In the series wound machines, the magnets are wound with a comparatively short length of wire, thick enough to carry the whole current generated, and are connected in series with the armature and brushes. This dynamo must be excited by another machine or battery when first used. When the magnets have been excited a *residual magnetism* will remain in them, and this slight magnetism developes a feeble current in the armature ring. This current strengthens the magnets, and they in turn strengthen the current in the armature. These alternate currents or reactions continue until the maximum current the machine can supply is generated, which varies from one or two seconds with small machines, to about three minutes in large machines. The practical current that can be taken out of a machine is limited by the capacity of the wire to carry it without undue heating; and the maximum is limited, first by the external resistance, or, if the machine be short-circuited, it is limited by the magnets approaching their saturation point, and by the internal resistance of the armature.

In shunt wound machines the magnets are wound with a large quantity of thin wire, which is connected with the armature brushes *in quantity* with the lamps or other external circuit. The currents in the magnets and lamps then divide according to the ordinary rules of divided circuits.

In compound machines the magnets are wound partly shunt and partly series.

A shunt wound machine cannot be short circuited without stopping the current as it is all removed from the magnets.

Armatures and comutators of the different types of machines are of various patterns, and the magnets are placed in very many different positions by each inventor.

Ring armatures, in which a large number of coils of wire are wound round a ring.

Drum armatures are wound lengthways over a drum or spindle, the wire being laid parallel to its axis.

Pole armatures in which the rotating coils are wound upon radial bars of iron, as upon the arms of electro-magnets—something like a spur wheel. The coils are almost without exception made to rotate, being lighter than the magnets.

Commutators.—To send the current from the generator into the wires as a continuous supply, a special device is employed, called a commutator, which, in the earliest form of generator, consisted of a piece of copper or brass tube slit longitudinally into two portions and fixed upon the axis of revolution so as to revolve with it, the two halves being fixed on a cylinder of insulating material, one of the halves being connected with one end of the wire of the coil and the other half with the other end, and against the tube pressed two contact springs or brushes to conduct the currents away. (See figure K.) The induced currents in the coils flow towards the commutator in the upper half of the revolution, and from the commutator in the lower half; then each half of the split tube, will, as it passes over the top of the axis, deliver to the upper contact spring, or brush, the current flowing into it, while the lower brush will always be feeding the return currents back into the lower half of the commutator. Of course in modern generators there are a number of coils in the armature which are necessary to procure a steady and continuous flow of current, and these coils are so arranged that they shall be brought successively into operation, the current beginning in one coil before it has ceased in another, the aim being to always have some of the coils passing through the point of maximum efficiency thereby securing the best of results—a steady and continuous current. If the coil, as shown in figure L, is revolved between the poles S an N—as it rises and revolves the number of lines of force that pass through the coil increases until it reaches 1, where the maximum number passes through—the current generated being inverse. After passing this point the number of lines of force decrease, and a direct current is induced in the coil until it arrives at 2, where the maximum is reached. From 1 to 2 will be a direct current in the coil, 2 to 1 an inverse current, the line 1—2 marking the boundary between the direct and inverse currents, and which is known as the diameter of commutation—1 and 2 being the contact points of the commutator brushes which convey the current to the main circuit for distiibution to the lamps. The bars of the commutator are so arranged that one does not cease to touch the brushes until the next has come up to contact, and there being no break in the continuity, the current is practically continuous.

In the former part of this paper it was stated that the heat produced by the electric current was conveyed through conductors and passed through the smallest possible space, so as to raise the temperature and cause light. According to the nature of the conductor passed through and made luminous by the current three large classes of practical means of producing electric light may be formed :—

1. RAREFIED AIR.—Made luminous by the passage of a current.
2. VOLTAIC ARC.—Formed by the passage of a current in air raised to a high temperature. This air heats the carbons or other bodies employed, by direct contact, and renders them incandescent.
3. INCANDESENCE.—Solid matter, generally carbon, raised directly to a high temperature by the passage of a current.

