# MANUAL

OF

# ELECTRIC SEARCH-LIGHTING

COMPILED AT THE

## SCHOOL OF MILITARY ENGINEERING, CHATHAM.

---

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# PREFACE.

No book has, as yet, existed in which the theory and practice of electric search-lighting has been rendered accessible to those wishing to become acquainted with the subject. Most of the principles special to that branch of electric lighting have hitherto been handed down by a sort of oral tradition. This work has been undertaken in the hope that it may fulfil the want.

It has been thought fit to add some chapters on the principles underlying the construction of dynamos, not that there is a scarcity of books on this topic, but in order to render this work more complete.

Those seeking more information on this matter than it was possible to include in a work of this sort, are referred to Professor Silvanus Thompson's standard work, *Dynamo Electric Machinery.*

R. L. HIPPISLEY, CAPTAIN, R.E.

*Instructor in Electricity.*

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# CHAPTER I.

## MAGNETISM.

MAGNETISM is a physical agency closely connected with electricity. It is manifested by the attractions and repulsions produced by its means between bodies known as magnets or magnetic bodies.

It always produces polarity in the bodies in which it resides. This means that there exists in every magnet an axis or line called the axis of magnetization, and that one end of this axis and the adjacent parts of the magnet exhibit opposite properties to the other and the parts adjacent to *it*. These ends and adjacent parts are called the poles of the magnet. These poles are the seat of the attractive and repulsive forces by which the existence of magnetism is manifested to us.

Suppose that the poles of two long but very attenuated magnets are brought near together, and the force with which they act upon one another measured by any means. This force is found to be in inverse proportion to the square of the distance apart of the poles. It is necessary to the truth of this law that the cross section of the magnet should be small compared with the distance across which the attraction or repulsion is measured.

The force also varies directly as the strengths of both of the poles, that is to say it varies as the product of the strengths of the poles.

The strength of a pole is a quantity analogous to the quantity of electricity on a charged conductor. It is, however, impossible to obtain one magnetic pole on a body apart from the opposite pole as a quantity of electricity can be obtained. The strength of a magnetic pole is measured by comparison with the unit pole, which is defined to be the pole which, when placed at the unit distance (one



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centimetre) from an equal and similar pole, repels it with a unit force (one dyne). The unit force is the force that will produce, in one second, an acceleration of one centimetre per second on a mass of one gramme. The two opposite poles of any magnet are always equal in strength.

Any region where forces act is called a field of force. If the forces are magnetic, it is called a field of magnetic force, or, briefly, a *magnetic field.*

A magnetic pole must be conceived as throwing out lines of force in all directions into the surrounding space. These lines are straight unless diverted by encountering other lines, such as those from the opposite pole of the same magnet. They pass with apparent ease through all non-magnetic media and bodies. The existence and direction of these lines of force can be readily shown by shaking fine iron filings about the poles of a magnet. They merely represent the direction of the magnetic forces, and indicate the direction in which a compass needle would lie when subjected to those forces. *Fig.* 1 shows the distribution of the magnetic lines proceeding from the poles of a bar magnet, and *Fig.* 2 gives the appearance viewed end on.

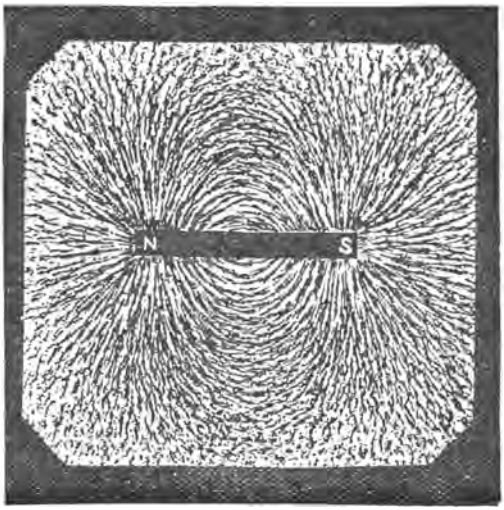



*Fig.* 1.

When the direction and magnitude of the forces are the same at all parts of the field, the field is called uniform. If we take a very

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strong magnet (*Fig.* 3) and place it at a great distance from us, and examine a limited portion, A, of its field near to us, we shall find that all the lines of force, or, in other words, the directions of the forces, are practically parallel to one another, as in *Fig.* 3,

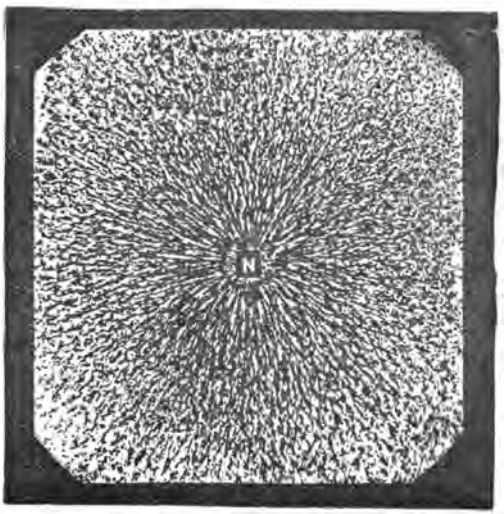



*Fig.* 2.

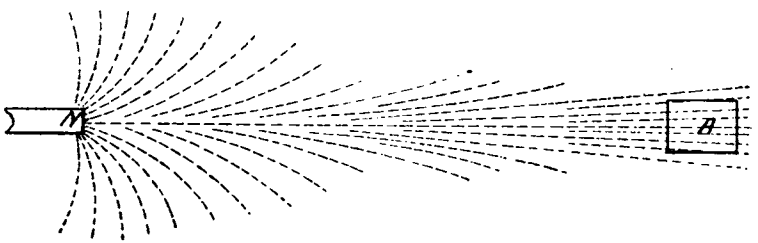



*Fig.* 3.

and at this great distance the variation in the magnitude of the forces will be in appreciable. The greater the distance and the smaller the portion of the field examined, the more nearly will this be true. Throughout a region a few hundred yards square, the earth's magnetic force may be considered uniform. Uniformity of field may be produced in other ways. Thus the field produced be-



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tween two very large magnetic poles placed very close together, as in *Fig.* 4, is practically uniform.

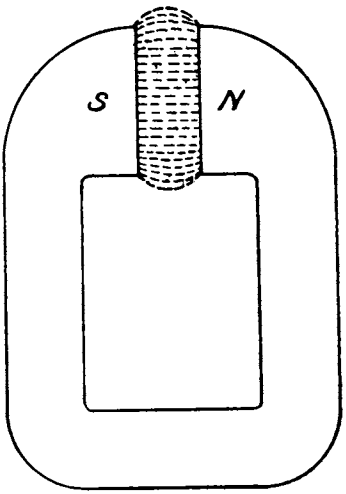



*Fig.* 4.

The intensity of a magnetic field is the force that a unit pole will experience when placed within it. The force acting upon one end of a magnet swinging in a magnetic field depends upon the strength of the pole and the intensity of the magnetic field. If the pole has a unit strength, and the force experienced is one dyne, the intensity of the field is said to be unity. It follows from this that the field of unit intensity is that produced by a unit pole at a distance of one centimetre, supposing the pole very small in size.

Iron and its compounds is almost the only body in which magnetism can be noticeably produced. Cobalt and nickel exhibit magnetic properties, but to a much less degree. It can be more easily produced in pure iron than in impure iron, but it is also more easily destroyed in the former than in the latter. In fact it is impossible to maintain magnetism permanently in a piece of pure soft iron on the removal of the exciting cause. Steel, however, will retain magnetism for an indefinite time when once it has been magnetized, but it is more difficult to produce polarity in it than in soft iron. There are a variety of ways of producing magnetism in a piece of steel, involving the expenditure of work, one way being to rub it in a peculiar manner with a strong permanent magnet. The method of doing this can be found in any treatise on magnetism.

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# CHAPTER II.

## PRINCIPLES OF DYNAMIC INDUCTION.

It is well-known that a conductor conveying a current will exert a deflecting force upon a magnet suspended in its neighbourhood. The point of application of this force is the pole of the magnet, and the magnitude of the force depends upon the following considerations:—(1), the strength of the current; (2), the length of the conductor conveying the current; (3), the distance of the conductor from the magnet pole; and (4), the strength of the pole. It is directly proportional to the strength of the current and the strength of the pole, and, if the length of the conductor is very small compared to the distance between it and the magnet pole, it varies directly as the length of the conductor, and inversely as the square of the distance.

Now, the unit adopted for measuring currents is the current, one centimetre length of which will act upon a unit magnet pole at a distance of one centimetre with a unit of force. If the magnet pole have a strength of $m$ units, such a current, so disposed, will exert a force of $m$ dynes, and, generally, a current of $c$ units and $l$ centimetres long, placed at a distance of $r$ centimeters from a pole of $m$ units strength will exert a force of

$$\frac{m\,l\,c}{r^2} \text{ dynes.}$$

Now, if the strength of the current be one unit, and its length one centimetre, the force it will exert upon a magnet pole of strength $m$ will be

$$\frac{m}{r^2} \text{ dynes,}$$

since $l$ and $c$ are both unity.

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Since a unit magnet pole will act upon another unit pole at a distance of one centimetre with a force of one dyne, it follows that a unit magnet pole will exercise a force on a magnet pole of $m$ units, distant $r$ centimetres, equal to $\frac{m}{r^2}$ dynes.

Therefore, it becomes apparent that, so far as the forces are concerned, the unit length of a unit current is equivalent to a unit magnet pole.

Now, the intensity of a magnetic field has been defined to be the force which a unit pole would experience if placed within it. It may, therefore, be equally well defined to be the force experienced by the unit length of a unit current.

The unit intensity of magnetic field will, therefore, be the field which will exert a force of one dyne upon the unit length of the unit current, and, therefore, a field of intensity T will exert a force of T dynes upon a unit length of unit current, and, generally, if the length of the current be $l$, and the strength of the current be C, the force that a field of intensity T would exert upon it will be

$$\mathrm{T\,C}\,l \text{ dynes.}$$

The equivalency of the unit length of unit current, and the unit magnet pole only relates to the magnitude of the forces they exert. The directions of the forces are different. Thus the direction of the force between two magnets, or between two short currents, is in the line joining the poles, or the line joining the centres of the two currents, but the direction of the force between a current and a magnet pole is such as would tend to move the current in a direction at right angles to the plane containing it, and at right angles to the magnetic lines of force which cut it; and, further, the direction of the current must be also at right angles to the lines of force for the maximum effect to take place. If the direction of the current be inclined to the lines of force, the force acting will be equal to the maximum force multiplied by the sine of the angle between the direction of the current and the lines of force.

Again, if the current be constrained to move in any other direction than the one it would naturally take, the force producing its motion will be less in proportion to the cosine of the angle which its direction of motion makes with the natural direction.

For a magnetic field, therefore, to exert its maximum force upon a current, the latter must lie in a plane at right angles to the lines of force, and must move in that plane at right angles to itself.

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It is this maximum force which is represented by the equation

$$f = \mathrm{T\,C}\,l.$$

The converse of all electro-magnetic phenomena is also true. Thus, as an electric current in a magnetic field is acted upon by a force of T C $l$ dynes, which causes it to move if it be free to move; so, if a conductor be moved mechanically in a magnetic field, a current of electricity will be developed in it. This current will be in a direction tending to oppose the mechanical force applied to the conductor, since it is by the expenditure of that force that it is produced.

As before, the direction of motion must be at right angles to the conductor, and to the lines of force, for the maximum inductive effect to take place.

On the principle of the conservation of energy, the force which is expended in the production of current will be exactly balanced by the force that such a current would experience when acted on by the magnetic field. Any additional force which it is necessary to apply to the moving conductor to overcome its inertia, friction, and the resistance of the air may, for the present purpose, be left out of consideration.

Hence, if a current of C units be produced by the movement of a conductor of length $l$ in a magnetic field of intensity T, a force of T C $l$ dynes will have to be applied to it.

To produce a current in this way work will have to be done. If the conductor be moved a distance $d$ in the proper direction, the work done will be T C $l$ $d$. If this work be all expended in the production of a current, that current will be doing precisely the same amount of work in the conductor. Now, the work done by the current $= \mathrm{C\,V}\,t$ where V is the difference of potential between the ends of the conductor, and $t$ is the time for which the current lasts, that is to say, the time taken to move the conductor through the distance $d$; hence

$$\mathrm{C\,V}\,t = \mathrm{T\,C}\,l\,d,$$

$$\text{or } \mathrm{V} = \mathrm{T}l\frac{d}{t};$$

now, $\frac{d}{t}$ expresses the velocity of the movement of the conductor across the lines of force. If, therefore, we write $v$ for this velocity, we have

$$\mathrm{V} = \mathrm{T}\,l\,v;$$

that is to say, the electromotive force in the conductor is equal to

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the product of the intensity of the field, multiplied by the length of the conductor, multiplied by the velocity of movement.

If the conductor is not a complete circuit, the electromotive force induced by its motion will not be able to cause a continuous current, but will only produce a current until the quantity of electricity conveyed from one end of the conductor to the other has produced a difference of potential between the ends of the conductor equal to V, then the electromotive force produced by the motion of the conductor is balanced by that resulting from the difference of potential set up by the current, and no further current will pass. If the motion of the conductor be suddenly arrested, the difference of potential set up by the current will then be free to act, and a current in the reverse direction will take place in the conductor until the potential of the conductor is equalised throughout.

Let us suppose, however, that the conductor forms a closed circuit. Let C D and E F (*Fig.* 5) be two fixed conductors lying in the direction of motion of A B, and let A B and I K be two

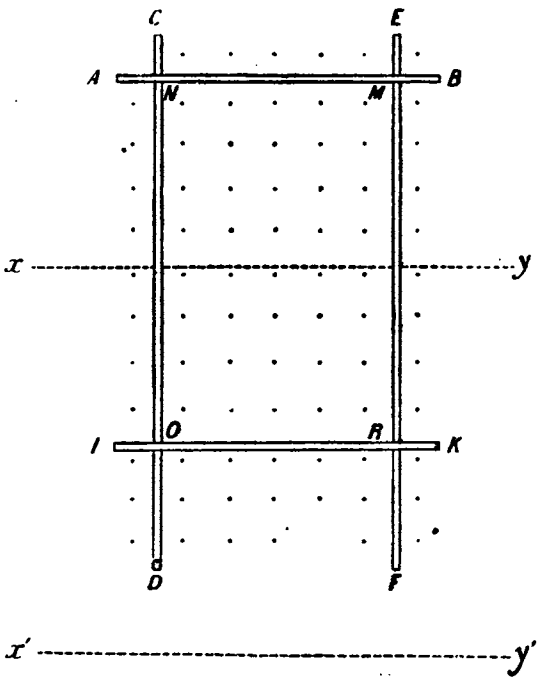



*Fig.* 5

moveable conductors lying across them. Let this system of

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conductors be in a plane perpendicular to the magnetic lines of force, which are shown in section as dots in the figure, and which are supposed to proceed from a north pole in front of the paper to a south pole behind it. If, now, A B be moved downwards across the lines of force with a velocity $v$ centimetres per second, there will be induced in A B an electromotive force V, which is equal to $T\,l\,v$. This electromotive force will urge a current of electricity from A to B, which will circulate round the whole rectangle in the direction N M R O, and if $r$ be the resistance of the rectangle the current will be equal to $\frac{T\,l\,v}{r}$. Such a current is always produced in the axles of a train in motion, the rails representing the fixed conductors and the exciting magnetic field being the vertical field of the earth's magnetism. As before, to get the maximum effect, the conductor, the direction of motion, and the lines of force must all be at right angles to one another. If they are not all perpendicular to one another, the length of the conductor, the velocity and the magnitude of the magnetic force must all be resolved in directions which are at right angles to one another by multiplying the actual magnitudes by the cosines of the angles they make with such directions.

It has been found convenient, for purposes of calculation, to represent the intensity of a magnetic field by the number of lines of force traversing a given section of the field. That is to say, a powerful field is represented as containing more lines of force, condensed more closely together, than a weak field.

It has been conventially arranged to represent a field of unit intensity by one line per square centimetre of section of the field.

The quantity T, therefore, is numerically equal to the number of these conventional lines of force per square centimetre. A field of intensity T will have T lines of force per square centimetre.

Now, $l$, the length of the conductor, is also expressed in terms of the centimetre unit, hence $l \times T$ will be the number of lines of force cut by the conductor in moving downwards through one centimetre, and as $v$ means the number of centimetres traversed by the conductor per second, $T\,l\,v$ will be the number of lines of force cut by the conductor per second. We now see that the electromotive force $v$, induced in a conductor moving across a magnetic field, is equal to the number of lines of force cut per second, and a moment's consideration will suffice to show that this is true, whether $T\,l$ and $v$ are all perpendicular to one another or not.

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If the conductor I K (*Fig.* 5) also move downwards with the same velocity $v$, the electromotive force produced in it will be equal to that induced in A B, and would tend to produce a current in the rectangle in the direction O R M N. This electromotive force would oppose the electromotive force induced in A B, and being equal to it, would balance it, and no current would result. But if the conductor I K moved upwards while A B moved downwards, then the electromotive force in I K would assist the electromotive force in A B, and a current would circulate in the direction N M R O. The electromotive force in the rectangle would then be $\mathrm{T}\,l\,v + \mathrm{T}\,l\,u$ where $v$ and $u$ are the velocities of the two conductors. If $v$ and $u$ are equal but in opposite direction, then

$$\mathrm{V} = 2\,\mathrm{T}\,l\,v.$$

Now, suppose A B and I K were rigidly fixed to the connecting rails C D and E F, motion could not, of course, be imparted to them by sliding them along the fixed rails, but a similar translation across the lines of force could be effected by causing the whole rectangle to rotate about an axis $x\,y$, situated in the centre of the rectangle and parallel to A B.

The velocity $v$ across the lines of force at the commencement of the rotation will be almost zero, because the conductors A B and I K will, during the first instant, be moving in directions very nearly parallel to the lines of force, but as the rotation continues the velocity of movement across the lines of force increases and attains a maximum when the rectangle has moved through 90°, for then the movement is wholly across the field. If, now, $v'$ represent the lineal velocity of rotation, the electromotive force induced in the rectangle at any instant would be $2\,\mathrm{T}\,l\,v' \sin \alpha$, where $\alpha$ is the angle which the plane of the rectangle makes with the vertical plane. The value of this electromotive force varies every instant from the value O to the value $2\,\mathrm{T}\,l\,v'$ and back again to O as the rectangle completes half a revolution. As the rectangle performs the other half revolution the velocities across the lines of force change their signs, and accordingly the electromotive force in the rectangle gradually varies from O to $-2\,\mathrm{T}\,l\,v'$ and back to O. The currents in the rectangle, of course, during a complete revolution vary with the electromotive force from O to $\frac{2\,\mathrm{T}\,l\,v'}{r}$, back to O, then to $-\frac{2\,\mathrm{T}\,l\,v'}{r}$, and back again to O, attaining the maximum values at 90° and 270° with the vertical.

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Now, to go back again to the rectangle with the sliding ends, we saw that if I K moved in the same direction as A B, and with the same velocity, the electromotive force induced in it, counteracted that produced in A B, and no current resulted. If, however, I K moved downwards with a less velocity than A B, the electromotive force induced in it would be less than that induced in A B, and accordingly a current would circulate in the direction N M R O, due to the preponderance of the electromotive force in A B over that in I K. The electromotive force in the circuit would then be $\mathrm{T}\,l\,v - \mathrm{T}\,l\,u$ and the current $\dfrac{\mathrm{T}\,l\,v - \mathrm{T}\,l\,u}{r}$.

These conditions can be fulfilled in the case of the rigid rectangle by causing it to rotate about an axis $x'\,y'$, situated outside the rectangle but parallel to A B.

The velocities of A B and I K *across* the field will at first be each equal to zero, and will, as before, attain their maximum values when the rectangle has completed a quarter of a revolution, but the velocity of I K will always be less than that of A B, because its distance from the axis of rotation is less.

Nearly all dynamo machines giving continuous currents are constructed upon one or other of these two types. Siemens machines consist essentially of a rectangular coil rotating about an axis situated symmetrically *within* it, and Gramme machines consist essentially of a rectangular coil rotating about an axis situated *outside* it.

The two foregoing types of armatures are usually worked in magnetic fields, which are designedly made as uniform as possible.

There are, however, a large number of dynamo machines specially constructed to give alternating currents, and in such machines the moveable conductors are made to traverse magnetic fields, which are constantly varying in intensity and altering in polarity.

Such a field would be produced if several magnets were placed vertically below the moving conductors, with their poles arranged as shown in *Fig.* 6. The vertical field produced by $\mathrm{N}_1$ would be most intense at the point occupied by the present position of the conductor A B, and if A B were to move along towards D and F it would pass through a field gradually diminishing in intensity as it receded from $\mathrm{N}_1$, but at a position half way between $\mathrm{N}_1$ and $\mathrm{S}_1$ it would begin to enter a field of reversed polarity and of gradually increasing strength. Therefore the current induced in A B would at first be in the direction B A, and after passing the central position $a_1 b_1$ would change direction and be from A to B. It would be at a positive maximum

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at the original position, zero at $a_1b_1$, and at a negative maximum on passing $S_1$.

Now the conductor I K, if it moved along with the same velocity and in the same direction as A B, would be passing a south pole while A B was passing a north pole, and *vice versa*, and, therefore,

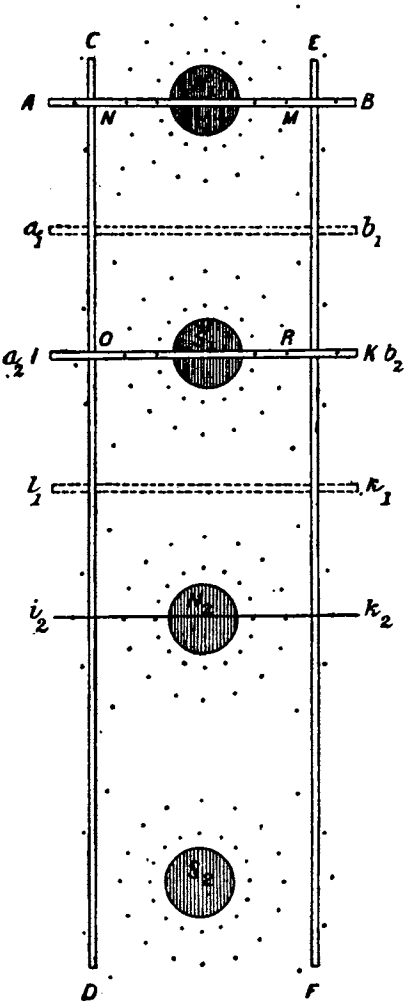



*Fig.* 6.

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the current induced in it would not oppose but assist the current produced in A B, both circulating round the rectangle M N O R in the same direction. The current would diminish to nothing as the rectangle approached the position $b_1 a_1 i_1 k_1$, and then would become reversed and increase to a negative maximum as the rectangle arrives into the position $b_2 a_2 i_2 k_2$.

This state of things could be produced in a rigid rectangle if it were made to slide over the periphery of a wheel, the spokes of which were magnets.

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# CHAPTER III.

## ARMATURES.

Reverting to the two first types of armature alluded to in the preceding chapter, we see that the Siemens armature is based on the principle of the revolution of the rectangle A B K I (*Fig.* 5) about an axis $x\,y$ situated symmetrically within the rectangle.

If the rectangle revolve so as to cause A B to approach in front of the paper and downward, and I K to pass through to the back of the paper and upwards, and if the lines of force proceed from a north pole in front of the paper through the rectangle towards a south pole at the back of the paper; then the current in A B will be from A to B, *i.e.*, in such a direction as will oppose the motion, while the current in I K will be from K to I, so that a current will circulate round the rectangle in the direction N M R O.

This will continue until A B and I K have exchanged positions, when the direction of the current will also change. This movement of the rectangle is shown in *Fig.* 7.

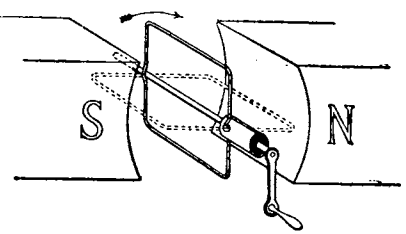



*Fig.* 7.

In order to obtain a current in an external circuit, we must tap the rectangle at the most convenient point, and arrange by means of

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sliding connections, so that the free rotation of the rectangle is not interfered with. This is done in the following way, viz., by dividing

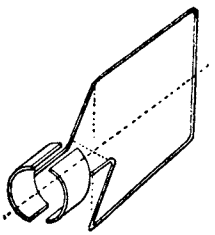


*Fig.* 8.

the short side of the rectangle, and inserting two hollow half cylinders in it. The rectangle now no longer forms a closed circuit. as the interval between the cylinders causes a break in it. The electromotive forces induced will therefore no longer produce a current; but if two springs are made to rest on the surfaces of the split hollow cylinder (*Fig.* 9), and connected to an outside circuit, then the electromotive force excited in the rectangle will cause a current to flow.

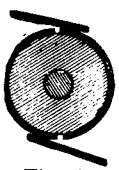


*Fig.* 9.

This is called a two-part commutator, and it has this further property, *i.e.*, of annulling the effect in the external circuit of the reversal of the electromotive forces in the rectangle when it has changed position; for, as the upper side approaches the position now occupied by the lower side, where the electromotive force changes direction, so do the springs slide off one cylindrical plate to the other. In consequence, that portion of the rectangle in which the electromotive force is positive, is always in connection with the upper spring, and that in which the electromotive force is negative, is always in connection with the lower spring.

This gives rise to a current in the external circuit which is always in the same direction.

The difference of potential between the commutator plates, due to the electromotive force induced in the rectangle, can be increased by using a coil of wire instead of a simple rectangle, and by connecting

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the ends of the coil with the commutator plates. *Fig.* 10 shows a coil consisting of two turns, in which the electromotive force would be doubled; and *Fig.* 11 shows a coil of many turns, in which the electromotive force would be multiplied many times.

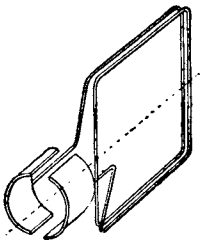


*Fig.* 10.

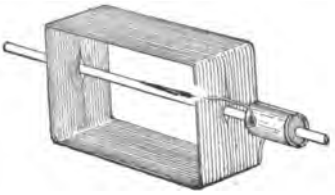


*Fig.* 11.

Now, if the rectangular coil shown in *Fig.* 11 be wound upon an iron core, the effect is very much further to increase the electromotive force. Iron, when placed between the poles of a magnet, becomes temporarily magnetized by induction.

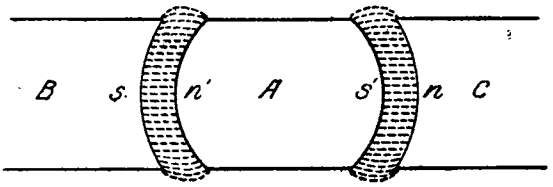



*Fig.* 12.

Thus, in *Fig.* 12 the piece of iron A, when placed between the poles B and C, becomes magnetized with a polarity as lettered in the figure. The effect of this is very much to increase the intensity of the magnetic field in the immediate neighbourhood of B and C. It is as if the pole C had been brought up to the position $n'$. And, as is well known, the intensity of a magnetic field depends upon the distance apart of the poles.

We saw that $E = T \times l \times v$. Therefore, other things being equal, E varies as T.

The original Siemens shuttle-wound armature consisted simply of

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a rectangular coil, similar to that shown in *Fig.* 11, wound upon an iron core with a groove cut in it for the coil.

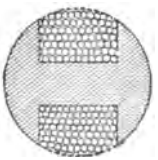


*Fig.* 13.

This, when supplied with a two-part commutator, gave rise to a pulsating current, always in the same direction as regards the external circuit.

Now, reverting to *Fig.* 7, the electromotive force induced in the rectangle is a maximum when its plane is passing the poles S and N, because here the wire is cutting the lines of force at right angles, and here

$$E = 2 T l v,$$

where $l$ is the length of one side, T the intensity of the field, and $v$ the lineal velocity; but at any other position

$$E = 2 l T v \sin \alpha,$$

where $\alpha$ is the angle between the plane of the rectangle and the vertical plane through the axis.

Hence the electromotive force in the coil at any moment varies as sin $\alpha$, that is, will, if graphically represented, have the appearance shown in *Fig.* 14, which is a curve of sines where the horizontal *abscissæ* measure the magnitudes of the angles and the ordinates the values of the sines of those angles.

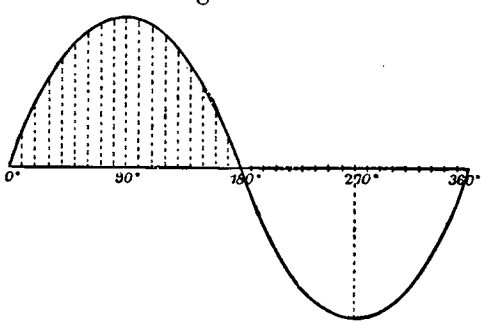



*Fig.* 14.

The current in the external circuit will also vary as sin $\alpha$, but since the commutator makes it unidirectional, it will be represented



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by *Fig.* 15, in which the lower portion of the curve in *Fig.* 14 has been turned over to the positive side of the axis.

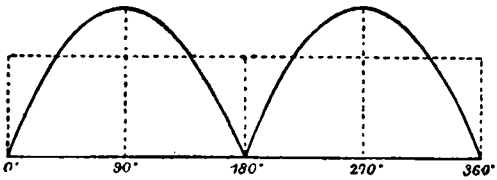



*Fig.* 15.

It will be observed that, so far as furnishing electromotive force is concerned, the wire at the ends of the rectangle is idle, and only offers useless resistance to the current; it is necessary to the arrangement, for otherwise the circuit would not be continuous. Therefore, the longer the rectangle is in comparison to its breadth, the more economical it is. But there is a limit to the attenuation of the coil, or armature, fixed by mechanical difficulties of construction, and by the decrease of lineal velocity produced when the diameter is very small. The best proportion is reached when the length is $2\frac{1}{2}$ times the diameter.

The first improvement was to add another set of coils at right angles to the first, as shown in *Fig.* 16. The commutator is divided into four plates, and the brushes adjusted so as to touch the centre of the commutator plates attached to the coil, which is undergoing maximum induction.

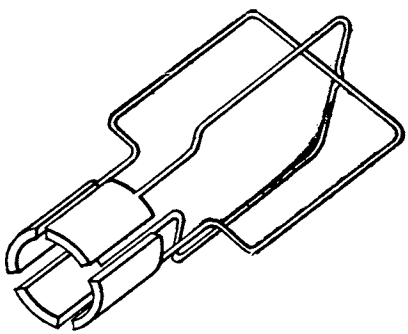


*Fig.* 16.

In this arrangement each coil is put into connection with the brushes by the commutator at the time during which it is most usefully employed in generating electromotive force, and cut out of connection when its motion is parallel to the lines of force, or when its electromotive force is zero or very little.

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The resulting current in the external circuit is represented by the curve in *Fig.* 17.

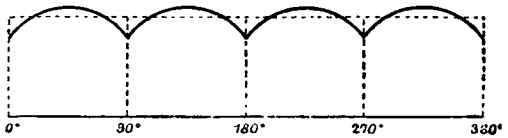



*Fig.* 17.

This current consists of more frequent pulsations, but instead of varying from zero to a maximum, they only vary from one value to another about $1\frac{1}{3}$ times as great. By further dividing the commutator into eight plates, and having another pair of coils between the other two, we can still further diminish the fluctuations in the current, see *Fig.* 18, until, by employing a sufficient number of coils, we can get a current that is sensibly uniform.

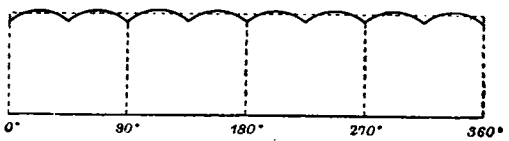



*Fig.* 18.

Now, by inspecting the curves in *Fig.* 17, and comparing with *Fig.* 19, in which the full curves are drawn, it will be seen that there

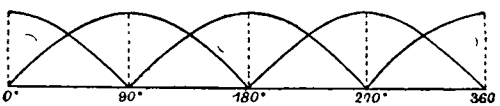



*Fig.* 19.

is a considerable amount of electromotive force generated in the coils, even when they are not in connection with the brushes, *i.e.*, all the electromotive force, which is generated during their motion from the vertical position to the position inclined at 45° to the vertical. This electromotive force is wasted, and it is the great merit of the next improvement that by its means this electromotive force was also collected and added to the other, increasing enormously the efficiency of the machine. The improvement was suggested by the invention of the Gramme ring, which will be described presently; but in order to complete the subject of the Siemens armature, we will anticipate the principle here.



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First of all, it is obvious that if, instead of attaching one coil to each of the pairs of commutator plates, we attach two, as in *Fig.* 20,

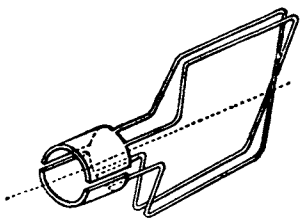


*Fig.* 20.

we shall be employing two parallel coils, in each of which there will be excited an electromotive force equal to that excited in the coils in *Fig.* 8, and the result will be similar to that in the case of two cells of a battery which are connected up in parallel, in which case the resulting electromotive force in the circuit will be the same as that due to one cell, but the internal resistance will be halved.

But suppose, instead of doing precisely this, we make the arrangement, which is shown in next figure (*Fig.* 21).

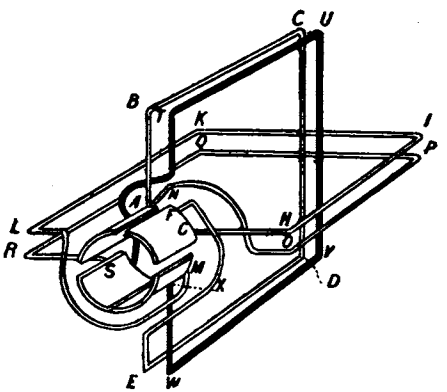



*Fig.* 21.

Here the ends of the coils, instead of being connected to opposite commutator plates, are connected to contiguous commutator plates. We still have the two parallel coils as before, each having excited in it the same electromotive force; but it will be seen that the whole forms two complete circuits in parallel.

Starting from A, the first circuit is A B C D E F G H I K L M, and the other is N O P Q R S T U V W X, the commutator plates A and

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M forming their common terminals. These two parallel circuits are precisely similar: each consists of a conductor in each of the four positions, E D, K L, B C, H I, and the electromotive force in each circuit is that due to the sum of the electromotive forces induced in all parts of it. There is, therefore, in this arrangement, no electromotive force wasted, as there was in the arrangement shown in *Fig.* 16, and the resulting current curve, instead of being that shown in *Fig.* 17, becomes one in which the ordinates of the two component curves are added together. The electromotive force at any time being the sum of the electromotive forces in the various parts of each circuit.

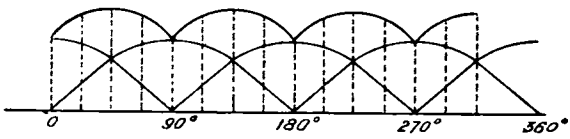



*Fig.* 22.

It will be observed that this arrangement furnishes nearly twice the maximum electromotive force which the other did.

The brushes must now be placed at the top and bottom instead of at the sides.

All Siemens drum armatures are developments of this, the number of coils and number of commutator plates being generally about 40 or 50, giving a practically continuous current.

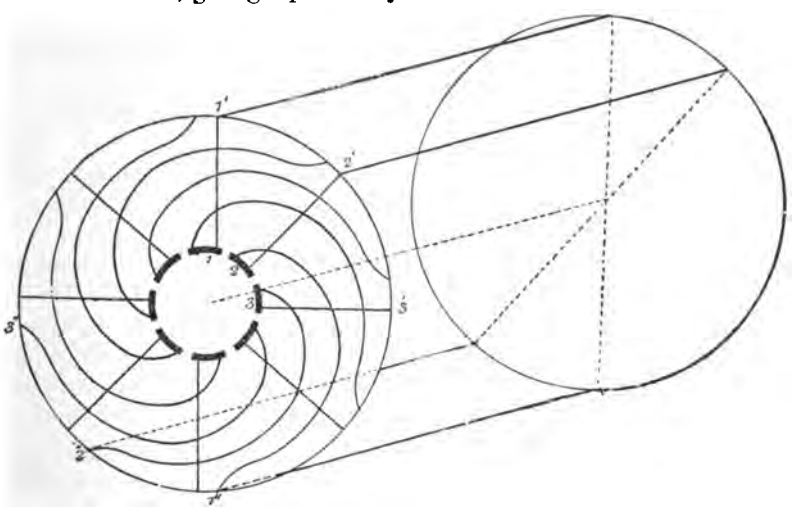


*Fig.* 23.

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*Figs.* 23 and 24 show how the coils are wound practically. The parallel coil has to be wound over the other, so that any defect in

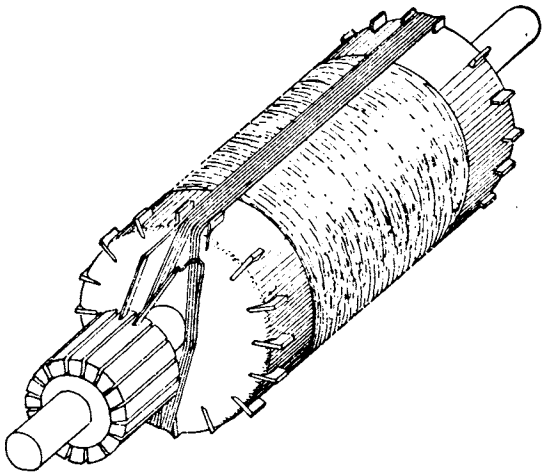


*Fig.* 24.

the other can only be rectified by completely unwinding the whole. Further, owing to the absence of free ventilation to the inner coil it becomes much heated by the passage of the current. These are serious defects in the Siemens drum armature.

### Type 2.

We now come to the second type of armature, known as the Gramme ring, which is based on the principle of the revolution of the rectangle A B K I (*Fig.* 5), about an axis $x'y'$, situated outside the rectangle, but parallel to the sides A B and I K.

In this case, suppose the rectangle to revolve about an axis $x'y'$ in the plane of the paper, so as to approach towards the observer and downwards in front of the paper.

Suppose, also, the lines of force to pass through the paper from a north pole in front of the paper to a south pole behind it. Then, as before, an electromotive force will be excited in A B in a direction from A to B, and one will also be induced in I K in the direction I K. These tend to oppose one another, and the resulting current in the rectangle is due to the difference between them. The electromotive force is greater in A B than in I K, because its lineal motion across the lines of force is greater, and therefore the current circulates in the direction A B K I.

