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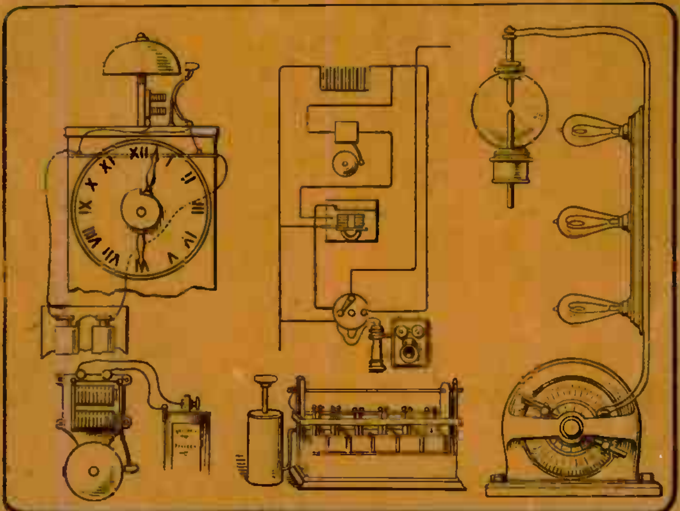
Practical Electrics

A Universal Handy Book

ON

ELECTRIC BELLS, BATTERIES, ACCUMULATORS, DYNAMOS, MOTORS, INDUCTION AND INTENSITY COILS, TELEPHONES, MICROPHONES, PHONOGRAPHS, PHOTOPHONES, ETC.



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PRACTICAL ELECTRICS:

A UNIVERSAL HANDY-BOOK

ON

EVERYDAY ELECTRICAL MATTERS,

INCLUDING

CONNECTIONS, ALARMS, BATTERIES, BELLS, CARBONS, INDUCTION-,
INTENSITY- AND RESISTANCE-COILS, DYNAMO-ELECTRIC MACHINES,
FIRE RISKS, MEASURING, MICROPHONES, MOTORS,
PHONOGRAPHS, PHOTOPHONES, STORAGE,
AND TELEPHONES.

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PREFACE.

THIS little work is addressed to the very large class of scientific amateurs who dabble in electrical matters, in the hope that it will be found to contain a fund of information of an eminently useful and practical character, though not of sufficient importance to merit a place in more pretentious works. To those having electric bells, telephones, or electric lights in their houses, it should form a convenient and accessible reference book, offering many suggestions in various directions. It is a reproduction of the chapter on Electrics in the Third Series of 'Workshop Receipts.'

INDEX.

PRACTICAL ELECTRICS.

THE accompanying figures of connections in general use will constitute a fitting preliminary to the discussion of electrical apparatus in its various developments. Fig. 1 shows an ordinary terminal to be fixed to the base of an apparatus. Fig 1*a* shows a modification that allows the wire to be either in the eye when large enough, or between two flat parts when fine or flattened. Fig. 1*b* is provided with a conical screw, and designed to be fixed to apparatus whose under part is not accessible. Figs. 1*c* and 1*d* show terminals secured by a lever: either a small bar fixed permanently to the head of the screw (Fig. 1*a*), or a nail that may be introduced into apertures in the head (Fig 1*d*). This is especially adapted to cases where space is limited, and there is no need of changing the wire attachments often. Fig. 1*e* shows a flat terminal head secured through flat clamps. Fig. 2, with flat clamp, is employed especially on telegraph apparatus; it is fixed by means of a screw, as in 1 and 1*a*, and is prevented from turning by a snug at the lower part. When two wires are to be united, Fig. 3 is used. This consists of a brass cylinder containing an aperture that runs lengthwise through it, and into which the two extremities of the wire are inserted, and held in place by two binding screws. Figs. 4 and 7 are used on Bunsen piles for connecting the carbons with the copper plates. Fig. 7 shows an ordinary clamp, and Fig. 5 a terminal for a zinc plate. Fig. 6 is the clamp used by Trouvé in his bichromate of potash piles for simply and quickly connecting the elements. With galvanometers, there is need of often substituting one apparatus for another, and of establishing two communicating wires. To effect this, the two wires of the galvanometer (which is not always easily accessible) are connected once for all with two terminals arranged upon a small block of paraffined oak or ebonite (Fig. 8). This latter is fixed within reach, and to the two terminals thus arranged

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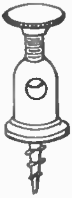
1a

1b



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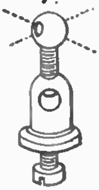

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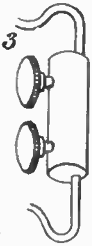
3



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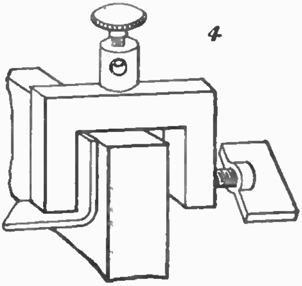

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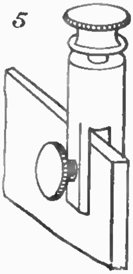

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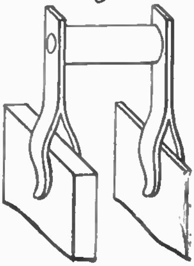

the wires are attached at every measurement.

Connections between movable apparatus and fixed terminals are effected by flexible or connecting cords as shown in Figs. 9, 10, and 11. Fig. 9 is a flexible cord whose extremities are connected with plugs when perforated terminals are used. Fig. 12 is the Radiguet attachment, especially adapted for flat clamps. Fig. 10 represents the mode of fixing telephone cords. Accidental tractions act upon a cylinder of wood held between the two cords and kept in place by a screw. For communications of feeble resistance, use notched strips of metal like that shown in Fig. 11.

