mains two electric conductors, we are able to reproduce the energy communicated to the electricity at the dynamo machine in the form of mechanical energy at the spindles of the electric motors, which take the place of the turbine shown on the hydraulic diagram. The analogy is not quite perfect, but it is sufficiently so for my purpose. You will see that, after all, electricity itself is no more power than water itself is power. It is only a means of transmitting power; for just as surely as the power put into the centrifugal pump by its belt is transmitted by the means of the water to the belt of the turbine, so is the mechanical energy on the belt of the dynamo, transmitted by means of the electric current passing through the conductors to the belt of the electric motor. In fact, after all, we use electricity as a very long and flexible connecting rod which enables us to transmit energy to distances hitherto unthought of. I shall refer again to this hydraulic analogy when I come to describe the various modes of *distribution of energy* in my second lecture. I must tell you that electric currents are of two kinds—the one, comparatively easy to explain, the *continuous current*, which is so greatly analogous to the flow of water along a pipe—the other, second, what is known as the *alternating current*, which is not so easy to explain. The continuous current and its energy may be represented by the diagram No. 4, where the E.M.F., Current, and, Energy, can be measured along the vertical line of the diagram and the time along the base line. I think this is the time to name the terms that we use to designate Electrical Measurements. We measure current in Amperes, the E.M.F. in Volts, the Resistance of the conductors to the passage of the current in Ohms, and the Energy, that is to say, the current multiplied by the pressure, or the Amperes by the Volts, in Watts. One Volt, multiplied by one Ampere, equals one Watt, and 746 Watts equals one actual H.P. We Electrical Engineers, wishing to use even numbers, prefer to use the term Kilowatt or 1,000 Watts instead of a H.P. It is equal to $1\frac{1}{3}$ H.P. When electrical energy is sold by Act of Parliament, the unit of sale is one Kilowatt for one hour, or which is equal to

$1\frac{1}{3}$ H.P. for one hour, and the present price of this in London is 8d. It is very easy to apply these measurements to the simple *continuous current*, but in the case of the *alternating current* the matter becomes rather more complex. An alternating current is one which alternates in direction at short intervals of time, that is to say, the generating machine produces an E.M.F. in one direction for a fraction of a second which causes a corresponding flow of current in that direction; it then reverses its direction and produces a corresponding E.M.F. and current in the opposite direction. In diagram Fig. 4, the continuous current is shown by the dotted horizontal line parallel to the base line. The distance between these two lines may correspond with the amount of current generated by the E.M.F. at command, which is shown by the thick line. In this diagram the measurements along the horizontal line represent time. If the current is perfectly continuous its line will be drawn exactly parallel to the base line, but in most cases it is slightly wavy, as very few generating machines give a perfectly continuous current. For instance, every beat of a steam engine driving a dynamo is likely to cause a corresponding wave in the line, but for the purposes of my description we may take this line of current practically as a straight one. The thin upper line shows the current multiplied by E.M.F. in Watts and the area of the diagram enclosed between the base line and the energy line is the energy multiplied by time in units.

In the case of the alternating current, however, energy corresponding with that of the continuous current just shown, would, when drawn along a base line representing time as before, have to be shown as I have it here in the lower part of Fig. 4. You will see that the current mounts considerably beyond the distance between the two lines in the first diagram, descends again, cuts the base line, passes below it to an equal distance to that it previously passed above it, and so on, producing the wavy line shown. Although the alternating current is more difficult to describe, difficult to calculate and to deal with, it is the easiest one to generate by Mechanical Energy; in fact I may say that all currents when generated are in the alternating form; they are afterwards commutated or redressed into the form of continuous currents by special apparatus called *Commutators*, and as most of the machinery that is now used for ship-lighting is direct current machinery so redressed and commutated, I will dwell more particularly on the machinery for generating such continuous or direct currents.

Returning to the hydraulic analogy, the duty of our electrical pump, which we call the Dynamo-machine, is to maintain a sufficient E.M.F. or electrical pressure at its terminals to force the required

FIG. 3.



Parallel System with Accumulators.

FIG 4

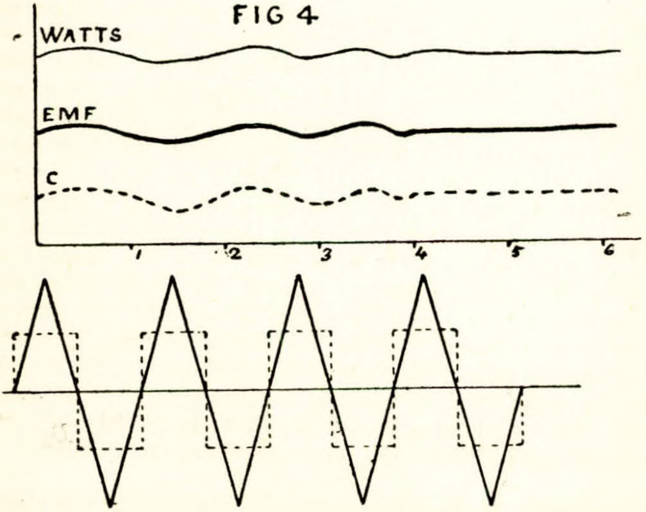
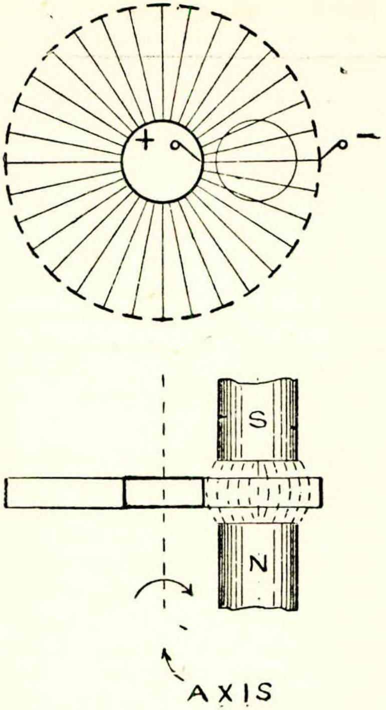
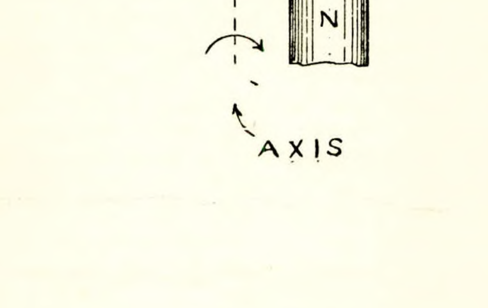


FIG. 5.



Wheel Dynamo.

FIG. 9.



Ring Dynamo.

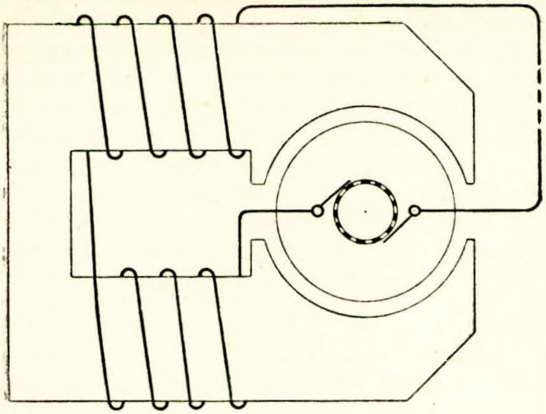
current through the electrical conductors. I cannot pretend in the course of this lecture to go very deeply into the details of construction of Dynamo-machines. I can only attempt to explain to you the general principles on which they work, and the ideas which have governed the recent developments of the machines with which you are now likely to come in contact. The production of E.M.F., and hence current, in an electric conductor by means of mechanical energy was, as you all know, discovered by Faraday. He found that in the space which exists near or between the poles of a magnet, and which is generally called the Magnetic Field, the matter exists in a condition of strain, that if an electric conductor is moved through this magnetic field, E.M.F. and hence current, is generated in that conductor, he further found that this E.M.F. is proportionate to the strength of the magnetic field and to the speed at which the conductor is moved through it.