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Now, the Gramme ring consists of a number of rectangular coils of wire wound round an iron ring of rectangular section. *Fig.* 25 shows one such coil attached to a two-part commutator. This arrangement corresponds to that shown in *Figs.* 8 and 11, and if it were revolved about the dotted axis it would give rise to a current

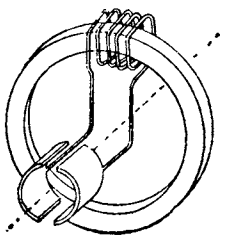


*Fig.* 25.

in the external circuit which would fluctuate in strength according to the curve given in *Fig.* 15.

A coil may be wound between the same commutator plates in parallel with the above, having the same effect as the parallel coil in the Siemens armature (*Fig.* 20), viz., of halving the resistance of the armature without increasing the electromotive force. It is not necessary, however, to wind this second coil *over* the first, as in the Siemens armature, because, the ring being hollow, it can be wound on the opposite side of the ring, as shown in *Fig.* 26 ; and if due regard be made to the direction of the winding, and the connections with the commutator, the current induced in the parallel coil

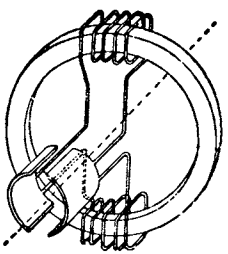


*Fig.* 26.

will be in the same direction, as regards the external circuit, as that induced in the first. This constitutes one of the advantages of the Gramme armature.

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The addition of another pair of coils and the further division of the commutator into four plates (*Fig.* 27), will have the same

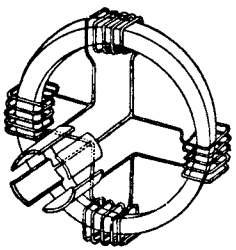


*Fig.* 27.

effect as the device of *Fig.* 21, and will produce an external current varying as shown in *Fig.* 22. *Fig.* 28 gives a representation of a Gramme armature with four pairs of coils, with which the fluctuations of the external current are still further reduced.

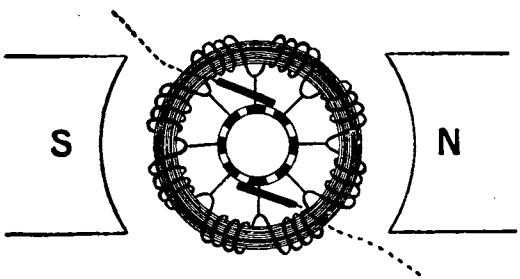



*Fig.* 28.

The construction of the Gramme ring armature naturally suggests the idea embodied in the description of *Fig.* 21, namely, that of making the whole armature one continuous circuit throughout, and thereby realising all the electromotive forces generated in all parts of it. It was, as has been stated, the invention of the Gramme ring which led to this great improvement in dynamo construction.

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*Fig.* 29 shows a Gramme ring in its ideal simplicity where

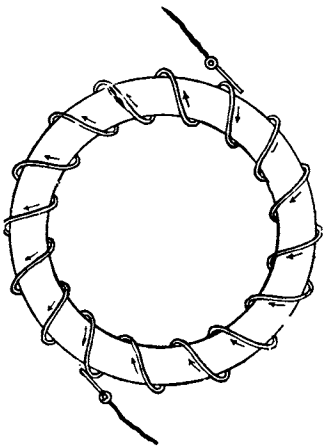


*Fig.* 29.

the commutator is removed, and where the brushes make contact with the coils themselves. The continuity of the whole armature is fully apparent. When this ring is rotated in a magnetic field like that represented in *Fig.* 28 (the brushes remaining fixed), a current is generated in each half of the ring. These currents are urged by the sum of the electromotive forces in each turn of the half-ring. The current on the left side is in the opposite direction from that on the right, since the movement of the conductor across the magnetic lines of force is in the reverse direction. The two currents unite at the brushes and flow out to the external circuit. If the motion of the ring is in the direction of the hands of a watch the currents will flow in the direction indicated by the arrows.

The current induction is greatest in the coils opposite to the poles of the field-magnets (compare *Fig.* 7), for at these points the motion is at right angles to the lines of force. It is zero at the brushes. In the intermediate positions it varies according to the sine of the angular displacement from the brushes. The effect of the induction in the whole ring is similar to the effect produced by the total electromotive force of two series of voltaic cells of different electromotive forces. Supposing one represents a cell with a large electro-

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motive force by a large cell, and those with less electromotive force by correspondingly smaller cells, as in *Fig.* 30, the parallel will be complete.

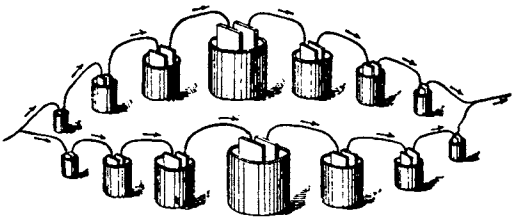


*Fig.* 30.

The brushes should be placed where the electromotive force changes sign, and where the induction is least. If placed where the electromotive force is highest the potentials of the brushes would be equal, and no current would take place in the external circuit (see Chapter VI.).

The effect of the iron ring in the Gramme machines is curious. Iron may be considered to be a conductor of the magnetic lines of force. The lines of force will pass from the north pole of the field magnet to the south pole along the route which offers them the best path. They will not proceed straight from one pole to the other across the intervening space, as they would do if the iron ring were not there, but will be bent into the ring, traverse round the ring, and will emerge at the other side, as in *Fig.* 31; very few will

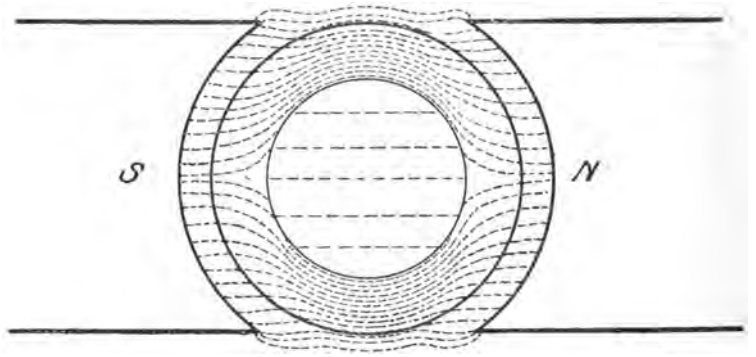



*Fig.* 31.

pass across the open space inside the ring. This has the effect of very much reducing the counter electromotive force induced

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in the wire on the inside of the ring—the side I K of *Fig.* 5—because these portions of the coils cut scarcely any line of force. This results in the current in the coils being much greater than it would otherwise be.

## Multipolar Armatures.

A large number of dynamos are made with more than a single pair of field magnet poles. Some are made with two pairs, and some with three or four pairs. Such dynamos are termed multipolar dynamos. *Fig.* 32 gives a representation of a four-pole armature,

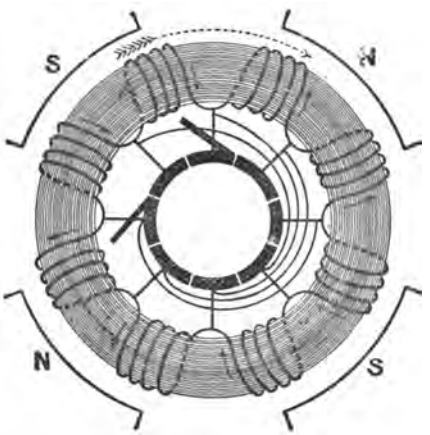



*Fig.* 32.

the positions of the pole pieces being shown at S N S N. This armature may be considered to consist of two complete ring armatures coupled together in parallel, the upper half with the upper pair of poles constituting one, and the lower half with the lower pair of poles constituting the other.

If the connections of the armature be followed round from brush to brush, it will be seen that instead of there being two parallel circuits, as in *Fig.* 28, there are four parallel circuits, each consisting (in *Fig.* 32) of the two coils immediately under each pole piece, together with their connections, direct or otherwise, to the brushes. The circular connections shown have the same effect as if there were four brushes placed round the commutator at intervals of 90°, and

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the opposite ones connected together by wires. In some four-pole dynamos this device of employing four brushes is adopted in preference to that of the circular cross connections, in order to avoid complicating the winding of the armature.

The electromotive force of a four-pole armature is only that due to the summation of the electromotive forces induced in one quarter of the number of coils in the armature, while in the two-pole armature it is that due to one half of the coils; but since the current furnished by the machine has four paths in the armature instead of two, the section of the wire employed in the winding may be reduced to one half that of the wire in a two-pole machine, and so twice the number of turns can be made in the same space. The electromotize force of the armature will by this means be brought up to the same amount as in a two-pole machine. The resistance of such a four-pole armature is, however, the same as that of the similar two-pole machine, notwithstanding the reduced diameter of the wire in the coils.

The "Victoria" machine is an instance of a four-pole dynamo, having cross connections in the armature and only two brushes.

The cores of the Gramme ring armatures are made of very various sections, from a nearly flat disc as in the earlier Victoria dynamos, to a hollow cylinder, or drum, as in most of the more modern two-pole machines.

Whatever the shape of the core may be, it is essential that the section should be sufficiently large to absorb all, or nearly all, the lines of force generated by the field magnets. If this be not the case, some of the lines of force will pass outside the armature, and some will pass straight across the interior hollow of the armature. Those which pass outside are wasted, and are merely created by a useless expenditure of part of the magnetising current in the field magnets, impairing thereby the efficiency of the machine. Those which pass cross the interior of the hollow are not only wasteful and detrimental to the efficiency, but they actually weaken the electromotive force of the armature, since they are productive of a counter electromotive force in those portions of the coils which lie in the interior of the ring.

In order not unnecessarily to increase the size of the armature, the iron of which the core is composed must be of the purest and softest description, for then it is more permeable to the magnetic lines, and a smaller section will suffice.

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## Lamination of Cores of Armatures.

For precisely the same reason as that which causes currents to be induced in the coils of the armature, currents will be induced in the substance of the iron core upon which the coils are wound. These currents will circulate round the iron core in the same direction as those in the coils. They will have a low electromotive force compared to those in the coils, since the latter make a considerable number of turns round the core, whilst the core itself can only be considered to consist of one turn.

But since the resistance opposed to this electromotive force is very small, the resulting currents may become considerable. They are not directed into the external circuit, and therefore are doing no useful work, their energy being only expended in heating the armature core.

It is desirable to keep the armature as cool as possible, since it gets more or less hot from the currents in the coils. But the currents in the cores are prejudicial to the efficiency of the dynamo machines, because it is at the expense of the power exerted by the steam engine that they are generated. It therefore becomes desirable to eliminate them if possible. This is done by dividing the iron of the core into laminæ formed by planes at right angles to the direction of the currents, and insulating the laminæ from one another. Since the electromotive force of these currents is slight, sufficient insulation is obtained by varnishing the laminæ; and indeed sometimes the natural oxide which forms on the iron is found to be sufficient to reduce the currents to an inappreciable magnitude

These currents are called "Foucault" or "eddy" currents.

The lamination of an armature depends upon the direction of the lines of force which enters the armature. Thus a Siemens armature consists of a number of discs of iron placed upon another on a common axis, this axis being the axis of rotation of the armature.

In an ordinary Gramme ring the lamination is effected by superimposing upon one another a number of flat rings; whilst in those armatures intended to be rotated between pole pieces of the Victoria type, the core must be built up of iron tape coiled on a strong foundation ring, for the magnetic lines of force enter from three directions.

If the armature coils are made of very stout bars of copper, such as would be required for machines furnishing very large currents, not only must the cores be laminated, but the copper bars must be

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laminated also, because, on account of their considerable sectional area, the outer portions will be travelling in the field with a greater lineal velocity than the inner portions, and, in consequence, circular currents will be generated in the conductors which will not appear in the external circuit; and these currents will be fulfilling no useful purpose, but on the contrary, will be absorbing the energy of the steam engine in needlessly heating the armature.

## Armature Coils.

The coils of the armature must of course, offer as little resistance as possible to the passage of the current, in order that the percentage of power lost in driving the current through the armature, and the consequent heating of the coils, should be as small as possible. For this purpose they must be made of copper of a high degree of conductivity, and should be as short and thick as is consistent with obtaining the electromotive force required at a reasonable speed.

Armature coils should not be wound too closely to one another, for since it is impossible so to reduce their resistance as to eliminate all heating, it is necessary to provide spaces which are constantly being ventilated as the armature revolves rapidly in the air.

The insulation of the coils from one another, and from the core, should be effected by means of some substance which does not become injured by a rise of temperature.

Since the centrifugal force acting on the parts of the armature is very considerable, care must be taken both to render the construction as rigid as possible, and to balance the armature very exactly on its axle.

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# CHAPTER IV.

## ELECTRO-MAGNETISM.

It was stated in Chapter I. that it had been conventionally arranged to represent a magnetic field of unit intensity as containing one of the imaginary lines of force per square centimetre of cross section. Such a unit field is produced at a distance of one centimetre from a magnet pole of unit strength. If such a pole belong to a long thin bar magnet, of which the other pole is far distant, all the lines of force from the pole will radiate into space at equal angles with one another, so far as the region immediately surrounding the pole is concerned, and will produce a field of unit intensity at every point on the surface of a sphere of one centimetre radius, described with the pole as a centre, that is, will produce one line per square centimetre of the sphere's surface; and, since there are $4\pi$ square centimetres of surface in the sphere, there will be $4\pi$ lines cutting the sphere. All these lines will form closed circuits. They are considered to originate from the north pole, where they emerge into space and describe curved courses, gradually bending round until they arrive at the south pole. From this point they all collect together and traverse the interior substance of the magnet from end to end to the point whence they originally started. This is shown in *Fig.* 33. If the strength of the magnet pole be $m$, it will give rise to $4\pi m$ lines of force.

Now, a wire conveying a current of electricity will behave in a similar manner to a magnet in giving rise to a magnetic field or to lines of magnetic force. These lines will, in the case of a straight current, circulate round the wire in a series of parallel and concentric circles (see *Fig.* 34). If the wire be bent into the form of a circular

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ring, all the lines on the concave side will be condensed together

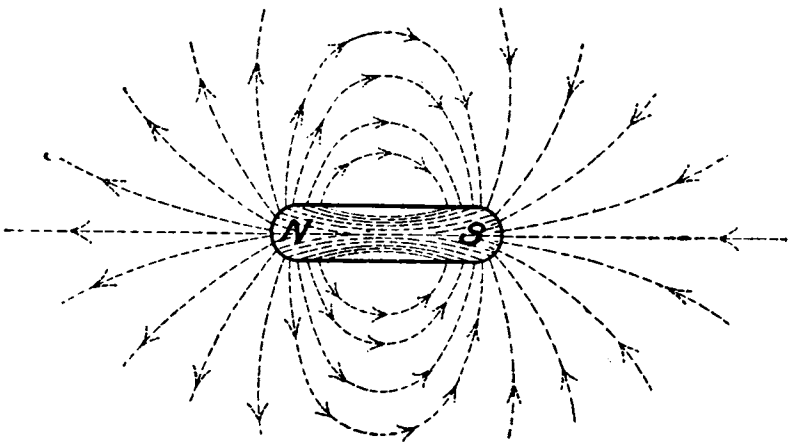



*Fig.* 33.

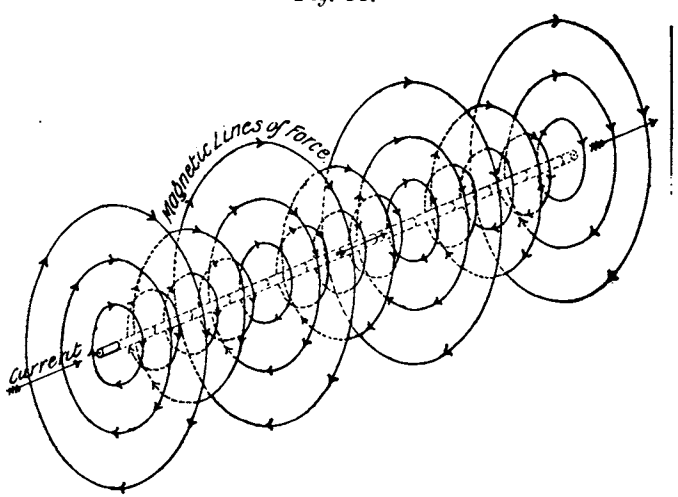



*Fig.* 34.

within the circle (as in *Fig.* 35, which shows only a few of the lines). Now, the disposition of the lines in this case immediately suggests a parallel between the circular current and a very short, thick magnet; and it has been shown by Clerk Maxwell that a circular current produces exactly the same external field as that produced by a very thin section of a bar magnet, whose cross section is equal to the area enclosed by the current, and whose

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edges coincide with the position of the wire. These sections of bar magnets are called "magnetic shells."

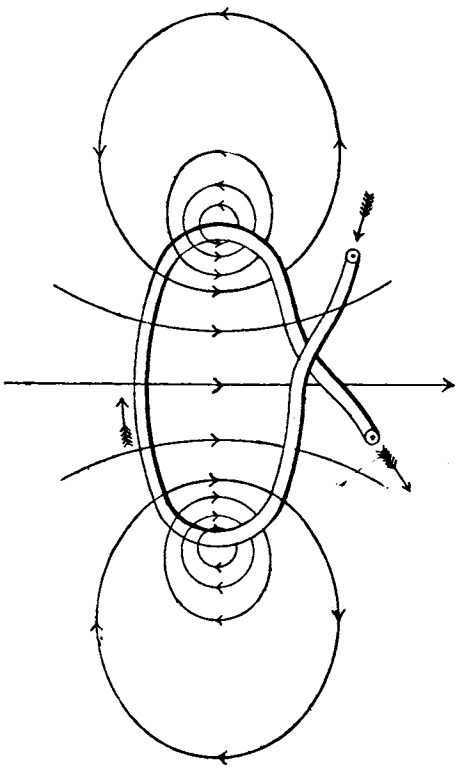


*Fig.* 35.

If, instead of one single ring, we take a helix consisting of $n$ turns,

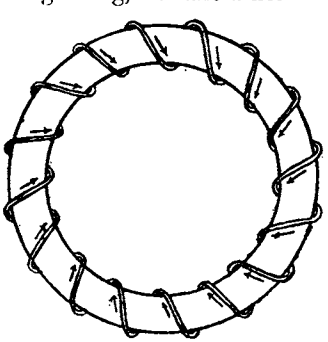


*Fig.* 36.



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the number of lines of force are increased. It has been demonstrated by Clerk Maxwell that the number of lines generated through any section of a helix is

$$\frac{4\pi n \mathrm{A C}}{l},$$

where $l$ is the length of the axis of the helix, C the current, and A the area of the cross section; provided that the helix is so long that the distribution of the free polar magnetism at its ends does not need to be taken into account.

If the helix be bent round till its ends meet so as to form a closed circuit (*Fig.* 36) it will have no polar ends, and will, in fact, if the winding is very close together, exhibit no external magnetic properties at all. Then, if the core be of wood or other non-magnetic substance, the expression

$$\frac{4\pi n \mathrm{A C}}{l}$$

exactly represents the number of lines of force generated within the coils, $l$ being, in this case, the length of the circumference of the curve described by the axis of the helix.

The total number of lines of force induced through a helix is called the "total magnetic induction," and is usually denoted by B.

In the case of a helix without an iron core, the total magnetic induction also measures what is called the "magnetising force," of the helix, cause and effect being equal. But if the helix enclose an iron core, the case is very different. The magnetic induction is enormously increased without there being any increase in the magnetising force. It is as if iron possessed a multiplying power analogous to the multiplying power of glass, mica, ebonite, and other dielectrics for statical electric forces. Iron possesses a sort of increased magnetic conductivity, or "permeability," similar to the superior power possessed by solid dielectrics for conveying lines of electric force. The magnetic induction B now becomes equal to the magnetising force (H), multiplied by a coefficient $\mu$, which is called the "coefficient of permeability," and the number of lines generated by a current C flowing in a helix of $n$ turns round an iron core of length $l$, and sectional area A will be

$$\mu \times \frac{4\pi n \mathrm{A C}}{l}.$$

The coefficient $\mu$ varies not only with the class of iron employed, but also with the magnetic state of the iron. It is very large for soft iron, and gradually decreases to a value 1 as the iron approaches

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magnetic saturation. The symbol $\mu$ always expresses the ratio of the magnetism evoked to the magnetising force.

It is supposed that all magnetisable substances consist of molecules which are always magnetised, that is, are little magnets having a pole on each side. It is further considered that, when the mass exhibits no external magnetic properties, the molecules are indiscriminately arranged within the mass with their poles pointing in every direction, but so that, taken in the aggregate, they neutralize one another, or, in other words, form closed magnetic circuits.

It is the function of the magnetising force to move the molecules until they all face one way, and by destroying the continuity of the magnetic circuits within, to cause the iron, as a mass, to exhibit free polarity. This function is resisted by the molecular forces, which may be considered to remain nearly constant. As the molecules turn round in obedience to the magnetising force (which is always in the direction of the resulting magnetism) the force always acts at an increasing disadvantage. An increment in the force will not produce a proportional increment in the magnetism evoked. It will take an infinite force in the direction of the axis of magnetization to turn the molecules the last infinitesimal portion of their path, so as to make them all face in the direction of the axis.

When all the molecules face in the direction of the axis, the magnet is then perfectly saturated. This ideal saturation is never reached with any finite magnetising force, but there is a limit which is reached sooner or later, depending on the mass of the iron, beyond

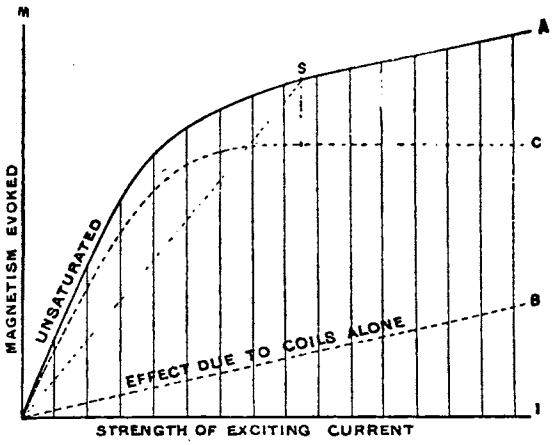



*Fig.* 37.



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which it is useless to proceed further, and which is practically taken as the saturation limit.

If, therefore, $\mu$ express the relation between the magnetism evoked and the magnetising force, $\mu$ must diminish as the magnetism increases.

*Fig.* 37 shows the curve of magnetism produced for different magnetic forces. In the same electro-magnet the magnetising force will be proportional to the strength of the exciting current. The line B gives the magnetic induction due to the helix itself, and which, representing the magnetising force, is strictly proportional to the strength of the current. The curve C gives the magnetism evoked in the iron, or the number of lines of force added by the iron to those already existing. The saturation of the iron is indicated by this curve becoming horizontal. The curve A gives the total magnetic induction due to core and helix together. It is the relation of the ordinates of this curve to those of curve B, which is represented by $\mu$, becoming 1 as regards the additional magnetism evoked, where curves A and B are parallel.

We showed that the magnetic induction

$$B = \frac{4\pi\mu n A C}{l}.$$

This equation may be written

$$B = \frac{4\pi n C}{\frac{l}{\mu A}}.$$

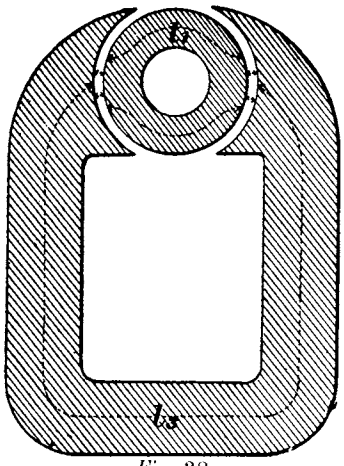


*Fig.* 38.

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The numerator $4\pi n C$ is sometimes called the magneto-motive force, and is strictly proportional to the number of ampère turns. The denominator $\frac{l}{\mu A}$ is called the magnetic resistance, or "reluctance," being proportional to the length, and inversely proportional to sectional area of the iron core considered as a conductor of magnetic force. The permeability $\mu$ here evidently expresses the specific magnetic conductivity of the iron.

We have hitherto considered the iron core as the only thing through which the lines travel. This is the case in an electro-magnet wound like a Gramme ring where the ring forms a closed magnetic circuit. But, in the case of the field magnets of a dynamo, the magnetic circuit is not similar throughout. There are air gaps to be considered. The cross section of the cores, yoke, etc., may not be uniform throughout. The magnetic lines emerge from the poles of the field magnets and enter the armature. The permeability of the armature may be, and generally is, different from that of the field magnet cores, and will certainly be of different section.

Under these circumstances, we must substitute for the quantity $\frac{l}{\mu A}$ in the denominator of the fraction given above a quantity which will take the form

$$\frac{l_1}{\mu_1 A_1} + \frac{l_2}{\mu_2 A_2} + \frac{l_3}{\mu_3 A_3} + \ldots\ldots$$

where $\mu_1, \mu_2, \mu_3 \ldots\ldots$ are the permeabilities of the different parts of the magnetic circuit, and $l_1, l_2, l_3, \ldots\ldots$ and $A_1, A_2, A_3 \ldots\ldots$ are their respective lengths and cross sections. For the air gaps $\mu$ can be taken as unity.

The formula

$$B = \frac{4\pi n C}{\frac{l_1}{\mu_1 A_1} + \frac{l_2}{\mu_2 A_2} + \frac{l_3}{\mu_3 A_3} + \ldots\ldots}$$

enables one to calculate, approximately, the number of ampère turns with which it is necessary to wind the field magnet of a dynamo in order that the intensity of the field in which the armature revolves may be of the requisite strength. For the intensity of the field (T) is very nearly equal to B, divided by the area of the polar ends of the field magnet. It is not quite so, because the field produced is never perfectly uniform; but in a well constructed continuous current machine the air gaps are so small that the lines traversing it are very nearly all parallel to one another.

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# CHAPTER V.

## FIELD MAGNETS.

THE magnets used for producing the powerful magnetic field in which the armature is to be revolved are called the "field magnets." They may be either permanent magnets (*Fig.* 39) or electro-

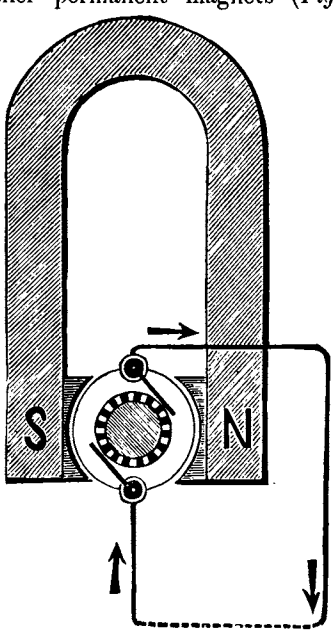



*Fig.* 39.

magnets (*Fig.* 40). Weight for weight, however permanent

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magnets are not so powerful as electro-magnets ; the latter are therefore exclusively used where weight and bulk are of consideration. If the field magnets are magnetized by means of a current furnished by a battery, or by another machine, the dynamo is said to be separately excited (*Fig.* 40). If the field magnets are excited by

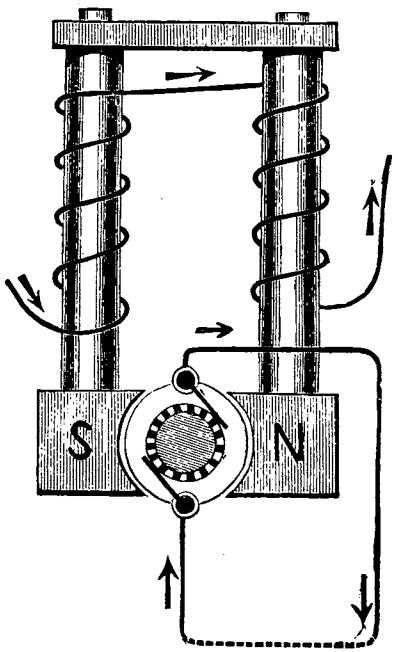



*Fig.* 40.

the current from the armature, the machine is called "self-exciting" (*Figs.* 41 and 42). Generally speaking, self-exciting dynamos are found more convenient. In these a portion, or the whole, of the current from the armature is passed round the field magnet coils. Self-excitement is made possible by the fact that iron having once been magnetised does not lose the whole of its magnetism on the cessation of the magnetising force, a small amount called residual magnetism remaining for a very considerable time. When the armature is revolved in the weak field produced by this residual magnetism, a feeble electromotive force is induced, which drives a current round the field magnet coils in such a direction as to increase the magnetism ; this increases the field, and consequently

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the electromotive force, and a larger current circulates round the magnets, and so on until the machine is fully excited.

The name "dynamo-machine" was originally given to those machines in which the field magnets were self-excited without any extraneous aid. The term is now extended so as to include all machines in which the current is produced by the expenditure of mechanical energy, whether the field is produced by permanent magnets or by electro-magnets either separately or self-excited. Self-excited dynamos may be "series wound," "shunt wound," or "compound wound."

In the series wound dynamos (*Fig.* 41) the whole of the current from the armature passes a few times round the field magnet.

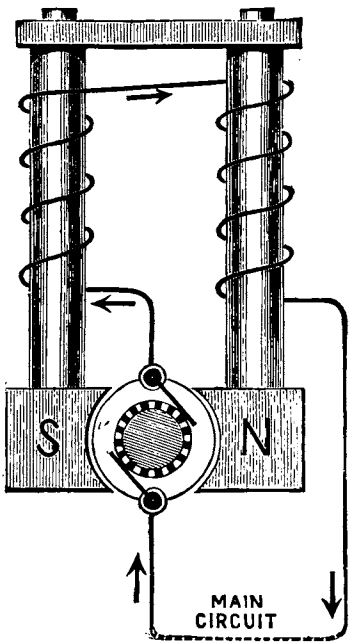



*Fig.* 41.

In the shunt wound dynamo (*Fig.* 42) a small portion only of the current passes round the magnet coils a great number of times, the coils being in divided with the external circuit. These two machines are evidently suited to be used in different ways; a series dynamo will not excite till the external circuit is complete, and then only when the resistance in it is below a certain amount, called the

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"critical resistance;" on the other hand, the shunt machine excites best on open circuit, and its power gradually falls off as the external

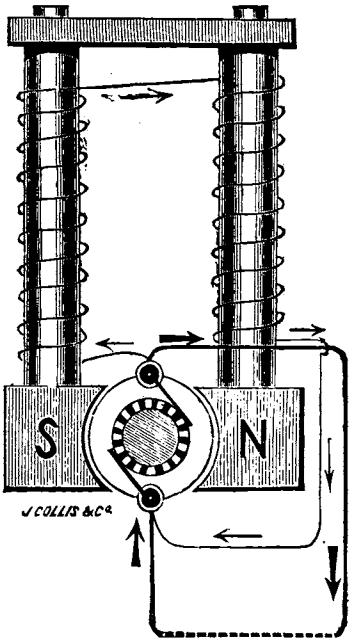



*Fig.* 42.

resistance is reduced. A shunt machine is evidently unsuited for working an arc, as the machine loses nearly all its magnetism just at the important moment when the carbons are brought together to start the arc. A series dynamo will keep and start an arc very well, but the fact that the machine does not excite till the carbons are closed is a disadvantage.

In the compound dynamo (*Fig.* 43) the field magnet is wound with both series and shunt coils so adjusted that at a constant speed the difference of potential at the terminals is very nearly the same whatever resistance is in circuit. Roughly speaking, this is brought about as follows:—On open circuit, and when there is a very large resistance in circuit, the magnetism is maintained by the shunt coils. As the resistance is reduced, the current in the series coils begins to make itself felt, and helps the shunt coils, which, at the same time, gradually lose their effect. At very low resistances the magnetism is almost entirely kept up by the series coils.

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The effect of compound winding will be more clearly seen by considering what are called the "external characteristics" of dynamos.

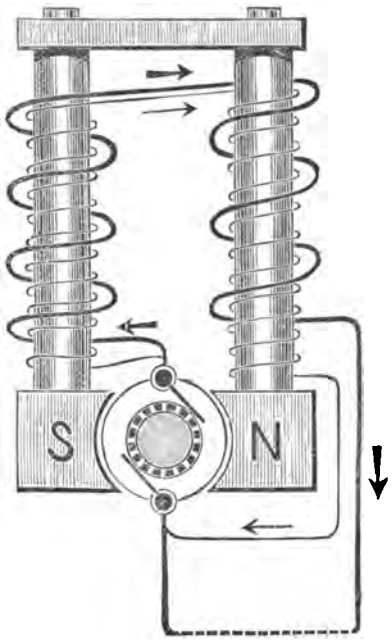



*Fig.* 43.

The external characteristic of a dynamo is a curve which expresses the relation between the difference of potential at the terminals of the machine and the external resistance. It is constructed by measuring as abscissæ the external resistances, and setting up as ordinates the differences of potential observed to result at the machine terminals.

Let V = difference of potental at terminals.

E = electromotive force induced in armature at a certain speed with field magnets *excited to saturation.*

$c$ = resistance of series coils of series wound machine.

$a$ = resistance of armature of series machine.

$a'$ = resistance of armature of shunt machine.

$r$ = external resistance.

The resistance of the shunt coil in a shunt machine is usually high compared to that of the armature and external circuit, and therefore

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the resistance of the divided circuit composed of the shunt and external circuit can be taken to be equal to $r$.

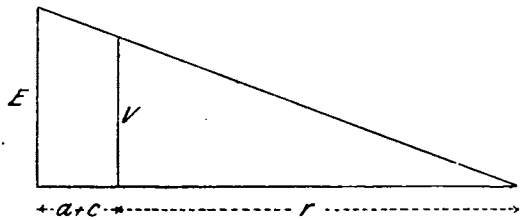



*Fig.* 44.

Now with a series machine—

$$\frac{V}{E} = \frac{r}{a + c + r} \quad (Fig.\ 44),$$

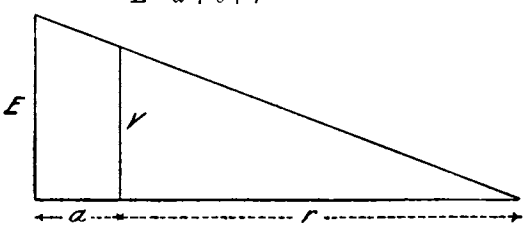



*Fig.* 45.

and with a shunt machine—

$$\frac{V}{E} = \frac{r}{a' + r} \quad (Fig.\ 45).$$

If $a = a' + c$ these equations are the same, and we can get a curve showing the values of V for varying values of $r$, this curve is shown in *Fig.* 46. When $r = O$ evidently $V = O$, since no difference of potential can exist between two points connected together without resistance, and therefore the curve passes through the point O; also

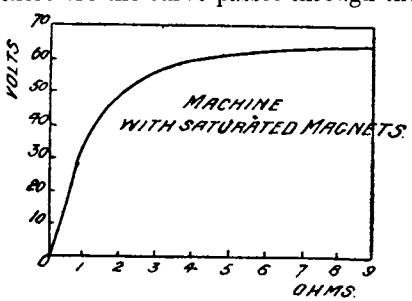



*Fig.* 46.

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when $r$ = infinity V = E. This curve (*Fig.* 46) is not perfectly true for either a shunt or series machine, as the field magnets are not always saturated, and therefore E is not a constant. The variations in the value of E would, in a shunt machine, have the effect represented by the curve, *Fig.* 47. With very low external resistances

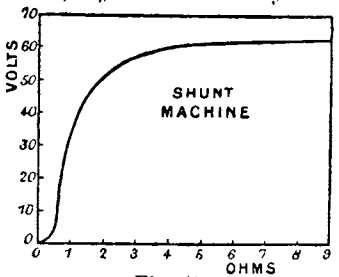



*Fig.* 47.

the machine will not excite, but after passing the critical resistance the value of E gradually rises, and the curve eventually coincides with the previous one (*Fig.* 46).

The curve for the series machine is different. At low resistances a very large current will pass through the series coils and the magnets will be saturated, but as soon as the external resistance becomes sufficient the magnetism will fall off, and E will eventually become zero. When $r$ = O, V = O, as before, though the value of E is at its maximum. The curve will, therefore, pass through the point O (*Fig.* 48). It will rise steeply at first, because the saturation of the magnets is not perceptibly affected by the slight diminution in the current caused by the insertion of a very low external resistance, while the difference of potential between the terminals of the machine is suddenly increased from a value O to a maximum. When the external resistance is further increased so as to considerably reduce the current in the magnet coils, both E and V fall gradually to zero.

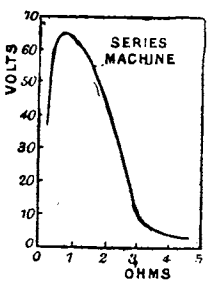



*Fig.* 48.

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The curve of V for a compound machine is found by adding together the ordinates for the curves for the shunt and series machines, because roughly speaking the value of V is found by adding together the parts of it produced by the field magnetism due to the shunt coils and to the series coils respectively. The curve of V is then represented by the top line in *Fig.* 49, which shows that

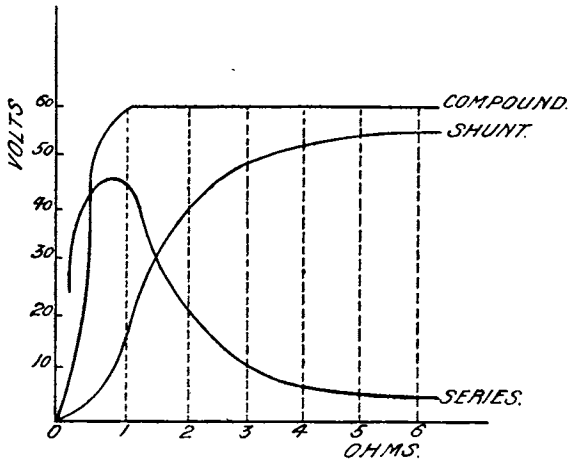



*Fig.* 49.

in a properly compounded machine we can get very nearly a constant value for V for all resistances over a certain amount. A machine so compounded is said to have a "straight characteristic."

By altering the relative powers of the shunt and series coils, dynamos can be made with "rising" or "falling" characteristics, *i.e.*, to have lower V at low resistances than at larger ones, or the reverse. Search light dynamos have hitherto been compounded to give constant V for varying loads, but it is found that when the carbons are brought together, the large current through the armature tends to pull the dynamo up, reducing the speed and lowering the volts just when plenty of power is wanted to start the arc. Dynamos will, therefore, in future be compounded to give a "falling" characteristic, giving about 55 volts on open circuit and 75 at their full load (say 150 ampères) at the proper speed, so that although the dynamo may be pulled up to a certain extent on closing the carbons, yet even at the reduced speed there will be sufficient voltage to form the arc.

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Machines are sometimes compounded with what are known as "long shunts," that is with shunt coils connected to the terminals of the machine instead of to the brushes. This is shown in *Fig.* 50.