Alarms.—Electrical apparatus is eminently adapted for alarms, tell-tales, and time signals.

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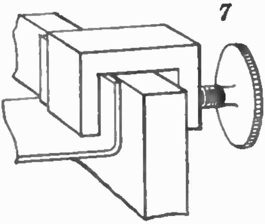

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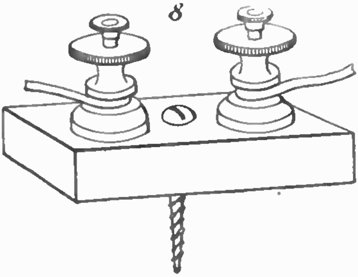

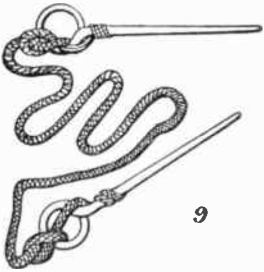

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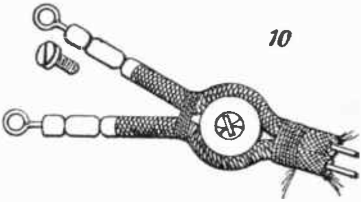

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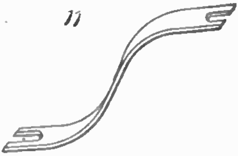

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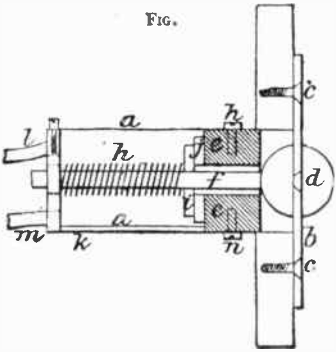
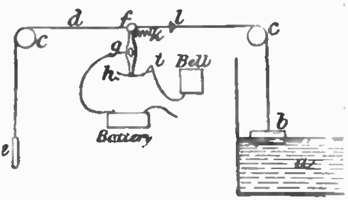
House Electric Alarm.—In Fig. 13, *a* is a small piece of brass tubing, having a brass disc *b* soldered on to one end of it. This is drilled and countersunk for screws, as at *c*; *d* is a small brass knob, either screwed or soldered on to the brass rod *f*, and protruding about half-way through a hole in the disc *b*; *e* is a circular disc of ebony fitting into the tube *d*, and having a hole through its centre to allow *f* to slide freely. The ebony is held in place by screws. To one end of the ebony disc is fitted a brass circle *j*, of rather smaller diameter than *e*, also having a central hole to admit of *f* sliding. *h* is a spiral spring, which keeps the brass cross piece *i* (passing through a hole on *f*) in contact with the brass circle *j*. *k* is a brass disc closing the end of the tube, and also allowing *f* to slide. One wire *l* is attached to this; the other wire *m* passes through a hole in *k*, and is attached to the brass circle *j*. On pressure being applied to *d*, the points of contact are forced apart, and no current can pass. Immediately, however, on the pressure being removed (as by opening a door or window), the spring recovers itself, and brings the cross-piece into connection with *g*, thus closing the contact. These contact-makers are sunk in the lintel of the door or in the groove of the window, as shown in the figure. One of these must be used for each door or window to be guarded. The wires *l* and *m* should be guttapercha-covered, as, in fact, all wires used in this job should be. The rest of your work is comparatively easy. You must have an indicator in your bedroom to show which room is attacked. This will be precisely similar to those used in ordinary electric-bell work. At some point in the battery wire which goes to the indicator, you may insert an interrupter, which is merely a brass arm pivoted at one end and resting on a brass stud at the other. When you desire to throw the arrangement out of gear, you have only to remove the arm from the stud.

FIG.



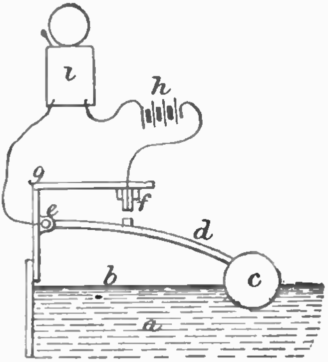
Tell-tales for Cisterns.—(1) In Fig. 14. *a* is the tank, *b* the float, *c* V-wheels. *d* light wire rope, *e* counterbalancing weight (which must be adjusted so as not to prevent the float *b* falling with the water), *f* eye (through which the wire rope passes), fixed on arm, which, being pivoted at *g*, is kept against the stop *h* by spiral spring *k* until the stop *l*, fixed on the wire rope, is brought in contact with *f* by the rising water, when the weight *e* pulls the arm over to *i*, which brings the bell into circuit. By moving the stop *l*, the bell can be caused to ring at any level of the water, and by having another contact at *h*, and bell, and also a stop on the other side of *f*, the bell will ring when the tank is empty. When 2 bells are fitted up, the arm must be arranged to remain between the contacts, when not acted upon by the stops on the wire rope. An indicator and scale attached to the weight *e* will show the height of water in the tank.

FIG. 14.



(2) In Fig. 15, *a* is the tank, the height of the water being at *b*; *c* is a tin float attached to the end of an iron rod *d*, moving on a hinge at *e*. *f* is a metal

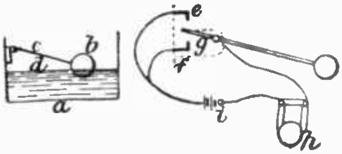
FIG. 15.



stud tipped with platinum. A small piece of platinum is also soldered on to the point on the rod *d*, opposite to *f*. *g* is a wooden support to which *e* and *f* are fastened. A wire from *f* is carried to the battery *h*, which consists of a few Leclanché cells. The other terminal of the battery goes to one of the binding-screws of the electric bell *i*; the other binding-screw is connected by a wire to *e*, but care should be taken to have this wire in good *metallic* connection with the rod *d*. When the water rises to a certain height, the points at *f* will be put in contact, which completes the electric circuit and sets the bell ringing. The bell would cost about 4*s.* or 5*s.*; the batteries about 3*s.* each.