The first named has not been practically applied ; the second, commonly called the " Arc," and the third the " Incandescent," are the sources of electric illumination.

The arc lamp is the most powerful. The principle on which it is worked may be described as follows. If a conductor along which electricity is passing is cut in two, and the ends are slightly separated, the current will cross the space so formed. The break, however, offers great resistance to the passage of the current, and intense heat is produced (the heat generated in any portion of a circuit being always proportional to the resistance of that part), Supposing, then, that a rod of carbon is placed to form part of a circuit, and whilst the current is flowing through the carbon be broken in two, and its ends be drawn a very short distance apart, a luminous arc of great brilliancy, called the Voltaic Arc (after Alexander Volta, F.R.S., Italian Professor), will be formed at the break. A small quantity of the carbon being volatilised, the light is caused, partly by this intensely heated carbon vapour through which the current flows from one point to the other, and partly through the extremely high temperature of the carbon points themselves. The rods of carbon used in arc lamps are sometimes called electrodes, the upper carbon being usually the positive, and the lower the negative. In placing the positive carbon at the top the current is directed downwards, repels the rising gases, and the arc becomes shorter and narrower, compressed, concentrated, and consequently more intense. (See figure M.)

These carbons are acted upon by trains of wheels, and worked in guides by electro-magnets, forming part of the electrical circuit of the lamp, and thus a uniform light is obtained by keeping the carbons at the same distance apart as they burn away. There are many other modes of regulating or adjusting the carbons by springs, weights, and floats, etc. The current is sent through the two carbons, which touch each other end to end, and as soon as the current is established the carbons are separated slightly, and the current continues through the heated air, which is a partial conductor of high resistance.

Intense heat is produced at the ends, or poles, of the carbons, and particles of carbon become detached, and float in the heated air between, and form a luminous arc. The carbons being slowly consumed are actuated by the machinery before described, so as to keep the resistance as constant as possible. The arc light gives a much stronger light than the incandescent. The carbon, being thicker, can be raised to a higher temperature, the carbons used varying in diameter from $\frac{1}{8}$ inch to as large as $3\frac{1}{2}$ inches.

The temperature of the positive carbon ranges from 2000 to over 3000 degrees Centigrade, according to the size of the carbons, and it will perhaps be interesting to state that of all the artificial sources of heat the electric arc is the most intense.

The regulating electric lamps designed by "Brush" are a remarkable success. The feed is actuated by gravity alone, while it is controlled solely by the influence upon a bar of iron of a magnetic field, the intensity of which varies with the strength of the electric current passing through the lamp circuit. The lower carbons are fixed, and as they burn away the upper carbons follow them, so the arc gardually descends, but for certain special installations, such as light-houses, or for purposes of projection, a focus-keeping arrangement has to be supplied. Like most of the modern electric lamps, the upper carbon descends by its own weight until it touches the lower carbon, and the circuit is thereby completed, the effect of this in the lamps is to cause a soft iron plunger to be drawn to a greater or less extent within a hollow coil, sometimes called a sucking magnet, and through the intervention of a lever and an annular clutch surrounding the rod of the upper carbon like a washer, the upper carbon is lifted away from the lower, and the arc is at once established. As the carbons burn away the arc has a tendency to become longer, and its resistance to increase, and this by reducing the strength of the current, diminishes the supporting power of the magnetic helix, allowing its plunger to descend, and in so doing to lower the carbon, and shorten the arc until the proper strength of the current is restored, when the rising of the plunger once more holds the carbon in position. So sensitive is the controlling apparatus to the smallest variation of current, that there is practically no reciprocating action such as this description might lead one to suppose, but the normal condition of the upper rod is to be slowly sliding through the clamp as the carbons become shorter; but if by any chance the rod slides a little too far, the clutch at once raises it again, and the carbons are adjusted to their proper distance.