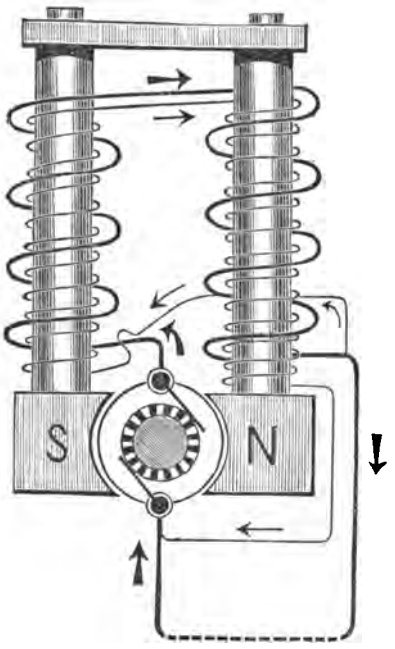



*Fig.* 50.

The arrangement makes the shunt rather more sensitive to variations in the external load, and for some purposes this is an advantage.

## Practical Method of Compounding.

Dynamos are compounded practically as follows. The following points are first decided upon:—(1). Safe speed at which the armature can revolve without injury. (2). Resistance of armature. (3). Volts at terminals required on open circuit and at full load. (4). Resistance of shunt coil, which should be 300 to 400, or sometimes 1,000, times that of the armature (see page 49). (5). The current through the shunt coil, which is known from the last two. (6). Current at maximum load. The armature is then run at the

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proper speed ; the field magnet is excited by means of a moveable coil of a known number of turns (the current being supplied from an external source) till the proper volts are given at the terminals on open circuit ; the current in the moveable coils is then measured, and from this the ampère turns required to fully excite the field are known. The current through the shunt coil is known, and, therefore, the number of turns can be calculated. Secondly, some resistance is put in circuit to represent the maximum load, and the machine is run as before at the proper speed till by varying the current in the moveable coils the proper volts are given.

The current in the moveable coil is then noted, and from this the ampère turns to fully excite at full load are known ; from this the ampère turns required on open circuit are subtracted, and the maximum current being known, the required number of turns of the series coils can be calculated.

## Field Magnet Cores.

Theory shows that the field magnet should be heavy and massive. This is for two principal reasons ; (1), the amount of magnetism which they are capable of holding is greater ; and (2), it reduces the magnitude and variability of the lead, and consequently the amount of sparking at the brushes.

Plenty of iron is also required so that saturation may not be too soon reached, and that the magnetic resistance of the circuit may be kept low. For the same reasons the core should be made of soft iron ; this is, however, not generally done on account of the expense, it being much easier to cast a magnet of the required shape. Cast iron has an advantage over soft iron in retaining more residual magnetism. This enables the machine to be more quickly excited. The cores of the $D^2$ Siemens machines are of soft iron, and consequently are much lighter than than if they had been cast iron ; these machines, however, spark considerably with variations in the load.

The core should be circular in section in order that as little wire as possible may be used to wind the necessary number of turns ; with very thick magnets, however, it is considered advisable to make the section rectangular with rounded corners, because the centre of a very thick cylindrical core is too far from the coils to get properly magnetised.

In order to economise wire in the coils it is also now recognized

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that the divided magnetic circuit formerly used (as in the Siemens, Gramme and Victoria machines) is a mistake; the single magnetic circuit is now generally adopted.

In order to reduce the magnetic resistance the core should (as before stated) be short and thick, and their poles or pole-pieces should be as close to the rotating armature as is consistent with safety in running. The air gaps and copper of the armature coils offer a resistance to the magnetic lines of force from 5,000 to 20,000 times as great as if the space were filled with iron.

The edges of the poles or pole-pieces should be rounded off, because corners invite leakage of the lines of force.

There should be no joints in the iron of the field magnet across the direction of the lines of force; if joints are unavoidable they must be carefully planed true and fitted.

The grain of the iron should lie in the same direction as the lines of force, and where they are to leave the iron and pass out into the air, the grain should be on end. This last rule is not observed in the $D^2$ Siemens machine.

Dynamos usually rest on cast-iron bed plates. A dynamo with single magnetic circuit, with its poles downwards on an iron bed plate, must be magnetically insulated from the bed plate by a thick piece of brass, zinc, or other non-magnetic material.

It is, however, impossible by any device to avoid magnetising the bed plate to a certain extent, even though there be a thick plate of non-magnetic material between it and the field magnet. Some of the lines of force will, therefore, traverse the bed plate and be diverted from their intended purpose of passing through the armature. Machines are not generally constructed in this manner on this account, unless it is a matter of consideration to get the armature as low as possible. Such a construction might be necessary for dynamos intended for launches, or when coupled direct to a Willans and Robinson engine.

## Field Magnet Coils.

The field magnet coils must be thick enough to carry the maximum current, for which the machine is designed, without getting seriously heated. They must also have a sufficient number of turns to saturate the magnet when the machine is fully loaded. As it is not advisable to waste energy by introducing unnecessary resistance

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into the circuit, the coils should be made of copper of the best conductivity. They are generally insulated with cotton and shellac. With well shaped magnets of low magnetic resistance it does not appear to matter much where the coils are placed, it is, therefore, obvious that it is better to distribute the coils pretty evenly along the whole length than to heap them up at one or two points. The Victoria machine having a 4-pole divided circuit field magnet has eight coils. (*Fig.* 61., p. 68).

Sir William Thomson states that in a series dynamo the resistance of the field magnet coils should be a little less than that of the armature, and that both should be small compared with the external resistance. In modern dynamos the tendency seems to be to reduce the resistance of both field magnets and armature as much as possible. His rule for a shunt machine is to make

$$R = \sqrt{r_s r_a},$$

when R, $r_s$, and $r_a$ are the resistances of the external circuit, shunt, and armature respectively.

Further, to obtain a high efficiency, the resistance of the shunt coil should be 300 or 400 times as great as that of the armature. To obtain 90 per cent. efficiency, it should be at least 324 times as great.

## Cardew's Winding.

When it is desired to divide the power furnished by a dynamo into two or more arc lights, a difficulty is experienced in making the lights independent of one another.

If the arc lamps are placed in series, when one goes out the other will go out also; if they are placed in parallel, and one goes out, the other need not be affected until the points of the first lamp are brought together again to start the arc; but when this happens all the current will be diverted from the second lamp, owing to the short circuit formed by the first.

Various devices are constructed to obviate this interference, but it is found practically that by the method of winding the field magnet coils now to be described, nearly all interference is obviated, provided that the engine speed can be kept constant.

Cardew's method of winding (see *Plate* 7) consists of replacing the single series coil of the machine by as many parallel coils as there are lamps, into which it is required to divide the current. Each



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series coil is led to a separate terminal at one end, and to one of the brushes at the other end. The other brush is connected to a terminal. The machine is compounded with a shunt coil between the brushes. Victoria machines on this principle have hitherto been wound with four series coils for working four lights, but this subdivision into four only enables each lamp to be supplied with one-quarter the total current the machine is capable of producing (30 to 40 ampères), and this current is only sufficient to furnish a light of very moderate penetration, so that for search light purposes machines with two coils, for two lights, are found to be adequate to the requirements.

The terminals in connection with the series coils form the positive terminals of the machine, whilst the single terminal connected to the brush forms the negative terminal.

It is not safe always to assume this to be the case, however, for the machine is liable to reversals of polarity. The positive terminals are fixed on a commutator, by which they can all be joined together in case the full power of the machine is required for one light, or sub-divided in case two or four lights are desired.

The principle upon which this method works is that of dividing the circuits to the separate lamps at the brushes, instead of at the terminals of the machine. This introduces into the separate circuits the additional resistance of one of the series coils (·02 to ·03 ohms), and this, together with the resistance of the leads to the lamp, prevents the short circuiting of one lamp seriously affecting the others.

If these machines were compounded so as to give a constant difference of potential at the brushes, the independence of the lamps would be complete.

Each series coil need only be made of one-quarter the gauge necessary for a machine of equal out-put with only one series coil, since each coil only takes one-quarter of the total current, so that the cost of copper and bulk of the coils is no greater in these machines than in others.

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# CHAPTER VI.

## COMMUTATORS, BRUSHES, ETC.

### COMMUTATORS.

THE commutator of an ordinary armature, such as is used in the Service, consists of a number of parallel bars of copper, or gun-metal, or phosphor bronze, arranged round the axle of the armature. They are insulated from the axle and from each other by layers of vulcanised fibre, mica, asbestos, or some other insulating material.

As the bars, or plates, are liable to be heated by imperfect contact, and corroded by sparking, and also are always being worn away by the friction of the brushes, they must be made of good stout strips of metal. *Fig.* 51 gives a section of a commutator, the black spaces representing the insulation between the copper bars.

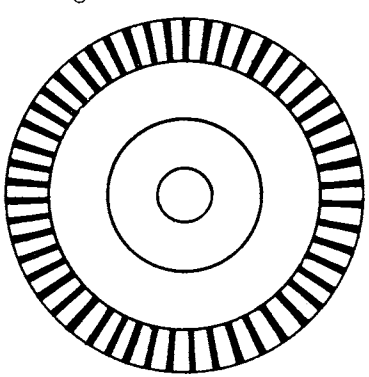


*Fig.* 51.



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## Brushes.

The brushes are usually made of several rows of copper (sometimes tinned) wires laid side by side and soldered together at one end, the number of contacts thus obtained between the brush and commutator diminishes the sparking. Brushes are also made of broad thin strips of copper, slit at intervals, and also of alternate layers of strips and wires. Brushes are generally two inches or three inches broad.

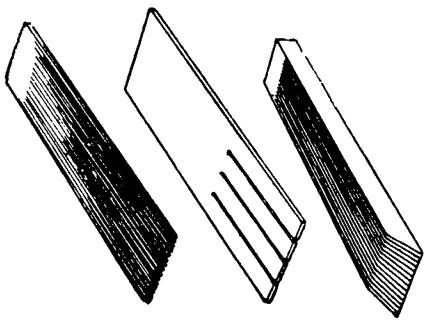


*Fig.* 52.

The brushes should be made to touch the commutator at those parts where the potential is the highest and the lowest, in order to get the largest current in the external circuit.

These are, generally speaking, the points where the neutral axis crosses the commutator, and will be, therefore, the position of least induction and of least sparking.

## Brush Holders.

The brush holders should be made of good solid pieces of gun-metal, with slots for taking the brushes, B, and screws, S (*Fig.* 53), for clamping them in place. They must be insulated from each other and from the body of the machine. The brush holders are provided with springs Z to make the brushes press firmly but lightly on the commutator; if this pressure is too great the commutator will wear away into ruts, if it is too light the brushes are likely to jump and spark. The tension of the spring can be regulated by the nuts D D. The best pressure is one of about 2lbs., measured where the end of the brush touches the commutator A. The brushes should rest on the commutator, making an angle of about 50° with the

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tangent; if, however, the dynamo is to be run as a motor so as to rotate in either direction, the brushes must rest tangentially on the commutator, otherwise the wires will be bent and twisted when

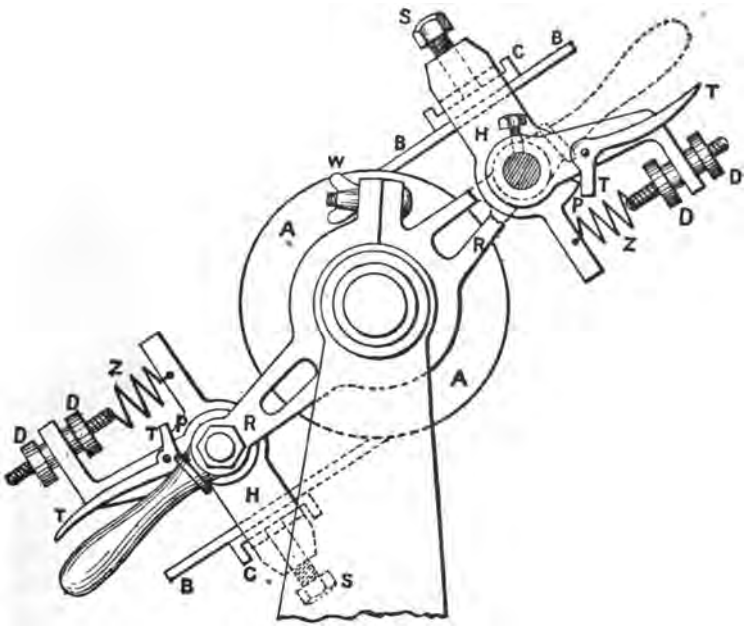



*Fig.* 53.

the machine is reversed. A light pointer is sometimes fixed to the brush holders; this is useful to show the attendant how much the brush is wearing away and how much it should be periodically fed forward. Two brush holders are generally placed side by side, so that the brushes may be re-adjusted or a fresh one put in without stopping the machine.

The brush holders are carried on a rocking lever R R, which can be clamped in any desired position by the thumbscrew W, as described on page 54; they are connected electrically with the proper terminals by means of flexible insulated leads, capable of carrying the full current of the dynamo.

The brushes can be lifted off the commutator and secured in that position by the catch T which engages in the projection P on the

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brush holder H. C C are metal plates intended to distribute the pressure of the screws S S evenly over the brushes, and to prevent damage to the brushes.

## Position of Brushes.

On referring to *Fig.* 29, it will be seen that when the rotation is right-handed, or the same as the direction of the movement of the hands of a watch, and the south pole of the field magnet on the left, and the north pole on the right, the induction in the armature tends to produce a current of electricity in both halves of the ring, from the bottom to the top, so as to make the upper portion of the armature core a north pole and the lower portion a south pole, in accordance with Ampères' well known rule. The polarity in the ring will thus tend to oppose the rotation imparted to it, as by Lenz's law it ought to do. This transference of electricity from the bottom to the top in both directions round the coils of the ring will tend to charge the upper part of the coils positively and the lower part negatively, producing a difference of potential between those points. It will be between those particular portions of the ring that the maximum difference of potential exists, while at the points horizontally opposite to one another no difference of potential will exist, for they are both receiving equal charges of electricity at the same time if the currents in both halves of the ring are equal. To realise the maximum current in the external circuit the brushes must be placed so as to touch the commutator at the points where the maximum difference of potential exists. If they were placed horizontally opposite to one another they would be at the same potential, and no current would result in the external circuit. The difference of potential between the brushes and the consequent external current will gradually diminish to zero, as the brushes are displaced from the position shown in *Fig.* 29 to that of horizontality.

## Lead and Sparking at the Brushes.

Although, theoretically, the proper position for the brushes is at the points where the neutral line of the field cuts the commutator, or, in other words, at right angles to the line joining the poles of

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the field magnet, yet, practically, they have to be displaced from this position to another slightly forward in the direction of rotation. If this be not done, not only will they not be at the points of maximum difference of potential, but considerable sparking will take place between them and the commutator. This forward position is called the "lead," and is explained as follows :—

When any mass of iron is placed between the poles of a magnet it becomes magnetised. This naturally happens to the iron core of an armature, as shown in *Fig.* 54. Poles are developed at $n'$ and $s'$.

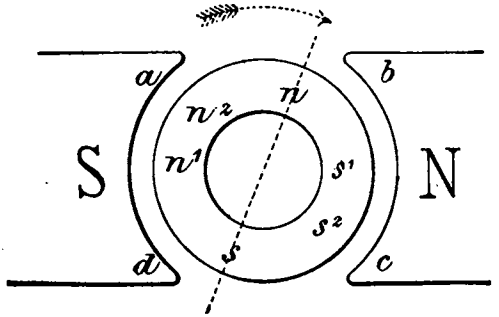



*Fig.* 54.

When the armature is revolved this state of affairs is not altered, the iron alone revolves, the poles remaining stationary. When, however, a current passes through the armature coils a second magnetising force is brought to bear on the iron. It will be seen, in *Fig.* 29, that the current passes in opposite directions through the coils on the two halves of the ring, uniting at the brushes. The effect of this is to magnetise the two halves in opposite directions, so that the ring becomes two semi-circular magnets placed north pole to north and south to south. It will be found, if the directions of lines of force, rotation, etc., are carefully considered, that if the poles of the field magnet and direction of rotation are as shown in *Fig.* 54, that the poles induced in the ring by the current will be $n$ and $s$, and those due to the field magnets $n'$ and $s'$. This is easily remembered, as $n$ and $s$ will always tend to retard the rotation of the armature, $n$ being attracted by S and repelled by N and the reverse with $s$.

These two magnetising forces will produce resultant poles $n^2$ and $s^2$ somewhere between $n$ and $n'$ and $s$ and $s'$, their exact positions being determined by the relative strength of the magnetising forces. If the field magnet is very powerful in comparison with the magnetism produced in the armature by the current, the poles $n^2$ $s^2$ will

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be very near to $n'$ and $s'$, and will approach nearer to $n$ and $s$ as the strength of the current in the armature coil increases; $n^2$ and $s^2$ also re-act on S and N, apparently dragging them round in the direction of rotation, *Fig.* 55. The result is that the most intense fields are

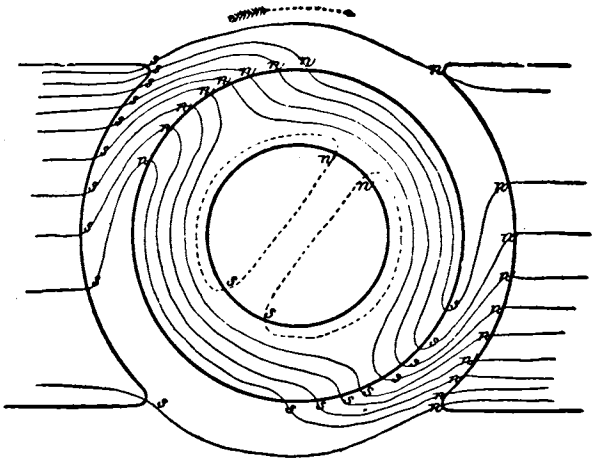


*Fig.* 55.

not directly opposite the poles but rather forward in the direction of rotation, consequently so also are the neutral points, being at ends of a diameter at right angles to the line joining the poles of the field magnets; the brushes must therefore be pushed forward to these points. This will have the effect of shifting $n$ and $s$ so that the real neutral points will be still further forward. As the movement of the brushes only slightly displaces $n^2$ and $s^2$, a point is soon reached at which no further forward movement is necessary. The distortion of the field and general lie of the lines of force is shown in *Fig.* 56, which is drawn from the pattern produced experimentally.

As above stated, the correct "lead" varies with the current the dynamo is generating, so that if a dynamo is to be used with different loads some arrangement must be made to enable the attendant to shift the brushes backwards or forwards as required; this is generally done by fixing the brush holders on a "rocker" concentric with the axis of the armature, as shown in *Fig.* 53.

The arc is an unsteady load, and consequently the correct position of the brushes is constantly varying; it is, however, impossible to follow every slight change of load, and the brushes are fixed for as

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near the average load as possible. This is done by observing the position where the sparking between brushes and commutator is least.

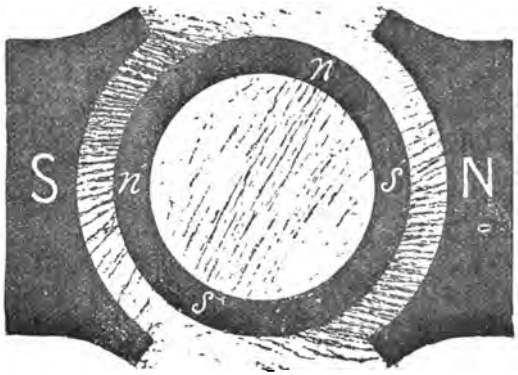



*Fig.* 56.

A good dynamo should have very little lead, as then changes of load require only slight shifting of the brushes, or if the changes are only small, none at all; this is obtained by making the field magnet very powerful, so that the poles induced by it entirely overpower those produced by the current in the armature.

The sparking above referred to is chiefly caused by the brushes not being exactly at the neutral points. The brushes must not break contact with one commutator plate before they touch the next, for otherwise the circuit will constantly be momentarily broken. The coil at the brush is therefore always short-circuited for an instant, and then immediately opened. If the brush is not exactly at the neutral point this coil will be having a slight electromotive force generated in it; and as the resistance of one coil is very small, the current in it, when short-circuited, may be considerable, and the consequent sparking, on opening the circuit, very destructive. Since the coil, which is being short-circuited at the brush, occupies a certain length of the ring, it cannot all be at the neutral point at once, and hence it is impossible to avoid a certain minute amount of sparking.

Another cause of sparking is the roughness of the commutator, or the shakiness of the brush holder, which makes the brushes jump.

All sparking is very detrimental to the commutator and brushes.

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## Bearings of Dynamos.

The bearings of dynamos are generally made of "white metal," cast round the shaft so that a perfect fit is secured. When the bearings have worn away and the shaft works loose, they can easily be re-cast. They must be kept well lubricated at first, but when a machine has been in use some time, very little oil is required. Rangoon oil is generally used in the Service, but of course there are various other kinds of oils which would do equally well. The oil is conveyed through a hole in the cap of the bearing from the lubricator, which consists of a glass or metal bottle or box, from which the oil is allowed to drop slowly. The lubricators in the Siemens dynamos are called "needle" lubricators. They consist of glass bottles inverted over the holes in the caps; a pin with a knob at the top closes the hole leading to the bearing, and prevents the oil running out when the dynamo is at rest; but when it is at work, the jarring causes sufficient oil to run down into the bearing. The lubricators for the Victoria machines consist of iron boxes with one or more tubes through the bottom communicating with the bearings. Down each tube is passed a piece of copper wire, to the top of which some cotton wick is attached; this dips into the oil; when the machine is worked the oil is drawn down the tubes to the bearings. This form of lubricator is not reliable, nor can the supply of oil be regulated by them. The best form of lubricator is one in which the oil drips through an inverted cone with a hole at the apex; the supply is regulated by another cone inside the first, which can be screwed up or down so as to entirely cut off the supply or give the exact amount required, which can be seen through a hole or glass tube provided for the purpose. Such lubricators are called "sight" lubricators.

## Driving the Dynamo.

The dynamo is driven by an engine, either—

(1). Direct.

(2). By toothed gearing.

(3). By friction gearing.

(4). By belting.

(1). The first method is being gradually introduced into the trade in proportion as high speed engines become perfected. An ordinary

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engine, having many moving parts, is not adapted to high speeds; whereas a dynamo, to work efficiently, must be driven at a high speed.

Turbo generators, in which the moving parts are reduced to a minimum, and which have no reciprocating parts, are being introduced for direct dynamo driving, but they are, however, somewhat wasteful of steam.

It is possible that some form of high speed cylinder engine, coupled direct to the dynamo, will be introduced into the Service at an early date.

In direct coupling, the power expended in driving belts and counter shafts is entirely saved, and space is greatly economized.

The Brotherhood's patent three-cylinder engine is used with the D Gramme, and has been used to drive two $D_2$ Siemens machines, but it has been discarded as unsuitable.

(2). The method of driving by toothed gearing has been adopted in the Service for the portable electric light equipment, in which a dynamo is mounted on a steam sapper. It is rather noisy, but the noise is greatly reduced by the employment of vulcanized fibre for the teeth of the driving wheel, and of gun-metal for the pinion wheel. It is inconvenient for use except with the dynamo for which it has been specially designed. This arrangement is more suitable for outdoor work than belting, which slips and stretches in wet weather.

(3). Friction gearing is not used for search light work, as the sudden strains caused by the closing of the carbons would cause it to slip. It requires much attention, and scrupulous cleanliness of the bearing surfaces, otherwise it ceases to act satisfactorily.

(4). Belting is generally used in the Service for indoor work; when used with intermediate shafting it is very convenient for working two or more machines, even at different speeds, as pulleys of different diameters can be used. A certain amount of work is, of course, expended in driving the shafting and in bending the belt. When driving a dynamo from a large pulley, or from a fly-wheel of an engine, care should be taken that the dynamo is not placed too close to the driving wheel: for if it is, the belt will not wrap round a sufficient portion of the dynamo pulley; and, unless so tight as to cause an excessive strain on the bearings, will slip under heavy loads. On the other hand, a very long belt is liable to sag, jump, and slip off the pulley. From 9 to 12 feet from engine to dynamo is a suitable distance. The underneath part of the belt should

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always, when possible, be the driving part. The slack part being uppermost, its sag tends to make the belt wrap further round the pulleys, while, if the driving part is uppermost, the reverse effect is produced. Belts are always liable to slip: this can be prevented to some extent by using powdered resin, or syrups of various kinds. These are applied to the inner surface of the belt, and soon spread themselves over the entire surface.

Belting may be made of leather links, or of ordinary single or double leather, laced or riveted. Hemp, cotton, canvas and india-rubber, etc., cotton rope, chain belting, etc., are also sometimes used. In the Service leather belting (linked or solid) is generally used. The former is supposed not to be good for transmitting power, but is very convenient for jointing, and consequently runs very smoothly.

The solid leather belting is, however, most generally used. Butt or lap joints, laced or riveted, may be employed, the former, of course, giving the smoothest running. In order to enable the belt to be tightened without unlacing it, the dynamo should be mounted on rails, with screws for moving it away from the engine when required.

## Care of Machines, Etc.

The principal parts of the dynamo which require attention are the brushes, commutator, bearings, and lubricators.

### Brushes.

Before fixing the brushes in the holders they must be carefully trimmed and bevelled off at the proper angle.

For this purpose an iron clamp C C (*Fig.* 57) is provided, in which the brush B is firmly fixed. One edge of the clamp is bevelled so that the end of the brush can be filed off to the proper angle. The brush is held tight by the screws S S. The clamp is then put in a vice (which should grip at *d d*) and the brush is filed off to the proper angle with a flat file.

The insides of the brush holders, and the parts of the brushes which will come in contact with them, having been cleaned, the brushes are clamped in position, a sufficient length of each

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brush being allowed to project through H (*Fig.* 53) so as to make them rest against the commutator at the proper angle. The tension of the spring Z (*Fig.* 53) is then regulated The two brushes

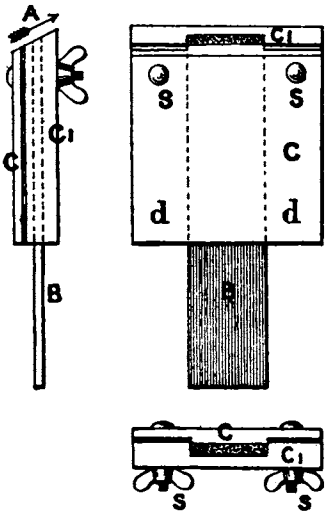



*Fig.* 57.

side by side must be set exactly square, and the opposite brushes must rest exactly on opposite commutator plates. To insure this, the plates must be counted, and two opposite ones marked; of course, with a four-pole machine, the brushes are set at one-quarter of the circle apart.

If a dynamo is kept running for long, it may be necessary to feed the brushes forward occasionally; in doing this, the little pointer alluded to above will be found useful. In an ordinary night's run no feeding should be required unless the sparking is excessive.

## Commutators.

On starting the machine, the commutator should be smooth and clean and free from metallic dust. While running, a *very little* oil applied occasionally with a piece of clean rag (not cotton waste) will prevent undue wearing of the plates. The even wearing of the commutator is much promoted by lining up the machine on its

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foundations so carefully that the shaft travels slightly backwards and forwards on its bearings while it runs. End play is allowed for this in those dynamos whose construction admits of it. It is of course impossible, in the case of dynamos whose armatures revolve between pole-pieces of the Schuckert or horse-shoe type. Such dynamos have, on the other hand, special white-metal rings at the ends of the bearings to prevent end play.

Should the commutator wear into ruts, it should be smoothed down with a fine file, followed with fine emery cloth. If the ruts are very deep, the commutator must be turned down in a lathe.

## Adjustment of Rocker.

The position of the rocker should be carefully adjusted, so as to obtain a minimum of sparking at the brushes. This position will be a little further forward in the direction of rotation for a heavy than for a light load. The best position for the upper brush for full load is generally indicated on the machine by an arrow or pointer; if there is no pointer, the position must be ascertained by trial, and it should be remembered that the actual position of the poles of the dynamo gives no clue to the correct position of the brushes; for makers very often twist the connections between the coils of the armature and the commutator plates, so as to bring the brushes into a convenient position.

## Speed of Rotation.

Every dynamo has, or should have, the speed at which it is intended to be run clearly marked on it, and this speed should not be exceeded except for a special reason. The speed can be indicated by a tachometer, but as a rule it is more convenient to make the engine driver drive by a voltmeter connected to the two terminals of the machine and hung near the engine; it is very easy for him then to drive a few volts higher or lower, according to orders sent him from the officer in charge. The speed at any moment can be taken by means of the velocimeter described on page 107.

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# CHAPTER VII.

## SERVICE DYNAMOS.

A LIST of the Service dynamos, with full particulars as to resistance of coils, etc., is given in Appendix C. The figures in the column, "Candle power," are, of course, only approximately true.

### $D_2$ SIEMENS.

The first dynamo introduced into the Service was the $D_2$ Siemens shown in *Fig.* 58. A considerable number of these will be found at stations either in their original state, or converted as explained below.

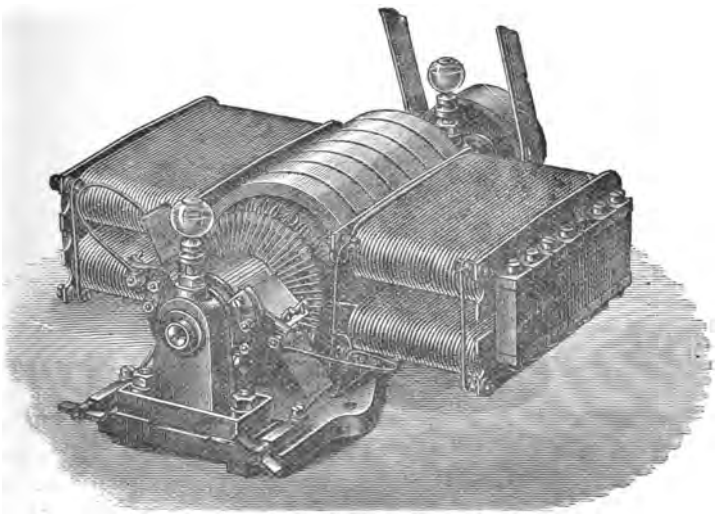


*Fig.* 58.

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The core of the armature consists of a cylinder composed of iron wire wound on the axle to the requisite diameter, wire being employed to prevent eddy currents. Over the iron wire the sections of insulated copper are wound longitudinally, the ends of each section being attached to two neighbouring commutator plates; there are 56 sections and 56 plates in the commutator. The field magnet consists of two rows of soft iron bars (*Fig.* 59), arched above and




*Fig.* 59.

below the armature, and bolted together at the ends; the coils wound on brass bobbins fit over the cores. *Plate* 1 shows the arrangement of the coils, by which it will be seen that these are four in series with the armature, two on either side.

## $D_2$ Siemens Converted.

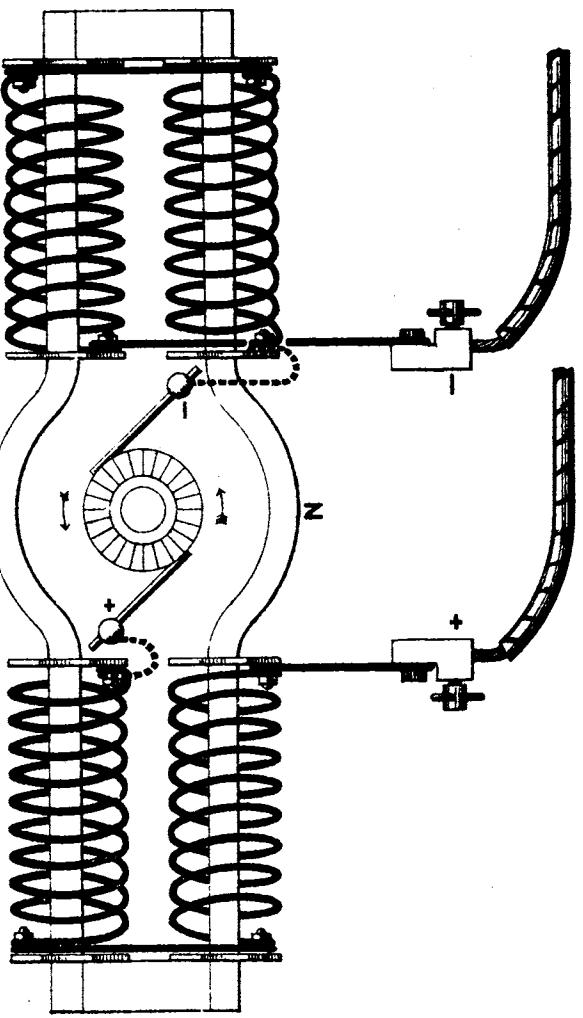
Most of the Siemens machines in the Service have been, or are being, converted into compound wound machines on account of the inconvenience of working an arc with a series wound machine. One series coil on each side is removed to make room for the shunt coils. The arrangement is as shown in *Plate* 2. The machine, as now compounded, has a falling characteristic giving about 66 volts at 700 revolutions at full load, *i.e.*, 30 ampères and 50 volts at the same speed on open circuit. To prevent this machine being over-run, a resistance at least ·3 ohms should be put in circuit with the lamp; part of this resistance will necessarily be provided in the leads, and an iron wire gauze resistance of ·2 ohms mounted in a wooden frame is provided with each machine to furnish the rest. As 30 ampères gives but a poor light, two or four of these machines will generally be used in parallel as shown in *Plate* 3, in which it will be seen that the positive brushes as well as the terminals are connected together. It is found that dynamos so connected give no trouble, as they regulate each other. The reason of this is that should one by any cause begin to go slower than the rest, its electromotive force will drop and the machine will consequently absorb less power. The power being thus unequally distributed, the slow machine will tend to

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# SIEMENS' DYNAMO

## D.2.

*The Leads shewn dotted are the only ones that have to be disconnected when coupling two Machines for working in parallel.*



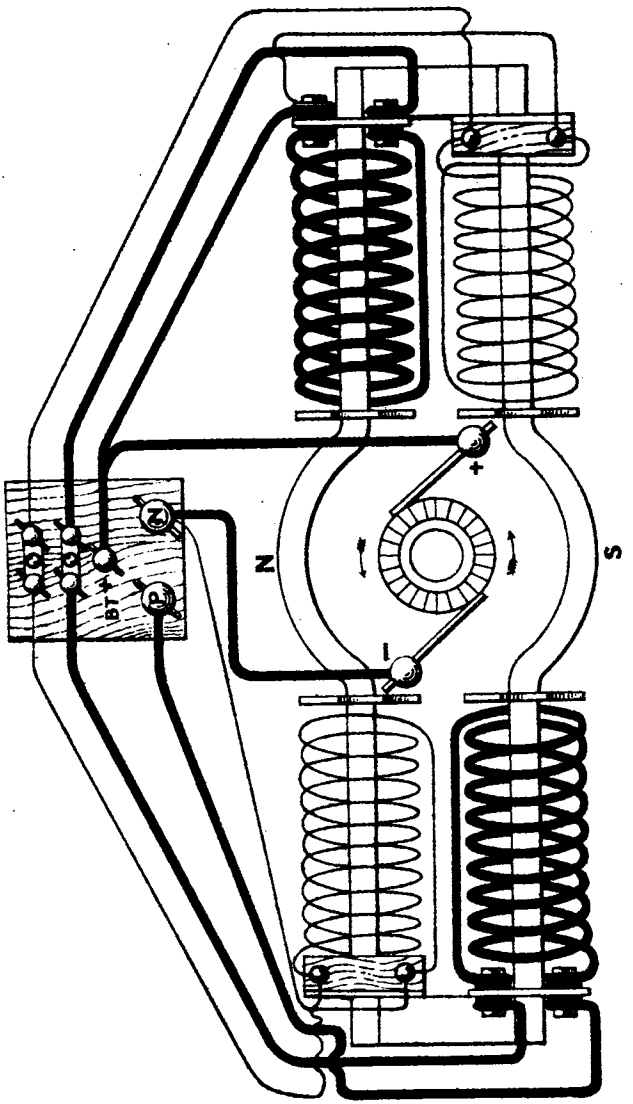

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PLATE 2.

## D2 SIEMENS' DYNAMO.

*Converted Type.*

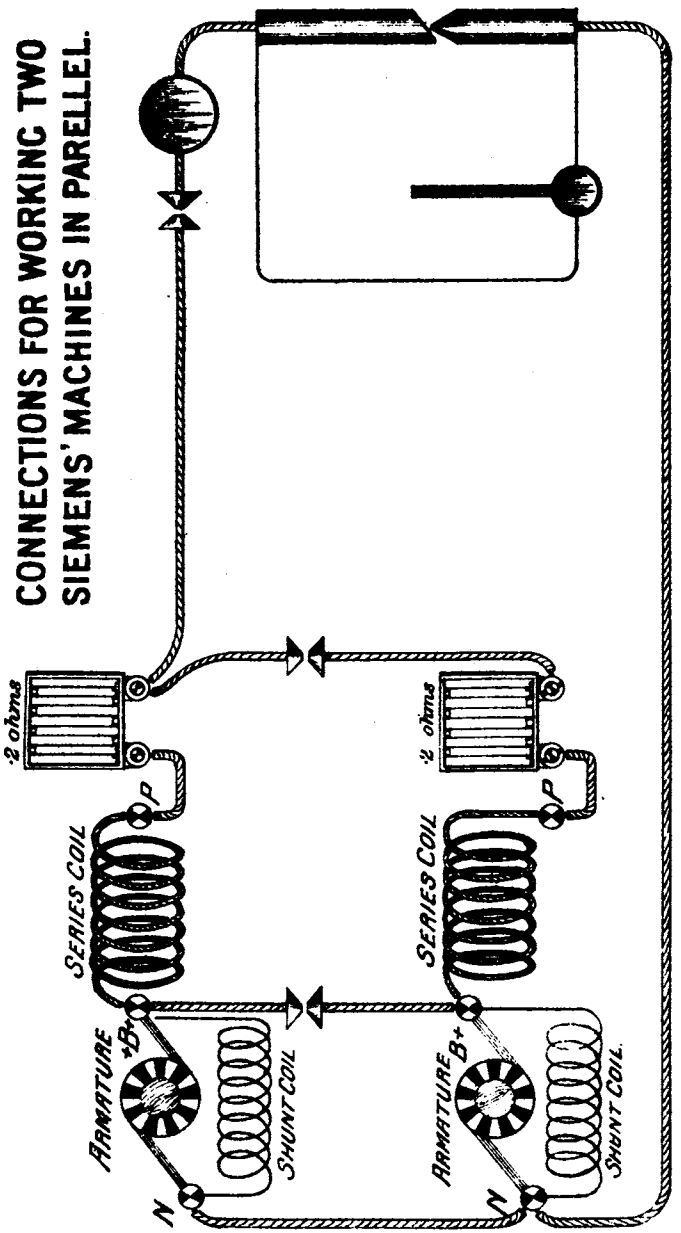



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# PLATE 3.