All dynamo machines have been constructed with the end in view of producing as strong a magnetic field as possible, and of moving the conductors in which current is to be generated, through this field at the greatest practicable speed. A strong magnetic field is most easily produced in a closed iron ring. In this case the magnetic field is entirely inside the iron of the ring and consequently it is impossible for us to utilize it. Our next approach to it is to cut a section out of the side of the ring and, if we can then cause a conductor to pass rapidly through the cut thus made, we may obtain E.M.F. in the conductor. Diagram Fig. 5 shows the simplest form of dynamo machine constructed on this principle. The magnetic field is here produced between S and N, which may be the two sides of the cut ring, and the conductors that are moved through this field are arranged as spokes in a wheel. The circuit is completed by a rubbing brush, or spring, pressing against the centre boss of the wheel, and another brush rubbing against the end of the spokes. When the wheel is revolved by mechanical power at any desired speed, E M.F. is generated in each spoke in turn, and causes an electric current to traverse the circuit connecting the two rubbing pieces, in proportion to the total resistance of the circuit connecting these two rubbing surfaces ; for instance, if the machine I have shown in the diagram generated an E.M.F. of one Volt in each spoke as it passed through the field, and that the entire resistance of the machine itself and of the wire connecting the two rubbing pieces is one Ohm., the current that will pass will be one Ampere. At present such a simple machine as I have here shown is not used in practice, for the reason, as I have said before, that the E.M.F. produced—depending as it does upon the length of the conductor which traverses the field ;

the speed at which it traverses the field, and the strength of the field itself:—with this short spoke will give results which must be exceedingly feeble unless the machine were made on a gigantic scale. In practice, we, by various arrangements, succeed in procuring the effect of a lengthened spoke by winding the conductor many times round the wheel, and this is not easy to do with this simple wheel or disc-form, of machine. Before however leaving it, I may tell you that the machine of the future is probably neither more nor less than this *wheel-form* of machine, the armature conductors being simple iron spokes; the difficulties I have already mentioned having been got over by using a great number of these spokes, and by an ingenious method of coupling the spokes together electrically at the centre and at the rim. The form of dynamos now most generally used, and which you most commonly meet with, are those in which the conductor, which has to pass through the field, takes the form of a long wire, wound on a cylindrical drum or ring.

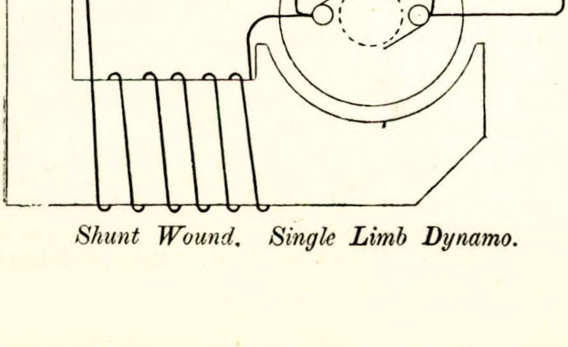
Turning to diagram, Fig. 7, we have here a machine of the ordinary form. You will recognise that the magnetic field is produced by the cut ring, or horse-shoe magnet, and in this case, the conductors which cut the field are wound on to what is called a *core*, that is to say, a cylindrical mass of iron, which is placed free to revolve in a space bored out to receive it, between the poles of the magnet. This cylindrical shaped core which is formed of soft iron, and has a conductor wound on it, is usually called the Armature of the machine. It is made in two forms, one called the plain drum armature, and the other, the ring or Gramme armature. The diagrams, Figs. 8 and 9, show the difference between these two. In the drum form, Fig. 8, the core is solid and the winding is passed longitudinally over its surface from end to end, and over its ends, whereas in the ring form, Fig. 9, the ring is of soft iron, and is separated from the spindle and is supported by a casting made of non-magnetisable material. The winding in this case is also longitudinal or parallel to the axis of the spindle, but instead of passing over the ends, each turn passes through the hole in the middle of the ring. The first or drum form of winding was invented by Hafner Van Altenack, and is commonly used. It has its advantages and disadvantages, but on the whole is theoretically the most perfect form of winding. It is more generally used for the larger class of machines. The ring form which is generally associated with the name of its inventor Gramme, is that generally used for smaller machines, or for machines used of very high E.M.F. It also has it advantages and disadvantages, which I will hereafter refer to.

Fig. 6.



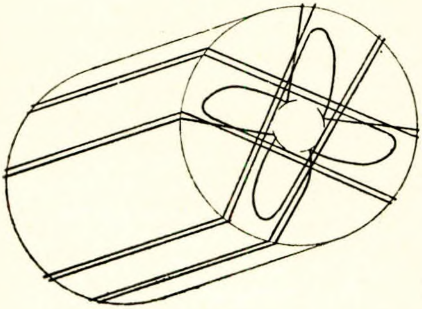
Series Wound. Single Limb Dynamo.

Fig. 7.



Shunt Wound. Single Limb Dynamo.

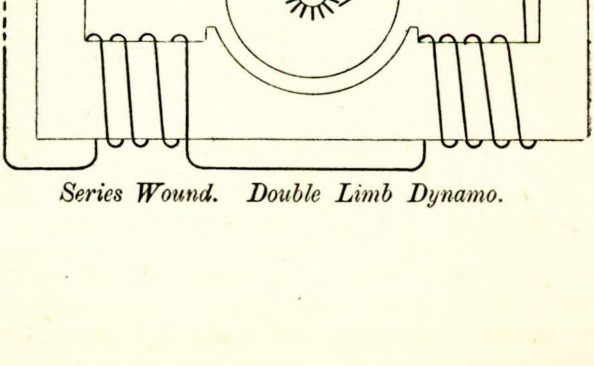
FIG. 8.



Drum Armature,

Shewing Winding.

FIG. 10.



Series Wound. Double Limb Dynamo.

The part played by the Armature core is a twofold one. First it acts as an armature or continuation of the magnets themselves. If there were no core the space between the poles of the magnets, to admit of the winding, would be so large that the magnetic field between the poles would be excessively weak, but by the introduction of the soft iron core, this space is reduced to the two small spaces which are partly taken up by the winding and partly by the clearance or air space necessary to allow the entire armature to revolve at a high speed without fear of the winding touching, or coming into contact with, the bored-out surface of the cavity in the field-magnets. In addition to this, the armature core plays the part of giving a firm mechanical support to the winding, and of transmitting the horse-power from the spindle to the winding, and I may here remark that this is a very serious matter. To those who use dynamo machines and motors for the first time, it is a matter of astonishment where the *horse-power* goes to, they cannot understand why a large heavy belt, or if the machine is direct driven, a large steam engine, is required to revolve the armature, when to all appearance there is nothing to oppose its revolution but the mere friction of the bearings. Until the current begins to be generated the magnetic field does not exist, and consequently the armature may be revolved freely without any apparent resistance to its motion, but so soon as the field-magnets become what is technically termed *excited*, that is to say when they become powerful magnets, by the passing round them of a part of the current produced by the machine, then the resistance to the motion of the armature is very real indeed, and the mechanical strain on all the parts supporting the winding is very great. It is in connection with the transmission of these strains, from the spindle to the winding, that many of the difficulties that so trouble builders of dynamo machines exist. A very large horse-power has to be transmitted from the spindle to the winding, but for electrical reasons we are debarred from the use of metals best suited to transit the strainsand in no case can we use metal to metal, but nearly everywhere we have to interpose layers of insulating material of comparatively small mechanical strength between the various parts of the armature.

The diagrams are not correct representations of the armatures of machines as we make them in practice, as on the diagram it is not possible to show the large number of turns of winding required for machines used for electric lighting purposes. But they actually do resemble the winding of machines for purposes where very low E.M.F. is required, such as those for electro-plating; but to bring actual facts home to you I will describe shortly the general dimensions and mode of construction of a working dynamo machine intended to supply about 166-16 C.P. lamps, or 332-8 C.P. lamps, of 100 volts E.M.F., and with conductors that will carry 100 amperes without unduly heating.

Taking the armature and working outwards, we have a steel spindle with journals at each end, revolving in pedestals which may be of any approved construction. The armature core consists of a number of thin discs of excessively soft, well-annealed, pure wrought iron, generally Swedish iron, about 9 in. external diameter and with a 5½ in. hole punched through them. These discs are about No. 20 B.W.G. thick, and as the length of the armature is about 9 in. it requires about 180 of these discs to make up this length. The discs are supported concentrically to the spindle by being forced on three gun-metal frames or radial bars, which are held at their inner edges by three deep grooves or key ways cut on an enlargement of the spindle and which hold the discs in position at their outer edges by being milled into a dovetail corresponding to dove-tail shaped notches punched in the discs. The discs are cramped up on the radial bars, the ends of the bars are riveted over, and the outsides of the discs are then carefully turned in a lathe and the whole is balanced so as to revolve without vibration when run at the required speed in its bearings. After balancing the mounted core is insulated by being carefully covered with one or more layers of mica alternated with strong linen tape soaked in copal varnish. A certain number of fixed projections or driving teeth—for the purpose of preventing the winding which has now to be applied, from moving on the smooth surface of the armature—have now to be fixed in the core. One way of doing this is to drill the laminated core with the required number of rows of holes, and this can be readily done with a very sharp twist drill. The driving teeth, which are T shaped drop-forgings made of Delta metal or Aluminium-bronze, are driven into these holes and are afterwards covered with insulating material.