(3) In Fig. 16, *a* is the cistern; *b*, a float; *c*, the contact maker; *d*, a projection to hold float. The right half of the figure shows the contact-maker. *e* is a brass stud in contact with the line wire and *f* is another stud also connected with the same wire. *g* is a piece of brass spring with the other wire attached to it; *h* is an electric bell, and *i* the battery. Platinize all contact points. The action is as follows:—When the cistern is full, the brass spring *g* touches *f*, and the bell rings. When the cistern is empty, the spring *g* touches *e*, and thus completes the circuit. It will be found very useful to employ a switch, so that when the cistern is full, the circuit can be broken, and thus save your battery. The same can be done when it is empty.

FIG. 16.



(4) In Figs. 17, 18, 19, the wheel *a* is actuated by the float, and when revolving, causes the bar carrying the contact-pins to rock on its centre *b*, thus producing a circuit on one side or the other by immersing the pins *c* in the mercury *e*, the pendulum *d* bringing the bar into its normal position. The pins are shown in a line for the sake of clearness, but they can be placed anyhow, so long as they dip together. By using mercury, you will make a great deal better contact than you can with solid metals, but the pins on the bar and the connections must be well insulated For the recording instrument you will require a couple of ratchet wheels of equal size, but fastened together a little apart, and mounted on a common centre. You must have as many teeth on them as your float-wheel has pins, and the teeth must be cut in an opposite direction to one another, so that when the electro-magnet *g* attracts the armature

FIG. 17.

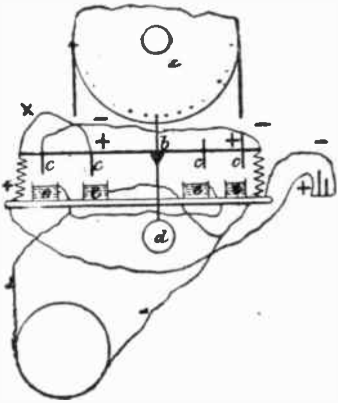
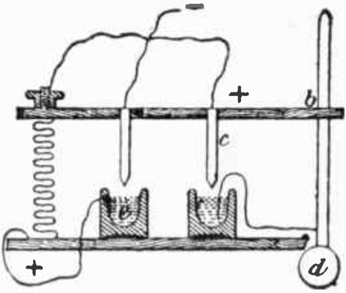
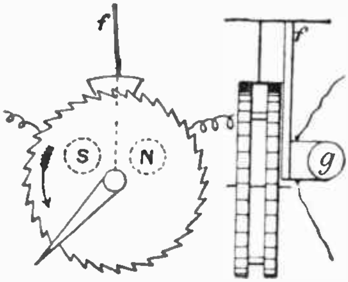


FIG. 18.



and escapement *f* toward the pole marked *S*, the wheel at the back revolves in the direction of the arrow (and with it the wheel and index that are shown); the reverse action takes place when armature, &c., is drawn towards N.

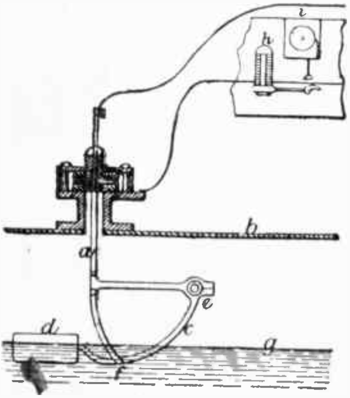
FIG. 19.



There are several disadvantages in this plan—viz., the necessity of having the batteries at the reservoir, the liability of the instrument to get out of step, and the continuous action if the pins on float-wheel should happen to hold the bar down.

(5) Field & Thompson combine a low-water alarm with an anti-incrustator for steam boilers, as shown in Fig. 20.

FIG. 20.

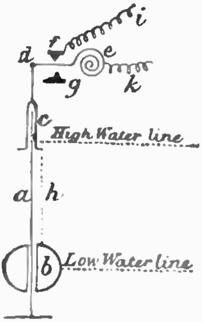


The current of electricity is caused to pass from the shell of the boiler to a negative electrode situated in the water so long as the level of the water does not fall below a predetermined point; when this level no longer obtains, the current, or a part of it, operates a signal. A dynamo, or other electric generator is provided, and a conductor in connection with the negative pole (that is, the pole which comes from the zinc plate in an ordinary voltaic cell) is passed through the shell or body of the boiler, in such a way that it is electrically insulated. This conductor, which terminates in, or acts as, an electrode, is so arranged that it is normally in connection with the water in the boiler, and by means of friction, part of it is kept clean and bright, so that it may make good electrical connection with the water.

To convey the electric current to the water, and keep the conducting surface or electrode bright, there is fixed to the insulated negative conductor *a*, at or near the level of the low-water line in the boiler *b*, a metallic surface, against which *c* is made to rub, the motion of the latter being derived from some contrivance such as a float *d* actuated by the motion of the water. The float and rubbing surfaces *c* are insulated (at the joint *e*) from the boiler *b*, and from the negative conductor *a*, when not in contact with the submerged clean surfaces *f*. The float and rubbing surfaces are so arranged that when the level of the water *g* in the boiler falls below the predetermined point, the rubbing piece *c* shall not be in contact with the cleaned surface *f*. Thus all electrical connection between the rubbing surfaces of *f*, and the negative conductor or electrode *a*, will be broken, and the electric current through the boiler (whose shell forms part of the circuit) will be stopped. The circuit through the water being broken, the low-water alarm or indicator is brought into operation. A convenient method of indicating this is to cause the current to pass through the coils of an electro-magnet *h*, which attracts its armature so long as the current flows. When the circuit is broken, the armature will fall, and the current will be "switched" into the signalling apparatus *i*, which may be of any suitable construction, such as a trembling bell, or an electric lamp, or an electric motor that will open a steam or water-cock and extinguish the fire.