## CONNECTIONS FOR WORKING TWO SIEMENS' MACHINES IN PARELLEL.



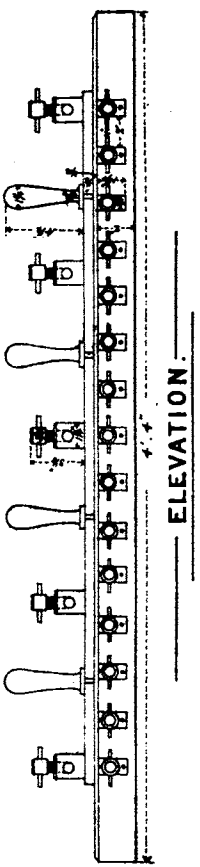

TO FACE P. 64

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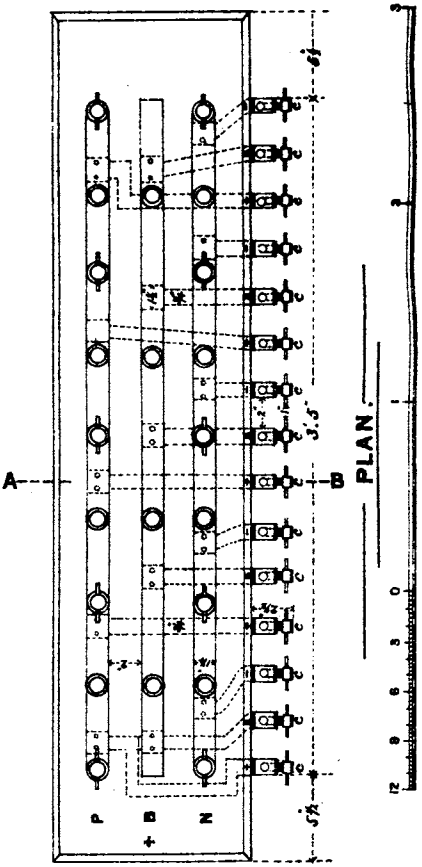
# PLATE 4.



SECTION A-B.



ELEVATION.



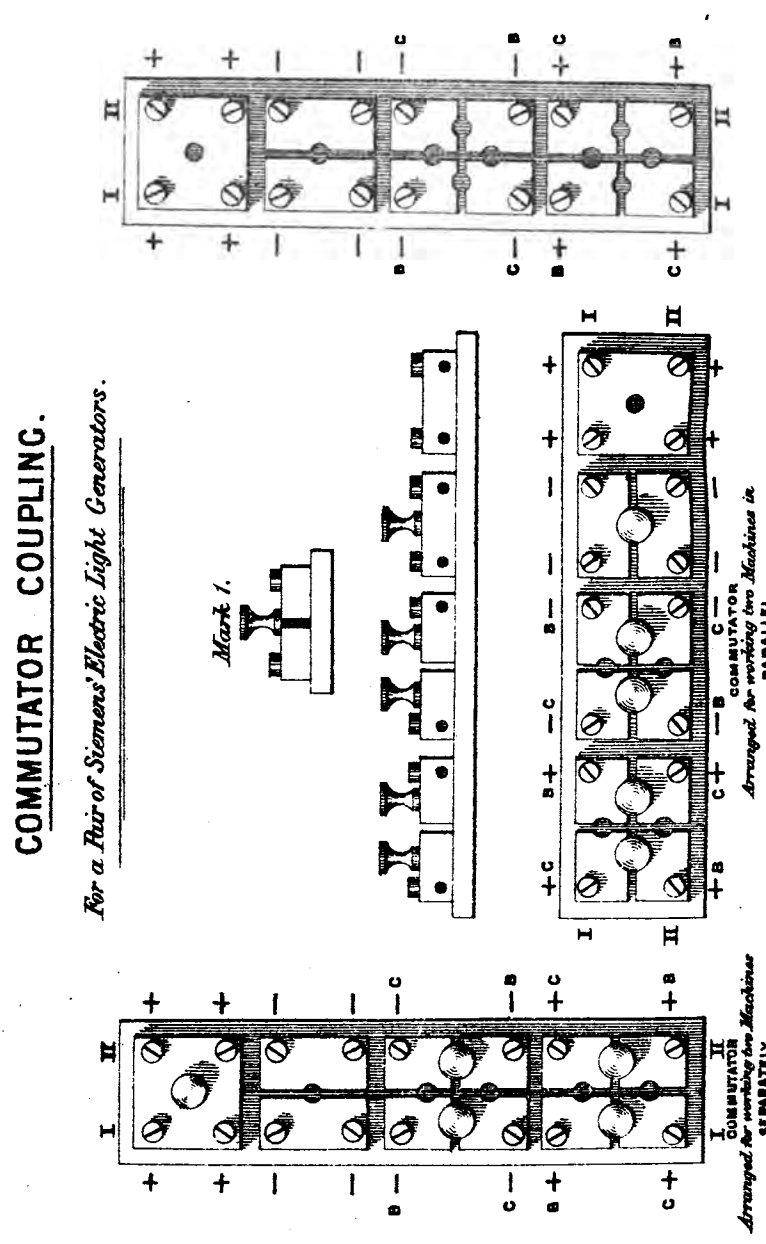

PLAN.

SCALE 1/12

TO FACE P. 65

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PLATE 5.




TO FACE P. 65

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race, while the faster ones will tend to slow down. The commutator board C (*Plate* 2) is intended to facilitate the connections of machines in parallel. If several machines are provided, a suitable switch board is required to enable any number to be used as occasion demands. *Plate* 4 shows such a switch board. The terminals at the bottom of the board are to be connected to the dynamos. There are three for each dynamo, the centre one of each three being joined to the + BT terminals of the dynamos.

The terminals on the face of the board are for the lamp leads, the upper ones being positives and the lower ones negatives. The switch board shown is intended for five dynamos.

When all the screw plugs are removed five separate lamps can be burned. When it is desired to couple two dynamos together to work one lamp, all that is necessary is to screw in the three plugs belonging to the holes between the two pairs of lamp leads. If all the plugs are screwed in, all five dynamos are then directed on to one lamp.

Before connecting up two machines in parallel their polarity must be ascertained; if a machine has been reversed its polarity must be reversed back again by passing a current through the coils in the proper direction.

*Plate* 5 shows a form of switch board which has been introduced for coupling two Siemens *series* wound machines in parallel. To do this the current from the armature of one machine must be made to excite the field magnets of the other machine, and *vice versa*. If this be not done the machines are liable to reversals of polarity, for if the current from one machine preponderates over that from the other, a current will traverse the second in the wrong direction. But by connecting up, as stated above, the current from the armature of the stronger machine tends to increase the current produced by the weaker machine, and all chances of reversal are avoided.

To facilitate the change of connections between the machines, the leads shown dotted in *Plate* 1, are disconnected, and connections are made as follows:—

The positive terminal of each dynamo to one of the screws on the top plate of switch (*Plate* 5), the positive of lamps being connected to the two remaining screws of same plate. The negative terminal of one dynamo, and the negative terminal of its lamp, are connected to the two left-hand screws of second plate, and those of the other dynamo and lamp to the right-hand screws. The negative brushes of each dynamo are then connected to the screws marked – B, the



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positive brushes to those marked + B; the negative end of the series coils to – C, and the positive ends of the series coils to + C.

Care must be taken to keep all the connections belonging to one dynamo and its lamp to the left-hand side of switch, and those belonging to the other dynamo and lamp to the right-hand side.

By arranging the screw plugs as shown in the bottom diagram on *Plate* 5, the machines will be joined up in parallel, and, by arranging as shown in the left-hand diagram, they will be working the two lamps separately.

## D Gramme.

*Fig.* 60 shows a Gramme machine, "A" pattern. The Service machine, the "D" Gramme, is similar in general construction to this. The armature is a ring of an oblong section, wound with 112

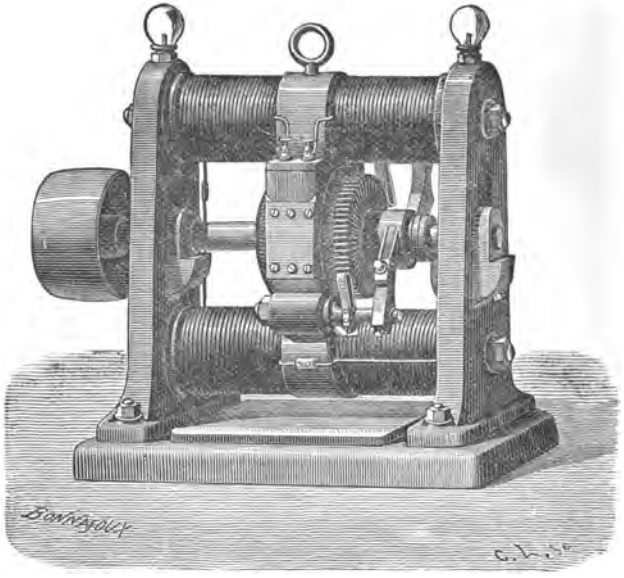


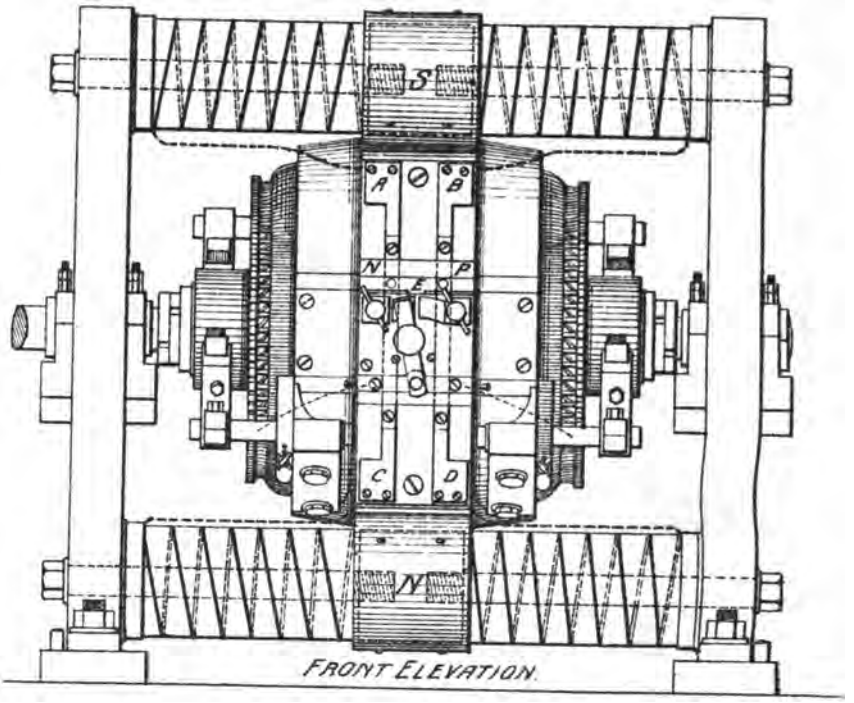
*Fig.* 60.

coils, and having a 56-plate commutator at each end. Alternate coils are connected to opposite commutators, forming two complete windings entirely separate from each other; the four brushes are connected together in pairs, so the two coils work together in

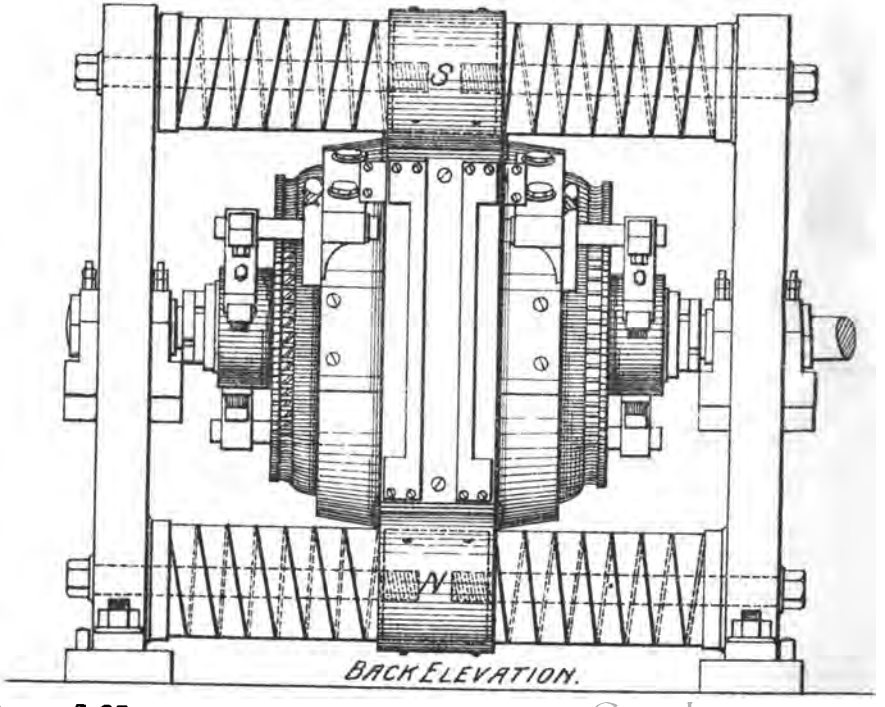
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PLATE 6.

# D. GRAMME.




FRONT ELEVATION.



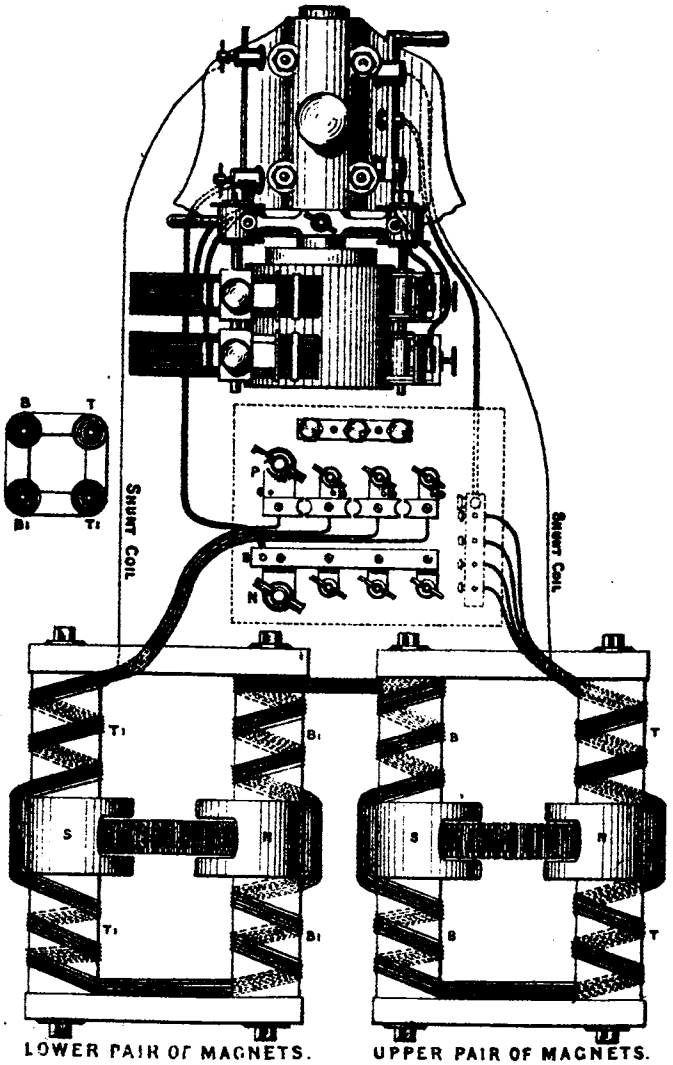

BACK ELEVATION.

TO FACE P. 67.

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# PLATE 7.

## COMPOUND VICTORIA DYNAMO.




*TO FACE P. 67.*

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parallel. The field magnet is of the divided circuit shape, with poles above and below the armature; it is wound with four series windings in divided with each other. The bearings are carried by the yokes of the field magnet, the necessity for separate supports being thus avoided. The brush holders are not very conveniently arranged, the contacts between brushes and commutator depending entirely on the spring in the brushes themselves. *Plate* 6 gives front and back views of this dynamo, showing the connections between the field magnet coils, brushes, etc.

The copper strips, A B C D, are all connected by means of the piece E with the negative terminal. They are each connected to one of the ends of each of the series coils. The other ends of the series coils are all in connection with the upper brushes. The lower brushes are connected through the switch to the positive terminal. The switch is for the purpose of breaking the main circuit.

## $D_2$ Victoria.

The Victoria, or Schuckert-Mordey dynamo (*Fig.* 61) has a disc-shaped ring armature (in the newest machines almost square in section), built up of layers of hoop-iron, separated by varnished paper to prevent eddy currents. It has a 60-plate commutator, and 60 coils wound on the armature. As the machine is a 4-pole machine, every opposite pair of commutator plates are connected across, so as to obviate the necessity for four brushes. The coils do not entirely cover the core, so good ventilation is obtained. The field magnet has four poles, and is of cast-iron, with suitable supports for the bearings, brush holders, and terminals cast on it. The winding is compounded to give 65 volts at the terminals, both on open circuit and at full load for a constant speed. The coils are wound in eight places, the series coils being under the shunt coils. The series coils consist of four coils in divided, wound side by side throughout, the ends coming to a divided plate on the switch-board, so that two, three, or four lights may be burnt in parallel, as explained on page 123. The actual connections of the machine are shown on *Plate* 7, and the general appearance in *Fig.* 61. The brush holders are arranged on a rocker, and are provided with springs for keeping the pressure of the brushes equal; the brushes should, of course, be set at 15 commutator plates apart. There are two brushes on each spindle. The speed is about 650 revolutions per minute.



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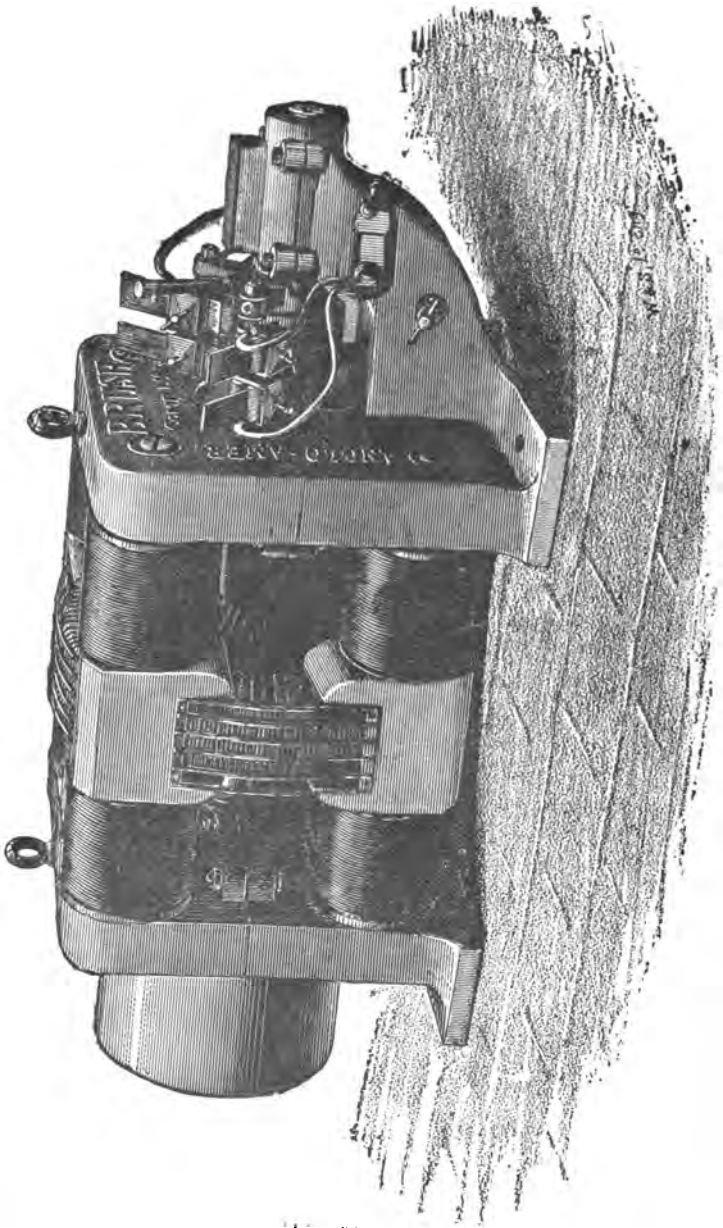


*Fig.* 61.

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### $D_2$ Victoria. S Type.

This type is rather more powerful, giving 70 volts 180 ampères at 810 revolutions. It has three bearings, but in general construction is similar to the regular $D_2$ pattern.

### $C_2$ Victoria.

This is also similar in construction to the $D_2$, but is rather less powerful, and is intended to be mounted on a steam sapper.

### Future Service Dynamos.

The specification for future Service dynamos is given in Appendix B. Several made by different firms are now under trial at the S.M.E. The resistance will probably be lower than that of the present dynamos; the field magnet will probably have only the single magnetic circuit with two poles, and the poles will probably be upwards; the armature will be of the drum or ring type, and the compounding will be, as the specification lays down, designed to give a falling characteristic.

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# CHAPTER VIII.

## TESTING DYNAMOS AND EXAMINATION FOR FAULTS.

### Continuity of Coils.

The resistance of the series and shunt coils, and of the armature, should be accurately balanced for resistance, or, in any case, tested for continuity on a low resistance galvanometer, such as the quantity coil of the ordinary "Lineman's detector." In testing the armature it should be remembered that a divided circuit is being tested, so that only a careful test is of any value. The continuity of the connections between the brushes and terminals should also be tested.

### Insulation.

The insulation may be tested by the test laid down in the Specification given in Appendix B, paragraph 12. While the machine is at rest, the ends of coils being separated from one another, and the brushes being raised from the commutator, the insulation between the various parts may be balanced with a Wheatstone's bridge, or tested with the Megohm resistance, as when testing the insulation of cables. It is better, however, not to rely solely on a bridge test, but to employ the test laid down in Appendix B, while the machine is running. For an insulation which seems very good with low volts may show weakness with high volts. There should be no contact between the body of the machine and series shunt or armature coils, or brush holders, or between series and shunt coils, or between the two brush holders.

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A single small leak is not of much importance if the rest of the circuit is well insulated, provided care be taken to see that the fault does not develope when the machine is used.

A good rough test can be taken with the intensity coil of a detector or 1,000-coil of a 3-coil galvanometer, and a 6 or 10-cell battery as follows :—

Let D = deflection with one cell through the galvanometer alone.

Let $d$ = deflection with $x$ cells through the insulation.

Then assuming that the deflections are proportional to the currents (which of course is not strictly true), the insulation resistance $= 100 \ (x \ \frac{D}{d} - 1)$ or $1{,}000 \ (x \ \frac{D}{d} - 1)$, according to which galvanometer is used.

## Inferences to be Drawn from Heating of Coils, etc., Whilst Running.

If any individual coil of the armature appears hotter than the rest after a run, this arises from a local short circuit at that coil. Examine the commutator connections, to see that they are not in contact, and that no metal, or oil, or dirt is lodged between them. See that the individual sections of the commutator are not in metallic contact. This may arise from a blow, bruising the commutator, or from the burring out of the metal when the commutator has been turned down to remove unevennesses. This test is best made on open circuit, but without the brushes on, so that the magnets are excited.

If, when running, any coils of the field magnet are cool, and the others hot, this points to the cool coils being short circuited.

## Failing to Excite.

If the machine fails to excite on open circuit, it may be assisted by short circuiting the terminal for an instant; if it still fails it may be due to (1) some sort of disconnection in the machine; (2) the brushes not pressing properly on the commutator; (3) the total loss of residual magnetism.

If the last be the reason a current must be passed through the shunt or series coils from another dynamo or from a battery.

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Some compound machines are, however, slow to excite on open circuit. This may be due to an insufficiency of wire in the shunt. Such machines should have the external circuit completed through a low resistance, when they will not fail to excite, and when once excited, will remain excited on open circuit.

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# CHAPTER IX.

## DYNAMOS USED AS MOTORS.

An electro-motor is the converse of a dynamo, *i.e.*, it is a machine for converting electrical into mechanical energy. All direct current dynamos can be used as motors, the armature being made to rotate by driving a current through the dynamo from an external source.

Let us first consider the case of a magneto machine, or separately excited machine, with, as has been always shown in this book, the south pole on the left and the north pole on the right (see *Fig.* 28).

A current supplied from an external source to the armature will produce powerful poles in it nearly at right angles to the line joining the pole pieces. Suppose the currents to be in such a direction that the south pole is at the top and the north pole at the bottom; evidently the attraction and repulsion of the field magnet poles will be such as to cause the armature to revolve right-handedly; if the current be reversed, the rotation will be reversed.

### Position of Brushes of a Motor.

If a motor is required to run in either direction, the brushes should obviously be set exactly at right angles to the line of the poles; but when the rotation is only required in one direction, the question of "lead" is introduced. The re-actions between the armature and field magnet in a motor are shown in *Fig.* 62; this should be compared with the same re-actions in a dynamo shown in *Figs.* 54 and 55. Taking, as before, the south pole of the field magnet on the left, and the south pole of the armature due to the current, at the top,

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evidently we shall get a resultant pole in the armature to the right of the highest point, and the magnetism of the armature will re-act on the field magnet, increasing its magnetisation; the dotted lines

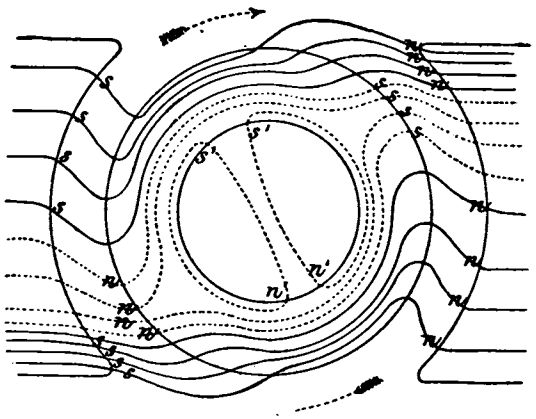


*Fig.* 62.

are supposed to be due to the armature. From this we see that to take advantage of the mutual strengthening of the two magnetic forces, we should give the brushes a forward lead, as this brings the resultant poles of the armature more nearly opposite to the field magnet poles. Also, that if we give a lead to the brushes, the armature will revolve without the field magnet being magnetised otherwise than by the induction of the armature, and the direction of rotation will be determined by the direction of the lead. But if a forward lead is given we shall get a great deal of induction going on in the coils short circuited by the brushes, because those coils will be moving across the lines of force of the field, and will be having an electromotive force excited in them as in the case of a dynamo used as a generator. There will, consequently, be a great deal of sparking. To prevent this, a backward lead would be required, increasing as the re-action of armature perturbing the magnetism of the field magnet increases. For if the armature re-action causes obliquity in the direction of the resultant field, the neutral points will be displaced backwards correspondingly. But a backward lead will make the polarity, produced by the current in the armature, weaken the field magnets. The field will then have to be properly excited before the armature will move. The way to prevent this perturbation of the field, accompanied by loss of motive power,

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or destructive sparking, is to make the field magnets very powerful in proportion to the armature. If this is done we get, as in the case of dynamos, no obliquity in the magnetic field, practically no lead and no sparking.

## Counter Electromotive Force.

When an electromotive force E is impressed on an armature of resistance $R_a$, and this armature is fixed, a current $\frac{E}{R_a}$ will pass through it, but if this armature be placed between the poles of a magnet, and is free to revolve, it will, as above stated, at once begin to rotate. If the current be now measured it will be found to be less than $\frac{E}{R_a}$. This is due to the fact that when the armature rotates in the magnetic field, an electromotive force is induced in it in the same way as if it were run as a dynamo, and this electromotive force is in the opposite direction to the impressed electromotive force, and reduces the current. This opposition to the impressed electromotive force is evidently analogous to the opposition offered by the magnetic forces to the power driving the armature in case of a dynamo.

If the motor is driving no machinery, the rotation will be very rapid; the counter electromotive force will be nearly equal to the impressed electromotive force; and the current, and consequently the energy expended, will be very small. If, on the other hand, the motor be heavily loaded, the rotation will be slow; the counter electromotive force small; and the current, and energy expended, large. If the motor be stopped it is obviously doing no work. If it be running at such a speed that its counter electromotive force is equal to the impressed local force it will be doing no work also, for, the current being nothing, it will be supplied with no power. It is proved mathematically that the speed at which a motor, with a certain impressed electromotive force, will do most work is such as will produce a counter electromotive force equal to half the impressed electromotive force. It can also be shown that the speed at which the motor works most *economically*, is that which will make the counter electromotive force as nearly as possible equal to the impressed electromotive force, and, since the more nearly this is achieved the less is the work done, it follows that a motor is working most efficiently when it is doing the least possible amount of work.

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# CHAPTER X.

## THE ARC, CARBONS, ETC.

"SEARCH lighting" necessitates the maintenance of a powerful source of light, the rays from which have to be reflected or refracted into a parallel or slightly divergent beam, and must, therefore, emanate as nearly as possible from a point (see Chap. XII., "Dispersion").

Such a source of light is found in the electric arc, which is therefore employed in the Service for this purpose.

If two points of any conducting material be maintained at a difference of potential of about 50 or 60 volts, they may be brought very close together without any electricity passing between them, but when they are allowed to touch a current of electricity will pass from the one at the higher potential to that at the lower, and the point of contact possessing a certain amount of resistance will be rendered incandescent.

If the points be now slowly separated the current will continue to pass, the space between them being filled with highly heated air, vapour, and finely divided particles of carbon, of metal, or of whatever material the points are composed. In other words, an "arc" will be formed capable of conveying the current, but offering a considerable resistance to its passage. If the points be separated too far the current will cease to pass, the distance to which the points may be separated varying with the current.

With a current of 100 to 150 ampères this distance is about half an inch.

The arc itself is very highly heated by the current, but being mainly composed of gases does not emit much light, the points, however, although at a lower temperature, emit a very intense light, especially that at the higher potential.

The best material for the points is carbon, which does not melt, and is very hard to volatilize, and which, unlike lime and other refractory

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substances, etc., is a conductor of electricity. With continuous currents the two points will gradually burn away, the one at the higher potential, *i.e.*, the one attached to the positive pole of the dynamo or battery, tapering slightly and hollowing into a crater at the end, while the other burns away to a point.

If the positive and negative carbons are of equal sizes, the former will consume about twice as fast as the latter. If, however, as is generally the case, the positive carbon is the thickest, this inequality is not so noticeable, with alternating currents the two carbons also burn away, but equally, to two blunt points equally brilliant. This system is not considered so suitable for the search light as the continuous current arc, in which the light is chiefly concentrated in the crater of the positive carbon. It is the crater, therefore, which should be placed in the focus of the mirror or lens.

Sometimes the carbons are placed horizontally, but by this arrangement a good deal of light is cut off from the mirror by the negative carbon. The usual arrangement in the Service is to burn the carbons inclined at about 20° from the vertical and with the negative below and a little nearer the mirror than the positive, so that the crater should not be exactly at the end but a little on one side, as shown in *Fig.* 63.

The distance between the carbons affects the burning considerably, for if too close together the arc burns with a violent hissing noise and very unsteadily, carbon being deposited on the negative, whereas if further separated the arc quiets down and burns steadily. It is necessary, however, occasionally to employ the hissing arc for the purpose of re-forming the points, which, when out of shape, will cause much flaring and unsteadiness of the arc.

## Size of Carbons.

The carbons must be of sufficient section to avoid their becoming overheated by the current they have to carry. The positive carbon must also be of sufficient section after tapering down to allow for the formation of its crater, but must not, however, be so thick as to admit the formation of a very deep crater surrounded by thick walls tending to form fresh arcs, and therefore causing unsteady burning.

If the carbons are too thin they will become incandescent for several inches beyond the points. This incandescence causes the carbon to burn away from the sides, reducing its thickness, and so

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increasing the mischief. Carbons which have been burnt for some time with currents too big for them will be found to have tapered or coned down throughout a considerable portion of their length.

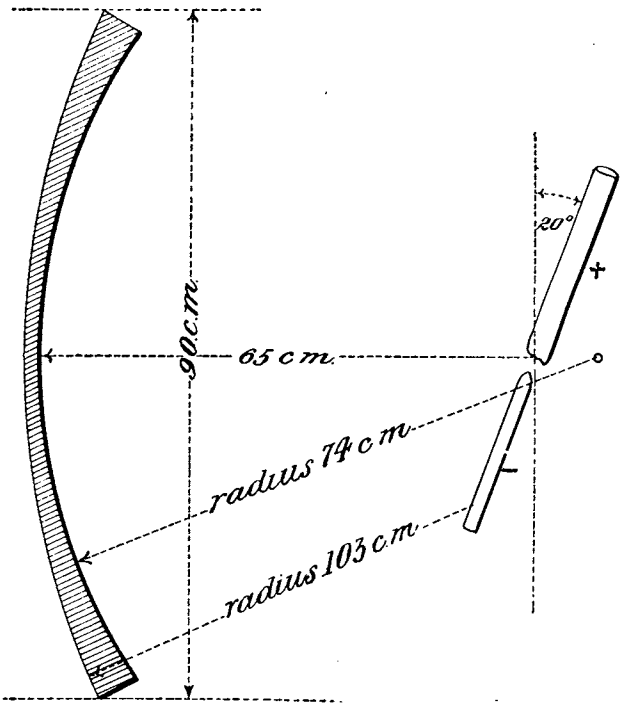



*Fig.* 63.

The following empirical formula gives a fair approximation for the size of positive carbon required for any current :—

$$D^2 = 6\,C + 40$$

where

D = diameter of carbon in millimètres.
C = current in ampères.

From this we get that currents of 150 ampères require 30 mm. carbons, and those of 100 ampères 25 mm. carbons ; as, however, 30 and 25 mm. carbons, if used for negatives, would obscure the light from the crater when badly pointed, smaller carbons are provided

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for use as negatives for currents requiring these larger positive carbons. It is also easier to maintain a sufficient point on a small carbon than on a big one. In order to give them the necessary conductivity they are heavily coated with copper, which also prevents disintegration and affords better contact with the carbon holders.

As the negative should be pointed it is found that hard carbon is best for it, whereas for the positive a softer material is more suitable.

The soft positive carbons are made by incorporating powdered coke or graphite with syrupy or tarry hydro-carbon into a paste, and consolidating the mixture by pressure in moulds. They are then carefully dried and burnt in air tight boxes with coke dust, in a kiln. It is found that a core of pure graphite, of good conductivity, improves the burning of the positive by keeping the arc directed into the centre of its crater.

The following table gives a list of carbons with the currents for which they are suitable :—

| Current. | Positive Carbon. | Negative Carbon. |
|---|---|---|
| 120 to 160 ampères ... | 30 mm. soft cored ... | 17 m.m. hard, coppered to 19 mm. |
| 80 to 120 ampères ... | 25 mm. soft cored ... | 16 mm. hard, coppered to 17 mm. |
| 50 to 80 ampères ... | 20 mm. soft cored ... | 15 mm. hard, coppered to 16 mm. |
| Under 50 ampères .. | 15 mm. lightly coppered | 15 mm. lightly coppered. |

NOTE.—30 mm. = $1\frac{9}{32}$-inch nearly.
25 ,, = 1 ,, ,,
20 ,, = $\frac{24}{32}$ ,, ,,
19 ,, = $\frac{23}{32}$ ,, ,,
17 ,, = $\frac{22}{32}$ ,, ,,
16 ,, = $\frac{20}{32}$ ,, ,,
15 ,, = $\frac{19}{32}$ ,, ,,

## VOLTS REQUIRED AT THE CARBONS.

It has been found that the current in the arc does not vary directly with the difference of potential applied to the carbons.

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This is accounted for by the existence of a "counter electromotive force" *in* the arc. The difference of potential necessary to maintain a certain current appears to be the sum of two quantities, viz., (i.) the volts required to balance the counter electromotive force of the arc, and (ii.) the volts required by Ohm's law to drive the current through the resistance of the arc. The counter electromotive force has been determined to be about 18 to 28 volts with the hissing arc, and 35 or so with the silent arc.

The resistance of the arc appears to consist of a constant part and of a part varying inversely as the current, the following values have been found to give in calculation fairly good results, viz., ·12 ohm for the constant part and $\frac{5}{C}$ for the varying part, C being the current in ampères. We have then, taking V as the difference of potential between the carbons, in volts :—

$$\begin{aligned} V &= 35 + C\,R \\ &= 35 + C\left(\frac{5}{C} + \cdot 12\right) \\ &= 40 + \cdot 12\,C \end{aligned}$$

From which we see that 150 ampères requires 58 volts at the carbons ; 100 ampères, 52 volts ; 60 ampères, 47 volts, and so on.

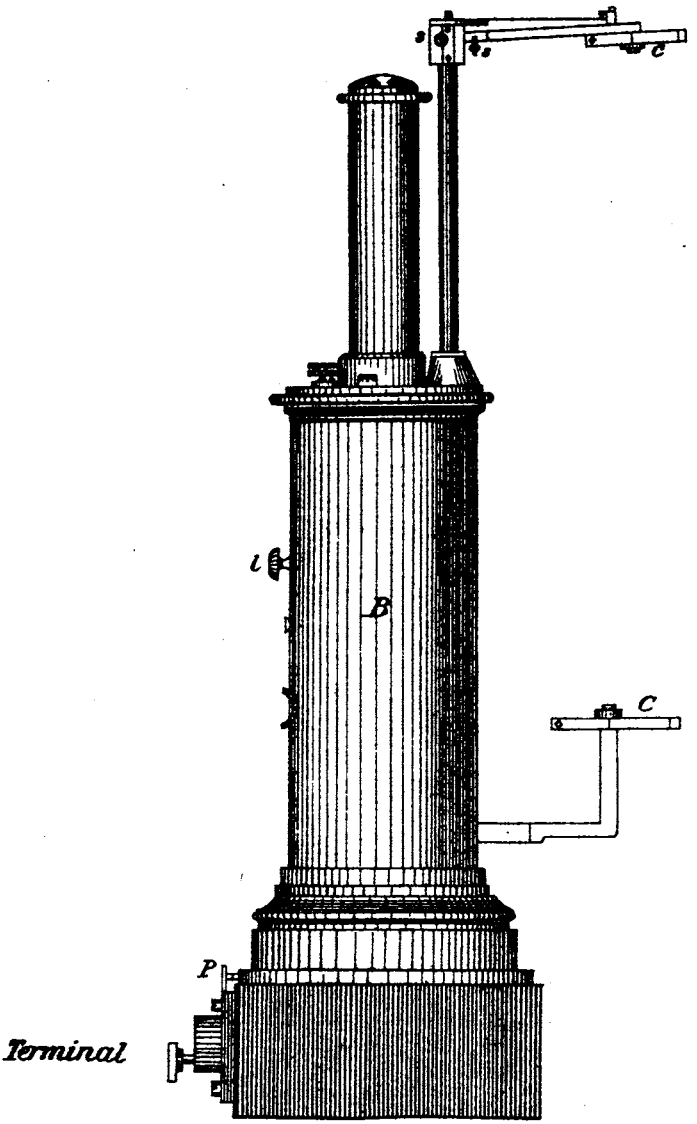
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# PLATE 8.