The mounted and insulated core is now ready for the winding, and in the machines I am describing this may consist of about 200 turns of wire of square section. The section is so calculated that when the wire is wound on in one layer on the external periphery, and in two layers where it passes through the internal hole, the width is such that it exactly covers the surface of the core in the spaces left between the driving teeth. The successful working and freedom from break-downs of dynamo machines greatly depends on the way in which this winding is carried out, and on close attention to the abutting of the turns, so that there is no movement or sliding action of the turns one on the other, all such movements tending to cause abrasion and certain destruction of the insulating material which separates the turns from one another and from the core. For this size of machine the insulating material most commonly employed is cotton, wound on by suitable machines in two layers and afterwards coated with copal varnish, and then thoroughly stoved. Cotton thus coated and stoved becomes excessively tough, and not only stands considerable abrasion, but when this varnish is used it does not become carbonized or get brittle under the action of heat until a comparatively high temperature is reached, say 300 deg. Fah. The ends of the winding of this machine may be brought out at every other turn or, possibly, at every third turn, they are then soldered into notches in what is called the Commutator or Collecting Cylinder.

The Collecting Cylinder is that part of the machine I referred to as *redressing* or converting into a continous current the alternating currents originally produced by the winding. Everyone who has seen a dynamo machine will readily recognize the collector as the copper polished cylinder, seen at one end of the armature, which appears to be divided off by a number of longitudinal black lines. This collecting cylinder is not a solid copper cylinder. The black lines are slips of mica which completely insulate from one another a number of copper segments which, when held together, form the complete cylinder. The segments are held in place by conical washers pressing against their two ends, corresponding washers made of mica or other insulating material being interposed between the ends of the segments and the washers.

The mode of winding this armature and of the coupling of the wires to the commutator is that shown on diagram Fig. 9, but of course as there are very much larger turns of wire than number of sections in the commutator, it at first sight appears much more complicated than the winding shown on the diagram, but it is really not so. The winding of the armature is simply an unbroken helix extending completely round the core. The commutator segments may be considered as projecting parts of the winding, bared of their insulation, which are soldered on to a sufficient number of the turns, in fact the same effect would be produced if the machine had no commutator, the last end being joined to the starting end and afterwards part of the insulation being removed by filing, or other means, so as to bare the outsides of the wire at the one part of the winding. This bared part would then act as, or become, a commutator, but it is readily seen that it would not have sufficient mechanical strength or wearing power for the purpose.

The collecting of the currents from the commutator is by means of Brushes or rubbers usually made of copper, either in the form of a bundle of copper wire or of a number of thin plates of what is called *stencil* copper, laid one on the other, the object being in both cases to ensure a soft and elastic contact, even when the machine is running at high speeds. This point at which the brushes rub on the commutator is the only point (in addition to the bearings) at which a dynamo machine is supposed to wear and require renewal. Unless carefully handled, the commutator is likely from time to time to get out of truth and requires to be trued up in a lathe, and considerable care must be taken in the right placing and adjustment of the pressure of the brushes. Nothing but practice can give this knowledge. One man will make his commutator and brushes last for years, whereas another man will frequently require new brushes and the commutator turning every few months.

The care of the surface of the commutator in very large machines is a very important matter, and has received much attention from many of us engineers, and I could quote cases were have machines actually run three years with one pair of brushes, and have maintained the surface of the commutator polished like a mirror. I have dwelt at considerable length on this point because it is a practical one with which you are all likley to come in contact, and nothing is so annoying or so distressing to the eye as to see bad lighting on board ship, caused by want of attention to the commutators of the machines; in fact it is one of the very common causes which produces flickering or unsteadiness of the electric light.

The Magnetic field, in which the commutator I have described revolves, consists in this case of a double horse-shoe magnet—shown in the diagram Fig. 10—as we find this form convenient for the purpose. The magnet consists of four rectangular bars of soft iron, arranged in pairs, separated at the required interval, and the space in which the armature revolves is bored out of the solid in a large boring machine. The magnets themselves are excited, or made into electro-magnets, by a portion of the armature current passing round them through what is called the *shunt coils*. The word shunt so often used by Electricians, is used to represent a conductor carrying a portion of the current diverted from the main conductor. It is usually a small current flowing in a channel of much higher resistance than that of the main conductor. In the case of this machine probably not more than 1-50th of the main current will flow through the shunt.

I have now briefly described the main organs, viz., the armature and the field magnets of this machine, which, as I have already said, is intended to produce an electric pressure or EM.F. at its terminals of 100 volts. The amount of current which will flow through the machine will slightly depend on the amount of external resistance through which the current has to pass. If this resistance be that produced by 166-16 C.P. lamps arranged in parallel circuit, then the current will be 100 amperes; if a smaller number are used the resistance will be increased, and from Ohms-law, already described to you, you will see that the current flowing will be proportionately diminished.

You will now ask me what it is that determines the power and output of a machine of the size that I have described? There are two limiting causes. In the first place, if the Resistance in the external circuit were to be reduced so that the current increased to three or four hundred Amperes, the driving power would then be found insufficient; the output of this machine in electrical energy would then be greater than it would be possible to communicate to the spindle by any reasonable arrangement of driving gear, whether by belts, ropes, or direct. In fact, the whole of the mechanical arrangements of the machine would be too small for their purpose; but in addition to this, another hindering cause would come into operation, namely, that a portion of the electric circuit is within the machine itself.

Now I must here go back a little and tell you what I have not told you before, that, wherever Electricity traverses a conductor, and hence meets with a Resistance, that Electrical energy is transformed into *heat energy*. The whole of the loss of E.M.F., or electrical pressure, which we find when a current traverses a conductor, is accounted for in the shape of heat energy, which raises the temperature of that conductor. In fact, when we are using electrical energy for electric lighting purposes, we utilize the energy solely in the form of heat produced in portions of the conductor, which being formed of filaments of carbon of excessively high resistance, are easily raised to an elevated temperature, at which the light rays are given off freely; but although the other portions of the circuit traversed by the electric current are not heated to the same extent, yet they are all heated more or less. As a rule we so arrange and design our conductors that the heating in the parts where the electricity is not to be utilized is kept as small as possible. We use for our conductors materials of the very highest conductivity, such as pure copper, and we make the sectional area as large as possible, but however much we enlarge the area there always will be some heating, and in the case of the machine I have been describing to you, the practical limit of the output of the Machine is the amount of current that can be safely carried by the Armature coils without heating them to an extent injurious to the insulation. This is a matter of the highest importance to you, who so often have to employ Dynamo machines worked in engine rooms where the temperature of the air is already excessively high. This high initial temperature *reduces* the output of your dynamos in two ways :—first, by actually raising the initial temperature of the copper and consequently *increasing* its resistance, so that the heat units generated by the passage of the current are greater than they would have been if the copper were cold ; and secondly, the initial temperature being so high, there is a very small margin of temperature through which the coils can be raised before reaching the 180 or 190 degs. Fahr., which I have already told you is the *limit* at which the insulation begins to become charred, and loses its mechanical strength.

I have not said anything as yet on the efficiency of these dynamo machines. By *efficiency* I mean the output in electric H.P., or in Watts, compared with the Horse-power put into the belt, or other means of driving the spindle. You have no doubt heard that of late years we Electrical Engineers have been very successful in this respect, and that the dynamo machine is *already* a highly efficient machine.

There are many firms who can make machines to give back at the terminals 94 per cent. of the Mechanical Energy put into the spindle; the whole of the small balance of 6 per cent. being changed into *heat energy*, which is wasted in the coils or friction in the bearings or brushes. I had hoped in the limits of this lecture to complete my brief sketch of Electric Generating Machinery by touching on the various modes of producing the H.P. required to revolve the spindle, but I find it will be necessary to withold this for my second lecture.

ELECTRICAL ENGINEERING,

BY

MR. R. E. CROMPTON

(HONORARY MEMBER).

PART II.