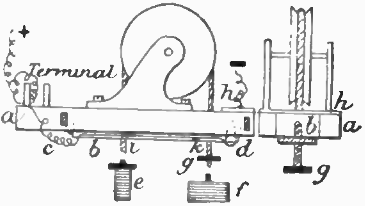
The drawing shows a trembling bell in conjunction with a plate on the back of the armature, which plate bears the word "stopped," and assumes an attitude in which it is plainly visible when the armature falls, as it does when the current through the boiler ceases. The electric generator may be used in conjunction with a second battery. In cases where the prime mover does not run during the night, a secondary battery is particularly serviceable, as it keeps up the action during the time when there is little or no circulation in the boiler.

FIG. 21.



(6) Fig. 21 shows an arrangement for signalling both high and low water levels: *a*, upright guide-rod firmly fixed to bottom of tank; *b*, hollow copper ball, with tube through it to slide over *a*; *c*, cap or tube with flange to slide over *a* at lower end, and attached at top end to *d*, lever arm mounted on spiral spring *e*, the centre of which is fixed to a rigid square pin; *f g*, 2 ends of a brass plate, projecting from a support at right angles to *d*: *h*, a light chain, connecting *c* and *b*, the length of which regulates the water-levels at which the bell will ring; *i k*, terminal wires, attached respectively to *f* and *e*. At low-water level the weight of *b* will bring *e* into contact with *g*; at high level, its buoyancy will bring *e* into contact with *f*.

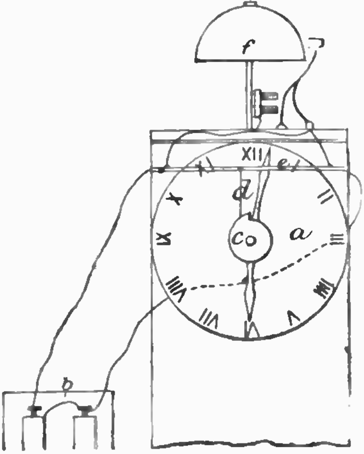
FIG. 22.



(7) In Fig. 22, *a* is a wooden frame; *b*, contact-lever; *c*, hinge to contact-lever; *d*, brass contact-screw; *e*, counterweight and stop to prevent weight from passing through lever; *f*, float; *g*, stop for same; *h*, piece of tin for *d* to contact on; carry wire to contact screw, as shown in sketch, along the lever. When the water gets below a certain point, it would leave the float suspended, which should by the counterweight *e* lift the contact-lever at *i*, and make contact at *d h*. On the contrary, the float *f* should lift lever at *k*, and again make contact at *b h*. To ensure success, the float should be as heavy as possible, the lever as light, and the counterweight heavy enough to lift the lever. The holes in contact-lever should be large enough to clear rope or chain. Pulley should not be less than 5 or 6 in. in diameter.

Time-signals. — (1) To ring at 6 o'clock. Fig. 23 shows a small clock *a*, with which to work the bell; *b*, battery consisting of two Leclanché cells; *c*, a disc, with a notch cut in it, running out to the diameter of the disc, and having a groove in it in which *d*, a small piece of wire runs; attached to *d* is a small strip of sheet copper *e*, and fixed to it is the gong *f*. Set the small point in *c* to the hour required for the alarm to ring, and it will be seen that, when the recess in *c* works round opposite the hour, the wire *d* drops down in the recess, bringing with it *e*, which falls on the two ends of the wire from the battery brought in at the sides of the clock. The strip *e* cannot be seen, being above the face. The disc could be fitted to any clock, being nothing more than a piece of sheet brass with a groove cut in it with a file, to prevent the wire from slipping out. There should be a

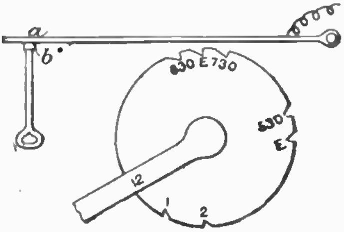
FIG. 23.



switch, to turn the current off or stop it. The gong is shown as fixed on the top of clock, and battery and clock on mantel-shelf. A common house-bell will do for a gong, supported on a piece of brass wire. The disc *c* is of course to be carried by the hour hand.

(2) Have a disc, about 2 in. diam., fastened on to the shaft of the hour-hand, so that it revolves once in 12 hours, and notched about ⅛ in. deep, to allow the pin of contact-rod to drop, and make contact at *a b*. Divide the disc into 12 equal parts for the hours, and half the spaces for the half-hours, and number them as shown in Fig. 24. when fixed, the centre of the hour-hand should always be over the figure 12. Carry the wire from the battery to the contact-rod, as shown, and not through the joint. This will ring the bell all through the night; but you can switch it off and on, or, if this is unsuitable, make the disc revolve only once in 24 hours, and divide and notch to suit, so that more than one half of disc would

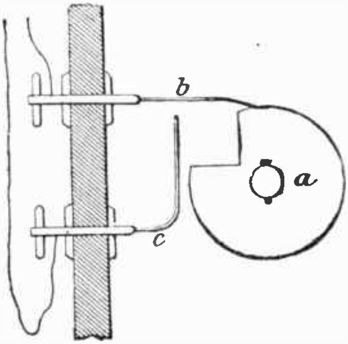
FIG. 24.



be blank. The contact-rod you must shape to circumstances, and make the minute and hour hands coincide.