## SIEMENS AUTOMATIC LAMP

*for Electric Light*

*General View*




*Scale ¼*

*To face P. 81.*

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# CHAPTER XI.

## LAMPS AND THEIR MANAGEMENTS.

THE apparatus for holding the carbons in their places, and feeding them forward as they burn away, is called the "lamp."

The lamps in the Service are—

(*a*). Siemens automatic lamp.
(*b*). Inclined hand lamp (I.).
(*c*). Electric hand lamp (II.).
(*d*). Schuckert lamp.

### SIEMENS LAMP.

*Plate* 8 shows a side elevation of the Siemens lamp. The interior mechanism is protected by a brass cover B, which can be removed at pleasure. The carbons are held in gun-metal jaws C C, in which they are fixed by means of screw clamps. The horizontal arm that carries the upper carbon passes through a collar on the top of the brass rod, and adjusting screws *s s'* are provided, whereby the carbon can be moved through a small angle in two vertical planes at right angles to one another. The motions of the arms carrying the carbons are kept in one line by means of brass rollers attached to them, and working in guide grooves inside the lamp. *l* is a milled key, by turning which the distance apart of the carbons can be altered. Before taking off the cover, withdraw the key *l*, and remove the upper carbon holder (which simply slides into its brass support).

At the base of the lamp are two connecting screws for clamping the leads from the generator, and a lever for stopping the wheelwork.



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From these connecting screws leads go to the guide grooves, which are insulated from the body of the lamp by ivory plates. The racks that carry the carbons are connected electrically in the above guides by the rollers, but the pinions that gear into these racks are insulated from the rest of the wheelwork by ebonite or ivory collars on their axles.

The current enters at one connecting screw, passes up the guide and rack to the upper, or positive, carbon, and thence to the negative carbon, returning through the electro-magnet, or stop *c* (*Plate* 9), as the case may be, to the other connecting screw.

The carbons are regulated by the following automatic arrangement:—

After being pulled apart, they will run together by their own weight, the rate of motion of the upper one being to that of the lower nearly as 5 to 2. *Plate* 9 shows the arrangement by which this is effected.

Attached to the upper holder is the rack *g*, gearing with a pinion *k*; a concentric pinion of two-fifths the diameter of *k* gears with *h*, which moves the other carbon holder.

By this arrangement, if left uncontrolled, the carbons would always remain in contact, and, to prevent this, the apparatus shown on *Plate* 10 is used. Here E is an electro-magnet, placed in continuous circuit between one carbon and one of the connecting screws at the base of the lamp.

The distance of the armature A from the poles of the electro-magnet is regulated by turning the screw *b* with a key, which screws the armature bodily to, or from, the magnet. It is seldom necessary to alter this adjustment, which will generally be found to be correct when the armature is $\frac{1}{4}$-inch from the core ends. The armature is kept apart from the magnet by the steel spring *e*, the pull of which is regulated by the milled screw *a*.

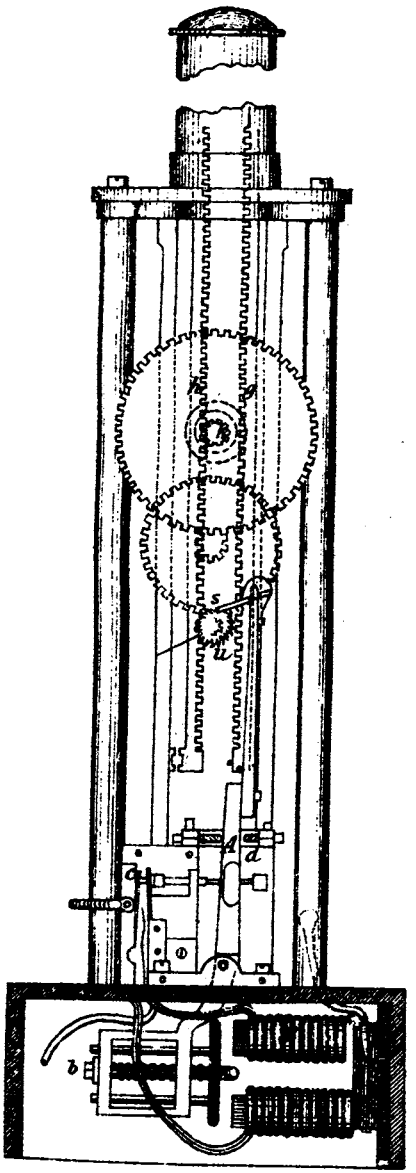
To understand the working of this arrangement, suppose the carbons to be pulled apart, and the current to be passing through the circuit. Then, as the carbons approach one another, the resistance of the arc is lessened, until a current, of sufficient strength to overcome the tension of the spring *e*, passes through the coils of the electro-magnet, when the armature is attracted and contact is made at *c* (*Plate* 9), which shunts the current from the electro-magnet coils. The resulting release of the armature breaks contact at *c*, the armature is again attracted, and this action is repeated, producing a vibrating motion of the lever and armature, which continues as

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# SIEMENS AUTOMATIC LAMP

*for Electric Light*

*Vertical Section*




*Scale ⅓*

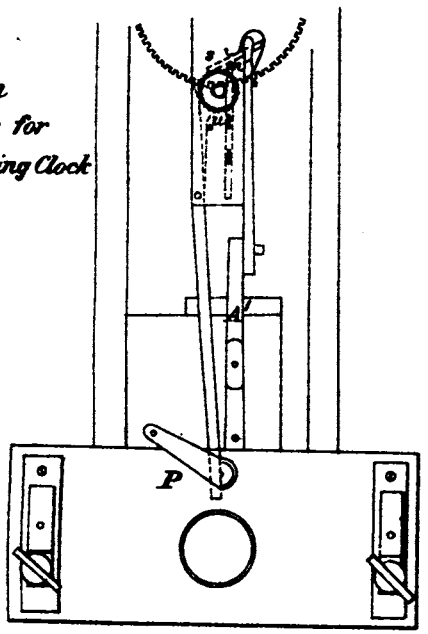
*TO FACE P. 82.*

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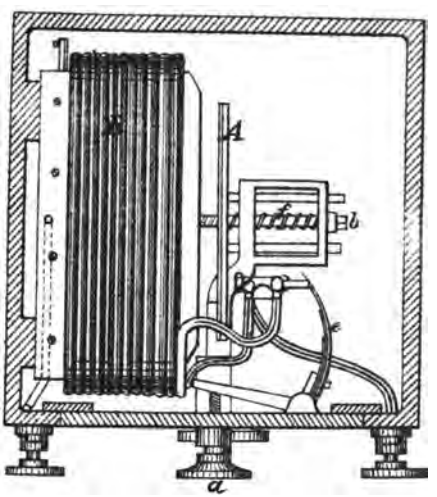
# SIEMENS AUTOMATIC LAMP.

*for Electric Light.*

*Section*
*Shewing gear for starting & stopping Clock work.*




*Plan of base.*




*Scale ½*

TO FACE P. 82.

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long as the current is sufficiently strong to overcome the tension of the spring *e*.

The spring pawl *s* at the end of the arm A′, oscillating with the arm, moves a fine toothed ratchet wheel *u* in gear, by means of a train of wheels and pinions, with the racks of the carbon holders, and thus resists the gravitating tendency of the upper carbon holder, while slowly distancing the carbons; increase of resistance results, the current gets weaker, and the armature oscillates through smaller angles and again rests on the stop *d*.

In this position the spring pawl *s*, by its inclined face bearing against a pin *n*, is released from the teeth of the ratchet wheel *u*, and the preponderating weight of the upper carbon holder now comes into play, and the carbons are carried towards each other, and the spur-pinion on the spindle of the ratchet wheel revolves now in the opposite direction; the decrease of length, and consequently of resistance of the electric arc, gives rise to increased current strength; the armature now oscillates through greater angles, and the carbons are distanced as before.

A hole is made in the back of brass cover, through which the working of the hand and ratchet wheel can be observed.

Another hole in the back is provided for the milled screw *l*, by turning which the carbons can be distanced and the luminous arc established. By pressing the milled head the pinion that works the upper rack can be put out of gear and made to gear with the lower rack, which can then be moved by turning the milled head. In this manner the luminous arc is placed in the focus of the lens or of the reflector. To obviate the necessity of re-adjusting the Siemens lamp, and to avoid unduly heating the coils when it is used with two Siemens generators coupled in parallel arc, each lamp has been fitted with a shunt of thick wire inserted between the extremities of the electro-magnet coil. This shunt can be switched into circuit when working with two machines, and its resistance is such that the portion of the current which then passes through the electro-magnet is equal to the whole current which previously passed from one Siemens generator. Thus, when two machines are to be employed, it is only necessary to throw in the shunt, and the lamp will continue to burn with little or no alteration of the adjustment.

### Siemens Lamp used on the Serrin Principle.

The Siemens lamp can also be used on the "Serrin" principle, in



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the following way. The light is started as in a hand lamp, *i.e.*, by letting the carbons run together, and separating them by the milled head *l* to a suitable distance. The tension and distance screws *a* and *b* are then regulated, so that before the arc is such a length as to cause the light to go out, the armature will be drawn back by the spring, and the arc will diminish, through the closing of the points, until the current becomes once more strong enough to check their motion by attracting the armature.

## Siemens Lamp as a Hand Lamp.

The Siemens lamp can also be used as a hand lamp. To do this it is only necessary to screw the armature of the electro-magnet as far as possible from the poles, and insert a wedge of wood between the armature and the magnet, so as to prevent the lamp from working automatically. The voltaic arc is then established by means of the distancing screw *l*, and is regulated by the brake lever P, the carbon points being allowed to run towards each other as required, and the brake being used to prevent them from shortening the arc too much. In order to make the lamp burn well it is necessary to release the brake frequently, and very little at a time, so that the length of the arc is kept nearly constant. As the automatic arrangements do not work very satisfactorily, the Siemens lamps are generally only used as hand lamps. On no account should a current of more than 60 ampères be used with them, and it is better as a rule only to use one of 30 ampères.

This lamp is for use with the holophote and parabolic reflector only.

As the gun-metal carbon holders expand when heated, it is necessary, if the carbons are put in while the carbon holders are quite cold, to screw them very firmly, otherwise they will slip when the points touch, and the lamp cannot then burn properly. When the parabolic reflector is used, the lamp should be fixed on the base before the carbons are put into the holders, and care should be taken that the carbons do not touch the side of the reflector. When the holophote is used, care should be taken to clamp the lantern well with the screw placed for that purpose on the right trunnion. If this be not done, the lamp may fall out backwards when being placed in the lantern.

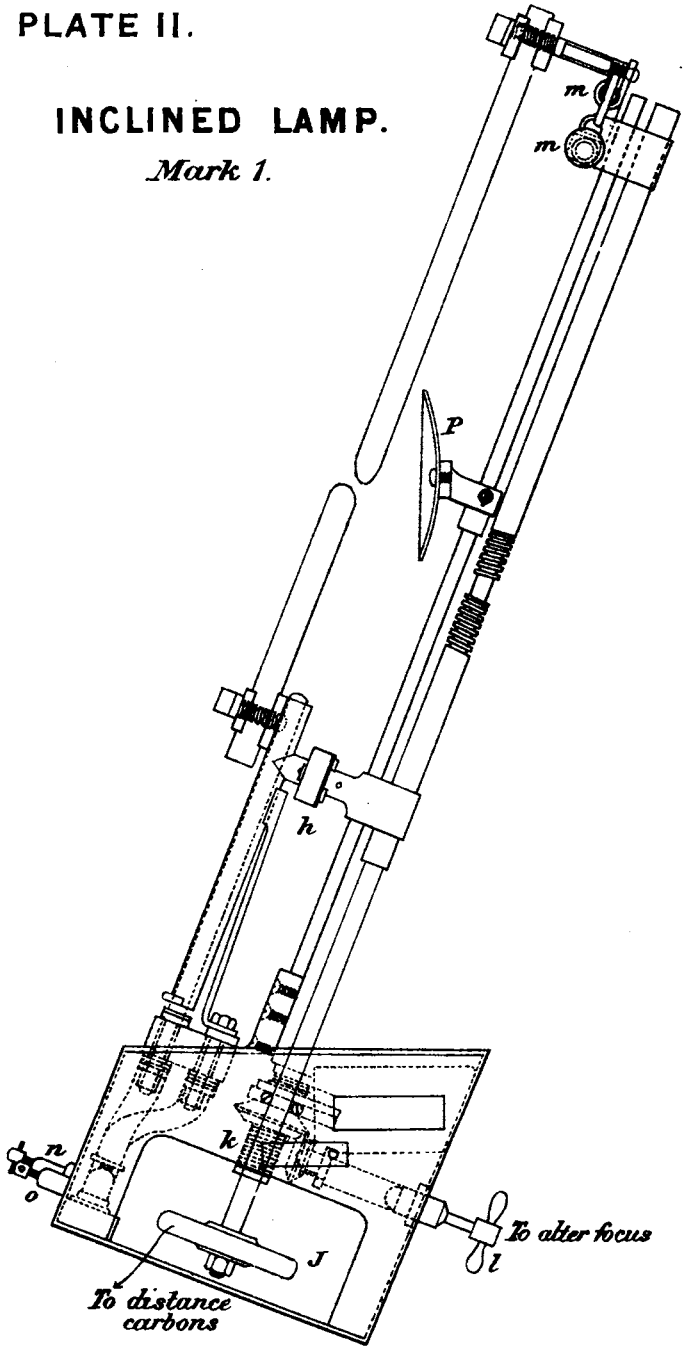
When altering the position of the carbon points by means of the

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PLATE II.

## INCLINED LAMP.

*Mark 1.*




TO FACE P. 85.

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milled head *l*, care must be taken not to force the head round when either of the carbon holders has arrived at the end of its travel; if this be not attended to, the cogs of the small pinion may be injured.

The brake P, for starting and stopping the train of wheels, must be moved to the left to start them, and to the right to stop them.

The screw for adjusting the distance of the armature from the electro-magnet should only be used after failing to find a proper adjustment by means of the screw with milled head (*a*), which alters the tension of the armature spring (*e*). Slackening this spring makes the wheels work faster and increases the electric arc, tightening the spring decreases the arc. The carbons should be pulled apart by hand while adjusting. If the lamp be in adjustment, it should, after the carbons are pulled apart and liberated, first let them approach, and then separate them to about $\frac{1}{4}$-inch for a single Siemens machine, or $\frac{3}{8}$-inch for two Siemens machines, without assistance. It is important that the adjustment should be such to obtain a good length of arc (the E.M.F. being sufficient), as the generator becomes unduly heated if the arc be too short. When working the light, the carbon points should never be allowed to touch, except instantaneously when striking the arc, or the armature of the dynamo may be damaged.

As the carbons consume, the points are kept at their proper distance automatically, or by hand using the brake. They should not be allowed to burn quite close to the carbon holders, as the heat is sufficient to fuze the metal.

To put in new carbons, pull the top carbon holder up to the end of its motion, check it there and clamp the top carbon firmly in the holders, projecting about two and a half times the length of the bottom one. Then clamp the bottom carbon, leaving a space of at least $\frac{1}{4}$-inch between the points. The top carbon is the positive, and should be bevelled off at about 45°; the negative should be pointed, and should be slightly eccentric with the positive, so as to keep the crater at the side, not at the end of the carbon.

## Inclined Hand Lamp (I.).

The inclined hand lamp (I.), *Plate* 11, is made to fit into the Mangin projector (Mark I.), and is of the following construction:—

The base is made of strong sheet brass forming a box of irregular shape with one side open, and carrying on the top a square iron

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pillar inclined backwards at an angle of 20°. On this pillar slide the carbon holders, the lower one being insulated from it by the ebonite block, *h*. Their distance apart is regulated by a screw passing through them, the upper part being right-handed, and the lower part left-handed, and the former having a double thread. By turning this screw with the handle, *j*, the carbons can be made to approach or recede, their relative rates of motion being as 2 is to 1. The lower bearing of the distancing screw is in a socket, *k*, which can be raised or lowered by turning a handle *l*, at the end of the base, which works a mitred wheel, so as to bodily raise or lower the carbons into focus. The carbons are each gripped very tightly between two flat plates secured at the ends by stout screws worked by a key. Two adjusting screws, *m m*, are provided, by means of which the upper carbon point can be moved laterally, or backwards and forwards, so as to regulate the relative position of the points.

The connection between the lower carbon holder and the negative terminal *n* of the lamp is made by a strong flat spring with platinised contacts pressing against the lower portion of the holder; the spring is connected by an insulated strap to the negative terminal, which is insulated from the body of the lamp by an ebonite block. The positive terminal *o* is in connection with the body of the lamp, and thus with the upper carbon holder. To work the lamp it is necessary to watch the carbon points, screwing them together from time to time as required. The small metal or carbon disc P, fixed on the square iron pillar, is to prevent the direct rays from the carbon points from illuminating the ground close in front of the projector.

## Electric Hand Lamp (II.).

*Plate* 12 shows the electric hand lamp (II.) altered as recommended by the R.E. Committee.

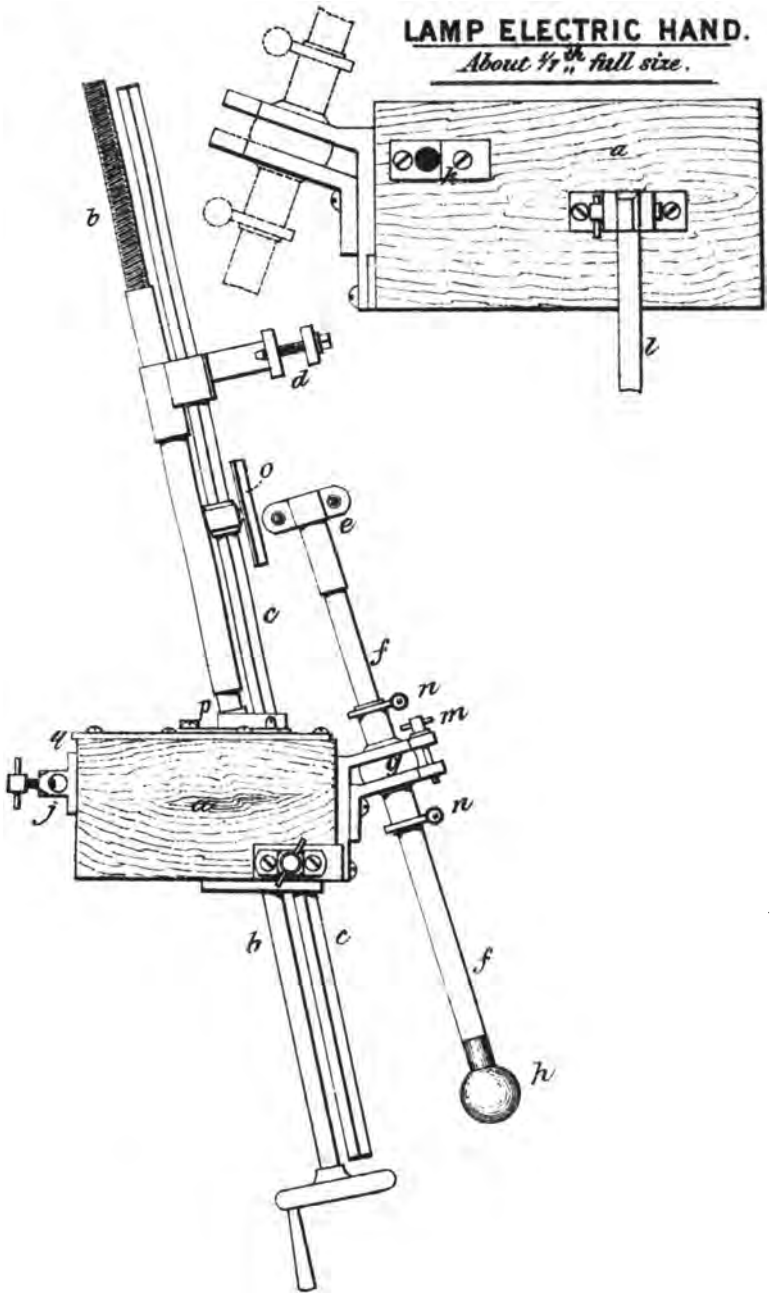
It consists of a wooden base *a*, through which passes the distancing screw *b* and guide rod *c*; these can be moved up or down six inches according as the lamp is to be used with the 2-foot or 3-foot projector, by unscrewing the bed plate *p*. The upper carbon holder *d* only is moved by the distancing screw. The lower carbon holder *e* is fixed on the end of a brass tube *f*, which slides in another brass tube fixed through the ball *g*. This ball works in a socket attached to the

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# PLATE 12.

## LAMP ELECTRIC HAND.

*About 1/1 th full size.*




TO FACE P. 86.

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wooden base, so that a slight movement can be given to the lower carbon when required, either to keep the light in focus or to alter the relative position of the two carbons. A wooden handle *h* is attached to the end of the brass tube carrying the negative carbon. The positive terminal *j* at the back of the wooden base is connected by a stout copper strap, through the guide rod and screw to the upper carbon holder. The negative terminal on the side of the base is connected by another stout copper strap through the ball and socket joint to the negative carbon holder.

Two flanges *q* on the top of the wooden base fit into grooves at the bottom of the projector.

The lamp is held in place by means of the inclined block *k* if used with the Mangin projector, or by the hinged bracket *l* if used with the 2-foot or 3-foot projector.

The amount of friction in the ball and socket joint can be regulated by the screw *m*, and that between the two brass tubes by the screws *n n*. The lower carbon holder will take 20 mm. carbons, or 17 mm. coppered to 19 mm.; the upper carbon holder will take any sized carbon.

A carbon disc *o* is fixed on the guide rod to screen the direct rays as in the inclined hand lamp.

In connecting the main leads from the dynamo to either of these hand lamps it is advisable to connect the negative lead first, as the terminal to which it should be connected is insulated from the body of the lamp. If the positive lead be connected first, an accidental touching of the body with the negative lead, while connecting the latter, will cause a temporary short circuit, if the dynamo happen to be running.

## Instructions for Managing the Arc when Using the Hand Lamp.

(1). The positive carbon should be filed away at an angle of 45°. The negative should be roughly pointed, see *Fig.* 64.

(2). The carbons should be firmly clamped in the holders, the end of the positive being as nearly as possible at the focus of the mirror, and the inclined face towards the mirror.

The carbons should be adjusted so that when they are brought together by working the lamp, the negative touches a point about 4 mm. in front of the centre of the positive crater.

(3). The engine having been started, the switch should be closed,

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a short contact (make and break) being first tried to see that there is no short circuit; if there be one, a flame (arc) will be seen when at the switch, when the circuit is broken. If there be no short circuit the switch may be firmly closed.

(4). Close the carbons by means of the distancing screw and immediately separate a short distance; not too far, or the arc which is immediately established will go out.

(5). Time having been given the carbons to get thoroughly heated, they may now be gradually separated till a steady silent arc is obtained.

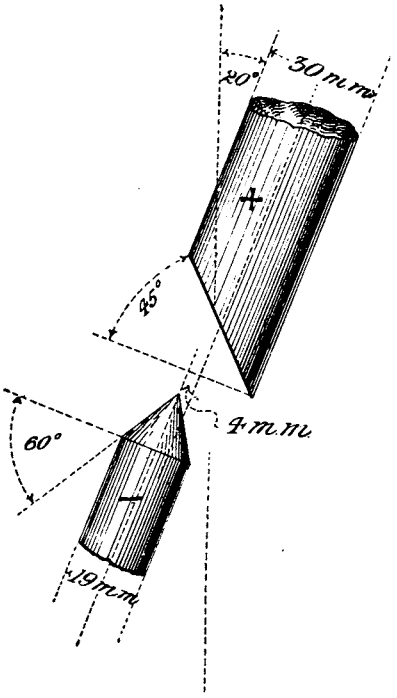


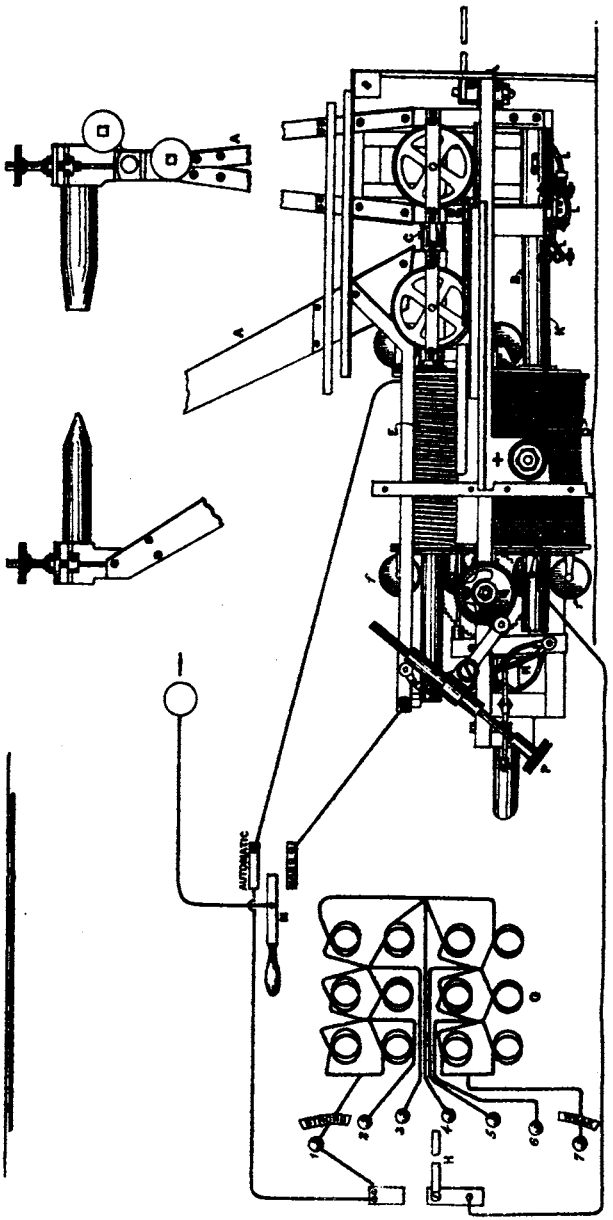

*Fig.* 64.

(6). From time to time the carbons should be fed forward by the distancing screw. If Mark II. hand lamp is being used the negative carbon holder will occasionally have to be pushed up in order to keep the light in focus.

(7). The proper relative positions of the carbon is maintained by means of the adjusting screws *m m* (*Plate* 11) on the positive

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PLATE 13.

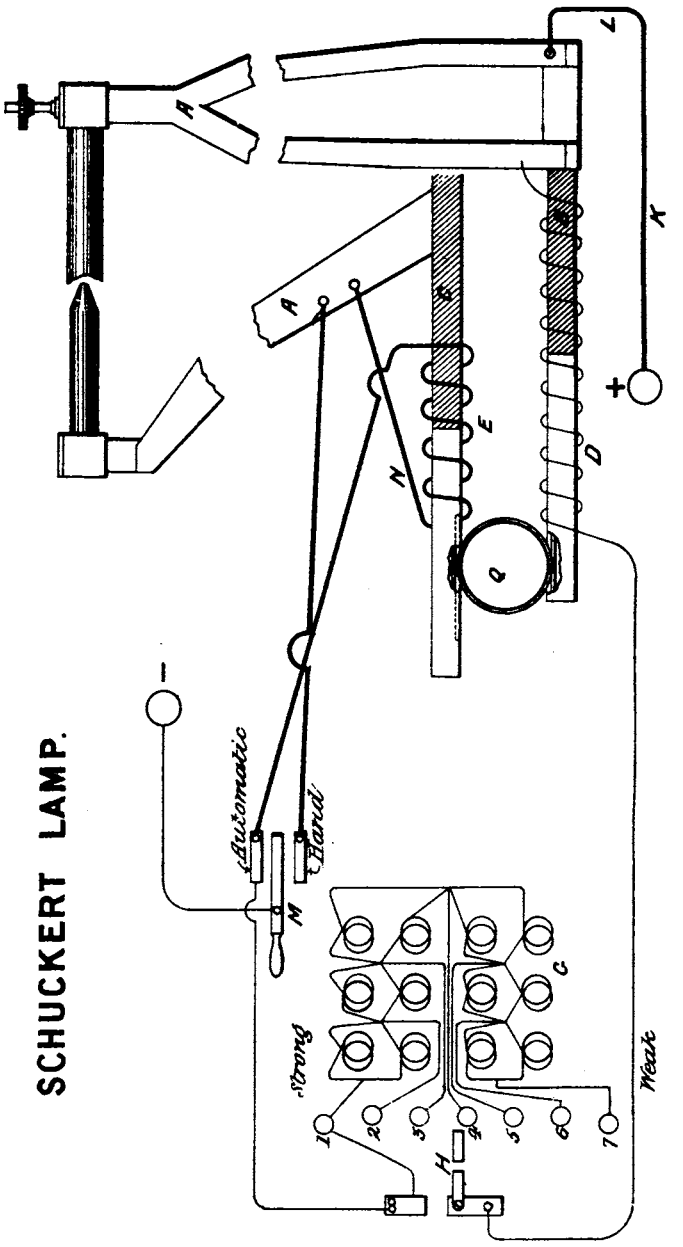



SCHUCKERT LAMP.

TO FACE P. 89.

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PLATE 14.




SCHUCKERT LAMP.

TO FACE P. 89.

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carbon holder in Mark I. hand lamp, and by using the ball and socket joint with Mark II. The crater should be kept facing the mirror as much as possible.

(8). With inclined lamps the arc will inevitably burn unsteadily from time to time, owing to the carbons losing their shape.

If the crater becomes unduly elongated the tail must be burnt off by approaching the negative to that part. If, on the other hand, the crater be found to be facing too much downwards, the negative carbon must be brought towards the front of the crater, so as to consume it away until its proper aspect is restored.

If the negative carbon has become blunt the arc will sometimes wander from one spot to another, and flare up the sides of the positive. This is due to there being no definite point on the negative which is nearer than any other to the positive.

When this happens the hissing arc will have to be employed for a short time, the carbons being brought close together. Carbon will be found to be deposited on the negatives, which will grow into a head like a mushroom. When the mushroom head has formed, the carbons should be slightly separated, so as to stop the hissing. The edges of the mushroom head will then drop off, and eventually a good point will be formed.

(9). The points must never be kept in contact, or the insulation of the dynamo will be liable to damage from overheating.

(10). If the light goes out, the points should be brought together, and the arc established as soon as possible.

(11). When the light is no longer required the engine should be slowed down till the light goes out. The switch must not be broken with the full current on, as the engine will race, unless automatically governed, and the extra current, on breaking, is liable to damage the insulation of the dynamo.

## Schuckert Lamp.

*Plate* 13 gives an elevation of the interior of the Schuckert lamp, with a partly diagramatic view of the internal connections, switches, etc. *Plate* 14 shows the skeleton of the lamp and the theory of its action.

The carbons are supported horizontally by two holders, A A, each upon a two-wheeled truck running on rails. Attached to each holder are iron rods B, C. The rods work into the interior of two solenoids, D and E, and extend into them so that when the carbon holders are

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separated to their fullest extent the rod B just enters the solenoid D, and the rod C extends to the left-hand extremity of the solenoid E. When the carbon holders are as near together as possible, the reverse is the case, namely, the rod B is wholly within the solenoid D, and the rod C is just entering the solenoid E.

The iron rods B and C are joined to gun-metal prolongations, which extend through and beyond the solenoids, and are supported by friction wheels, *f f*, so that they and the carbon holders will respond to the slightest moving force.

The solenoid D is wound with fine wire, and is connected as a shunt to the lamp. It is, therefore, actuated most strongly when the carbons are separated, that is to say, when the difference of potential between them is the highest.

The solenoid E is, on the other hand, wound with a thick wire carrying the main current, and is, therefore, actuated most strongly when the carbons are close together, that is to say, when the main current is strongest.

It will be seen, on reference to *Plate* 14, that the resistance coils G and the commutator H form part of the circuit of the shunt wound solenoid D. The lever H can be made to touch any of the studs 1, 2, 3, 4, 5, 6, 7 at pleasure, and, according to its position, so are more or less of the resistance coils included in the circuit. The introduction of this resistance will weaken the effect of the solenoid D by reducing the current flowing in it.

The lamp figured is intended for a maximum current of 150 ampères, and the proportion of ampère turns on the two solenoids is such that when it is receiving this current, and when the commutator lever H touches the stud 1, the effect of the two solenoids balance one another when the carbons are separated to exactly their proper distance, and when the arc is burning at its best.

When the carbons burn away the current in the circuit diminishes, and the effect of the solenoid E is decreased. At the same time the difference of potential between the carbons rises, and the effect of the solenoid D is increased. These two changes result in bringing the carbons closer together, until the balance is again established.

If, on the other hand, the carbons get too close together, the reverse effect takes place, and the carbons are slightly separated.

Should it be desired to use the lamp for currents smaller than 150 ampères, the lever H should be moved so as to introduce resistance into the circuit of the shunt solenoid D. For, as explained in

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Chapter X., the volts required to be maintained between the carbon points do not vary exactly as the currents flowing in the arc, but are greater in proportion for small currents than for big ones. But the volts required at the ends of the shunt solenoid must be strictly proportional to the currents flowing in in the series solenoid in order to obtain the necessary balance between them. The surplus voltage must, therefore, be absorbed in inert resistance.

The positive terminal is connected by the copper strip K and the flexible leads L to the positive carbon holder, and also to one end of the shunt coil D. The negative terminal is connected to a switch M, which, when placed at "automatic," connects it through the solenoid E and the flexible leads N to the negative carbon holder. The other end of the shunt solenoid is connected through the resistances G to the negative terminal.

When the switch is to "hand," both the solenoids are cut out of circuit, and the negative terminal goes straight to the negative carbon holder. The lamp can then be worked as a hand lamp, the only thing necessary being to place the tangent screw P in gear with the pinion Q, by which the carbons can be manipulated with ease.

Horizontal arc lamps have the great advantage of being very easy to work either by hand or automatically. In the first place, the crater is burnt symmetrically, and needs, therefore, no manipulation to maintain its shape at its best. The difficulty of maintaining a properly shaped crater in an inclined lamp is considerable, necessitating constant attention. In the second place, the force of gravity has no effect, and, therefore, automatic working is not rendered difficult by the reduction in weight of the burning carbons.

The disadvantage of horizontal carbons is that more light is obscured from the mirror by the central position of the negative point. This obscuration is not so noticeable, however, as would at first sight appear to be the case.

It is found that, in order to maintain a true-shaped crater, the point of the negative carbon should be directed a little below the centre of the crater, as the arc has a tendency to strike upwards and to burn the top of the crater more than the bottom.

This can be remedied, to a great extent, by placing a piece of metal of the shape of half a hollow cylinder just below the arc, so as partially to embrace the lower part of the arc. This seems to cause the arc to strike horizontally into the centre of the crater, probably by preventing the upward draught. The liability of this piece of metal to fusion from the intense heat has rendered its employment of doubtful expediency.

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# CHAPTER XII.

## PROJECTORS AND MIRRORS, ETC.

### Catoptric and Dioptric Apparatus.

The rays from the carbon points are collected into a parallel beam by means of reflection, refraction, or a combination of the two. If reflection alone is used the apparatus is called catoptric; if refraction alone, dioptric; and if the combination, cata-dioptric. If refraction is used for large solid angles of light, the rays get broken up into prismatic colours, and therefore reflection has to be resorted to; in any case a certain amount of light must be lost by absorption, etc.

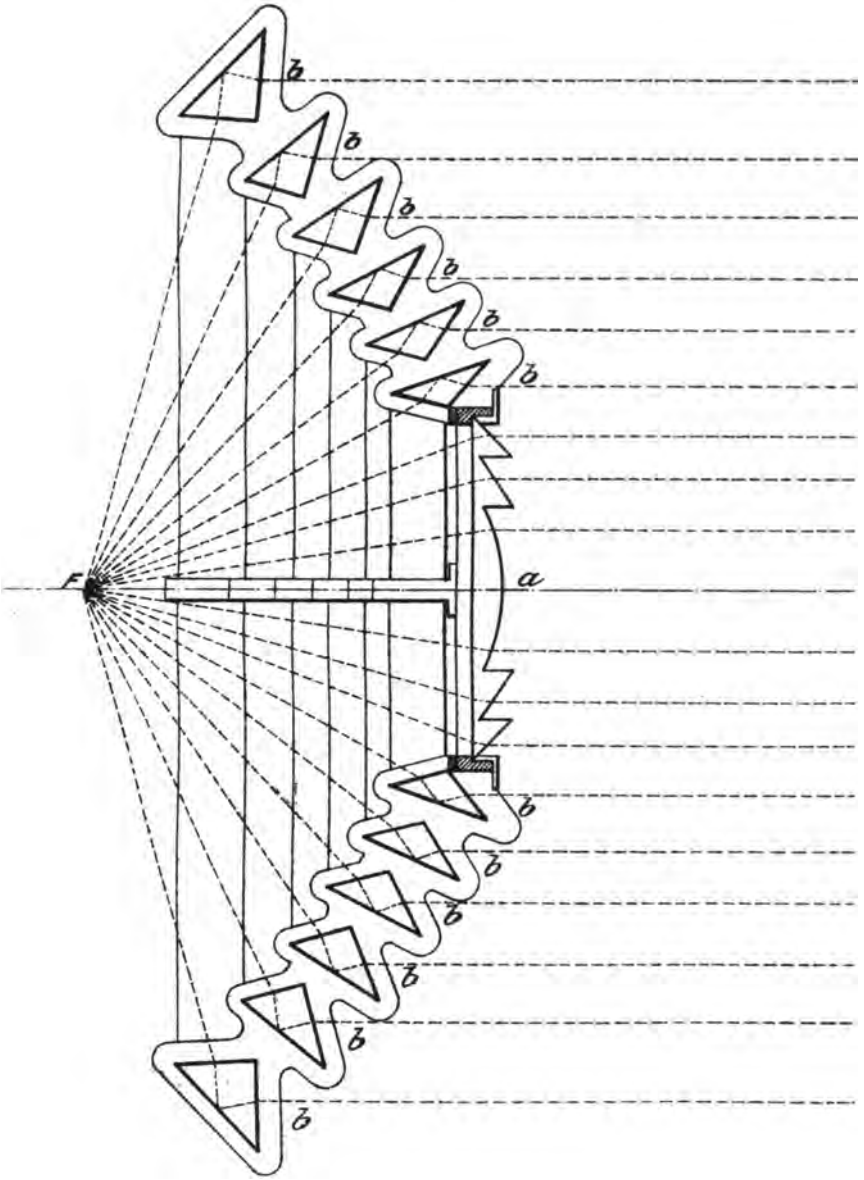
### Fresnel Holophote.

The first apparatus introduced into the Service was the Fresnel holophote, which consists of a central lens (*a*) *Plate* 15, surrounded by totally reflecting rings (*b b b*) as used in lighthouses, the whole held together by a brass frame. The focal distance is from six to eight inches.