Figure N gives an illustration of the principle by which the arc is controlled; X and Y represent the terminals of the lamp, which in this case consist of hooks, which, by being dropped over pins attached to the ceiling, and which are in connection with the line circuit, place the lamp in circuit with the machine. The current entering at X is transmitted through the two hollow bobbins, H and H^1, in parallel circuit, the out-coming ends being joined together and connected to the upper carbon holder, N. If the carbons are in contact the current flows through them and by the vertical rods of the lamp to the terminal hook, Y. The effect of this is to convert the two solenoids, H and H^1, into magnets, which, by drawing into themselves the two iron plungers, N and S, lift one edge of the washer-clutch, W; this, by its oblique action, seizes the carbon rod (much in the same way as a tent-rope tightener grasps its cord), and lifts the upper carbon until its influence is balanced.

The carbon pencils consumed under the brush system are a foot long, and are electroplated with a thin covering of copper, which increases the life of the carbons; they last for eight hours, during which time about nine and a-half inches of the positive, and about four inches of the negative carbon are consumed. When the lamps are required for a longer period double carbon lamps are used, fitted with two pairs of carbon holders, and each is controlled in the same way as the single carbon lamp; the controlling apparatus, however, is not duplicated. When the lamp is started, the arc is formed between one of the pairs of carbons, and when they have burnt out the other pair automatically starts into action. The change from the one pair of carbons to the new ones is effected by a purely mechanical means, and by a contrivance which is extremely simple.

Figures O and P will show the action of this apparatus, and the washer clutch will be more plainly shown than in figure N.

C C is the hollow solenoid or sucking magnet, which exercises a magnetic influence upon the soft iron-plunger P. The rising or falling of this plunger raises or lowers the frame K by the lever L. R^1 and R^2 are carbon holders, which pass vertically through the casing of lamp. W^1 and W^2 are the clutch washers which surround them. One side of each of these washers passes between a pair of jaws, forming part of the frame K, and when the frame is drawn upwards it tilts the washers, and causes them to clutch the rod on diagonally opposite corners. One pair of jaws is slightly higher than the other, and it takes a grip before the other begins to act, and, therefore, lifts its corresponding carbon higher than its neighbour; the consequence is that only one arc is established; viz., across the lesser distance; and in all the subsequent feeding and controlling the pair of carbons first started are alone affected, because, although both carbons are raised and lowered together, the lower end of the reserve carbon is always higher than the other by the difference in the height of the two pairs of jaws on the frame K. Owing to the shortening of the consuming carbons they can no longer meet when the frame is dropped, and the current by which they are again separated can only be transmitted by the reserve carbons coming into contact—the circuit is thereby completed, the new carbons are separated, and the arc between them continues to be controlled by the magnet and clutch in the same way as the first arc was.

The arc light is used almost entirely for outside lighting, being unsuited for interior illumination, which is better provided for by the "Incandescent" lamp, in which a filament or small wire of carbon placed in an air-tight globe, to protect it from the chemical action of the air, is raised to incandescence, by the passage of a current, and produces light for a very long time before it is destroyed. The length of time the filament lasts, or the life of the lamp is often more than 1000 hours of total lighting, in fact some of the best manufacturers guarantee an average life of 2000 hours. Woodhouse and Rawson's lamps have in some instances been in use for over 4000 hours, and the Edison lamps at the Theatre Royal, Manchester, have run 6000 hours. For a given temperature the durability of the filament depends on its uniformity, and on the completeness of the vacuum. Below a certain temperature, nearly corresponding to that of melting platinum, a well made filament in a good vacuum is very durable, and lamps will, under these conditions, last six or even twelve months of ordinary domestic work. The chief lamps now in use are the Swan, Edison, Maxim, Lane-Fox, Swinburne, and Brush Victoria, they differ principally in the shape and method of preparing the carbon filaments, and the manner in which the conducting wires are attached. (See figures Q^1.)