(3) In Fig. 25, *a* is a disc of thin sheet brass, with notch cut in it;

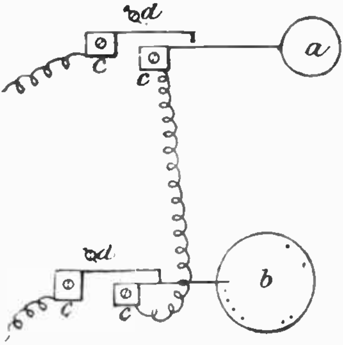
FIG. 25.



through the centre is soldered a tin tube to slip tightly on the spindle of the wheel that carries the small hand of the clock, with 2 brass pins soldered on the outer face, just long enough to project through the face of the clock to turn the disc round with. *b* is a piece of brass wire about ⅛ in. thick, screwed at one end about 1 in. down, and with 3 nuts fitted; the other part is hammered flat, to form a spring, and filed down to the required stiffness, which of course must not be great. The end that presses on the edge of the disc has a small notch cut in to prevent slipping. *c* is another brass wire, same thickness as *b*, with 3 nuts, and bent as in sketch. Take off the clock face and hands, bore 2 holes through the side of clock-case, one above the disc and the other below, as shown; then by means of 2 nuts fix each wire in position; the other nut serves to connect the wires from battery. All is hidden when the face is put on. A small piece of platinum should be soldered on the spring *b*, where it drops on *c*, also a piece on the end of *c* to form more perfect connection. The action is thus:—Suppose 6 o'clock is the time you require to rise in the morning: at 6 o'clock in the evening, turn the disc round by means of the pins until the spring drops into the notch and falls on *c*; the connection is then made. As the clock moves, the disc raises *b* until 6 o'clock A.M., when it drops, and sets the bell ringing. The clock may be in the kitchen, and the wires go through ceiling to bell hanging on wall in bedroom. A simple break is made thus:—Solder a small plate with 2 screw-holes on 3 in. of $\frac{1}{4}$-in. brass tube, and nail it to the wall in bedroom; then put a small piece of cork in the bottom of tube, cut one of the wires from battery, file one end to a point, and push it up a short way through the cork; to the other wire, solder 8 in. of gilt picture cord with a brass wire 3 in. long soldered to the other end of picture cord, then pour a small quantity of mercury into the tube. When retiring for the night, merely wind up the clock, and put the brass wire at end of picture cord into the tube, which forms the connection. When the bell rings in the morning, take the wire out of tube, which breaks connection. Gilt picture cord forms good flexible connections to the clock; solder about 8 in. to end of each wire.

(4) Put 2 pins in the minute-wheel, and let them lift a light spring; this will give a contact-maker every half-hour. Then a pin on the hour-wheel to suit each hour that a signal is wanted for. Count the teeth, and divide that number by 12, thus having so many teeth for each hour. Mark one tooth "12," and at equal distances others "1," "2," &c. Miss pins at hours not wanted, and where a half-hour signal is needed, insert a pin half-way between the hours. The arrangement is shown in Fig. 26:

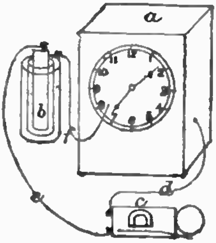
FIG. 26.



a, minute-wheel, with its 2 pins; *b*, hour-wheel, with its pins; *c*, light brass springs, to be lifted by the pins in the wheels; *d*, adjusting screws. The spring-studs must, of course, be insulated from the clock plate.

(5) Fig. 27.—*a* is the clock; *b*, battery; *c*, bell. The wire *d* from one terminal of the bell is connected with any part of the works behind the clock; the wire *e* leads from the battery to the other terminal of the bell; and the wire *f* is placed at whatever hour the bell is wanted to ring. *f* has a little crook at the end, so that, when the hour hand of

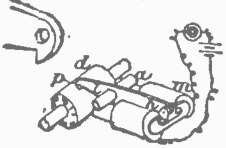
FIG. 27.



the clock touches it, it is carried round with it, the bell continuing to ring till the crook detaches itself by the hand going round—*i.e.* about 3 hours. *f* is placed in such a manner that, although the hour hand touches it, the minute hand passes above it. This adjustment, though not so scientific as others, is equally successful.

Tell-tale Clock.—A drum *d* (Fig. 28) carries a strip of paper wound upon it. The surface has grooves cut in it, either circular or (if to indicate for more than 12 hours without attention) spiral. In the latter case, one end of axis of drum is cut with a screw of the same pitch as the grooves on the drum, and works in a fixed nut, so that, when rotated, the drum travels along an axial line at such a rate that the grooves retain the same relative position to a fixed point, such as the indenting point, presently to be described. The drum has the hours engraved at one end, and is made to rotate once in 12 hours. A spring (not shown) holds the cylindrical armature off the face of electro-magnet *m* until a current passes, when the lever *l* is drawn down, and the point *p* makes a puncture in the paper. The position of this puncture relatively to lines drawn from the figures on end of drum along the paper in direction of drum's length, will indicate the time at which current passes. A simple contact spring, such as is used for ringing electric bells, is pushed by the watchman when making his rounds, and a record is made on the paper.

FIG. 28.