On account of the short focal distance and the unequal expansion of glass and brass, the holophote is very apt to crack. The focusing is also a matter of some difficulty, as if the crater is the least out of focus the rays cross in all manner of directions, and it is impossible to tell at a glance which way it should be moved. No new apparatus of this pattern will be purchased for the Service.

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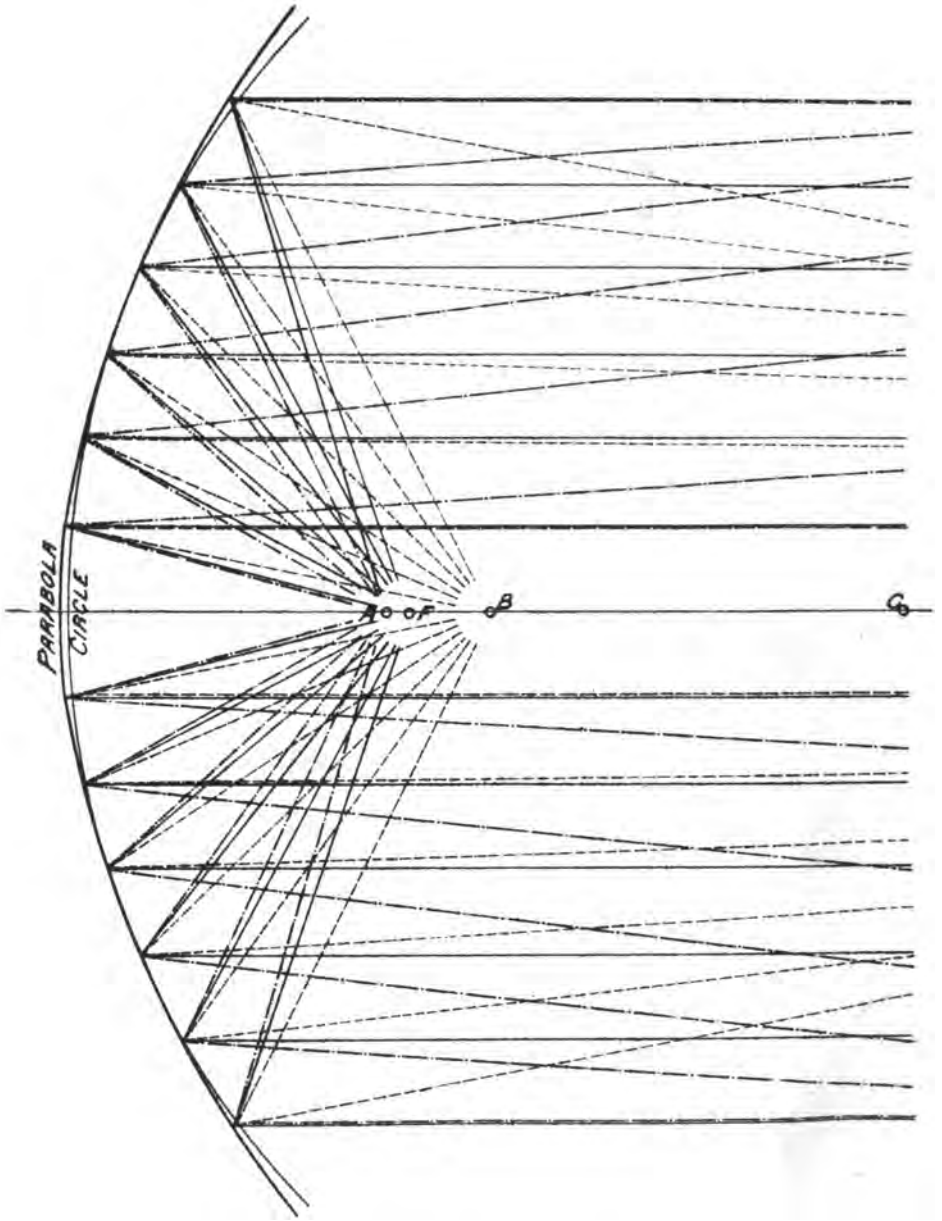
# FRESNEL HOLOPHOTE PLATE 15.




TO FACE P. 92

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## PLATE 16. SPHERICAL ABERRATION




TO FACE P. 93.

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## Parabolic Reflector.

The proper shape for a reflector required to give a parallel beam is a paraboloid.

The parabolic reflector (*Plate* 19, *Fig.* 2) is made of stout copper, with its concave surface silvered; it is $23\frac{1}{2}$ inches in diameter, and has a focal length of $3\frac{3}{4}$ inches; it has two vertical slits in it through which the carbons pass, the lamp being placed behind it. This apparatus can only be used for small currents, and even for them is not found satisfactory, as owing to the high temperature of the arc it is very difficult to keep the surface polished. When in store the surface should be protected with a thin solution of beeswax and turpentine. Should the surface become stained it should be cleaned with spirits of wine and cotton waste, and then polished with dry plate powder and chamois leather. The reflector is mounted on a wooden stand, which also carries a Siemens lamp.

## Glass Mirrors.

No more metal mirrors are likely to be purchased, glass mirrors with silvered backs being found more suitable.

Of silvered glass mirrors the following are likely to be met with in the Service :—

1. Mangin.
2. Chance (ground).
3. Chance (unground).
4. Schuckert (parabolic).

## Spherical Aberration.

It will be seen, on reference to *Plate* 16, that within certain limits the curve of a parabola does not vary very much from that of a circle. For small central conical beams the curvature of a spherical surface is sufficiently nearly that of a parabola to render it applicable for practical purposes. For the central portion of a spherical mirror the focus is at B, a distance from the mirror of half the radius. The rays emanating from a source of light at this point, which strike the peripheral portions of the mirror, are not reflected into a parallel direction but are rendered convergent, as shown by

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the plain dotted lines. If now the source of light be moved nearer to the mirror, to a point A, so as to render the peripheral rays parallel, those reflected from a zone between the central and peripheral portions are rendered divergent, as shown by the chain dotted lines. This impossibility of finding a focus to suit all parts of a spherical mirror is due to what is called spherical aberration. F (*Plate* 16) is the focus of the parabolic curve. The rays emanating from this point, and their course after reflection from the paraboloid, are shown by firm lines.

### Mangin Mirror.

On account of the difficulty that has hitherto been experienced in producing large glass mirrors of paraboloidal form, a mirror was invented by Colonel Mangin, consisting solely of spherical curves in which the aberration is almost perfectly compensated by a double refraction. The Mangin mirror is therefore a cata-dioptric apparatus, which refracts as well as reflects the rays from the crater. The front and back surfaces of the mirror are spherical, but ground to different radii, the rays from the focus being successively refracted, reflected, and refracted again as shown in *Plate* 17. Most of the Mangin mirrors in the Service are 90 c.m. in diameter, with 650 m.m. (29 inches) focus; the front surfaces have a radius of 740 m.m. and the silvered ones 1030 m.m. (see *Fig.* 63); 60 c.m. and 30 c.m. mirrors are also made.

### Chance Mirrors.

The Chance mirrors are much cheaper, being of plate-glass bent while hot into a paraboloidal mould, the best ones are then polished on one or both surfaces, the cheap ones are left unpolished. They are distinctly inferior to the Mangin, but good enough for moderate ranges. Bent mirrors in which the glass is already in a state of strain are found liable to be broken by the concussion of heavy guns fired near them.

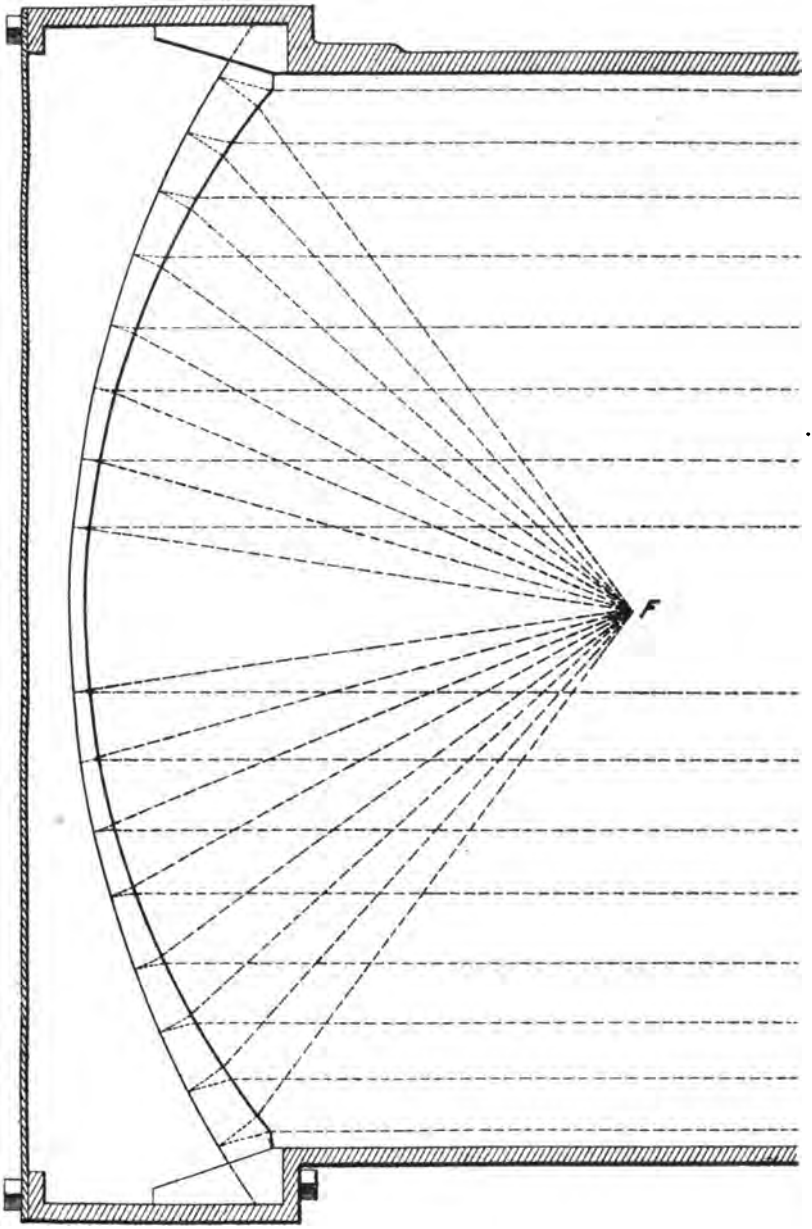
### Schuckert Mirror.

In making the Schuckert mirrors the difficulty of grinding a parabolic surface has been satisfactorily overcome.

These mirrors are truly parabolic. They are three feet in diameter, and of 450 m.m. focal distance. The focal distance being

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## MANGIN MIRROR PLATE 17.




TO FACE P. 94.

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less than that of the Mangin, the solid angle of light collected is consequently larger.

The light collected by a surface being inversely proportional to the square of the distance of the source of light, the 450 m.m. Schuckert will collect more than twice the light collected by the 650 m.m. Mangin. The first Schuckert mirrors sent from Germany had a focal distance of 310 m.m., and therefore their collecting power was still greater. It must, however, be remembered that after a certain limit has been reached, the amount of light received by the mirror does not continue to increase as the solid angle, on account of the obscuration effected by the walls of the crater. This obscuration begins to tell after the section of the solid angle has reached about 65°.

The shorter focus Schuckert mirrors were liable to damage from the close proximity of the arc. They were, however, rejected chiefly on account of their dispersion being too great.

## Dispersion.

If light emanated from a point exactly at the focus of a perfect paraboloidal mirror, the beam would be rendered absolutely parallel. In the case of the arc, however, the light comes from the crater of the positive carbon, which is of appreciable size, especially with large currents. Every point on the mirror is therefore struck by a cone of light, the angle of the cone depending on the size of the crater and the focal distance, consequently the whole beam after reflection disperses at the same angle. Evidently, therefore, small mirrors can only be used with small currents if a parallel beam is required, although if the source of light were a point, a 1-foot mirror with a 1-foot focus would be as good as a 2-foot mirror with a 2-foot focus, both taking the same solid angle of light. The sizes used in the Service are 3-foot or 90 c.m. for first class lights in fortresses, 2-foot or 60 c.m. for moderate range in fortresses and for field service; 1-foot or 30 c.m. might perhaps be used for light field equipment.

The dispersion of a Mangin mirror burning 30 m.m. positive carbons with 150 ampères is about 2°. That of the Schuckert 450 m.m. mirror is about the same. This shows the superiority of the paraboloidal mirror over the Mangin, since the dispersion is the same though the focal distance is less, and the light-collecting power therefore greater. The dispersion of the 310 m.m. Schuckert mirror was about $3\frac{1}{2}$° or 4°.

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## Fixing Mirrors.

For protection the mirror must be fixed into an iron holder of some kind; the best plan is to wedge it in with wooden blocks faced with indiarubber. As, however, any sulphur in the indiarubber is certain to attack the silver, the latter must be protected with several coats of paint; and to prevent the paint sticking to the indiarubber, two thin pieces of talc should be inserted between them, otherwise the silver film will be damaged when the mirror is removed.

## Focusing.

Focusing with a mirror is a very simple operation. If the beam disperses, the lamp is too close to the mirror, if the rays cross it is too far out; if the crater is too low, the beam will throw up, and *vice versa*.

## Plane Mirrors.

Expensive curved mirrors should only be exposed when searching for the enemy, or when he is very distant and his fire feeble, but when there is a reasonable chance of the projector being struck, it should be placed under cover, and only a plane mirror reflecting the parallel beam should be exposed as shown, *Plate* 23. Of course, a good deal of light is lost by this second reflection, but that is unavoidable.

Glass mirrors silvered or quick-silvered could be used, but one shot would probably dispose of them, so that when the fire is at all hot silvered coppered mirrors must be used, a few shots through which do but little harm. These mirrors are made by stretching a thin silvered copper sheet on an angle-iron ring, as shown in *Fig.* 65.

## Dispersing Lenses.

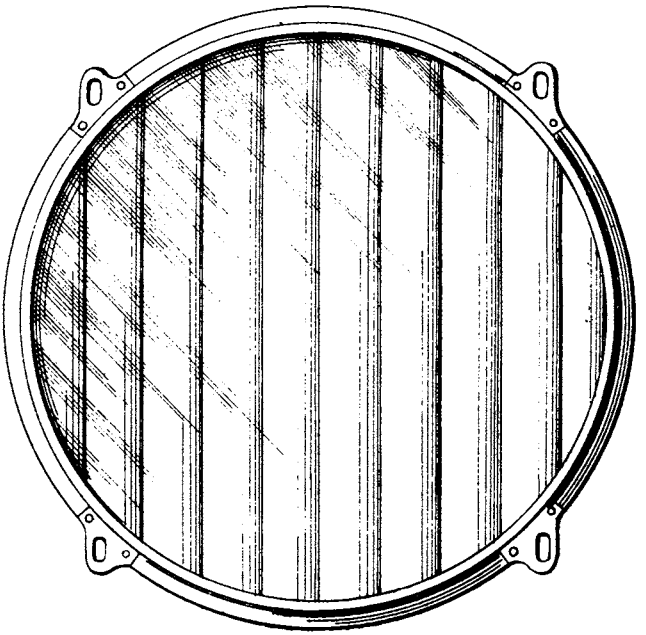
At short ranges it may be advisable to disperse the light to some extent; this may be done by burning the light rather out of focus. This is, however, not a good plan, for it would generally be necessary either to light up a broad band when the projector is on about the same level as a plain over which an enemy is expected to advance,

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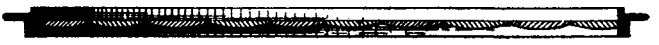
PLATE 18. **DISPERSING LENS.**

*for 60 c.m. Mangin Projector.*

Front Elevation.



Horizontal Section.



*Scale, ⅛ full size.*

*To face P. 97.*

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or to illuminate a long narrow strip for the defence of a narrow channel, with the projector on a high cliff. Dispersing lenses

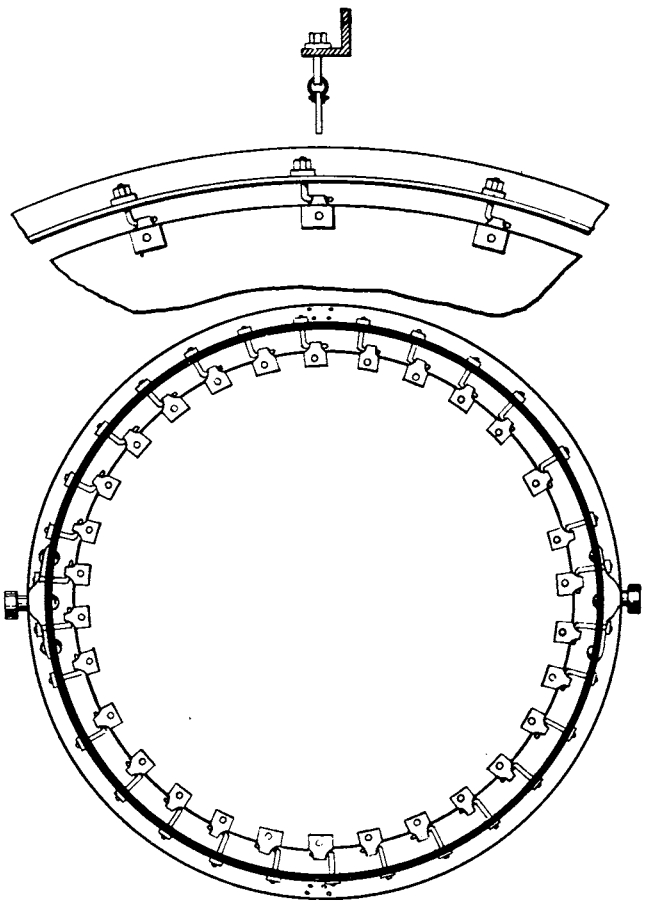


*Fig.* 65.

generally consist of a series of plano-convex prisms (*Plate* 18), mounted in an iron ring, which, when placed on the front of the projector, have the effect of dispersing the parallel beam vertically or horizontally, according as the prisms are placed horizontally or vertically in front of the light.

Corrugated moulded glass has also been used for this purpose, and although optically inferior, has the merit of cheapness.



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## Detail of Plane and Curved Mirrors.

The following is a detail of plane and curved mirrors, and the purposes for which they are intended to be used, which was furnished to the Inspector-General of Fortifications and Engineers, by the R.E. Committee, dated 28. 5. 87.

### Detail.

*Mirrors (Curved).*

I.—90 c.m. Mangin for long ranges and important positions.

II.—60 c.m. Mangin for portable electric light equipment.

III.—Ground Chance, 2-foot, in cheap projector for fixed beams of moderate range, and extemporised emplacements.

IV.—Cheap Chance, 2-foot, substitute for (III.) and for short ranges in cheap projector, and for portable electric light equipment, in addition to the 60 c.m. Mangin and ground Chance.

*Mirrors (Plane).*

V.—3-foot diameter, circular, stretched copper, silvered, mounted on Y frame, on tripod for short ranges in connection with I. and II.

VI.—Glass, quicksilvered, commercial forms, mounted on improvised stands, for moderate ranges when they can be procured locally, in connection with I. and III.

VII.—Glass, silvered, 3-foot diameter, circular, mounted on Y frame, for moderate ranges, with I., II., and III., to be supplied where quicksilvered glass reflectors cannot be obtained locally.

Note.—With reference to the above detail, the R.E. Committee remark that it is not proposed to use the 60 c.m. Mangin mirror on disappearing carriage (page 102) under ordinary circumstances; it is, however, recommended for use in a cheap form of projector for portable search light equipment, and it would also probably be used for land fortresses in cases where the limited range and other reasons would not warrant the expense of a 90 c.m. Mangin. In such case, the substitute mirrors would be ground Chance, and, on emergency, cheap bent unground Chance mirrors.

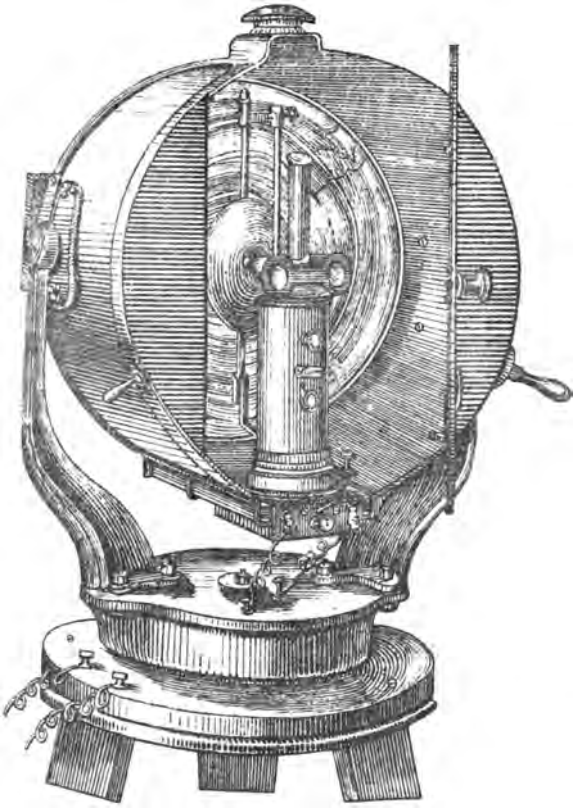
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PLATE 19.

## LANTERN AND HOLOPHOTE LENS

*with Siemens Electric Lamp inserted*

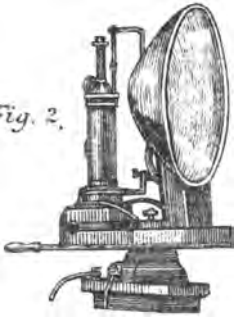
*Fig. 1*



## THE PARABOLIC REFLECTOR

*and Siemens Electric Lamp*

*Fig. 2.*



*To face p. 99.*

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## Complete Projectors.

A projector consists of a metal (generally iron) case or lantern, fitted to hold the electric lamp. At the back of it is fitted the catoptric or cata-dioptric apparatus. It is also provided with a glass door in front to keep off draughts; trunnions and Y frame or suitable arrangements with slow motion screws for manœuvring the beam.

The following is a list of Service projectors :—

(*a*). Holophote or lantern, complete with Fresnel lens mounted on base, with horizontal and vertical motion.

(*b*). Reflectors, parabolic, on stand.

(*c*). Projector, Mangin's (Mark I.).

(*d*). Projector, 3-foot, new (Mark II.).

(*e*). Projector, 2-foot.

### (*a*). Holophote.

The lens described on page 92 is fixed in the front of a cylindrical iron case, *Plate* 19, 1 foot $10\frac{3}{8}$ inches diameter, and 1 foot $5\frac{1}{8}$ inches long. This case has a plain glass front to protect the above mentioned lens from currents of cold air, and this front is carried in a brass frame, in which are cut three bayonet joints. A sheet-iron hood forming a cylinder, 2 feet long and 1 foot $10\frac{3}{8}$ inches diameter, and fitted with three studs, is supplied with the lantern, and can be readily attached when required. The interior of the hood is painted black, and it is useful for intercepting the dispersed rays which are strong enough to illuminate objects in the immediate neighbourhood of the light, and which it might be desirable to keep hidden. The lantern has a ventilator at the top, and a hinged iron door, with handle and catch at the back. The door is provided with windows through which the light can be observed. The lantern is swung on trunnions (one having a clamping screw) which revolve in strong supports branching from a base plate. The base plate pivots on a lower stand, rollers being fixed between to lessen the friction. Provision is thus made for altering the position of the beam of light, both in altitude and azimuth, two handles being placed on the back of the lantern for this purpose. The base plate is provided with two large clamping screws for the main leads, and with two smaller connections for the smaller leads, to the electric amp.



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This apparatus is made to carry the Siemens lamp, on which is fitted the spherical reflector shown on *Plate* 19, *Fig.* 1. This reflector collects the back rays from a cone of light, having an apex of 120 degrees, and throws a large proportion of them to the front through the luminous arc. Two small holes in the back of the reflector are fitted with pin-head lenses and with conical tubes, the axes of which are directed on the focus of the reflector, which is the proper position of the arc. The tubes terminate in screens of ground glass, on each of which an inverted image of the incandescent carbon points is thrown. This enables the operator to adjust the carbons and focus the light.

### (*b*). Reflector, Parabolic, on Stand.

This reflector, described on page 93, is not provided with a lantern, but is fitted on a wooden stand provided with ball and socket joint, so that the light can be turned in any required direction. On this stand behind the reflector is placed the Siemens lamp without the spherical mirror and focus observer, which are only used with the holophote; the carbons pass through two slits in the mirror, *Plate* 19, *Fig.* 1.

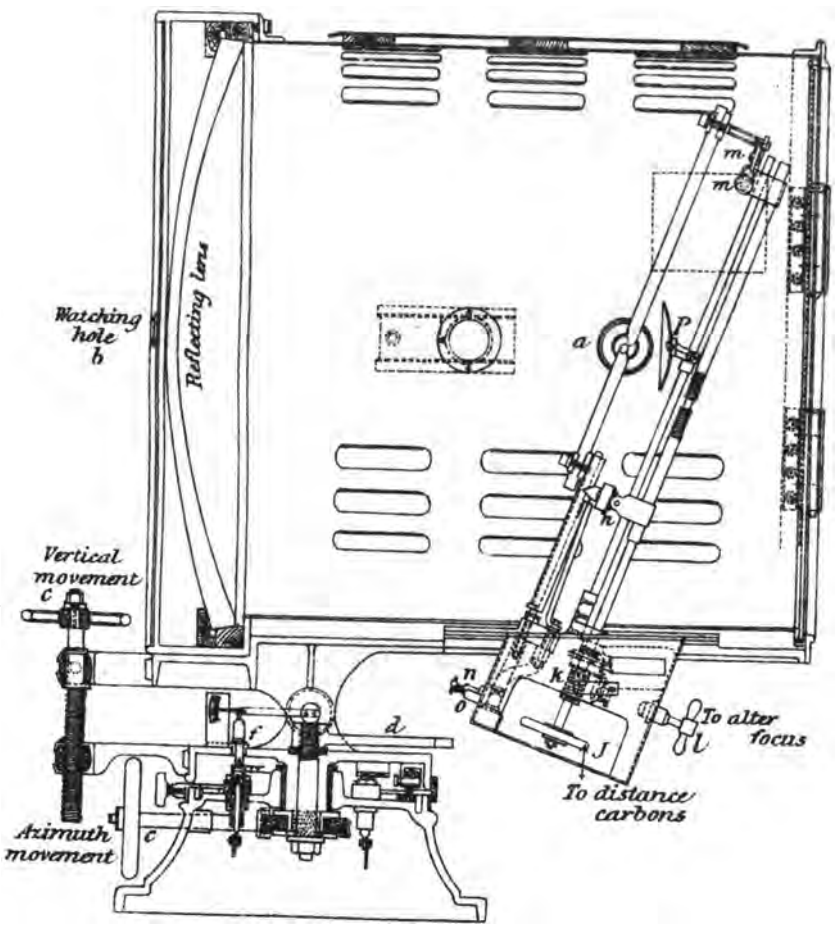
### (*c*). Projector, Mangin.

The 3-foot Mangin mirror is fixed in an iron case, which is screwed to the back of a 3-foot iron cylinder or lantern (*Plate* 20). Should the mirror be broken, the iron case can easily be unscrewed and another substituted. This projector is made to take the inclined hand lamp (Mark I.), the flanges of which rest on the edges of a slit cut along the bottom of the lantern; screws are provided for clamping it and moving it backwards and forwards in order to obtain the right focus. The front is closed by a glass door to keep out the wind. Instead of the door a dispersing lens may be used. The lantern is well ventilated, for the large currents (150 ampères and upwards) used with this apparatus develope a considerable quantity of heat. The arc is observed by means of two "focus observers" (*a a*) (*Plate* 21), through the dark glass watching hole (*b*) in the centre of the mirror, or through dark glass windows cut in any suitable position through the lantern. The pro-

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# INCLINED HAND LAMP

*in Mangin projector.*



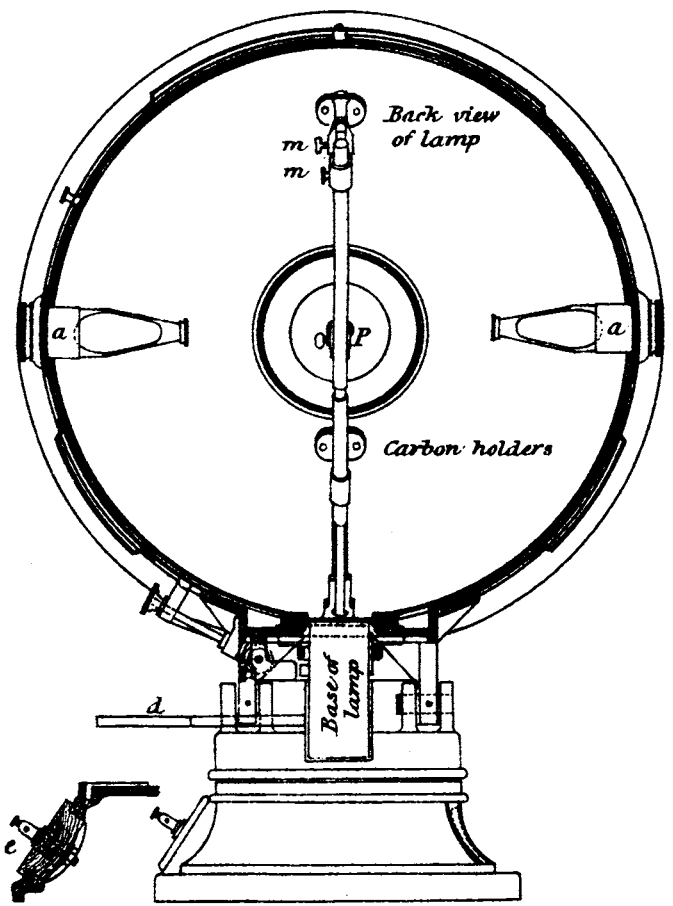

*Scale ½*

TO FACE P. 100.

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# MANCIN PROJECTOR

*and inclined hand-lamp.*



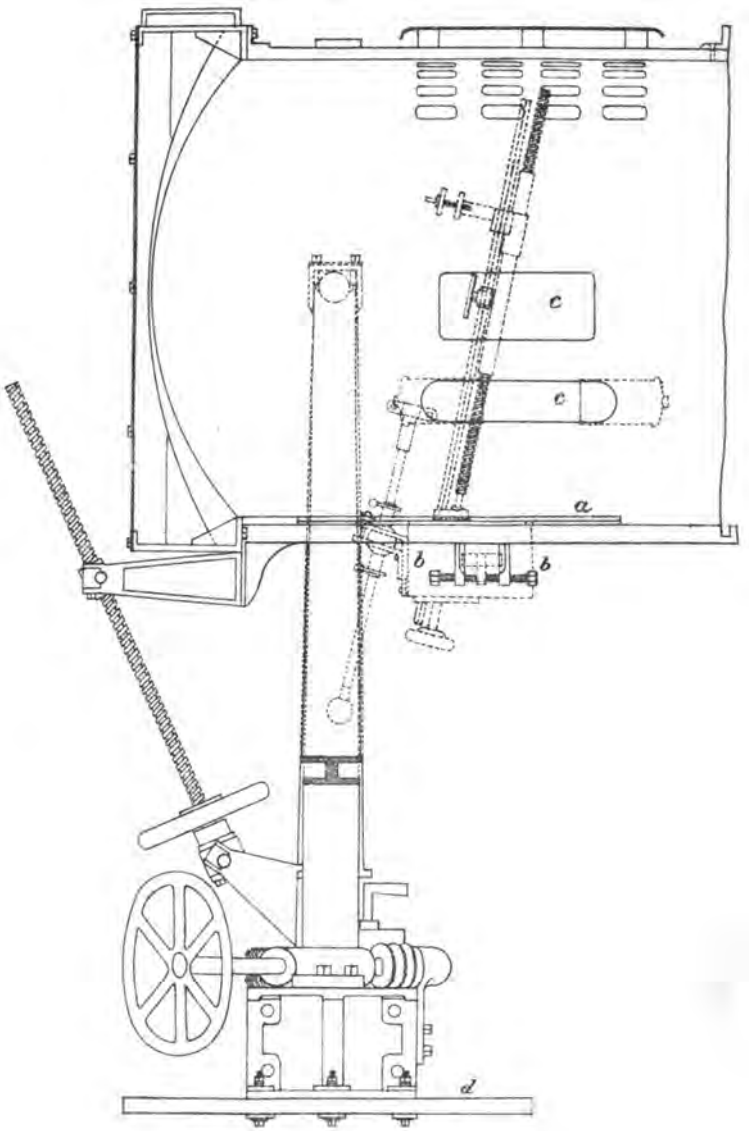

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PLATE 22.

3 Ft. PROJECTOR WITH MANGIN MIRROR.




TO FACE P. 101

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jector is mounted on a base on which it can be moved in altitude and azimuth by means of slow motion screws (*c c*), it can also be swung round quickly by hand if required by unclamping the arm (*d*). Graduated arcs with pointers are provided so that the elevation and training for any particular object in view having been fixed, it can readily be found at any moment. Large terminals (*e*) are fixed on the base to which the leads from the dynamo are attached; these terminals are electrically connected to terminals (*f*) on the upper surface of the base by rubbing contacts, which must be carefully inspected and cleaned from time to time, otherwise a considerable amount of energy will be wasted in heating them. These terminals (*f*) are connected by flexible leads to the terminals on the inclined hand lamp.

### (*d*). Projector, 3-Foot., New (Mark II.).

The 3-foot projector (*Plate* 22) is an iron cylinder three feet in diameter, mounted on trunnions on a Y frame. It is fitted to take the 3-foot Mangin mirror in replaceable ring at the back and has a glass door in front. The flanges on the base of the electric hand lamp run in the grooves *a*, and it is clamped in position by the two screws *b b* gripping the hinged bracket on the base of the lamp. The arc is observed through the dark windows *c c*. Flexible leads are provided to connect the lamp with the main leads. The projector can be mounted on an iron plate *d* or on the girder of the see-saw apparatus.

### Projector, 2-Foot.

The 2-foot projector is practically the same as the above (except that the diameter is two feet), and is intended to carry the 2-foot Mangin, ground Chance, or cheap Chance mirror.

When using the electric hand lamp with this projector, the distancing screw and guide rod must be shifted down six inches in the base, otherwise the lamp will not fit into the projector.

### Mounting the Projector.

The projector may be mounted on any suitable stand according to local requirements.

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It may be made to disappear or to run into a shelter, from which the beam is projected on to a plane mirror. It may be mounted on a truck or trolly.

The only carriage which has been specially constructed is the see-saw apparatus, which is shown, together with the emplacement in which it should be fixed, on *Plate* 23.

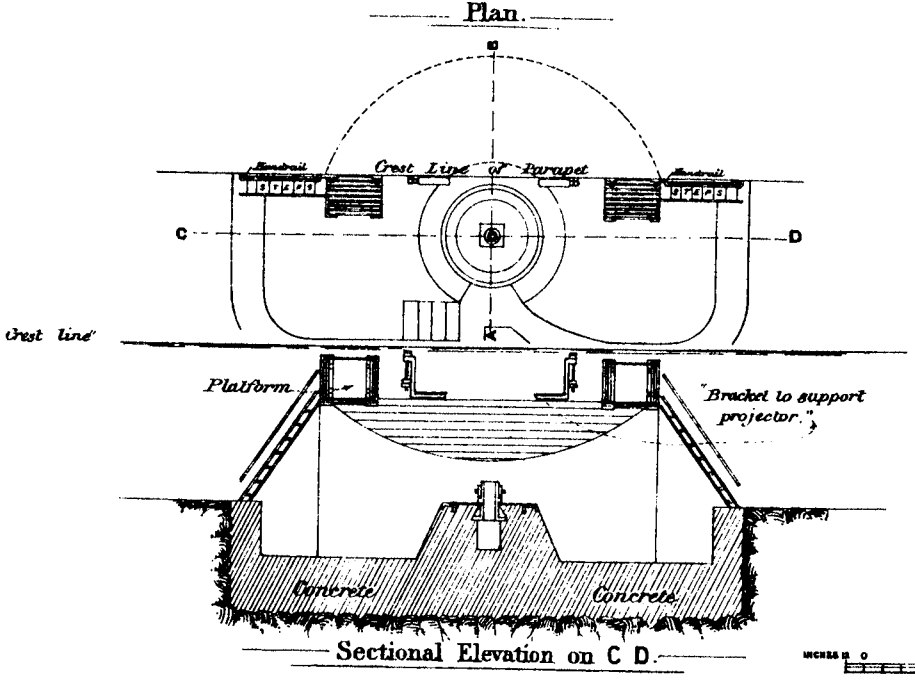
It consists of an iron girder *a*, carrying the projector at one end and the plane mirror at the other; it is supported at the centre on the traversing support *b*, so that either the projector or plane mirror can be exposed above the parapet; the plane mirror end is loaded with lead so that the girder is nearly balanced. The support *b* traverses about the pivot *c* on the racer *d*. When the projector is to be exposed, the girder is traversed so as to lie parallel with the parapet; the projector is hoisted up and a support placed under it. When the projector is to be placed under cover, it is first lowered, and then the girder is traversed round till it lies at right angles to the parapet; the projector will then be well under cover, and the plane mirror alone exposed to fire.

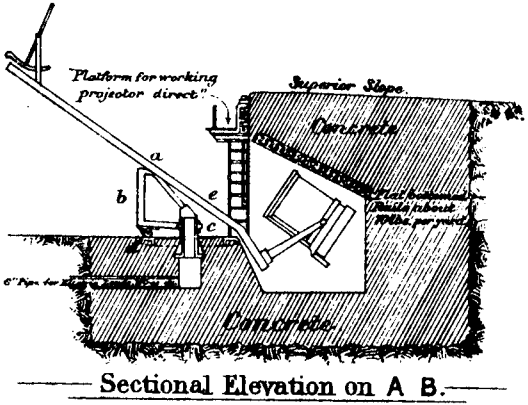
The two methods of directing the light can be used with this apparatus, see page 116. If the motors are used they are mounted on the girder at the position marked *e*; if the signalling apparatus is used the stretched wires from the plane mirror come to two handles near *e*. The projector itself can only be worked by the signalling apparatus.