In my last lecture I brought you up to the point where I had given you a few practical details on the construction and working of the dynamo machines that we used for generating electrical energy, and told you that, as a machine for converting energy, it has already reached a high point of efficiency, in fact that there is not much more margin left for improvement. I cannot complete the subject of Generating Machinery without reverting to the highly important question of the best means of producing the power for driving it.

Of course any means of producing mechanical energy is useful for driving dynamo machines. Setting aside the most important, the steam engine, we have a choice of gas, hot air, petroleum and hydraulic engines worked by high pressure water, and, where ample water power is available, the various forms of water wheels and turbines, but for the present I propose to speak only of driving by means of steam engines. I assure you that the study of the improvements which have been necessary to be made in the engines driving our dynamo electric machines has been one of the largest and most difficult problems that we electrical engineers have had to tackle. The principal requirements in a steam engine intended for driving electric light machinery are the following. 1st. It must be economical of steam. 2nd. It must not occupy much space. 3rd. It must be free from vibration and silent in running. 4th. It must govern well. 5th. It must not only run at a number of revolutions per minute but also run with sufficient regularity of speed throughout each revolution.

We might divide the steam engines used for driving dynamos into two classes. 1st. The older class which are coupled to the dynamos by some form of gearing, whether tooth, frictional, rope or belt driving, so that the armatures of the dynamos can run at a much higher speed than the crankshaft of the engine; and 2nd. Those engines which are used for direct driving, that is to say, the spindle of the armature of the dynamo and the crank-shaft of the engines are arranged in one line and are coupled to one another, metal to metal. I may say at once that the former class is that which is used for the smaller installations and chiefly on account of the lower price of the dynamo. I must here explain to you that if you require the same output and the same efficiency in two dynamos run at different speeds, the cost of the dynamo will be nearly inversely as the speed; that is to say, the 10 unit dynamo of 90 °/₀ efficiency that runs at 800 revolutions will cost little more than one-half of one giving the same output and the same efficiency at 400 revolutions, and perhaps it would be well if I here remind you of the cause of this.

In my former lecture I told you that the E.M.F. required to cause a current to circulate in the armature conductors, depended on the speed with which these conductors traversed the magnetic field of a given strength. It follows that if the speed be halved, the E.M.F. is halved. You might then ask the question why, therefore, if I require a slow speed dynamo I do not put a greater number of turns on to the armature and thus obtain the desired result. My answer is that I can do this and it is often done, but in order to get the increased number of turns on to the armature the wire must be of smaller diameter, so that I have not only the increased length and resistance of wire due to the extra number of turns, but I have also the increased resistance of wire due to the fact that it is of smaller diameter; consequently, if we take an armature of a given size and put double the number of turns on it, at the same time reducing the section of the wire to one-half, the resistance of the armature to the passage of the current becomes four times what it was before, and therefore the loss and heating in the armature becomes four times as great as before. For this reason, when we require a slow speed machine, we must considerably increase the diameter or length of the armature, in other words increase the weight, and hence the cost, of the machine. The sole reason why the cost of the 400 revolution machine is not quite double that of an 800 revolution machine, is that there are certain manufacturing costs and expenses which are common to both sizes of machines, and moreover the dimensions of some parts of the slow speed machines may be reduced, as the strains due to centrifugal forces are not so great. I have gone at some length into this subject because so many of you gentlemen so naturally prefer to use slow speed dynamo machines, and perhaps you have wondered why we makers of dynamo machines are always recommending the higher speed machines; and you will see that it simply arises from the fact that I have briefly stated above and the desire on our part to give you as much value for your money as possible. Machines that are to be geared to the engines are usually made to run at speeds varying between 600 revolutions and 1000 revolutions, according to the size of the machine, and they can be made so that they are a perfectly satisfactory job when running at these speeds. No trouble, either with vibration or extra wear of the bearing, or at the brushes need be experienced from causes connected with the speed. Naturally, on land, we might use any type of steam engine for driving a dynamo machine by gearing, but at sea, where space is so valuable, in most cases vertical engines are used. In some cases horizontal engines are used with the cylinder end placed next to the dynamo, so that you can utilise the length of the engine to get sufficient length either for belt or rope driving. I have not space in this lecture to enter into the comparative merits of belt and rope driving and gearing. The subject is an excessively interesting one to my profession as well as to yourselves, and there is a great deal to be said on it, but we find that day by day engineers are preferring to order the larger and more expensive slow speed dynamo, necessitated by direct driving, finding that as soon as a certain size, say 20 units is reached, the direct driven sets are so much more certain and satisfactory in their driving, and require so much less attention than the geared sets, that in the space of this lecture I hardly think it worth while to take up further time describing the geared sets. Direct driven sets are of two kinds: 1st, the very slow speed sets driven up to 200 revolutions per miuute by the ordinary open type of double acting engine; and 2nd, those driven by a close type of single acting engine which go to 400 or even 500 revolutions per minute. I have had considerable experience with both classes of engines, but must confess that, for land purposes, the closed type of engine has given such satisfactory results that it seems hardly worth while, for the present, to pay the greatly increased price necessitated by halving the speed of the dynamo in order to revert to the double acting open type. I have put down a great number of large sized engines made by MESSRS. WILLANS & ROBINSON, of Thames Ditton, of the closed type, and both in economy of steam and oil, petty stores and labour, freedom from vibration and noiselessness, these engines are most remarkable specimens of modern engineering. I shall have great pleasure at some time in showing to the members of this Society, some of these engines at work in the central stations in London. Another maker of the close type of engines, which has been successfully used on board ship, has been that known as the Bumsted Engine. I recently heard that one of these that was fitted on board one of MESSRS. THOMAS COOK & SONS' Nile Steamers, is so perfectly silent, that it cannot be heard anywhere over the steamer, although, being constructed of thin sheet steel, these steamers are exceedingly susceptible to noise, the dropping of a spanner at one end being heard all over the place. I merely mention these two makers, as I have had considerable experience with their engines. No doubt there are others which I have not come so much in contact with that also give good results. I am praising this class, however, thus strongly, because I know that among you Marine Engineers there is a considerable prejudice in favour of the older type of engines. The objection to the old double-acting type of engine, when used for direct driving for land purposes, is the great difficulty we find in keeping them perfectly silent, as 180 to 200 revolutions per minute although very and uneconomically slow for a dynamo, is still very fast for the double-acting engine. It is very difficult to keep the brasses in such perfect order that one can hit the happy medium between running hot and knocking. The makers of this class of engine have not been asleep but have endeavoured to meet this class of difficulties by very perfect design and workmanship, and in many cases they have been very successful. It would be invidious to mention any name, many of you present will no doubt have been in charge of very beautiful engines of this class. Before I leave the subject of direct driving engines, I must point out the extreme importance of the proper proportioning the areas of pistons of compound engines used for this work. If the right proportion between the cylinders is not hit upon there is a great tendency to unequal turning throughout the strokes, which makes a most unpleasant effect on the lights, every revolution of the engine being perceptible in the rise and fall in brilliancy of the lamps, and it is quite impossible to get over this fault by increasing the weight of the flywheels. With triple expansion engines, with cylinders side by side, the difficulty does not appear so great, at least some of the most regular turning engines of this speed that I have ever seen were triple expansion engines. An improvement in the direction of simplification that was introduced partly by my own firm and partly by MESSRS. WILLANS, was the omission of the dynamo bearing next the engine, the armature of the dynamo having a coupling forged or driven on to it and bolted metal to metal to a coupling at the end of the crank-shaft. This intermediate bearing was always a great trouble and cause of heating, and since we have done away with it we have greatly reduced the causes of stoppage of direct driven sets.

I have now come to the end of the first part of my subject, viz., the generation of electrical energy by the dynamo machine.

There are other means of generating electrical energy in addition to the dynamo machine, such as by primary batteries, but for practical purposes it is not worth while discussing them here. You are all familiar with the inventor of various forms of primary batteries, who is going to produce electricity for practically nothing by the large sums for which he hopes to sell the waste products of his battery, but it is needless to enlarge on this subject to practical men like yourselves. Energy cannot be produced in any form without corresponding expenditure of energy, whether from the consumption of fuel or from chemical combinations, which are virtually the same thing. The man who produces his electricity by the consumption of zinc plates in a primary battery is practically using zinc fuel,—and a very expensive fuel it is,—to take the place of the coal we use for driving our dynamo machines through the boiler and steam engine.