Batteries.—A galvanic battery consists of 2 electrical conducting bodies placed in a fluid which will exert greater chemical action on the one (the "positive element") than on the other (the "negative element"). The substances commonly used as elements are zinc opposed to carbon, cast iron, copper, platinum, and silver; while the usual chemical exciting fluids are nitric acid, sulphuric acid, copper sulphate, and potash bichromate. The positive element of the battery is at the same time its negative pole (or cathode), the former term applying only to the portion of the plate within the exciting fluid, while the latter denotes the portion outside the fluid. In the same way, the negative element is the positive pole (or anode).

The continuous arrangement of 2 or more cells, as just described, in a set, constitutes a compound battery. There are two ways of arranging the set, according as quantity or intensity of current is desired. In the former case, the anodes of all the single cells are attached to one wire, and the cathodes of all to another: the effect is then equal to the product of a single cell whose element surface corresponds to the sum of the surfaces in the single cells. To increase the intensity of the current, the anode of one cell is united to the cathode of the next, throughout the series, so that the current from each cell circulates through all. Other conditions being equal, the power of a battery is dependent upon the area of its negative element; and in making an intensity arrangement, it is very important that the negative elements of all the cells shall be of equal area, as the power will be regulated by the smallest negative element in the series.

The anode of a quantity battery is any part of the wire to which the anodes of the single cells are joined, the cathode in like manner being any part of the wire receiving the individual cathodes; but the anode of an intensity battery is the unconnected anode of the last cell of the series, and its cathode is that of the first cell. To apply a battery, the current is conveyed from each of its poles by means of electrically conducting wires arranged without interruption.

Making Batteries.—The construction of batteries may best be discussed in general terms before proceeding to explain the special features of the different forms of battery in use.

Zinc plates.—These generally constitute the positive elements by whose oxidation the current is produced. The best kind is "rolled Belgian," about $\frac{3}{16}$ in. thick, and costing something like 4*d.* a lb. New plates are coated with a greasy film, which needs dissolving off with caustic soda solution. This done, pieces of the required size are cut off by making a deep incision on each side, and letting mercury rest on the line, which it soon penetrates sufficiently to facilitate breaking the plate by bending over an edge. Cylinders may be formed by placing the plate in hot water, and curling it round a wooden roller.

The plates for some batteries (e.g. Bunsen's, Callan's, Grove's, Smee's), used to be amalgamated with mercury when the battery is made, and re-amalgamated subsequently at intervals. The amalgamation is performed by laying the plate in sulphuric acid of the same strength as the exciting fluid, and allowing it to remain some minutes. It is then taken out, and, while wet, has a globule or two of mercury rubbed over its face and edges, so that it may present a uniform silvered appearance. This is to prevent "local action:" its necessity may be thus exemplified. If a piece of unamalgamated zinc be put into dilute sulphuric acid, the surface will be immediately covered with minute bubbles of hydrogen, and the acid solution will soon become in a state of effervescence. This will go on until the zinc is dissolved, or the solution is saturated with zinc sulphate. On the amalgamated plate no action of this kind will take place; the smoothness of surface communicated by the mercury appears to cause the hydrogen first evolved to adhere to the plate, which is thus protected from any further action. This immunity only exists while the plate is detached from the other part of the battery, or the circuit between anode and cathode is severed. When the plate is in place, and the circuit is completed, the mercury affords no protection, as the hydrogen then is evolved at the negative element. When zinc plates, after being washed, look black in parts, they need re-amalgamating. (Dyer.)

The prepared plate is provided with one of the various forms of binding-screw, or has a strap of sheet copper, 5 in. long and uniform in width, soldered to it. The attachment is best effected by drilling a hole through both plate and strap, and firmly riveting; the strap must be clean at the joint, and the latter may be preserved from the action of the acid by a coat of varnish. For soldering a joint, use soft solder, zinc chloride solution for the flux (or rosin for copper to copper or brass), and a "tinning iron."

Negative elements.—These vary with the kind of battery, as described hereafter.

Exciting fluids.—The same remark applies here.

Separating the elements.—Obviously the positive and negative elements of a battery must not be in contact within the exciting fluid; they should be separated by a space of ⅜ to ½ in. In the case of batteries without porous cells, periodical attention will need to be given to ensure this condition being maintained.

Cells.—Containing cells are made to hold ½ pint to 1 gal. Single-liquid cells have but 1 containing vessel; double ones have 2. Outer cells are made, as a rule, of glazed earthenware, though glass may be used; porous cells, of unglazed earthenware. The latter are put inside the zinc cylinder, or U-plate, and generally contain the positive element. Such cells should not be too hard and dense, nor the thickness of the sides exceed $\frac{3}{16}$ in. The softest are of red ware; but better cells, and sufficiently porous, are made from white clay. A test of the porosity is made by placing water in the cells, and allowing them to stand for about 15 minutes: if then no dew appears on the outside of the cell, it is probably too hard or thick, and will offer too great a resistance to the current; while if the water actually runs off the side, the cell is too porous, and will shorten the period of action of the battery by too rapid transfusion of the liquids into each other. One-liquid cells, though convenient for short experiments, rapidly acquire a film of gas upon their negative plates, whereby the development of the current is impeded; consequently such cells, unless the excitant is agitated in some way, are unfit for supplying current for a length of time. This fault is termed "polarization." In two-liquid cells, the negative plate is surrounded by a liquid rich in oxygen (e.g. nitric acid in Grove's), which absorbs the hydrogen liberated at the negative plate, and keeps the latter free from film. But two-liquid cells are more troublesome. (Urquhart and Webb.)

Following are the most common forms of battery.

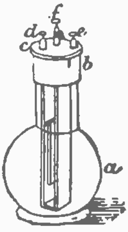
Antimonized Carbon.—Antimony is precipitated on the carbon cells described on p. 84, and in conjunction with these are used unamalgamated zinc rods and a solution of ammonium chloride. Such a battery may be useful for general laboratory purposes, being somewhat similar to Smee's in action, but with much cheaper negative elements, and a more economical utilization of the zinc. The carbon cells can be made small enough to be nearly close to the zinc, while, by having the containing vessels of ample size, the constancy of the current is enhanced.