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TO FACE P. 102

# SEARCH LIGHT EMPLACEMENT.



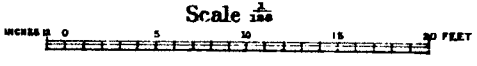
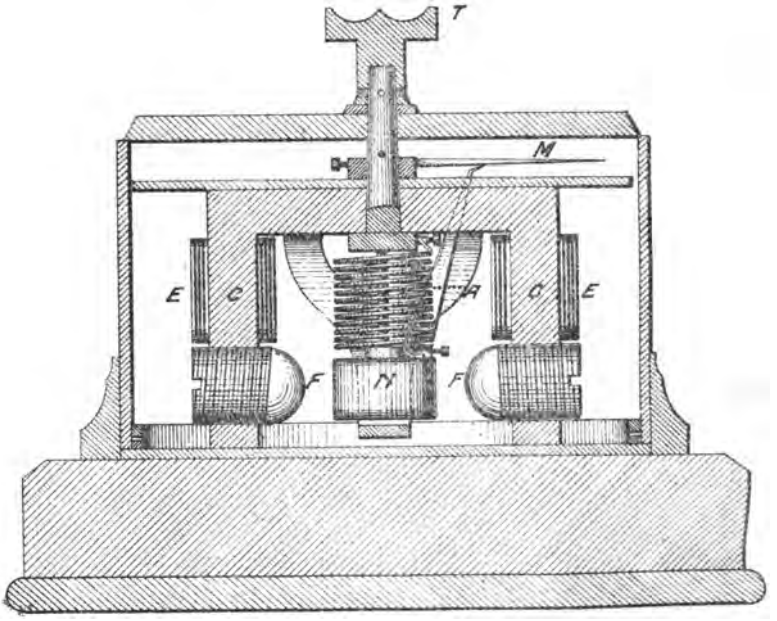
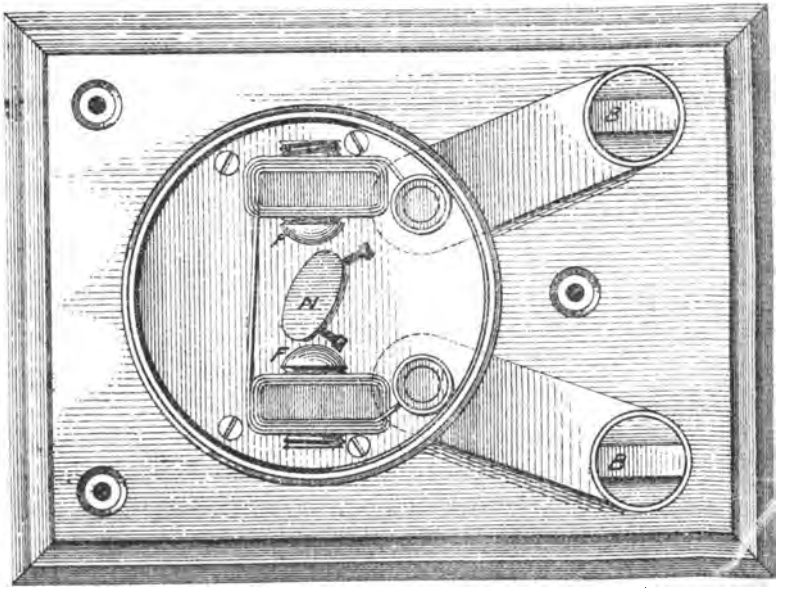




PLATE 23.

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# PLATE 24. CUNYNGHAME WOODHOUSE & RAWSON AMMETER.




TO FACE P. 103

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# CHAPTER XIII.

## MEASURING AND TESTING INSTRUMENTS.

THE instruments required for search light work are :—

(1). Ampère meters or ammeters.
(2). Voltmeters.
(3). Velocimeters.

### (1). AMMETERS.

An ammeter should be (*a*), "dead beat;" (*b*), direct reading; (*c*), uninfluenced by external magnets; (*d*), and should absorb a minimum of energy in working. By "dead beat" is meant that the needle or indicator should come quickly to its reading and remain there without oscillating to and fro.

An ammeter is invariably placed in the main circuit, and as it is required to carry large currents, it must be of sufficient conductivity. The usual place for the ammeter is in the dynamo room.

The ammeters used in the Service are :—

(*a*). Cunynghame, Woodhouse & Rawson.
(*b*). Siemens.
(*c*). Schuckert.

### THE CUNYNGHAME, WOODHOUSE & RAWSON AMMETER.

This ammeter, shown in *Plate* 24, consists of a thick electro-magnet C C, wound with a few turns of stout copper strap, coming

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to the terminals B B. Into the poles of the magnet are screwed two round-headed pole-pieces F F, between which is pivoted the soft iron needle N, the axis of which is at an angle of 30° with the line of the poles. The needle is held in this position by a spiral spring, capable of being turned by the milled head T, to which its upper end is fixed. The angle through which the milled head is turned is indicated by a pointer M, moving over a graduated scale. To the needle is attached a light arm A, the end of which passes through a small slit in the dial, its play being limited by a pair of stops. When no current is passing through the coils, and the pointer of the milled head is at zero, the arm attached to the needle should rest midway between the stops. When a current is passed through the coils the electro-magnet is magnetised; the electro-magnet magnetises the needle by induction, and the latter consequently tends to place itself axially with the poles, the arm being dragged over to the left-hand stop. The attractive force can be balanced against the torsion of the spring by turning the milled head till the arm again rests midway between the stops.

The attractive force of the electro-magnet on the needle varies as the square of the current, as, saturation not being reached, the strength of the poles, both of the electro-magnet and needle, vary as the current. The torsion of the spring varies directly as the angle through which the milled head has been turned; therefore, the current varies as the square root of this angle. The scale is marked in ampères according to this rule. It is found that the readings given by this instrument vary slightly, according to the direction of the current: this is due to traces of permanent magnetism. In consequence, the ammeters are generally marked with an arrow, which shows the direction the current should flow through the instrument.

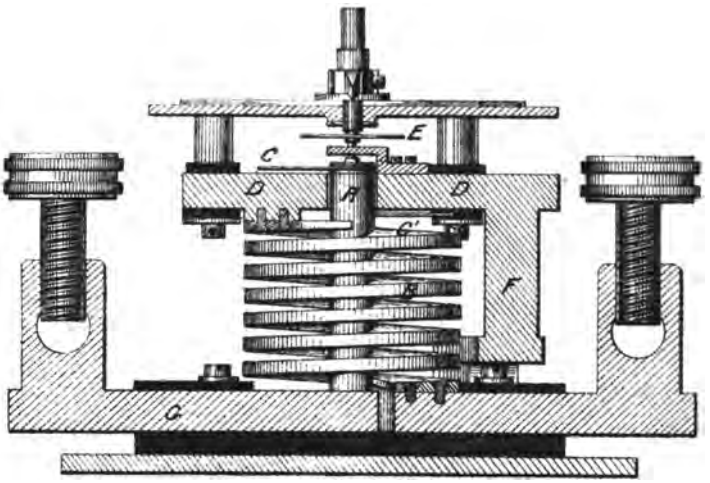
### Siemens Ammeter.

The Siemens ammeter is rather an expensive instrument, and is provided for use as a testing and calibrating instrument for the use of officers in charge of several installations of electric lighting. For this reason it is enclosed in a teak box, padded with sheets of india-rubber, so as to prevent damage from rough handling.

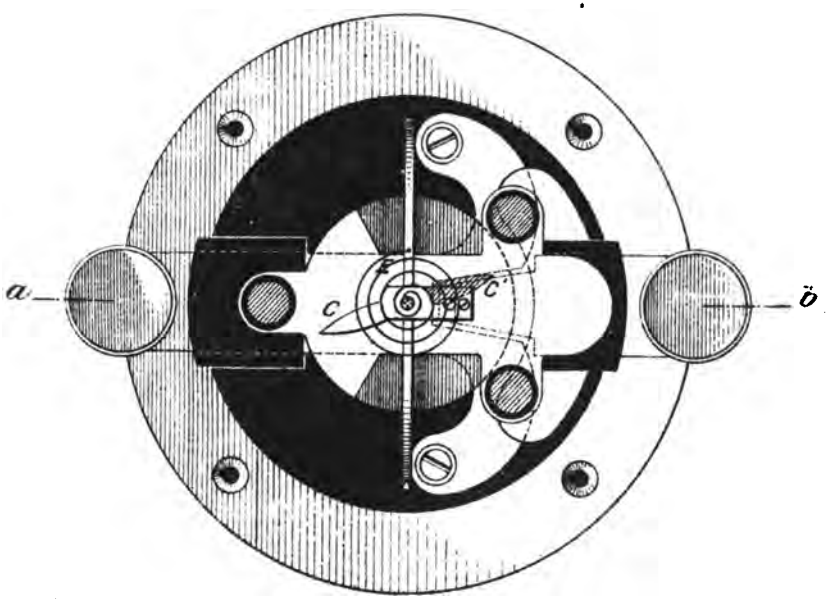
The principle of action of the Siemens ammeter is as follows (see *Plate* 25). A is a soft iron core pivoted vertically inside a helix

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## SIEMEN'S AMMETER. PLATE 25




SECTION *ab*.

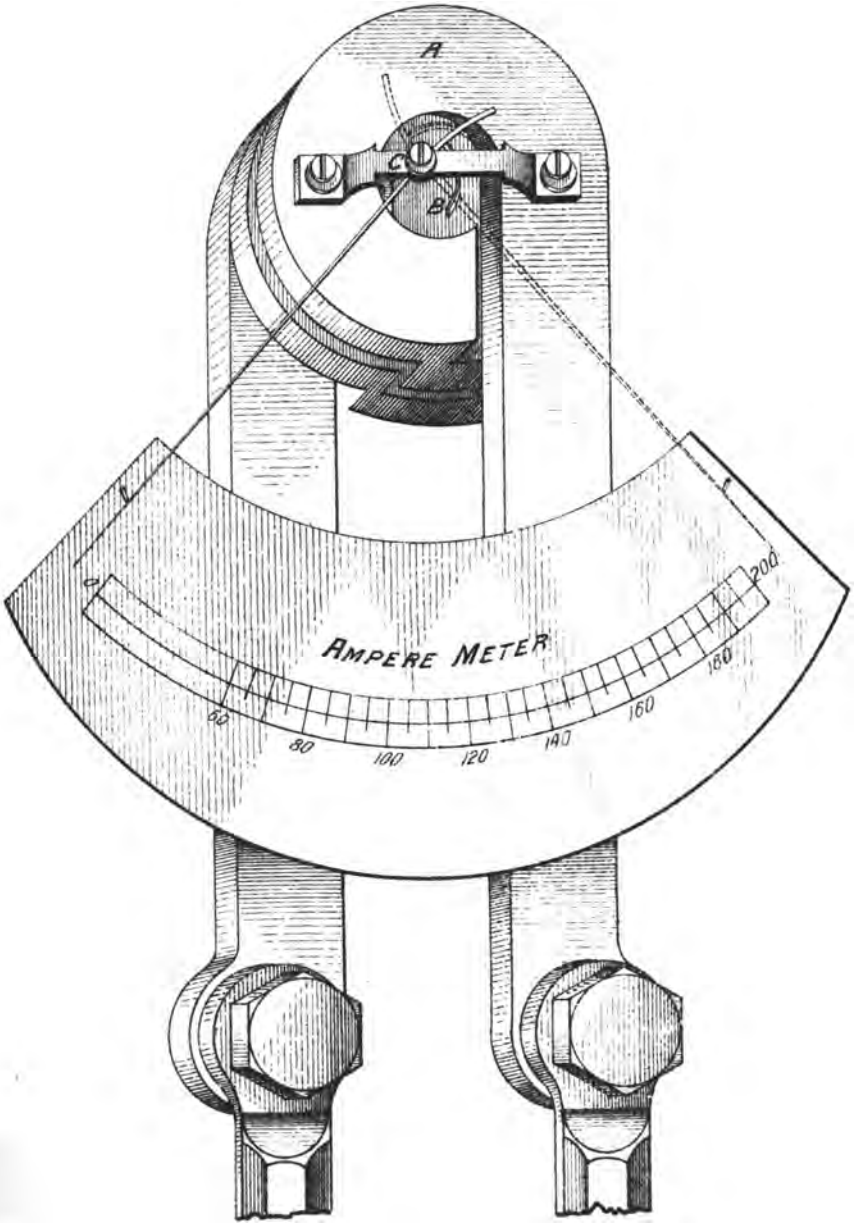



PLAN. IN SECTION.

TO FACE P. 104.

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PLATE 26. SCHUCKERT'S AMMETER.




TO FACE P. 105.

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B, through which passes the current to be measured, F being in conection with G. The magnetising power of the helix is sufficient to practically saturate the iron core with magnetism for all currents within the range of the instrument. C is a soft iron needle attached to the top of the iron core, and, therefore, also saturated with magnetism, forming, in fact, the free pole of the core. This moves just over a piece of brass D, through which the current flows, and which, therefore, exerts a deflecting force on the needle. C′ is a similar soft iron needle saturated with the same polarity as C, but projecting at 180° from it, so that no uniform magnetic field has any deflecting force on the system. C′ is, however, just underneath the brass conductor, and the deflecting force of the current on it is therefore added to that on C. This deflecting force is opposed by a torsion spring E, coiled like the hair-spring of a watch, so as to maintain the needle in the same position, and the angle of torsion necessary is indicated by a pointer moving over a scale, the indications being marked directly in ampères, the scale being uniform as soon as saturation is reached. Owing to the two soft iron needles being near together, no ordinary extraneous magnetic field is likely to appreciably affect the instrument, but, of course, it is affected if one pole of a magnet be held very near it. After taking a reading, the ammeter should be short-circuited and the pointer should be turned back to zero, so as not to leave any torsion on the spring.

## Schuckert Ammeter.

The Schuckert ammeter is a much cheaper instrument, and is intended to be fixed permanently in the circuit of each search-light as an indicator.

It is a direct-reading instrument which requires no manipulation. It is intended to be fixed against a vertical wall, and is in consequence very convenient for use in an engine room.

Its principle is as follows (see *Plate* 26):—

A is a helix of three turns of copper bar; B is a small curved piece of very thin sheet iron, moving at the end of an arm about a pivot C, placed eccentrically as regards the helix. A long pointer moves with the sheet iron over a scale. The arrangement is weighted, so that when no current is passing, the sheet iron is at some distance from the copper helix, although within it; and when

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a current passes through the latter, the iron moves so as to place itself in a stronger field (*i.e.*, nearer the copper conductor): as it does so, the opposing force (gravity) has its moment increased. The forces are, of course, very weak, and the chief drawback is that the instrument is not quite dead beat.

It is not affected by any uniform field, however strong, but, of course, is strongly affected if put near the pole of a strong magnet.

## (2). Voltmeters.

Voltmeters may be made on the same principle as any of the above ammeters, the only difference being that their coils must be of high resistance.

### Cardew Voltmeter.

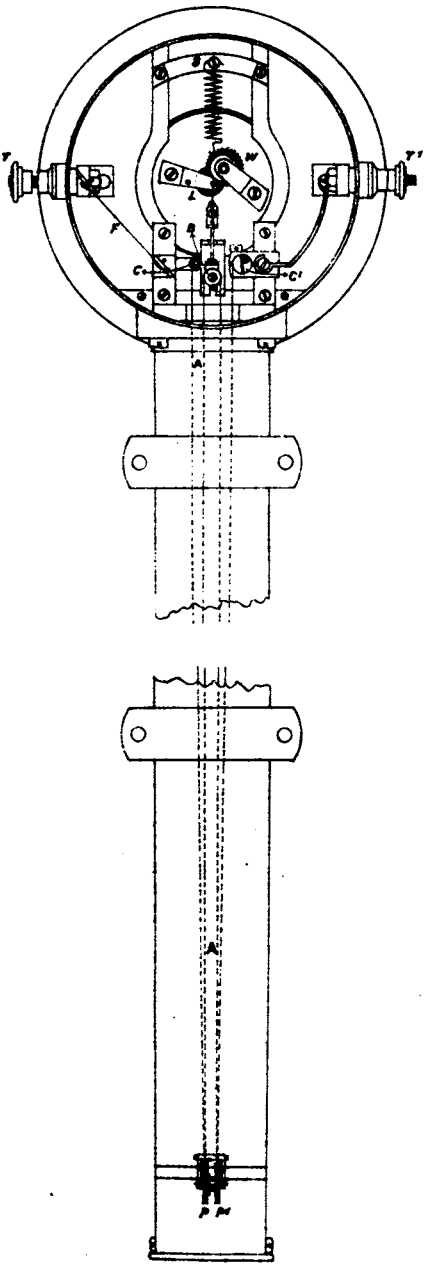
The Cardew voltmeter, however, which is adopted in the Service is on quite a different principle.

In this instrument the heating and not the magnetic action of the current is made use of, and, consequently, it is very suitable for use in dynamos and engine rooms, as it is absolutely unaffected by masses of iron, magnetised or otherwise, moving in its neighbourhood. The heating effect is measured by the expansion of a conductor connecting the two points, the difference of potential between which it is desired to know. As this conductor has a high resistance, the current through it is very small, and, consequently, so also is the energy absorbed.

The pattern used in the Service consists of a brass tube two inches in diameter, and about three feet long; at one end is fixed a wooden or brass box. The conductor A A (*Plate* 27) passes twice up and down the tube; it consists of 12 feet of platinum silver wire, ·0025 inch in diameter. The ends are fixed to the two supports C C′, which are in connection with the terminals T T′. The wire is then passed over the two pulleys P P′, and the centre is passed round the bone block B, which is held in place by the spring S attached to the frame of the instrument. The wire connecting this block to the spring passes round a grooved wheel, the shaft of which also carries a toothed wheel W, geared into a small pinion. On the end of the pinion shaft is fixed a pointer, moving over a

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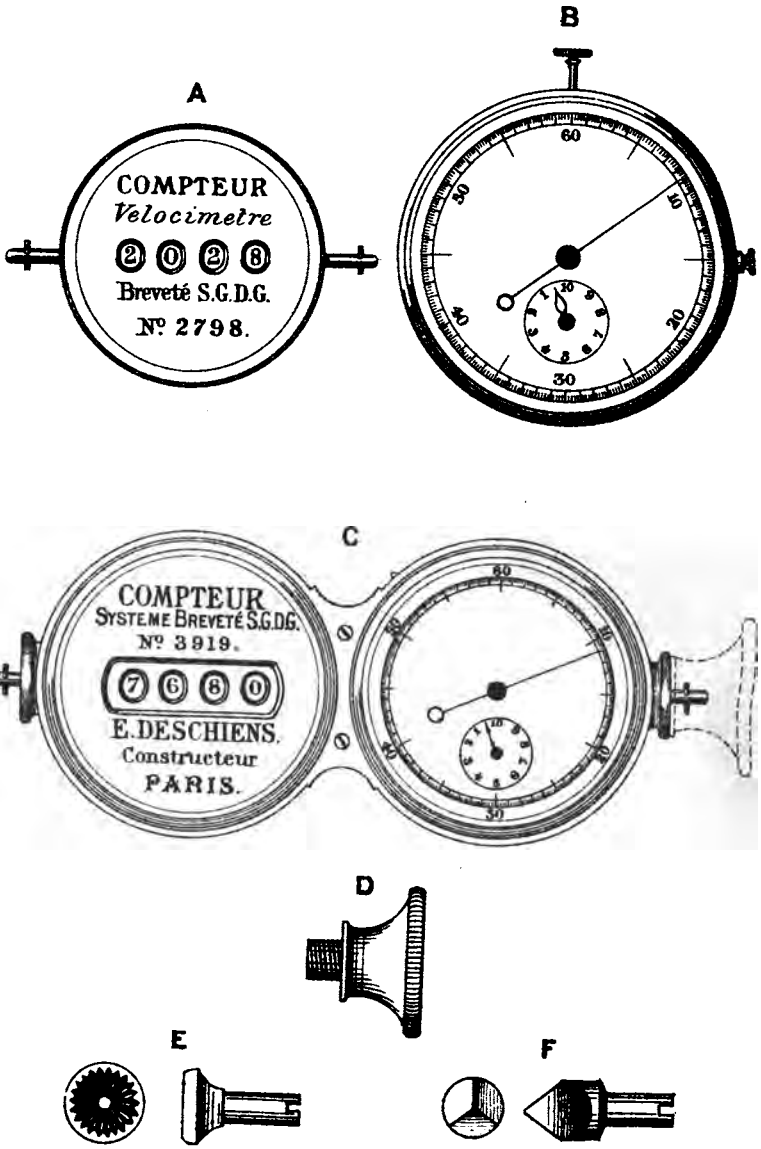
# CARDEW'S VOLTMETER. PLATE 27.



TO FACE P. 106.

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PLATE 28. VELOCIMETERS.




TO FACE P. 107.

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dial graduated in volts. The terminal T′ is connected direct to C′, but between T and C is inserted a fine fuze wire, F, ·0014 inch diameter, so that should the current get dangerously large by an accidental increase of volts, the fuze wire may melt, and so save the instrument.

The co-efficient of expansion for temperature of brass and platinum silver is almost the same, so that at all temperatures the instrument should be at zero when no current is passing through it. When any volts V are applied to the terminals, a current $\frac{V}{R}$ will pass through the wire, developing heat at the rate $\frac{V^2}{R}$ per second. This heat will raise the temperature of the wire, which will at once begin to radiate and heat the tube, which will also radiate into space; when the rate at which heat is being radiated away equals the rate at which it is being developed, the wire will be at a steady temperature, the temperature of the tube being somewhere between that of the wire and of the outside air. The difference of temperature between the wire and the tube is measured by the difference of expansion, which is indicated by the pointer on the dial. This difference of temperature is constant for the same difference of potential, except for the fact that the resistance of the wire varies slightly with its temperature. This has the effect of causing the reading for any volts to be slightly higher on a cold day than on a warm one; but as the platinum silver used only varies ·035 per cent. per degree centigrade, this error is not worth consideration, so long as the surrounding air is at an ordinary temperature.

### (3). Velocimeter.

The velocimeter, or revolution counter (*Plate* 28), is simply a mechanical arrangement for indicating by figures, arranged round the circumferences of four drums, the number of revolutions through which the spindle of the counter has been turned.

To take the speed of any shaft, etc., a point F is fixed on the end of the spindle and firmly pressed into the small hole usually found in the end of the shaft. The time should be taken by means of a stop-watch. The number of revolutions is the difference (either way) between the numbers on the dial before and after making the test. In some patterns of velocimeter the stop-watch and counter form

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parts of the same instrument, the former being automatically started as the point of the counter is pressed against the shaft, and stopped when the pressure is released. This form is shown at C (*Plate* 28). The point F can be fixed at either end of the spindle, the end not used being covered by the handle D. E is a form of point with a counter-sunk end intended to be used if the shaft whose revolutions are to be counted ends in a point.

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# CHAPTER XIV.

## ELECTRIC LIGHT LEADS AND OTHER ACCESSORIES.

THE following is a list of leads used for electric lighting, together with their resistances and safe-working currents; some of these are now obsolete, but stores of them exist at some stations.

TABLE.

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| Class. | Number. | Diameter of Conductor. | Outside Diameter. | Outside Covering or Armouring. | Dielectric. | Weight per mile. | Breaking weight, lbs. | Resistance at 75° Fahr. per mile. | Resistance at 75° Fahr. per 100 yards. | Safe current in ampères. | Designation in Vocabulary of Stores. | Remarks. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | inch | inch | | | lbs. | lbs. | ohms | ohms | | | |
| A | 6 | ·238 | ·290 | Nil ... ... ... | Tape primed with india-rubber | 917·5 | 1680 | 1·02 | ·06 | 92 | A 6 copper 0·238″ indiarubber primed tape | |
| B | 7 | ·243 double condctr. | $1\frac{1}{4} \times \frac{5}{8}$ | Layers of prepared tape | Guttapercha ... | 1775 | 3360 | 1·00 | ·06 | 92 | B 7 copper double ·243″ guttapercha taped and tarred | Obsolete |
| C | 3 | ·065 19 strand | ·437 | Indiarubber primed tape | Indiarubber ... | 1358 | 2383 | ·64 | ·04 | 150 | C 3 copper ·065″ 19 strand to ·437″ I.R., with indiarubber primed tape | Obsolete |
| C | 7 | ·068 37 strand | ·776 | Tape, serving of jute yarn, covered with tape | Pure india-rubber | 3281 | — | ·33 | ·02 | 250 | C 7 37 strand ·068″ covered with I.R. and tape | |
| C | 9 | ·068 19 strand | ·640 | Tape, serving of jute yarn, covered with tape | Pure india-rubber | 1870 | — | ·64 | ·04 | 150 | C 9 copper, 19 strand ·068″ each covered I.R. & tape | |

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These leads are not intended for use under water, the covering being only sufficient to prevent leakage into damp soil or wet grass, and to prevent the two conductors from touching when laid alongside each other.

For permanent installations they should be laid in pipes (earthenware or iron), precautions being taken to prevent the latter getting filled with water. It is desirable to use better insulated wires for underground work in pipes. If an iron pipe is laid it may be used as the return lead, care being taken to insure the joints being good, otherwise the large currents used will develop heat at these points damaging the dielectric of the cable and perhaps causing a short circuit.

The joints may be rendered electrically good by bridging them over with stout straps of iron about 2″ × ½″ section, and by bolting the straps to the pipe on each side of the joint with iron screws tapped into both pipe and strap.

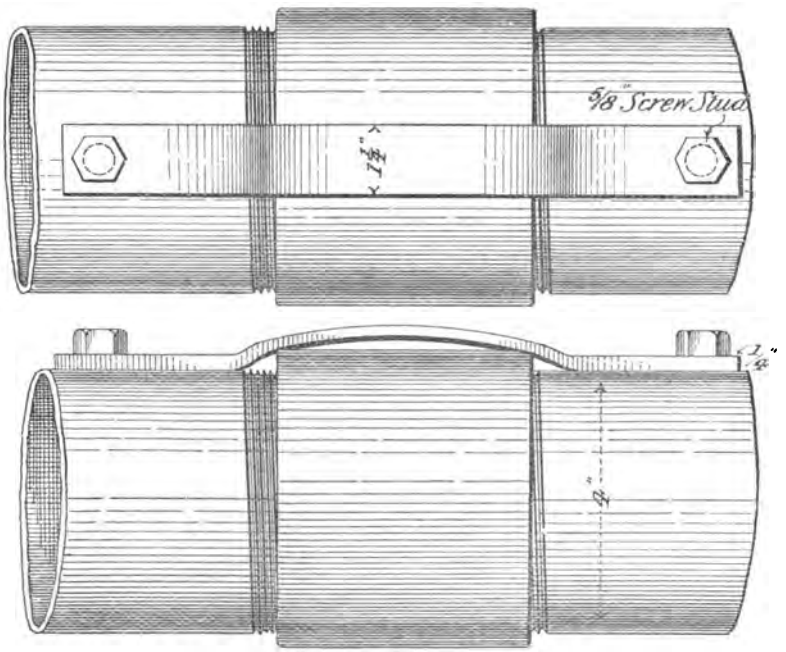



*Fig.* 66.

*Fig.* 66 shows plan and elevation of a suitable wrought iron

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pipe (originally intended for water pipes in the Suakin campaign of 1885); when the joints are carefully screwed up the resistance of this pipe does not exceed ·025 ohms per 100 yards. The cable should be carefully drawn through it, and it should further be protected with wrappings of old canvas, rope, etc.

*Fig.* 66 shows an iron strap secured to the pipes on each side of a joint with $\frac{5}{8}$ inches screw studs, the strap and pipe both being tapped to receive them.

### Joints.

To make a joint in strand wire electric light leads the whole of the inside strands should be cut away for about four inches and the outside ones spread out, straightened, and carefully cleaned. The two ends are now brought close together, the outside strands interlocked with each other. The outside strands of one cable are now tightly twisted round the standing part of the other, and *vice versa.*

The whole joint should now be sweated through with solder and insulated with indiarubber tape, and indiarubber primed or tarred tape.

### Voltmeter Leads.

The leads to the voltmeter may be of any of the Service insulated leads, such as $D_1$, $D_5$, $C_8$, $B_5$, etc.

### Flexible Leads.

Special flexible leads, capable of carrying the full current, are required to connect the lamp with the base of the projector. There are two kinds, one consisting of 935 strands of No. 28 B.W.G. copper wire for currents of from 50 to 100 ampères, and the other consisting of 1,064 strands of No. 20 B.W.G. copper wire for currents of from 100 to 200 ampères.

### Connectors.

*Plate* 29, *Fig.* 1, shows a connector for joining two electric light leads, the ends to be connected must be tightly twisted, cleaned, and firmly screwed into the holes at the ends of the connector.

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PLATE 29.

FIG. 1

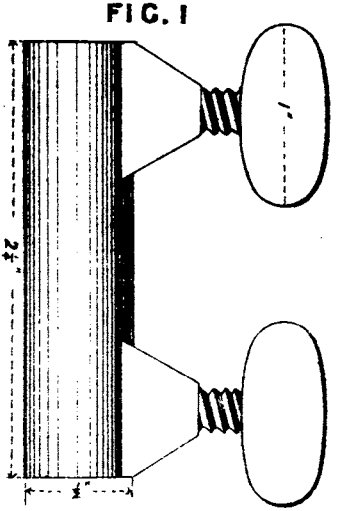



FIG. 2

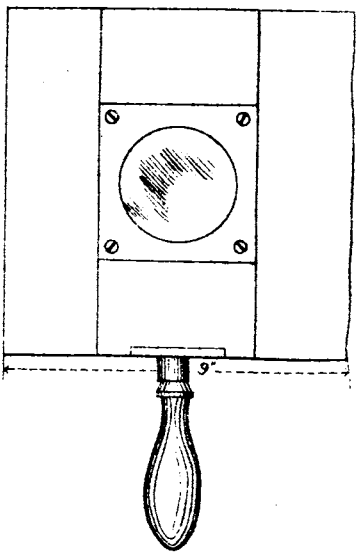
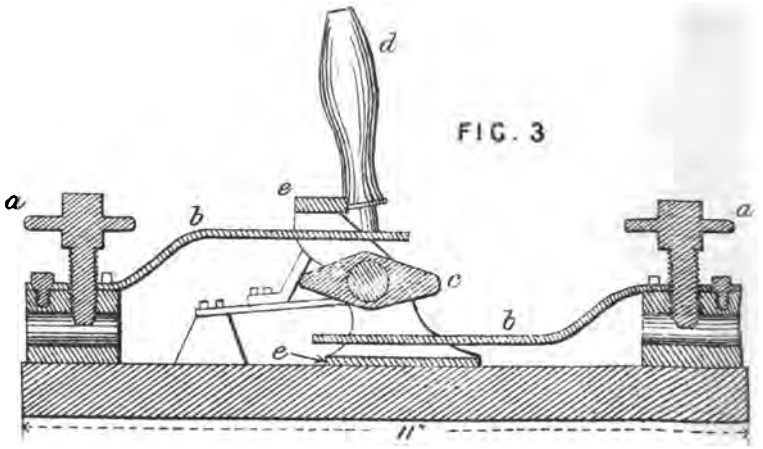



FIG. 3




TO FACE P. 113.

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## Switches.

Switches are necessary in electric light circuits so that the current may be switched on or off when required, although the latter operation should never be performed except in cases of necessity, for as before stated the currents, induced when a circuit carrying a large current is broken, are liable to cause damage to the dynamo. The switch must, of course, be able to carry without dangerous heating, the largest currents likely to be used. The Service switch shown (*Plate* 29, *Fig.* 3), is designed to carry 200 ampères. It consists of a wooden base carrying two terminals, *a a*, to which the stout brass straps, *b b*, are attached; contact is made between them by means of the shuttle shaped block, *c*, moved by the handle, *d*. When firmly pressed down the block *c* press the straps outwards, so as to make contact also with bridge *e*. The object of this is that on breaking a large current these surfaces (between *b b* and *e*) may not be damaged by arcing, as contact is kept up through *c* after the surfaces have separated, the surfaces between *b b* and *c* will be damaged when the current is finally broken, but this does not matter.

## Dark Glasses.

The arc may be observed with the focus observer, explained on page 100, or through dark glasses. The dark glass may be fixed in the side of the projector in a convenient position, or may be separate. Dark spectacles were used at one time, but a wooden frame with two thicknesses of dark glass let into the middle is now considered more convenient and protective to the eyes (*Plate* 29, *Fig.* 2). The frame is provided with a handle. If the glass is broken a fresh piece can easily be put in. There should be a layer of green glass and a layer of ruby coloured glass superinposed upon one another.

It should be borne in mind that it is highly injurious to the eyes to observe, even for an instant, the arc when at close distance. If a dark glass be not available an excellent temporary substitute can be made by smoking a piece of glass over the flame of a candle.



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# CHAPTER XV.

## AUTOMATIC SHUNTS.

When a dynamo is generating a large current, and the latter is interrupted from any cause, the engine, unless provided with a quick acting automatic cut off, is bound to race, and may do itself and the dynamo some injury. In order to give the engine work to do when the load of the arc is taken off it, automatic shunts are employed.

There are two patterns of automatic shunt:—

(*a*). Automatic shunt for use with Siemens apparatus.

(*b*). Automatic shunt, with resistance.

### (*a*). Siemens Automatic Shunt.

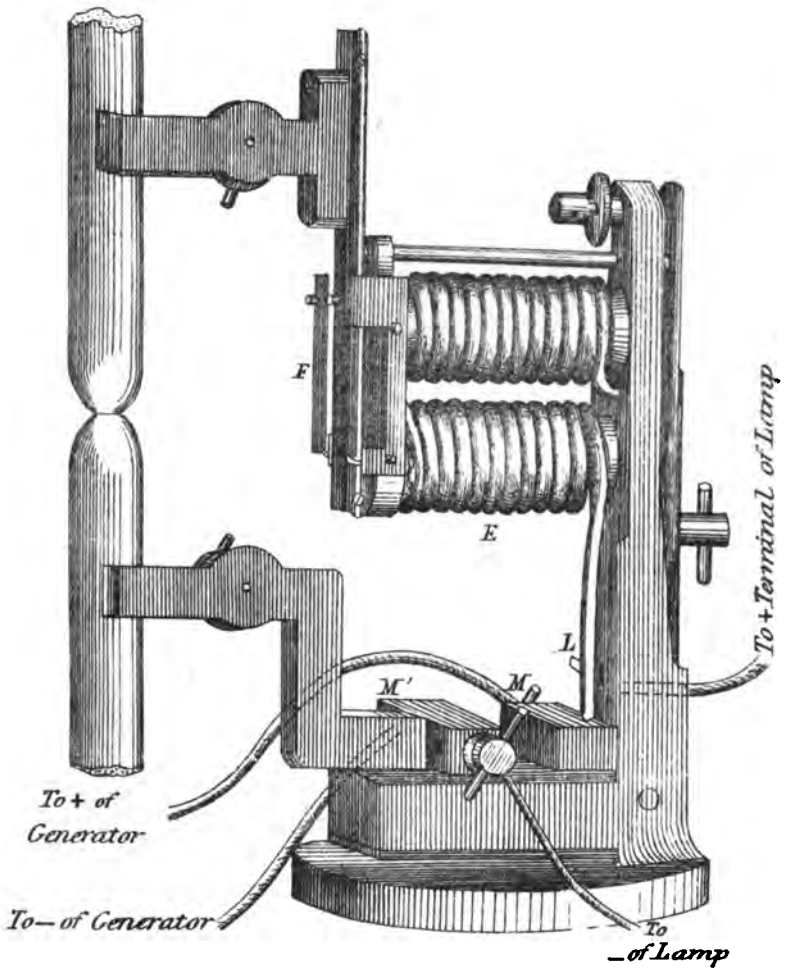
This shunt is arranged to throw an electric arc into circuit when the lamp goes out, thus giving the engine and dynamo a load almost equal to that of the lamp and preventing the former from racing. It consists of electro-magnet E, *Plate* 30, to the movable armature F, of which a carbon holder is attached. The lower carbon holder is fixed immediately below it, and when no current passes in the coils of the electro-magnet the carbons are in contact. When the lamp is working properly a strong current passes from the dynamo to M, through the coils of the electro-magnet (the other end of which is attached to the body of the shunt) to the terminal L to the positive of the lamp, through the arc, back to the lower carbon holder of the shunt and to M′, and thus to the negative of the dynamo. If the lamp goes out the current ceases, the carbons of the shunt drop together; the current is re-established through them, the shunt

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# AUTOMATIC SHUNT

*For use with Siemens' electric light apparatus*

*Scale ½*

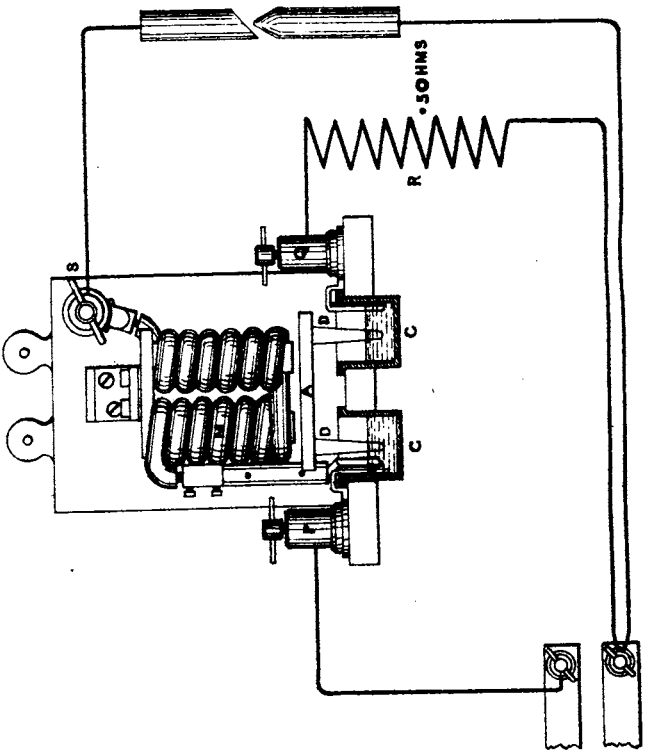



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PLATE 31.

# AUTOMATIC SHUNT WITH WIRE RESISTANCE




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coils striking the arc, and affording work for the engine. This goes on till the carbons at the lamp are brought together again, when the current is diverted from the shunt arc, which goes out, its carbons being still held apart by the current to the lamp.

This form of automatic shunt has not been found very satisfactory, and is superseded by the following.

### (*b*). Automatic Shunt with Resistance.

The new pattern of automatic shunt consists of an electro-magnet. M (*Plate* 31), wound with a few turns of insulated wire thick enough to take the whole current of the dynamo. The ends of the coil go to the terminals S and P. A is the armature which is furnished with two horns D D dipping into two mercury cups C C, one of which is connected to P, and the other to the terminal Q. R is a wire or gauze resistance, of about ·5 ohms resistance, and capable of carrying a current of 150 to 200 ampères. One main lead goes direct from one terminal of the dynamo to the lamp, and to this terminal of the dynamo one end of the resistance R is also attached, the other end being connected to Q. The other main lead is connected to S, and the other pole of the dynamo to P When the dynamo is started and run at, say 65 or 70 volts, a current of 130 to 140 ampères will evidently be driven through R. When the carbons of the lamp are brought together the current is shunted from R, and a large current passes round the electro-magnet coils. The armature A is attracted, and contract between P and Q is broken. When the light goes out the armature drops, and circuit is again established through R.

Automatic shunts are intended to be fixed in the dynamo room, and not at the search light.



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# CHAPTER XVI.