I now come to my second part proper, viz. : the utilisation of electrical energy, and I am afraid in the short space of time I have before me, I shall make very limited progress in such an interesting subject. If I were to follow the correct order of things and follow the current away from the dynamo machines, I should first have to describe the conductors and other means of distribution, but I think it will shorten matters if I say, that I now propose to describe the lamps for utilising the electrical energy as light, and the motors we use to reproduce mechanical energy for driving machinery. The electrical lamp with which you are most familiar, although it was not first in order of invention, is what is now known as the incandescent or glow lamp. Whether invented by EDISON or by SWAN it does not matter to us here. Both inventors at an early stage produced the same result, viz.: they have succeeded in obtaining continuous steady light from a short length of the conductor, which is raised to a high temperature by the passage of the current through it, protecting it from the wasting effect of the atmosphere, by enclosing it in a glass globe from which the air had been exhausted. All of you are familiar with the present EDISON-SWAN lamp, consisting of what is called a filament, or a thin wire made of carbon, attached to platinum terminal wires which are sealed into a glass globe. From this glass globe the air is exhausted, by means of mercury pumps, to such a high degree of vacuum that the fraction of air that remains may be expressed in millionths of the original quantity. For a long time the great difficulty was in obtaining this perfect vacuum. So long as the vacuum was imperfect the filament did not endure the passage of the current for any length of time. At first, it was not quite understood why this should be the case. It was seen that whatever oxygen remained in the small quantity of air left in the partially exhausted globe, must be very soon converted into carbonic acid, and consequently the filament could not be wasted any further by chemical action; but it was soon seen that the cause of the wasting was the mechanical effect of the connection currents of the inner gases which remained. These circulating currents exercise a washing or wearing effect on the filament and gradually wear it away. Also, so long as any gases, however inert, remain in the globe, there are always convection currents set up which transfer the heat to the exterior parts of the globe and thus radiate the heat away into space, and all this loss reduced the temperature of the filament and made the lamps far from economical. Now-a-days we can judge the excellence of the vacuum of a lamp by the temperature of the surrounding globe; with a good vacuum the globe is exceedingly cool. You can generally clasp a well exhausted lamp in your hand, but if the lamp is not perfect the globe becomes too hot to be thus clasped. I have taken the incandescent or glow lamp first, in order, because it is the very simplest method of producing light by means of electrical energy. As I told you in my former lecture, the passage of the electrical current through a conductor always produces heat, which is proportionate to the resistance of that conductor. I told you that, in the case of the dynamo machine, our object was to waste as little energy as possible in producing heat within the machine itself, or in the conductors which convey the energy to the point where it is to be utilized, but the reverse is the case in the lamps themselves. There we wish to produce light by means of raising a portion of the conductor to an extremely high temperature, and the material that has been best suited for this part of the conductor, and that is now employed in the lamps, is carbon. Although I have mentioned iron and copper, and although you actually can obtain a light from their use, these metals are unsuited for the purpose of such a conducting filament because they melt at a comparatively low temperature, and it would be thus impossible to raise them to a temperature suitable for economical light giving purposes. With platinum wire, or better still, with an alloy of platinum and iridium, useful light effects can be produced, and EDISON's first lamps were actually made with this alloy, but now we use a filament or wire of carbon, produced by a process of toughening threads of vegetable fibre by partially converting them into cellulose, treating them with various chemical solvents, such as dilute sulphuric acid, sulphate of zinc, cupro-ammonia, and similar solvents, and afterwards carbonizing these toughened threads; we are thus able to obtain filaments which can be raised to exceedingly high temperatures, and consequently great efficiency and long life for our lamps. I must here explain what is meant by lamp efficiency. It is the ratio which the quantity of light given by the lamp bears to the electrical energy which is absorbed in that lamp. This efficiency increases with the temperature of the filament, but there is a point beyond which it is dangerous to raise this temperature, as it would considerably shorten the life of the lamp. As the temperature to which the carbon is raised depends on its resistance, and on the E.M.F. or pressure, applied to its terminals, the makers of these lamps adjust the resistance to such a nicety, that when correct pressure for the lamp (and which is marked on the lamp) is applied to it, then the lamp gives a certain candle power, and the efficiency is obtained by dividing the number of candles of light by the number of watts of energy at the terminals, The lamps you meet with in practice vary between 3½ and 4½ watts per candle. We all of us are in hopes that this efficiency will be increased in the immediate future. At present owing to the restrictions of the patents there is little competition between makers in England. On the Continent the case is somewhat different. There we find considerable competition and already the efficiency has risen considerably. You may judge of the importance of this efficiency when I tell you that a rise of efficiency from 4 watts per candle to 2 watts per candle means halving the cost of the unit of light without any change or increase in cost of any part of your generating or distributing plant.

The other kind of lamp that is used for utilisation of electrical energy is the arc lamp, which has been often described. The electric arc is the phenomenon which is produced when the current is passed through a pair of carbon points first held in contact with one another and afterwards separated to a given short distance. Immediately they are separated, the points of the carbon become heated and disintegrated, and a steady stream either of disintegrated carbon or actually gaseous carbon passes between them. These particles being intensely heated, give some light, but the majority of the light is given from the points of the carbons themselves, which are raised to high temperature, far in excess of that of the filament of the incandescent lamp, by the violence of the chemical action which takes place at the surface of the carbon and of the air. The nature of these chemical actions is very complicated, and is not sufficiently well understood for me to enlarge upon them in this lecture. When the arc lamp was first introduced, the light was very unsteady and of bad colour, often blueish and purple, and there were frequent extinctions. As you know, in all these points it has been greatly improved. The point in which the greatest improvements was required was in the manufacture of the carbons themselves. These require to be homogeneous, of fine grain, and must be excessively pure, free from any ingredients which melt at a lower temperature than the carbons themselves, and which thus lower the temperature and consequently the light of the arc. A great many people imagine that the great improvement in arc lighting of recent years is due to the improvements in the lamps themselves. I am not quite of this opinion. I believe that very good lamps were made 7 or 8 years ago, and if these same lamps were used with the perfect carbons we have now, they would give just as good results as the more modern ones. As you know, the number of arc lamps is legion. Practically, arc lighting can be, and is, produced for use in the Navy, and for projectors used in the Suez Canal, by means of hand regulation. The carbons are held in guides, and when the current is turned on they are in contact, they are then screwed to a small distance apart by a right and left handed screw, and as the carbons wear away under the action of the current they are brought nearer together by the man in charge turning the hand wheel. Such a lamp requires little thought to understand its action. The case is widely different when we come to the automatic lamps which have to automatically adjust the length of the arc as the carbons burn away. The principle employed in all these lamps is substantially the same; it is, that some form of electro-magnet apparatus regulates the feed motion, as we call it, that is the progressive motion of one carbon towards the other. Every arc lamp has two separate motions. The first, that of what we call "striking the arc," that is, pulling the carbon suddenly apart to the required distance, which is very commonly from $\frac{1}{8}$ to 3-16ths of an inch at the time the lamp commences to burn, the second motion is retaining the points of the carbons the same distance apart. In some lamps the mechanism for these two different duties is kept quite separate. A simple electro-magnet is used to draw the lower carbon a fixed distance from the upper one, which is held in its original position by the second part of the mechanism. The second part of the mechanism consists of various arrangements of gearing which enable the descent of the other carbon, —generally the upper one,—to be controlled by very minute forces, such as those as are produced by the change or increase of electric pressure between the two sides of the arc, as it burns away or increases in length. As the arc burns the carbons waste away, and hence it increases in length, and the electric pressure then required to drive the current across the two sides of the arc increases proportionately. By having a fine wire circuit of high resistance placed parallel to the arc, as this electric pressure increases, the current which passes through the fine wire is also increased, and the electro magnetic effect is utilised to work mechanism, which allows the carbons to approach one another. The object is to carry out this rather complicated operation with the simplest possible form of machinery. Of the countless forms of arc lamps that have been invented, I am naturally best able to explain to you the one I am most familiar with, viz.: my own, which has been in use a great many years, and which is probably a fair specimen of its class. In this lamp the two duties I have been speaking of are performed by one piece of mechanism. The lower carbon is fixed to the frame, the upper carbon is carried by a heavy vertical rod, which is free to slide through guides, so that it can descend and keep in line with the lower carbon. On the side of the upper rod, teeth are cut forming a rack, which can be geared with a pinion mounted on an axis. On this same axis are two large wheels. These large wheels rest on the edges of a lever, and under ordinary circumstances, when the lamp is in action, the weight is borne on the edges of the wheels thus resting on the lever. The lever is held in a given position by a solenoid, which is a form of electro-magnet, having a cylindrical core, which can be sucked into the solenoid as the current round the solenoid increases. You will understand from the diagram, that the core is so placed that as the current in the solenoid, which is the same current which passes through the arc, increases, the core is sucked upwards, the lever is lifted, and the carbons are thus lifted apart. The arc is established, and the lamp begins to burn. In a short time, as the carbons waste away, the electric pressure between the two sides increases. You will see that on the top of the principal solenoid, through which the main current passes, is mounted a second solenoid. The length of the core is so designed that as the current is increased in the second solenoid, it opposes the action of the lower solenoid first mentioned. This second solenoid is wound with fine wire, and is permanently connected to the two sides of the arc, so that, as the resistance of the arc increases, the current through this fine wire solenoid also increases, and as its action is opposed to the action of the first solenoid, which lifts the carbon, you will see that the second gradually overcomes the first one and causes the end of the lever to descend. If the arc lamp were only intended to burn for a short time, it would have been possible to have mounted the upper carbon direct on to the core itself, and the regulation of the arc would have been effected through a certain limited stroke, but as we have to use carbons of great length in order to insure that the lamps burn for many hours, the carbon rod is mounted in the way shown. It will be seen that, as soon as the upper solenoid has forced the lever down to a certain range, the weight of the carbon wheels and pinion is gradually removed from the rims of the wheels to the finger F, which is placed farther back on the lever rather nearer to its fulcrum. As soon as the weight comes on this finger to a sufficient extent, the wheels are free to revolve on account of the weight of the rack-rod pressing on the pinion. The carbon accordingly descends through a short distance, the current is somewhat increased, and the E.M.F. diminished, the lower solenoid becomes more powerful and the upper one less powerful, as a result the core and lever rise again and the operation is repeated. If a lamp works perfectly, there should be no such extended cycle of operations, the lever should descend to what we call the feeding position, and at that position it should be in a state of balance, the wheels slipping round slightly and gradually so as to let the carbons feed together at a given rate. This description of an arc lamp is fairly representative of the great majority of the arc lamps that are actually in use. Although it is complicated to describe, the parts really are very simple. In early days there were many more wheels in these lamps, the object being to retard the too rapid descent of the rack-rod by introducing a train of wheelwork. The currents most suitable for arc lamps are continuous ones, for this reason, that the carbon attached to the positive terminal of the lamp has a crater or hollow worked in it under the action of the current, and this crater becomes much more intensely heated than the point of the negative carbon, and consequently gives off a very large proportion of the total light of the arc. As it is usual to place the carbons nearly vertical, with the positive as the top, this tendency of the upper carbon to form a crater is of great use, as it throws a great bulk of the light downwards over a sufficiently large area. With the alternating current there is no such tendency to form craters, both of the points are heated equally, and the light is diffused; just as much is thrown towards the sky as there is towards the ground, and no arrangement of reflectors we can use above the arc is able to overcome this defect, none is half so good as the direct rays from the crater of the positive carbon. When the light is used in a horizontal direction, as needed in the Suez Canal, or on board H.M. Ships for search lights, we get the crater of the positive carbon to one side of it by inclining the lamp, and in addition to that, putting the carbons somewhat out of line. In this way we get the crater almost at right angles to the line of the beam of light which proceeds from the projector.