Another form of this battery may be made with larger carbons and porous diaphragms, using for the outer liquid a mixture of antimonious chloride and ammonium chloride.

Plaster of Paris diaphragms can easily be made with dry plaster in the following manner:—Provide an inner core or mould of turned wood, a little tapering, and with a shoulder the thickness of the required diaphragm; round this tie 2 thicknesses of stout blotting-paper, well shake down the dry plaster between the wooden core and the paper, and immerse the whole in water. In a few minutes the diaphragm will be solid, and can be removed from the mould. (Symons, *Rep. Brit. Assoc.*)

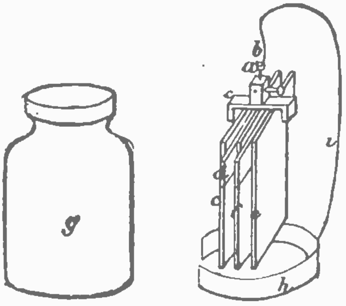
Bichromate.—Bichromate batteries of bottle shape as in Fig. 29, with 2 carbon plates, a sliding rod and movable zinc plate, are very extensively used by experimenters and lecturers, because they are always ready for being put to work with one motion of the hand, not necessitating any other preparation; and as soon as the desired result is obtained, the battery can be put out of action with the same facility. *a* is the bottle; *b*, a brass cap for the top; *c*, a disc of ebonite, to which the carbon plates are fastened; *d*, a binding-screw, connected with the 2 fixed and parallel carbon plates, between which is suspended a zinc plate of about half the length. This plate of zinc is fixed on a brass rod, whose extremity is shown at *f*, made to slide up and down in a brass tube, which is either close-fitting and split, or loosely fitting and provided with a set-screw. In either case, it must be connected, by means of a copper band, with the terminal *e*. The excitant is a saturated solution of potash bichromate, to which is added $\frac{1}{10}$ volume of sulphuric acid; another $\frac{1}{15}$ should be added after the battery has worked for some time, when it begins to become weaker in action. For all purposes where a strong current is required at intervals, such as the working of induction coils, medical coils, small electro-magnetic machines, and laboratory experiments, this battery is by many preferred to all others. The prices of such batteries range from 6*s.* 6*d.* to 24*s.*, according to the sizes and number of the plates, 3 carbons and 2 zincs being employed in the largest apparatus of the kind. Amateurs can hardly make this kind of battery so cheaply as it can be bought, because the bottles are high in price unless ordered in large numbers at a time.

FIG. 29.



For this reason, Wiesendanger has devised a form of bichromate battery having all the advantages of the one described above, and which can be made by amateurs at a fraction of the prices quoted. To make such a battery, take a marmalade jar *g*, measuring inside about 5 in. by 2½ in. diameter at the top. Get 2 plates of carbon, each 5 in. by 2¼ in., and a zinc plate (with terminals) of the same dimensions. Cut 2 pieces of thin mahogany board, 3 in. by ½ in. by ⅛ in., and a clamp *c*, such as shown in Fig. 30. The clamp *c* should have a ring *a*, at the top, so that it can be suspended from the hook *b*, when the battery is not in actual use. The 2 pieces of wood *d* are put right and left to the top of the zinc plate *f*, as shown, the 2 carbons *c* to the right and left of the pieces of wood, and the whole arrangement is clamped by means of the top-clamp *c*. The frame can be made with a piece of bent brass strip *h*, 9 in. × ½ in. × $\frac{1}{16}$ in., to which the upright brass rod *i* is soldered; or it can be made of stout brass wire, No. 7, altogether. In either case, there will be so much elasticity in the ring *h*, that it can easily be put on, and will hold firmly on the top of the jar. This frame can be bought ready made for 10*d*. When the battery is to be used, the plates are inside the jar and in the liquid, supported by the projecting ends of the wooden pieces *d*; when out of use, the plates are lifted and suspended from the hook *b*, by means of the ring *a*, at the top of the terminal clamp. (Wiesendanger.)

FIG. 30.



Trouvé has considerably improved the bichromate battery by supersaturating the exciting fluid. He takes 21 dr. of potash bichromate powder to 1 pint water, and adds, after shaking, drop by drop, 63 dr. sulphuric acid. The liquid warms, and the salt dissolves. No crystals form on cooling, nor are chrome-alum crystals deposited in the cell. With 12 elements and the foregoing solution, 10 incandescent lamps can be kept going for 5 hours, each lamp being equal to 10 candles. The electromotive force of the cell is 2 volts with fresh solution, and the intensity of the current at the beginning on a short circuit is 118 ampères. The resistance is 0·07 ohm; 4 batteries working a Gramme machine have produced 14 kilogrammeters of work during 3 hours without weakening in power.