## DIRECTING THE LIGHT.

THE best positions from which to observe distant objects illuminated by the electric light is 200 or 300 yards to a flank, or above or below the light. In order that an observer may be able to direct the light from such a position, two arrangements are used in the Service.

(*a*). An arrangement by which the observer traverses and elevates the plane glass mirror or projector by means of electric motors.

(*b*). An apparatus by which the observer signals to the party at the lamp in what direction he wishes the light moved.

### (*a*). MOTOR APPARATUS.

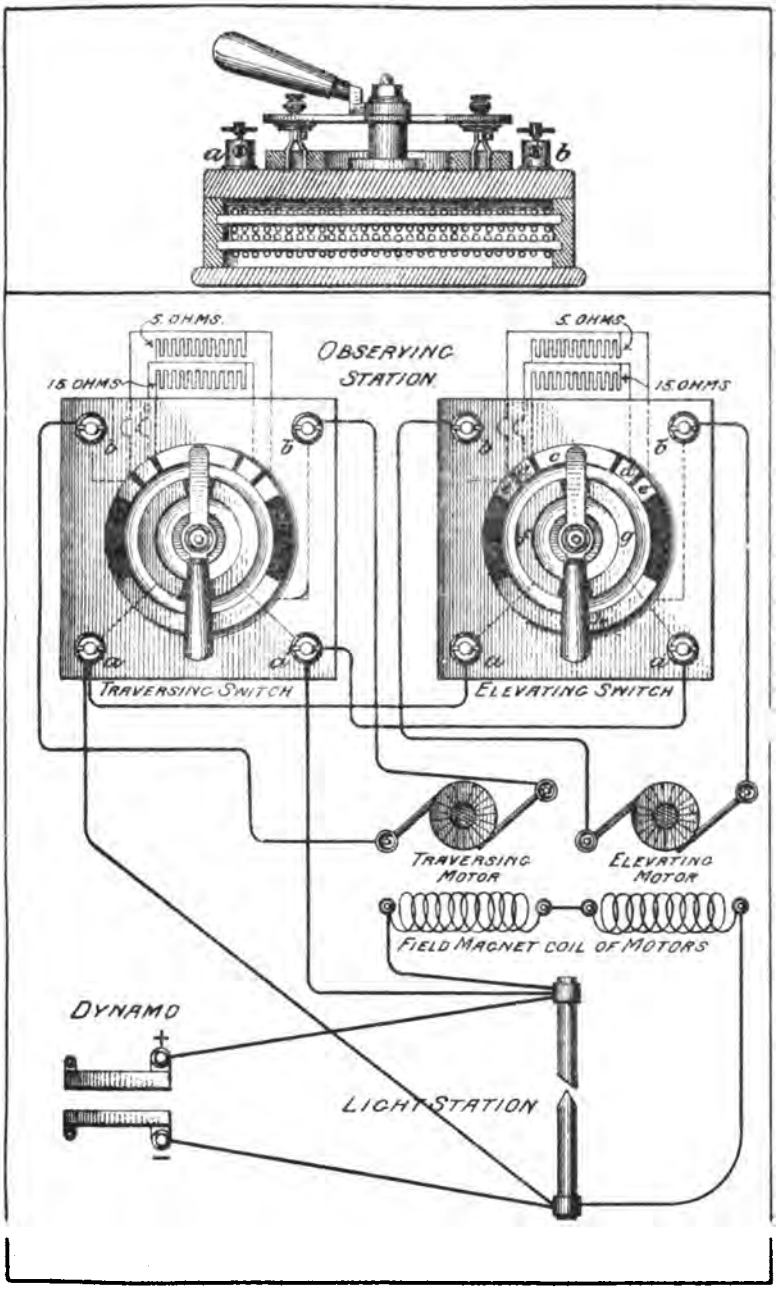
The motor arrangement (*Plate* 32) has, as yet, only been applied to moving the plane mirror on the see-saw apparatus, but it seems probable that the system will be extended so as to move the projector also.

Two small electric motors are mounted on the girder at the position *e* (*Plate* 23). These motors, by suitable gearing, elevate and traverse the plane mirror by means of stretched wires, one traversing and the other elevating and depressing.

The field magnets of the motors are excited in series with each other by a current shunted from the lamp. The brushes of both motors are connected by two pairs of leads to two switches at the observing station. These switches are capable of turning on a current in either direction through the motors, and with, or without,

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# SWITCH FOR MOTOR GEARING PLATE 32.

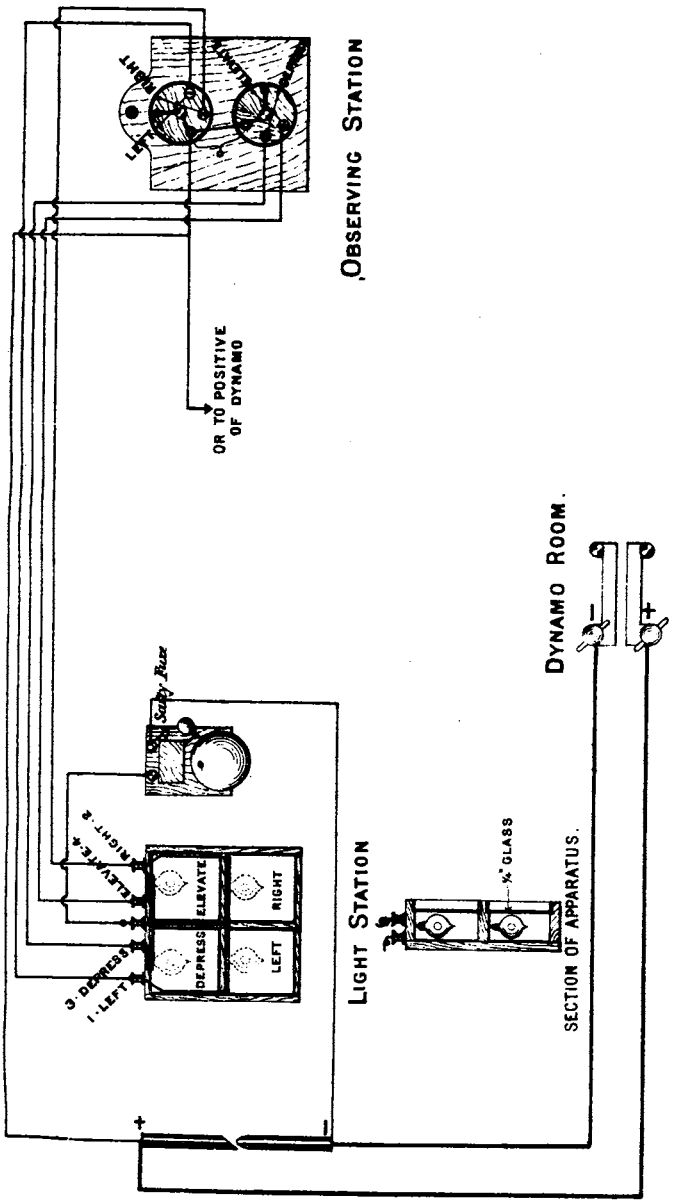



To face P. 116

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# APPARATUS SIGNALLING PLATE 33.

*For directing the El Light from a distance.*




*To face P. 116.*

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a certain amount of resistance in circuit, so that the movement of the motor armatures, and therefore of the beam, is entirely in the hands of the observer. The switches are directly connected to the dynamo by a separate pair of leads. *Plate* 32 shows the form of switch used at the observing station; the leads from the dynamo or lamp are attached to *a a'*, and the motor leads to *b b'*, although a reversal is of no importance.

Resistances of 5 and 15 ohms, wound on slate slabs, are fixed in the base of the switch, and are connected to the plates *c d d' e e'*, as shown in the diagram. The terminals *a a' b b'* are connected to the plates *f g e h* respectively. If the switch be moved over so that contact is made between *c* and *f*, and between *h* and *g*, the current will pass in a certain direction through the motor and the two resistances. If the switch be moved on to *d* the 15 ohms resistance will be cut out, the current will be greater, and the motor will move faster. By moving the switch on to *e* both resistances are cut out. If the switch be moved over the other way to *d'* or *e'* the current will pass through the motor in the opposite direction, and consequently the motion of the motor will be reversed.

Six leads are required between the light and the observing station. The 7-cored armoured cable used in submarine mining would be suitable, as it could then be buried.

### (*b*). Signalling Apparatus.

The apparatus for directing the electric light from a distance by means of signals consists of a sending and receiving portion.

The receiving portion (*Plate* 33), which is used at the light station, consists of a wooden box about 13 inches square and 5 inches deep, divided into four compartments, each containing a 60-volt 16-c.p. incandescent lamp. The front of each compartment is of glass, on the inside of which is pasted a paper with the words "elevate," "depress," "right," and "left," printed reversed on the inside. When any lamp is lit one of these words is clearly seen from the front. The four terminals on the top of the box marked "elevate," "depress," "right," and "left," are each connected to one terminal of the lamp in the corresponding compartment; the other terminals of each lamp is connected to the fifth, or general terminal, marked O.

A single stroke bell of low resistance is used in connection with the box of lamps to call the attention of the man who is to use the

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light. It works with the current for one incandescent lamp. It has two gongs, so as to ring both on make and break of circuit. Clips to hold a fuze wire are attached to it, and a fuze to cut out at about four ampères inserted; two ·003-inch platinum wires would be suitable.

The sending apparatus consists of two two-way switches attached to a board, as shown in *Plate* 33; one gives the motions "elevate" and "depress," and the other "right" and "left," the motion of the arm in each case corresponding with the desired movements of the beam. The central position for each arm is indicated by a slight catch, and when both arms are at this position, no lamp is lighted.

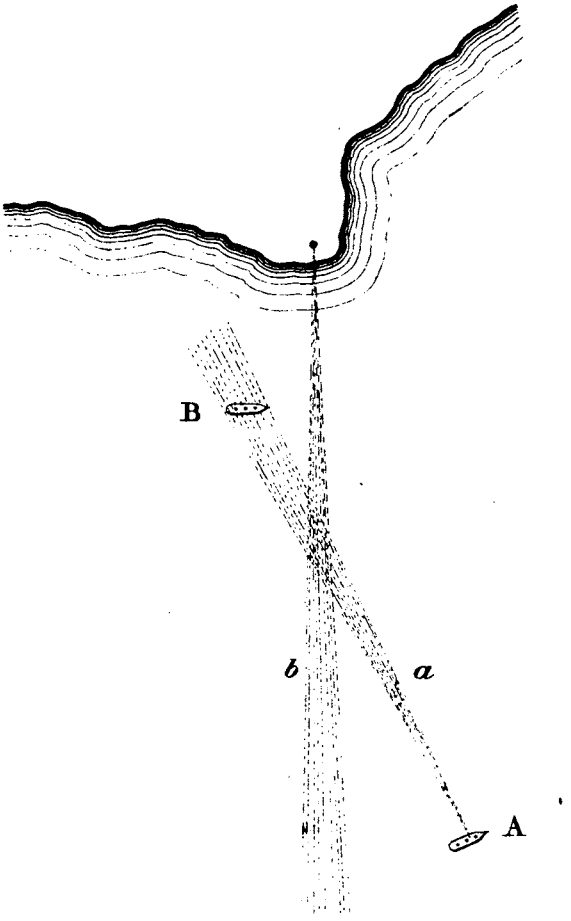
Four leads are required between the observing station and the light station, and, in addition, the two switch arms must be connected together, and to the positive of the lamp or dynamo, according to which is most convenient. The centre terminal on the lamp box is connected to one terminal of the bell, the other being connected to the negative of the lamp. Any of the light Service cables will be suitable for these leads; the 4-cored cable especially so. They should be carefully laid in pipes, or in some other suitable way, and the cores identified and marked at both ends. Arrangements should generally be made for one or more observing stations on each flank of the light.

The signals are as follows: a simple steady exposure of one word means that the light is to be moved *very slowly* in that direction till the word disappears; if a word is only shown for an instant, a very slight movement only is required. A series of long exposures, separated by short intervals of darkness, means that the rate of motion may be increased. A quick series of exposures, and intervals of darkness, means that the light is to be unclamped and quickly swung round by hand.

The limit of distance at which the observing station may be fixed depends upon the size of wire used for leads. It is undesirable to exceed an added resistance of 15 ohms in the circuit of each lamp, or say one mile of No. 8 B.W.G. iron wire.

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# PLATE 34.




TO FACE P. 119.

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# CHAPTER XVII.

## TACTICAL USE OF THE ELECTRIC LIGHT.

LITTLE is known of the use of the electric light in time of war; the following suggestions may, however, be found useful:—

The electric light may be used for two purposes: (i), to enable you to see the enemy; (ii), to prevent the enemy seeing you.

(i). This may be done in several ways—

(*a*). By using it as a moving search light.

(*b*). As a fixed beam across the ground the enemy must pass over.

(*c*). By illuminating a distant shore, rocks, etc., so that an enemy, passing between you and it, will be seen.

(*d*). By using the beam itself as a background against which the enemy will be seen silhouetted; a slight mist is most favourable for this use.

(ii). The enemy may be prevented from seeing you, or at least inconvenienced.

(*a*). By flashing the light in his eyes in order to dazzle him.

(*b*). By using the beam as a screen. It is found very difficult to see objects through the beam unless brilliantly illuminated, especially when there is any mist and the observer is looking obliquely through the beam. Thus a boat B (*Plate* 34), screened behind the beam *b*, would very likely be invisible to an enemy at A, although illuminated by his beam *a*.

The projector is extremely difficult to hit with shells or rifle bullets, on account of the impossibility of determining the range with any accuracy. It is practically impossible to *aim* rifles at the light The electric light also affords protection to objects in its immediate neighbourhood by the denseness of the obscurity which it casts around.

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It is found that if the beam be made to strike the ground between the enemy and the projector, but considerably nearer to the latter than to the former, the effect is as if the projector were situated immediately over the spot of ground illuminated; and if the beam be slightly elevated, it seems as if the projector itself were advancing. By manœuvring the projector in this way, it will become impossible to estimate its range from the front.

To utilize the full power of the search light, it is necessary that the arc should be tranquil, neither hissing, nor blown about by the wind. An unsteady arc makes it very difficult to observe the objects on which it is directed.

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# CHAPTER XVIII.

## DISTANCE OF LIGHT FROM DYNAMO.

SINCE there is necessarily a loss of potential in the leads varying directly with their length, it is evident that, to supply the same current with the same difference of potential at the lamp, the speed of the machine must increase to some extent for any increase of length in the leads.

As the new pattern machines, however, have such a very low internal resistance, not exceeding ·03 ohm, it is found desirable, though not necessary, to give the requisite steadiness to the lamp to work through a certain amount of external resistance, allowing for a loss of at least 12 volts.

This resistance will in general be most economically provided in the leads themselves.

Taking the normal current of the machine at 150 ampères, a loss of 12 volts implies a resistance of ·08 ohm, or,

(*a*). With C 7 leads 400 yards.

(*b*). With C 9 leads 200 yards.

The distance of lamp in each case being any distance up to one-half the length of leads, which, however, should not be shortened for shorter distances.

We arrive, therefore, at the conclusion that, for distances of 100 yards or less. C 9 leads should be used, and between 200 yards and 100 yards C 7 leads, with the minimum speed of machine.

These distances may, however, in each case, be exceeded by an increase of speed in the machine, or by using leads in parallel, or by using smaller carbons and a smaller current from the machine.

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The increase of speed admissable is limited by the following considerations:—

(*a*). The liability of the shunt coil of the machine to overheating from the increased current put into it, and to damage to insulation from increased tension.

(*b*). The increased liability to mechanical injury resulting to the engine or dynamo.

(*c*). The extra power required.

Taking these into consideration, it is not advisable to incur an increase of speed of more than 20 per cent. when the light is not likely to be required for long periods uninterruptedly, or of 10 per cent. where continuous running for many hours is necessary.

These limits may be exceeded in exceptional cases by adding a certain amount of resistance in the shunt circuit, provided that the necessary power is available.

To arrive at the increased distance available with this increase of speed, we require to know the difference of potential at the terminals of the dynamo in each case. This is obtained as follows:—

From the equation given on page 80, $V = 40 + \cdot 12\,C$, we obtain, as the necessary difference of potential at the lamp for a current of 150, a value of 58 volts. Adding 12 volts lost in the leads at normal running, we arrive at 70 volts at the machine terminals.

This difference of potential may safely be taken to increase for 10 or 20 per cent. increase of speed proportionally to it. With 10 per cent. increase of speed, therefore, we get 7 volts extra, or an additional increase in length of leads of

200 yards with C 7,
or
100 yards' distance.
} Total distance, 300 yards.

and 100 yards with C 9,
or
50 yards' distance.
} Total distance, 150 yards.

and with 20 per cent. increase of speed double these amounts.

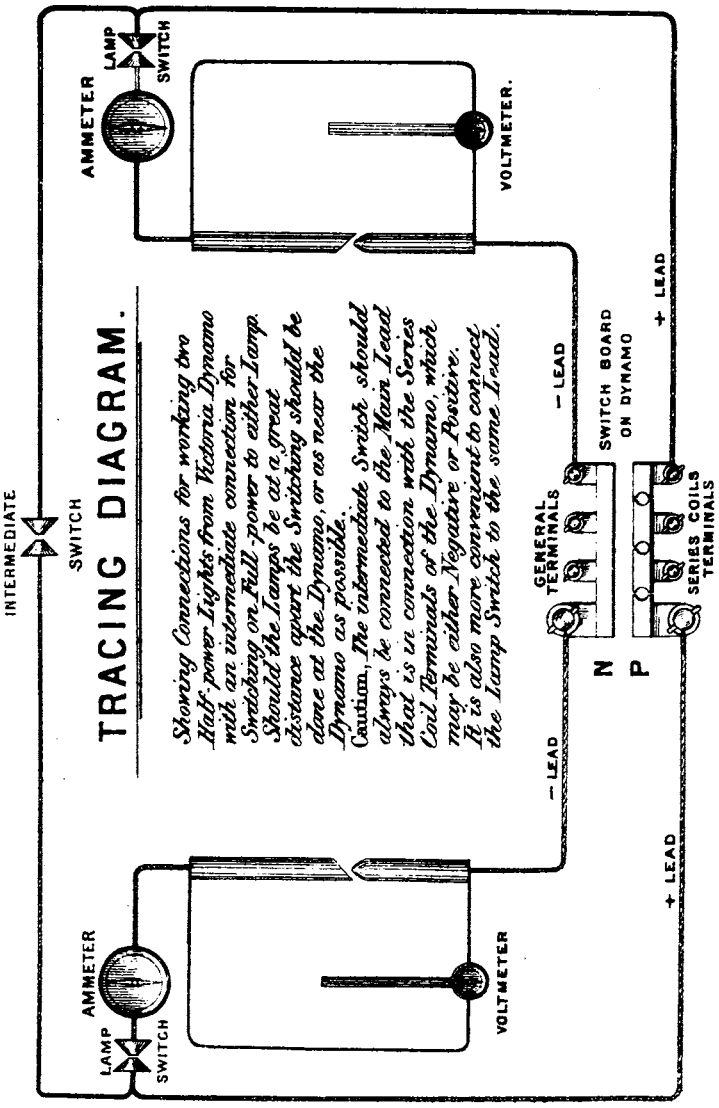
The increase of distance effected by the use of leads in parallel is, of course, easily calculated, and power will be saved by the adoption of this expedient.

The question whether it will be more economical to save power at a greater first cost of leads, of course depends upon the cost of power and the quantity expended during the year, according to Sir W. Thomson's well-known rule.

It may be remarked, however, that the power expended with a

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# PLATE 35.




To face P. 123.

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current of 150 ampères in 100 yards of C 9, or 200 yards of C 7 lead, amounts to 1·2 H.P., or 10 per cent. of that in the arc.

The use of a smaller current extends the distance both by a smaller rate of loss in the leads, and by the diminution in the volts required at the lamp.

Thus, taking 100 ampères, the volts required at the lamp will be 52, leaving at normal speed 18 volts for loss in the leads, or, with C 7 leads, a length of 900 yards, or 450 yards distance, and with C 9 leads, a length of 450 yards, or 225 yards distance.

It is obvious that where such lengths are used, or where the leads are used in parallel, greater attention must be paid to insulation, not only to prevent appreciable loss by leakage, but the probable deterioration of the insulation and metals of the conductors, and possibly of the machine, from the action of the leak. The insulation resistance should be at least 500 ohms, or, if there be dead earth on one side of machine, it should be 1,000 ohms for rest of circuit.

So far, one light alone from the machine has been considered, but where two or more lights are required, if it is also desired occasionally to utilize the full power in one light, special arrangements may be desirable to obtain the best result in each case.

When the two lights are stationed near each other, the arrangement indicated in *Plate* 35 will generally be sufficient; the two circuits being arranged for separate lights of 100 ampères, and the coupling together of the leads from the series coils being sufficient to provide the extra volts required for a single current of 150 ampères.

But when the lights are widely separate, necessitating separate circuits, it will not be practicable to run the lead shown at the top of the plate between the two lamps. Each circuit should be calculated for the full current of 150 ampères, and the peg switch T on the machine should be used; the voltmeter attached to the brushes in place of the terminals, and the machine run at speeds to give $72\frac{1}{2}$ volts for one light (equal to 70 volts at terminals), and $62\frac{1}{2}$ volts for the two lights; or, if an alteration of speed be impracticable, resistances of ·1 ohm must be introduced in each circuit for the separate lights. These resistances can be cheaply and efficiently obtained by the use of wire gauze, as used in the navy.

Finally, it will be judicious to consider whether, in some situations where the distance between machine and lamps is necessarily considerable, bare conductors, similar to those used in the C 7 and C 9 leads, could not be utilized, being supported and insulated in the

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usual way, being wrapped with indiarubber tape where they are led over the ground.

All the distances given above may be extended, if a hissing arc be employed, as follows:—

With 150 ampères, 400 yards increase of length, 200 yards of distance with C 7 leads; 200 yards of length, 100 yards of distance with C 9 leads.

With 100 ampères, 600 yards of length, 300 yards of distance with C 7 leads; 300 yards of length, 150 yards of distance with C 9 leads.

There is, however, no doubt that a quiet arc is to be preferred, both as giving more light for the same current and waste in machine and leads, and on account of the better burning of carbons.

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# APPENDIX A.

## DETAIL OF EQUIPMENT.

ELECTRIC light equipment is now issued in sets as follows:—

(*a*). Siemens.

(*b*). D Gramme.

(*c*). Victoria, or dynamo of similar power.

### (*a*). SIEMENS SET.

List of stores required for installation of five $D_2$ Siemens (converted) dynamos. In some cases three would be sufficient, and the list would have to be modified accordingly.

| | | |
|---|---|---|
| Apparatus, Signalling, for directing the beam from a distance, parts of:— | | |
| Receiving, with bell and lamps | No. | 1 |
| Transmitting, with switches | ,, | 2 |
| Lamps, incandescent spare | ,, | 4 |
| Cable, armoured 4-core | Mile | ¼ |
| ,, ,, single core | ,, | ¼ |
| Brushes, copper, for generators | Sets | 12 |
| Cans, oil, copper | No. | 2 |
| Carbons:— | | |
| Cored, 30 mm. | Feet run | 200 |
| ,, 25 mm. | ,, | 100 |
| Coppered, uncored, 17 mm. to 19 mm. | ,, | 100 |
| ,, ,, 16 mm. to 17 mm. | ,, | 50 |
| Conductors, $C_9$ | Yards | 500 |
| Clamps, trimming brush | No. | 2 |
| Counters, revolution | ,, | 1 |

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LIST OF STORES.—*Continued.*

| | | |
|---|---|---|
| Connectors, large, to take No. 0 wire ... ... ... | No. | 20 |
| Generators, dynamo-electric ... ... ... ... | ,, | 5 |
| Leads, flexible, insulated, conductor equal to No. 4 S.W. gauge ... ... ... ... ... ... ... ... | Yards | 50 |
| Instruments, measuring :— | | |
| Ammeters to read 10 to 150 ampères ... ... | No. | 1 |
| Voltmeters to read 30 to 120 volts ... ... ... | ,, | 2 |
| Detector ... ... ... ... ... ... | ,, | 1 |
| Resistance frames with wire gauze, ·2 ohm ... ... | ,, | 6 |
| Projectors, 3-foot, with Mangin mirror in replaceable ring ... ... ... ... ... ... ... ... | ,, | 1 |
| Spare 3-foot Mangin mirror in replaceable ring ... | ,, | 1 |
| Spare 3-foot Mangin mirror ... ... ... ... | ,, | 1 |
| Projectors, 2-foot, with ground Chance mirror in replaceable rings ... ... ... ... ... ... | ,, | 2 |
| Spare 2-foot cheap Chance mirrors, one in replaceable ring ... ... ... ... ... | ,, | 12 |
| Lamps, electric, hand ... ... ... ... ... | ,, | 3 |
| Spare parts for ditto ... ... ... ... ... | Sets | 1 |
| Switch board for five machines and four circuits, with switches and connections ... ... ... ... ... | No. | 1 |
| Switches, 200 ampères ... ... ... ... ... | ,, | 4 |
| Mirrors, plane, 4-foot... ... ... ... ... ... | ,, | 2 |
| Frames for ditto ... ... ... ... ... ... | ,, | 2 |
| Glasses, dark, in frame ... ... ... ... ... | ,, | 6 |

(*b*). D GRAMME SET.

| | | |
|---|---|---|
| Apparatus, signalling, for directing the beam from a distance, parts of :— | | |
| Receiving, with bell and lamps ... ... ... | No. | 1 |
| Transmitting, with switches... ... ... ... | ,, | 2 |
| Lamps, incandescent, spare ... ... ... ... | ,, | 4 |
| Cable, armoured 4-core ... ... ... ... | Mile | ¼ |
| ,, ,, single core ... ... ... ... | ,, | ¼ |
| Brushes, spare... ... ... ... ... ... ... | No. | 8 |
| Carbons, coppered, 20 mm. ... ... ... ... ... | Feet run | 400 |
| Conductors, $C_9$... ... ... ... ... ... ... | Yards | 250 |
| Clamps, trimming brush ... ... ... ... ... | No. | 1 |
| Counters, revolution ... .. ... ... ... ... | ,, | 1 |
| Connectors, large ... ... .. ... ... ... | ,, | 6 |
| Generator, D Gramme ... ... ... ... ... | ,, | 1 |
| Leads, flexible insulated ... ... ... ... ... | Yards | 20 |
| Instruments, measuring :— | | |
| Ammeter, to read from 10 to 150 ampères ... | No. | 1 |
| Voltmeter, to read from 30 to 120 volts ... ... | ,, | 1 |
| Detector ... ... ... ... ... ... | ,, | 1 |
| Projectors, Mangin, 90 c.m.... ... ... ... ... | ,, | 1 |
| Spare 90 c.m. Mangin mirror in replaceable ring, made to fit the projector ... ... ... ... | ,, | 1 |
| Spare 90 c.m. Mangin mirror ... ... ... | ,, | 1 |

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LIST OF STORES.—*Continued.*

| | | |
|---|---|---|
| Lamps, electric, hand ... .. ... ... ... | No. | 3 |
| Switches, 200 ampères ... ... ... ... ... | ,, | 2 |
| Mirrors, plane, 4-foot... ... ... ... ... ... | ,, | 2 |
| Frames for ditto ... ... ... ... ... ... ... | ,, | 2 |
| Glasses, dark, in frame ... ... ... ... ... | ,, | 3 |

## (*c*). VICTORIA, OR DYNAMO OF SIMILAR POWER.

| | | |
|---|---|---|
| Apparatus, signalling, for directing beam from a distance, parts of :— | | |
| Receiving, with bell and lamps ... ... ... | No. | 1 |
| Transmitting, with switches ... ... ... | ,, | 2 |
| Lamps, incandescent, spare ... ... ... ... | ,, | 4 |
| Cable, armoured 4-core ... ... ... ... | Mile | ¼ |
| ,, ,, single core... ... ... ... | ,, | ¼ |
| Apparatus, see-saw, to expose a projector or mirror fitted with motors for working mirrors from a distance, and hand wheels to work from below... ... .. ... | No. | 1 |
| Switch, elevating ... ... ... ... ... | ,, | 1 |
| ,, traversing ... ... ... ... ... | ,, | 1 |
| Switch for changing connections from signalling lamps to motors ... ... ... ... ... ... ... | ,, | 1 |
| Brushes, spare .. ... ... ... ... .. ... | ,, | 12 |
| Cans, oil, copper ... ... ... ... ... ... | ,, | 1 |
| Carbons :— | | |
| Cored, 30 mm.... ... .. ... ... ... | Feet run | 200 |
| ,, 25 mm.... ... . ... ... ... | ,, | 100 |
| Coppered, uncored, 17 to 19 mm. ... ... ... | ,, | 120 |
| ,, ,, 16 mm. to 17 mm. ... ... | ,, | 60 |
| Conductors, $C_7$ ... ... ... ... ... ... | Yards | 250 |
| ,, $C_9$ ... ... ... ... ... ... | ,, | 300 |
| Clamps, trimming brush ... ... ... ... ... | No. | 1 |
| Counters, revolution ... ... ... ... ... ... | ,, | 1 |
| Connectors, large ... ... ... ... ... ... | ,, | 20 |
| Generator, dynamo-electric ... ... ... ... ... | ,, | 1 |
| Leads, flexible insulated ... ... ... ... ... | Yards | 50 |
| Instruments, measuring :— | | |
| Ammeter, to read from 20 to 200 ampères ... | No. | 1 |
| Voltmeter, to read from 30 to 120 volts ... ... | ,, | 2 |
| Detector ... ... ... ... ... ... | ,, | 1 |
| Projectors, 3-foot, or Mangin with Mangin mirror in replaceable ring ... ... ... ... ... ... | ,, | 1 |
| Spare 3-foot Mangin mirror in replaceable ring ... | ,, | 1 |
| Spare 3-foot Mangin mirror ... ... ... ... | ,, | 1 |
| Projectors, 2-foot, with ground Chance mirror in replaceable ring ... ... ... ... ... ... | ,, | 2 |
| Spare 2-foot cheap Chance mirrors, one in spare replaceable ring ... ... .. ... ... | ,, | 12 |
| Lamps, electric, hand ... ... ... ... ... | ,, | 3 |
| Spare parts for ditto ... ... ... ... ... | Sets | 1 |
| Switches, 200 ampères ... ... ... ... ... | No. | 4 |
| Mirrors, plane, for see-saw silvered glass ... ... ... | ,, | 4 |
| ,, ,, metallic stretched ... ... ... | ,, | 2 |
| Glasses, dark, in frame ... ... ... ... ... | ,, | 6 |

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Of course the actual equipment supplied to any fortress, or position, will depend on the special requirements of the case, but the following may be taken roughly as the equipment suitable for an average fort.

### Engine and Dynamo.

(*a*). One engine and two dynamos (one spare), probably $D^2$ Victoria, or equivalent, in bombproof shelter inside the fort. Internal dimensions of shelter 44′ × 17′ × 11′ high.

### Long Range Apparatus.

Long range apparatus: 3-foot projector with 90 c.m. Mangin mirror, with spare Mangin mirror and parts, with glass and metal plane reflectors for short ranges. Apparatus for exposing either direct or reflected beam, and for working from a distant observing station, both by electro-motors and by signals; the observing stations being connected to the emplacement by six insulated leads, with suitable switches for changing from the motors to the signalling apparatus.

Emplacement for light: 20 feet of parapet, 15 feet breadth of banquette, 7 feet height of parapet, with recesses, etc., two observing stations, requiring 9 feet of parapet each.

Emplacement to be as far from guns as possible.

Observing stations: One on each side of the guns.

### Medium Range Apparatus.

Two medium range apparatus, each consisting of one 2-foot projector with 2-foot ground Chance mirrors, with spare cheap Chance mirrors, and spare parts.

Apparatus to be fitted up in emplacements outside the fort, one on each flank. To be directed from observing stations by means of signalling apparatus.

Each emplacement 24′ × 8′ with 4′·6″ parapet.

### Portable Equipment.

One steam sapper with portable search light equipment complete.

Six horse-power steam sapper-driving $C^2$ Victoria (mounted on it) by means of toothed gearing.

Two-foot projector with 60 c.m. Mangin mirror, with spare 2-foot ground and cheap Chance mirrors and spare parts, mounted on truck.

Signalling apparatus.

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# APPENDIX B.

## SPECIFICATION FOR DYNAMO MACHINE FOR ELECTRIC LIGHTING.

1. The dynamo is to be constructed to give a continuous current of 150 ampères, and 75 volts external, with an arc lamp burning 30 mm. positive carbons.

2. To be fitted with pulleys of such diameter as shall be directed, and wide enough to take a 10-inch belt.

3. The field magnets to be compound-wound, with a falling characteristic curve, the volts on open circuit being from 45 to 55 at the speed which gives 75 volts with full load.

4. The series coils are to be wound on the system to be seen on the Victoria brush dynamo generator at the S.M.E., Chatham, in which each series electro-magnet circuit consists of four separate coils, the ends of which are led to a commutator plate, so as to provide for taking separate leads from each coil to supply lamps in parallel, or connecting any number of coils together, to supply one large current at pleasure.

5. The machines must not be liable to injurious rise of temperature in any part from continuous running at the full capacity. This will be tested as follows :—

The machines will be run for one hour at a speed 10 per cent. in excess of proper speed, the resistance of the external circuit being such that the current attains a value of 10 per cent. in excess of the normal full current; after which—

(i). The temperature of the wire, either in the armature or field magnets (series and shunt coils), must not have risen more than 60° Fahrenheit.



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The rise of temperature to be estimated by balancing the resistance of each portion of the machine immediately before and after the run.

(ii). The brushes and collecting commutator must not be so hot as to be painful to the naked hand.

(iii). The bearings and axle must not be more than slightly warm to the touch.

6. The brushes must not press too firmly on the commutator, so as to cause excessive wear. This will be tested by measuring the force required to separate the brush from the commutator, the force being applied as close to the point of contact as possible. This force must not exceed 20 lbs. for each complete brush.

There must be an efficient and simple means provided of shifting the position of contact of the brushes on the commutator through an angle of at least 20°; also of replacing brushes while the machine is at work without at all interfering with the current; also of fixing the brushes back clear of the commutator.

7. The sparking between the brushes and the commutator must not be more than barely perceptible in daylight, either when the machine is running empty, or under any conditions of load; and it must always be possible to connect the terminals of the quantity coil of an ordinary quantity and intensity galvanometer to a brush, and to the revolving commutator, without producing a greater deflection than 30°.

8. The electric energy absorbed in the machine must not be more than $\frac{1}{10}$th of that given to the external circuit in any time when the full working load is on the machine.

9. The materials and workmanship throughout must be of the best quality, and the construction of the armature such as to efficiently resist the magnetic torque, and the centrifugal force due to its rotation.

10. The armature must be protected against injury from pieces of iron being accidentally drawn into contact with it while rotating.

11. The lubricators supplied must be thoroughly efficient and automatic in action, supplying exactly the necessary quantity of oil without waste.

12. As a test for insulation, the intensity coil of a Service quantity and intensity galvanometer will be connected to the base or frame of the dynamo, and to each of the terminals in succession, while the machine is running with the magnets fully excited, and with a

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difference of potential of 65 volts between terminals, when no visible deflection of the needle must be observed.

13. The insulation of the commutator and brush holders from the body of the machine must be provided by means of a thoroughly reliable and durable material, and must be of such thickness and so disposed as to preclude all risks of sparking or flashing across it, to the satisfaction of the inspecting officer.

## Test for Efficiency.

Each two machines (A and B) will be jointly tested for efficiency in the following manner:—

They will be fixed down parallel to each other and at a short distance apart, and the pulleys connected with a piece of belting, as represented in the diagram.

The terminals of A will be connected to a source of power, to be provided by the Contractor, by which a current, equal in power to the full capacity of the machine, viz., 150 ampères, 75 volts, can be supplied.

The series exciting coil of A may be either left out of circuit or reversed. The terminals of B will be connected to a suitable resistance R, capable of adjustment; A will thus be caused to revolve as a motor, and B to be driven by A.

The resistance R will be regulated until the proper working current of the machines is caused to pass through A.

The power P, electrically applied to A, and given out by B (P′) under these conditions, will be measured. P must be at least ·5 P′.

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# APPENDIX C.

## Constants of Dynamo Machines.

| Machine. | Type of | | Number of | | | Speed. | E.M.F | Current | Carbons to be used. | | Resistance in Ohms. | | | | Candle Power. | Weight. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Machine. | Armature. | F M Poles. | Brushes. | Sections of wire on Armature. | Revs. per minute. | Volts. | Ampères. | Positive. | Negative. | Machine. | F M Coil. | Armature Coil. | Shunt Coil. | | |
| $D^2$ Single Siemens | Series ... | Drum ... | 2 | 2 | 56 | 680 | 60 | 30 | 15 mm. lightly coppered | 15 mm. lightly coppered | ·64 | ·32 | ·32 | — | 8,000 | 4 cwt. |
| Do. Converted ... | Compound | Do. | 2 | 2 | 56 | 700 | 66 | 30 | Do. | Do. | ·48 | ·16 | ·32 | 38 | Do. | Do. |
| Two Siemens in parallel | Series ... | — | — | — | — | 680 | 60 | 60 | 20 mm. cored | 15 to 16 mm. coppered | ·32 | ·16 | ·16 | — | 20,000 | — |
| "D" Gramme ... | Series ... | Ring ... | 2 | 2 | 56 | 500 | 60 | 80 | Do. | Do. | ·32 | ·19 | ·13 | — | 25,000 | 20cwt. |
| $C_2$ Victoria ... ... | Compound | Disc and Ring | 4 | 2 | 60 to 100 | 710 | 60 to 75 | 120 | 30 mm. uncoppered and cored | 17 to 19 mm. heavily coppered | .0216 | ·008 | ·0136 | 8·44 | 92,000 | 15cwt. |
| $D_2$ Victoria, full power | Do. | Do. | Do. | Do. | 60 | 650 | 65 | 150 | Do. | Do. | ·035 | ·01 | ·025 | 7· | 50,000 | 17cwt. |
| $D_2$ Victoria, S type, with double pully no switch attchd. | Do. | Do. | Do. | Do. | Do. | 810 | 70 | 180 | Do. | Do. | ·023 | ·006 | ·017 | 11· | Do. | Do. |
| $D_2$ Victoria working as :— ¾ power ... | Do. | Do. | Do. | Do. | Do. | 650 | 65 | 120 | 25 mm. uncoppered and cored | 16 to 17 mm. coppered | ·938 | ·013 | ·025 | 7· | 32,000 | — |
| ½ power ... | Do. | Do. | Do. | Do. | Do. | 650 | 65 | 80 | 20 mm. cored | 15 to 16 mm. coppered | ·045 | ·02 | ·025 | 7· | 20,000 | — |
| ¼ power ... | Do. | Do. | Do. | Do. | Do. | 650 | 65 | 40 | 15 mm. lightly coppered | 15 mm. lightly coppered | ·065 | ·04 | ·025 | 7· | 8,000 | — |



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