I now come to the description of the various modes of distribution of the electric current. For arc lighting, and in some cases for incandescent lamps used for street lighting, where the conductors have to be many miles in length, the lights can be arranged in series with one another, that is to say, the same current passes in succession through the whole of the lamps. I need say little about it here, as this arrangement is at present the exception and not the rule. It is the best for arc lighting, as the arrangement of the lamps one in front of another steadies the light and effects a great economy in the cost of the conductors, but the great majority of lighting by incandescent lamps, and by such arc lamps as you require on board ship, or in our central stations in towns, is on what is called the parallel system, that is to say, the electric circuit consists of two conductors proceeding from the station, along one of which the current goes out, which may be called the *flow conductor*, and that by which it returns may be called the *return conductor*.

The various glow lamps, or arc lamps, or motors, are arranged in the form of bridges, or connections between these two conductors. The theory of parallel distribution is a very simple one. It is, that if the resistance of each lamp is properly proportioned to the current that it will have to carry, the whole system is self-regulating, that is to say, that if the current required by each lamp is one ampere and the E.M.F. 100 volts, that the resistance of that lamp must be 100 ohms, and as, according to Ohms law, which I have already given you, an E.M.F. of 100 volts will drive one ampere through 100 ohms, it is evident therefore that each lamp, as it is switched on, will take its own fair share of current, but this would only be correct if the lamps themselves formed the entire circuit; but as I have already told you this is impossible.

The dynamo itself, as well as the conductors, forms part of the main circuit, and however well they may be designed with an extremely low resistance, this resistance must always be appreciable and form a perceptible fraction of the whole. It is this resistance of the generating apparatus itself, and of the main conductors, that cause the distribution of electricity to be an expensive matter when the distance traversed by the main conductors is great. The difficulties caused by this waste resistance are two-fold. First, there is a dead loss due to it, and second—the beautiful self-regulating arrangement just described becomes no longer possible. Instead of each lamp receiving exactly 100 volts at its terminals when it is turned on, as each lamp is added, it receives somewhat less. At first the fall of pressure may be inconsiderable, but as a large number of lamps are added, it becomes very noticeable. In order to compensate for this it is usual to raise the pressure at the dynamo end of the conductors by running the machinery somewhat faster. If then a large number of lights are suddenly turned out there is no longer the same loss of pressure in the lamps near home, and the pressure suddenly rises and the lamps are destroyed, from getting too much pressure, hence too much current. A large number of plans have been devised to reduce the loss in the mains. One plan has been to reduce the current as much as possible by using high electric pressure, but there is a limit to the electric pressure we are able to use. In the first place it is not easy to get lamps with filaments sufficiently long and slender to give as small a light as 10 candles at a higher E.M.F. at the terminals than 100 volts. If lamps could be produced at 400 or 500 volts at the terminals a great point would be gained. There would be no sacrifice of simplicity of our arrangements, and as the current required by the lamps would be reduced in proportion to the increase of pressure, the size and cost of the mains and the loss in them would be similarly reduced; but, failing the introduction of such lamps, various devices have been introduced for carrying current at high pressure up to various points and at those points transforming it to currents of low pressure. Such transformation is extremely easy when alternating currents are used, and it is this facility of transformation from high to low pressure, or *vice versa*, which has led to the present great development in alternating current machinery. It will be covering too wide ground to attempt to explain to you the nature of the converter or transformer used for transforming high pressure alternating currents into low pressure. The only corresponding apparatus we can use in the case of continuous currents are really pieces of machinery which consist of a dynamo and motor combined. The motor is driven by a high pressure current and generates a current of low pressure, in the low pressure armature mounted on the same spindle.

Another device, however, is in regular use which has been very successful; that is to say, currents of moderately high pressure are used to charge batteries of accumulators arranged in series, the current is taken off from the terminals of these batteries at any pressure desired. For instance, to make this matter very clear we may place our generating station at A, and thence through a line a mile long to B, and thence another line to C and D and on to E, and thence home. In each of these stations, B, C, D, and E, are placed batteries of accumulators, each consisting of 52 cells, the E.M.F. at the terminals being 100 volts. From the terminals of the batteries are carried the conductors to the adjoining parts of the town, which are lighted from them by 100 volt lamps in the usual manner. Such a plan of distribution, with four batteries in series, is called the five-wire system. A similar plan has been greatly used in America, and is now being used in London, called the three-wire system. In this case there are only two batteries in series. I have only dwelt briefly on these points. The method of distribution to these lamps on board ship, presents no special difficulties. The whole of the parts of the ship are such a short distance from the dynamos, that the loss in the conductors and the want of regulation, due to the resistance of the conductors, is very slightly felt. On board ship there have been two systems of laying conductors introduced, one called the single wire and the other the double wire system.