The carbons consist of some vegetable substance, which has been carbonized by heat. Metal filaments, usually platinum, have been tried, but without success, and carbon is now solely employed for the purpose, the materials being jute, bast, manilla, hemp, cane, bamboo, cotton-thread, bass-broom, fibre, card-board, etc. Figure, Q^1.)

The ends of the filaments are connected to two platinum wires, which pass through the glass, and are melted on to it. Platinum is used, as its expansion rate being about the same as glass, the latter does not crack in cooling, and it also joints well with the glass, which, of course, is a very important consideration, seeing that a good vacuum is required to be kept. (Platinum fuses at 2000 deg. C.; carbon has never yet been fused).

The Swan carbon filament incandescence lamp was first exhibited in 1869. Mr. Swan experimented for many years, his earliest form of lamp being a glass bell, having a horse-shoe of carbonized paper. [See figures Q 2.] The small arch of carbonized paper being about one inch high, and half inch across—the lower ends clamped to small blocks of carbon, the bell being exhausted as far as possible. This lamp had not a long life as the filament when the current was passed through it became hotter on the inner than the outer edge, and under this unequal influence began to curl over, bending until the crown of it came into contact with the glass, causing it to shatter. Paper havingbeen found unsuitable for filaments, Mr. Swan ultimately adopted cotton thread, which, when prepared by steeping in sulphuric acid and water until the tissue is destroyed, and then properly washed and dryed, produces a horny homogeneous filament of very considerable strength, the density and uniformity of which is increased by passing it between compressing rollers, which flatten it, so that a somewhat increased area of incandescent surface is obtained. This filament, which is made of a length and thickness proportioned to the current to be employed in heating it, is held in its position by the platinum conducting wires, which pass through the body of the glass globe, and are fastened to the ends by clips or sockets, and sealed in by fusion. It has been ascertained that if the glass-bulb be exhausted of air to a very high degree, the life of the lamp is prolonged. In order to get a good vacuum, Gimingham's vacuum exhauster, which is a simplification of Dr. Spengell's mercury vacuum pump, is used. Whilst exhaustion is being proceeded with, the carbon filament is raised to incandescence by passing a current through it of a higher degree than that ultimately required to be produced in using the lamp. By passing this current through while the lamp is attached to the pump, all the gas is driven out of the carbon, and is removed by the pump, and the lamp is thereby rendered more durable, the wasting of the carbon, and the obscuration of the glass by the deposition of very minute particles of carbon on its surface is completely avoided. The lamp is sealed while the current is still passing. The Swan lamp is exhausted to the one-thousandth part of an atmosphere.

The process of manufacture of such lamps—*i.e.*, the manner in which the several parts are put together—is shewn in figures R. 1, 2, 3, 4, 5, 6. No 1 represents the filament which is attached to the platinum wires, and mounted on a glass bridge, little beads of glass being also formed on the wires where they are to pass through the walls of the lamp. The glass globe is blown as in figure 2, and with a file is cut into two pieces, as in figure 3. The carbon and platinum wires are inserted, and the latter fused on by the blow-pipe, as in figure 4. The portions of the globe are then joined together, and the lamp is complete, ready for attachment to the pump to be exhausted.

Holders for the lamps are made in a great many different forms. The one generally used consists of a block of boxwood, to which is fixed a spring wire with a ring which fits round the neck of the lamp, and two springs, one of which hooks into each of the platinum rings of the lamps. These contact springs are attached to little brass binding screws at the sides of the wood. It is important that both the contact wires should be springs, because if they are made in the form of simple hooks, they are liable to be displaced by vibration, and contact thereby becomes broken, and the lamp is extinguished. The conductors used for conveying the electric current from the generators to the lamps must be carefully proportioned to the work required of them, because, when electricity passes along a conductor it meets with a certain amount of resistance, which, as already stated in this paper, varies with the size of the wire, and the material of which it is made, and the conductor becomes more or less heated. When the diameter of the wire is small, the resistance to the passage of the electric