At one time the single wire system was used on land for houses, but it has been forbidden by the Post Office, by the Board of Trade, and other authorities on account of the supposed interference with the operations of the electric telegraphs. Whether rightly so or not, remains to be seen. In the case of the single wire system only one wire is run out from the dynamo, and from it branches are run to the various lamps. The other side of the lamp is connected to the skin of the ship, which again is connected to the dynamo. In the two wire system there is a completely insulated circuit throughout. A pair of wires are laid from the dynamo or switchboard, each of them completely insulated from the ship itself. Both systems have had their supporters and opponents. It is claimed for the single wire system that it is very much simpler, there are fewer attachments required, and that it is easier to protect the single wire by an armoured casing than it is possible in the other case. In fact the conditions on board ship are widely different from those on land. On land we use, nearly everywhere, two wires running in a grooved wooden casing and this is what was used on board ship, but it was found that water lodged in the casing, and even if the grooves were filled in with putty before the covering of the case was put on, there was still great trouble from the lodgment of sea water. Electrical engineers who have had all their practice in land installations, are far too apt to condemn the single wire system on board ship because they have had bad experience of it on land; but so many firms are now carrying out good work on this system, and so many engineers claim great advantages for it, that it certainly remains an open question whether it is not quite equal to, or better than, the double wire system which has hitherto been supposed to be far superior to it.

Another practical point to which I should call your attention, and which may conduce to the comfort or reverse of those, who have to deal with electric light installations, is the question of what I call the safety fuses or cut-outs, and the position in which these are placed. A safety fuse is a piece of apparatus consisting of a bit of wire, that fuses at low temperature, inserted in each of the branch circuits, the object being to prevent any great rush of current, and consequent heating of that branch wire, if accidentally a short circuit is made, that is to say, if instead of the flow of current being limited by the resistance of the lamp, or lamps, served by the branch wire, there happens to be a temporary connection made direct between the two sides of the circuit. In the case of a single wire system this is liable to take place between the insulated wire and the ships side, or in the case of double wire system between the flow and return conductors, in either case there will be a path of reduced resistance opened, and hence a great rush of current, and the smaller branch wire, through which the rush of current passes, will be overheated and may set the insulation on fire, the fusible wire inserted in each branch prevents this, as it melts and cuts off the current long before the copper wire itself is raised to a dangerous temperature. These protective fuses are very useful as a safety device, but also are a great source of annoyance. The lead or tin wire employed, usually gets more or less corroded at its contacts with the clips or holes in which it is placed, and high resistance is set in, and the heat due to the resistance of this bad contact may easily melt out the fuse, and therefore put either the single light, or the group of lights served by it, out of service. Most of these fuses, or cut-out boxes as they are sometimes called, are arranged, so that it is very easy to insert a fresh piece of wire, but of late years a very good plan has been introduced of grouping the whole of the cut-outs together at various points of easy access, so that instead of the man in charge having to go all over the ship to find out where the cut-out for each light is, he has them all under his eye at the entrance of each saloon, or each portion of the ship. We have applied this principle with great success for house wiring and its convenience is universally acknowledged.

CHAIRMAN'S REMARKS.

(Mr. G. W. Manuel).

The fact of Mr. Crompton giving so much of his time to us augurs well for the future of this Institute, and I hope that a greater interest will be taken in the subject he has so ably brought before us now that it has assumed such prominent proportions. Those present will, I am sure, look in a different light upon Electrical Engineering matters when they know where the current is generated, and the various ways there are of constructing and putting a Dynamo together. I have always found that men were better masters of their work when they knew the method and details of its construction properly, and could thus understand better the reasons for certain conditions existing and ruling in machinery or, indeed, in any class of work.

I have frequently observed in high speed engines a certain *hum* which was not pleasant on board ship, but I think that the direct acting system is better than where belts or friction gear is used.

Engineers should make friends with this new element with which they have to deal. Progress cannot be stopped. Oil lights gave way to gas, and now it seems as if the latter would, in its turn, be displaced by Electricity Certainly, gas is by no means perfect, owing to the dirt and unhealthiness it causes, and the only difficulty in accepting this, the latest introduction, is the question of cost. It is to be hoped, however, that in the near future we shall have the new light as cheap as gas. For the sake of Engineers I must say I do not think the engines are the cause of the break downs on board ship, in my experience the bobbins, wires, and armatures usually give way, and I have not known a case where the engine failed. One thing I must press very strongly upon Electricians, that is the necessity of executing contracts in the best possible manner to secure confidence. Everything should stand the light of day, and be in good order, espeially as regards wires and fixings, which connot be always under the eye and control of those in charge cf the machinery.

Every Engineer will agree with me, I think, when I say that on board ship there is already enough to do without the Engineers being called upon to rectify faults which may show themselves in connection with the Lighting Department.

It is very gratifying to know that Mr. Crompton, with the many and important claims which he has on his valuable time, has devoted his attention to enlighten us on a subject which is of such interest and importance to us, not only as members of this Institute, but as Marine Engineers.

Mr. J. MACFARLANE GRAY'S Remarks.

It was intended that I should have furnished the paper for this evening, also on Electricity, but instead, I have fortunately obtained for you a far abler lecturer, my friend Mr. R. E. Crompton of Crompton & Co., Limited, the "Arc Works," Chelmsford. He has kindly undertaken at very short notice to put the practical facts about Electricity before you in two lectures, of which you have now heard the first one. When we think how very busy Mr. Crompton must be with so many electrical installations under construction, and the management of the great Electrical Works at Chelmsford, and then look at the numerous beautiful diagrams he has prepared for these lectures, we see that he must have laboured very industriously to fulfil his promise to us, and we are very much indebted to him. He has spoken to us as a practical Electrician and Engineer to Engineers, and I think that every one present will be able to understand all he has told us. What I meant to have put in the paper, I thought of giving you, is something which will be more appropriate after you have heard MR. CROMPTON's lectures. You are all this evening, asking yourselves the question: What is that which we call Electricity, and which works in the marvellous manner so graphically described to us this evening? There are many hypotheses or guesses put forward in answer to this question, but none of these are confidently believed even by their own authors. I meant to have given you a modification of some of these, also as a mere hypothesis, but practically useful as serving to connect the various phenomena together according to a thinkable conception. Perhaps I may be able to give you that paper next session.

MR. JAS. ADAMSON'S REMARKS.

In reference to the remarks made by MR. CROMPTON as to the use of the older form of engine being much preferred by Engineers, I think this is probably due to the fact that the new types of engines which have been introduced within the last 10 or 12 years, have been not only somewhat novel in external appearance, but have so many very fine details that the difficulty of repairing a breakdown of the engine with the ordinary appliances of an engine-room outfit, at once raised objections. This idea was strengthened when it was found that many of these forms of engine, in the early months of their introduction at least, did prove somewhat troublesome; with a simple style of engine some shape can be made at the repairing and overhauling, while the difficulty in the way of discharging the same duties to complex engines is apparent.

Now that the recent types of high-speed engines have been brought to a higher stage of perfection we are less ready to offer objection to them. Most of us present have had more or less experience with the Willan and the Bumsted Engine, as well as Brotherhood's, Tower's, and other forms, and can quite endorse what MR. CROMPTON has said. My first introduction to a Willan's Engine was some years ago, it was fitted on board a steam launch which I was desired to survey with a view to purchase; I was greatly pleased with the results given, both in smooth water and in the sea-way. Since then Willan's Engine has been modified and improved to meet the demand for high-speed engines for electric lighting purposes, and no doubt it has given satisfactory results.

We are greatly indebted to Mr. Crompton for his kindness in preparing such eminently practical papers and for his courtesy in coming to read them, and explain what is not clear to us in reference to the dynamo and its working conditions.

Mr. P. SMITH'S Remarks.

I wish to ask Mr. Crompton a question regarding the commutator, which is sometimes troublesome to those who know very little about it. When the brushes take to sparking, the commutator soon gets rough and scored, is it advisable to touch it up frequently with emery cloth or glass paper, say, after a nights running, so as to keep a smooth surface? I usually find that one of the bars wears more than the others forming a flat the whole length of the commutator, and, although it be turned up quite true, it forms again in the same place.

I would like to know whether this is due to the bar being of softer metal, to a slight jar on the engine, or to some other cause which Mr. Crompton in his experience may have discovered.

Mr. JOHN A. ROWE'S Remarks.

Mr. Crompton's paper is indeed valuable to the practical engineers present. The sketches Mr. Crompton has made on the blackboard to illustrate points that words fail more or less to explain, have greatly enhanced the value of the paper. One slight omission has been made in the lecture, viz.: reference to the sketch of the arc-light, showing the screw arrangement that compels one carbon point to travel twice as fast as the other carbon point. Probably Mr. Crompton will refer to this in his reply.

Like most engineers present, I am more interested in electrical phenomena than versed in its laws, and what knowledge I gained a few years ago, by studying the subject at College, is I fear, to a great extent, lost. Hence, in speaking in the presence of an authority like Mr. Crompton, I am more inclined to ask for his explanation than to state my own, in regard to defects which have come under my notice.

Not long since, a personal friend asked me to visit his vessel to examine the installation fitted on board by electricians, who shall be unnamed. He had had some trouble with the lights, and desired to hear my opinion of the fittings. I found that the ship constituted the return wire. 1 also found that short-circuiting had occurred on one occasion, through the wire having been passed through a rivet hole in a beam end. The vessel was steel, the beam was steel, and was situated in a coal bunker, which was inaccessible for a portion of the voyage. The working of the ship no doubt wore away the insulation, but salt-water leaking through the decks might have hastened the process, which, when completed, produced short-circuiting and put the lights out. Now, it seems to me a foolish way of fitting unprotected wires through holes in beams situated in such an inaccessible place as a coal bunker.

Another defect was due to what electricians have given the name of "opening-circuits." In a bath-room, which in one direction was bounded by the ship's side, I found the lead very indifferently protected from chafing, and, worse than that, led fore and aft along the side of the vessel, by dipping under the side-scuttles. It seemed to me that the wire could have been led *above* the side-scuttle just as easily as under the side-scuttle; but the latter path had been chosen, with the result that splashes and drippings of salt water from the open port saturated the insulation of the wire, and after a time wasted away the copper wires themselves, which ultimately broke at their smallest diameter. In this case also the lights were put out; and, when it happens that the dynamo furnishes currents to the side-lights as well as to the other lights of a ship, such a defect becomes of serious importance. It would be nothing short of a calamity if the side-lights and mast-head light of a steamer, carrying hundreds of precious lives, were suddenly extinguished, just when wanted in crowded channels. Thinking the insulation might be defective, I asked my friend to cut off a piece so that I could examine it at my leisure. Here it is! Will Mr. Crompton be good enough to inform us, whether, in his opinion, the wires are properly insulated?

Mr. C. M. STORRARS' Remarks.

Mr. Rowe has just drawn attention to the danger arising to the wires by water trickling upon them, but there is greater danger when petroleum trickles upon the wires, such as happened in a ship carrying petroleum in bulk, and as the details came under my personal cognizance I will give them. The petroleum softened the insulation of the main wires in the hold and got to the wires, which wasted until the area of the wires was so reduced as to be unable to allow the full current of electricity to pass, therefore the wires at that point gave way, thus causing a spark or sparks which set fire to the surrounding wooden casing; this being saturated with petroleum the flames soon became nearly 2ft. in length and were lapping round a petroleum gauge glass, and as there was about 1,640 tons of petroleum on board at the time it may be considered to have been rather dangerous; however, the fire was extinguished as soon as possible and no great harm was done, but what I wish to draw the attention of Marine Engineers to is the danger of leading electric wires through store rooms where oil, turpentine, petroleum, and other inflammable materials are stored, or where inflammable liquids may be spilled upon the surrounding casings and thus damage the insulation and deteriorate the wires, with the result that it may set fire to the ship. I consider that more attention should be paid to this by those who design the lead of the wires and that they may be always accessible.

MR. CROMPTON'S REPLY.

In reply to the remarks made by your Chairman, I myself have often remarked the hum which he has observed, when certain high-speed engines have been used on board ship, but I think he will find that this only occurs with engines driven at an excessive speed, which is objectionable from other causes. At speeds from 350 to 500 revolutions, direct-driven sets can be constructed which do not hum.

In reply to MR. ROWE's remarks, I fully admit the importance of the points he has raised. I think everyone admits that there is no place where such high quality of insulation is required for the conductors as on board ship. Salt water itself is an extremely good conductor, and, in fact, we consider the most severe test to which we can put the insulation of wire is to immerse it for a length of time in a tub of salt water. In all such cases as he mentions, where wires pass through beams, the soft insulation of the wire should be protected by a sleeve of hard insulating material, such as ebonite, varnished hard wood. Porcelain and glass, although very excellent for this purpose, have the disadvantage that they are liable to get covered with a layer of salt which reduces their insulating properties.

The incident related by Mr. Storrar is of a thrilling kind. I can sympathize with his feelings. I believe that carefully insulated cable, drawn into a solid lead casing, is the best to use for petroleum ships. Such wire is now being largely used, and I am informed, with satisfactory results.

In reply to Mr. Smith's remarks, the fault which he mentions which caused a black mark on the commutator is called by us a "flat," and is caused by the brushes getting out of position, that is to say, not being diametrically opposite to each other. It is much more liable to occur on good machines than on bad ones. Those machines that constantly spark a little and constantly wear their commutator rarely produce a flat, but those machines that polish their commutators if the brushes are allowed to wear so long that they get out of position, are invariably found to produce these flats. The best way to get rid of them, if they have not gone too far, is to file them out by easing down the adjacent segments on both sides of the flat, and finally polishing with emery cloth. If, however, the flat has got too deep, it is necessary to put the armature in the lathe and take a light cut over the armature with a pointed tool which should be very sharp, otherwise it will bruise the copper down over the mica insulation. In turning, the commutator should first be polished with a small file and then with several grades of emery cloth.

In conclusion, I have to thank you for having listened to my necessarily very imperfect description of Marine Electrical Engineering. As the bulk of our business in England has hitherto lain in supplying electrical energy for lighting purposes, no doubt many of you think that this is its most important application. This may be true at the present moment, as the tide has at last turned in favour of such a healthy and convenient form of lighting, but I must confess, as an engineer, I look forward in the future to a time when the bulk of our business will be in the transmission of power. I think few of you have as yet realized how enormously the social condition of the working classes of this country may be affected by electrical distribution. At present the bulk of our workers are concentrated in factories, the reason being that the distance to which power can be conveniently and economically transmitted is limited by the length of the shafting of the factories. We may look on an electrical conductor a mile long as a piece of shafting, having the advantage that the power from this electric shafting can be taken into every cottage facing the mile of street along which it is laid. In this way a large number of manufactures, now carried on in crowded factories, could then be carried on by the worker in his own house, and you can readily see what a change this might make in the future comfort of the working classes.

If the principle was carried still farther, it might avoid that great concentration of the population in cities, which has been going on ever since the steam engine was invented. Who can doubt, that by further improvements, the electric transmission may be within a comparatively short period carried out profitably to distances of 10 or 12 miles from the centres of supply? When this is the case, every worker might live in a detached house, surrounded by his own garden, and carry on his trade, enjoying at the same time the advantages of country life. I call your attention to these facts, as they greatly increase the interest and attraction which electrical engineering ought to have to all you gentlemen, who are already trained Mechanical Engineers.

PREFACE.

THE BROADWAY,
STRATFORD,
May 13*th*, 1890.

A meeting of the Institute of Marine Engineers was held this evening, presided over by MR. G. W. MANUEL (President), when MR. DAVID PHILLIPS (Member) read a Paper on "The Relative Corrosion of Iron and Steel under various conditions". A large number of diagrams, photographs, and specimens were exhibited. These have been presented to the Institute, and the more important of the photographs are reproduced and will be found attached in the form of lithographs.

The length of the paper precluded any extended discussion on the same evening, it was therefore proposed, that in order to bring the whole subject up again, another paper should be written in the light of the very interesting data from the experiments made by MR. PHILLIPS, so that members might have an opportunity of giving a record of their experience, either by sending the same in writing or relating it at the discussion.

It is desired that members should volunteer to write such a paper or papers as have been indicated, in order that arrangements may be made for a continued discussion on the subject.

The remarks made in the course of the evening, and sub[illegible]quently, on the paper, by members, and the opinions expressed [illegible] well-known Engineers and others, in response to invitation, are [illegible]pended to the paper, and enhance its practical value.

JAS. ADAMSON,
Hon. Secretary.

NOTES ON THE PAPER ITSELF.

1.—It will be observed that on page 15, paragraph 2, sentence 2, should read "This and other patches in the steels were much more *unevenly* and much *more* affected than other parts of their surface, and *the adjoining surfaces* were brighter after cleaning, &c."

2.—It should be noted on page 17, paragraph 1, sentence 3, that the small patches of surface referred to as on the black side, are the *affected* patches of surface.

3.—In order to make perfectly clear what is meant in the foot note on page 22, Table I. By "exposed surface" is meant the *outside* of the heads, &c.

4.—It will probably not be unknown that the MR. RAYLTON DIXON referred to on page 29, paragraph 4, is now SIR RAYLTON DIXON.

5.—The terms of years given on page 32, paragraph 3, sentence 3, should be transposed, to be correct in accordance with the numbering of the Series in the experiments, and should therefore read 7 and 3 years respectively.