A test of Trouvé's battery has been made by Hospitalier with 2 sets of 6 cells each. The cells are of ebonite, and are arranged in a box or trough in such a manner that they can be easily removed—one side of the trough being hinged so that the cells can be slid out when the plates are drawn out of the solution. The elements are connected in series, the zinc of one cell being coupled to the 2 carbons of the next, and a winch and ratchet enables the plates to be wound up out of the solution, or to be immersed to any desired extent. The ebonite cells are no larger than is absolutely necessary, and the quantity of solution required for a battery of 6 is given by Hospitalier as 17·6 lb. water, 2·64 lb. powdered bichromate of potash, and 8 lb. sulphuric acid. This gives 5¼ oz. bichromate per 1¾ pint of water, or a solution half as strong again as that used by Poggendorf. Trouvé uses a much stronger solution on certain occasions. Care must be taken not to use a wooden stirrer, as that would be carbonised, to the injury of the solution. The total weight of a battery of 6 cells is said to be 74 lb. In the experiments made by Hospitalier, 2 batteries of 12 elements together were connected in series, and used to work 6 Swan lamps, the difference of potential at the terminals being, batteries 16·70 volts, lamps 14·15 volts. That was during the constant phase, for at the moment of immersion of the plates, there is great initial E.M.F. which produces a current of 12 ampères, and the object was to maintain a constant current of 8 ampères. The zincs were immersed at first to about ⅘ in., and after a few minutes the current reached its normal strength of 8 ampères. After ¼ hour the batteries had settled to steady work, and for 1½ hour the zincs were not lowered. After that time, the decrease in the delivery was compensated by gradually increasing the immersed surface. By this means, for nearly 4½ hours the variation did not exceed ½ ampère, but after that time the zincs were immersed to the full extent of nearly 6 in., and the current gradually fell, until, at the end of 5¾ hours, it had reached 5 ampères, and the experiment ceased. The result shows that each battery practically furnished ½ h.p.-hour, the consumption of zinc being 365 dr., bichromate 600 dr., and sulphuric acid 1800 dr. The h.p.-hour is 1,980,000 foot-pounds, and as that was practically obtained with the consumption stated, an estimate of the cost can be easily calculated. Hospitalier states that 5 batteries, of 6 cells each, would suffice to support for 5 hours an arc lamp having carbons fully ⅓ in. in diameter, with a current of 7 ampères, and a difference of potential of 40 volts at the terminals of the arc. No attempt was made to reduce the weight of the two batteries employed, which was 148 lb.; but, according to Hospitalier, it would be easy to construct 2 batteries of equal power to weigh not more than 110 lb., or considerably less than an accumulator capable of containing an equal amount of energy.

In working bichromate batteries, never place or leave the zincs in the excitant when the current is not needed; remove them the instant the battery is out of use; and, when in use, do not let them rest in the fluid for 5 minutes without disturbing either the plates or the fluid. The great defect of these batteries is the want of circulation in the fluid, and consequent decrease of the current. By applying heat sufficient to cause agitation, the current will retain its vigour almost till the solution is exhausted. Spent fluid may be evaporated down to recover the chrome-alum usually formed. A very convenient form of compound bichromate battery, is to have the plates attached at top to a support which can be raised by allowing it to depend by strings from a spindle; on revolving the latter, the strings coil on the spindle and raise all the plates at once. As to the number of bichromate cells required to give an electric light: 6 1-qt. cells will give a small light; 12 yield more than double; 24 afford a true voltaic arc and a brilliant light; 50 produce a light of 1500 candle power. Up to 50 1-qt. cells it is best to connect in series; any greater number should form a separate parallel circuit; and, finally, the negative wire from each series is led to one screw of the lamp and the positives to the other. By this arrangement, the electromotive force of the battery is not increased (that of 50 cells being usually enough), while the resistance of the elements that are doubled is halved. The guiding rule for grouping a given number of elements is to effect it so that the internal resistance shall equal the external. Not more than ½ hour's continuous light can be got from any bichromate battery. (Urquhart and Webb.)

A voltaic generator, based on a modification of Dr. Byrne's negative plate cells, has been devised by Urquhart, and is described by him as being inexpensive, easily managed, certain in results, cheaply maintained, and very portable. It is simply a potash bichromate cell with negative plates of peculiar construction, and so arranged that a powerful current may be obtained from even 6 cells by the aid of abundant agitation. He thus describes its construction.

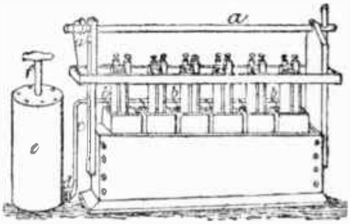
Each negative element consists of a copper plate to one surface of which, as well as to its edges, a sheet of compact platinum foil, free from pin-holes, is soldered, and to the opposite surface a sheet of lead—the three metals being so united that the copper is protected from the action of acids. The leaden back and edges are then coated with asphaltum varnish or an acid-proof cement; and lastly, the platinum face, being first rubbed over gently with emery cloth, is thoroughly platinised.

To effect this, fill a containing-vessel and a porous cell with acidulated water, and place the porous cell within the large vessel. Tie a strip of zinc by a clean wire to the plate to be platinised; dip the zinc in the porous cell, and the plate in the outer cell, and drop into the outer cell, while stirring, a solution of platinic chloride in water: add it drop by drop, with agitation, until the platinum surface is seen to turn dark, and to have acquired a granular deposit of platinum. Upon this surface depends to a great degree the power of the generator. If any difficulty is experienced in securing a good deposit, dip only a little of the zinc in the solution at first, and increase as the coating is seen to form. Dry carefully, and do not scratch the plate or remove the deposit, as easily happens before it is dry. Each cell contains 2 such plates, between which a single zinc is suspended; and when the elements are immersed so that the exciting fluid reaches to within 1 in. of the top, a large negative surface is brought into action. Thus the platinum alone is the negative, and the copper core is a conducting body merely; while the lead, being almost passive, serves no other purpose than to protect the copper, so that another (best, a non-metallic) substance capable of resisting the action of bichromate solutions, might, with advantage, replace it. The exciting solution used in this cell is prepared as follows:—

Potash bichromate . . .	2 oz.
Warm water	1 pint.
Sulphuric acid, when cool .	4 oz.

Fig. 31 represents a 6-cell generator of this kind. The ordinary, brown, glazed earthenware, oblong cells should be capable of containing at least 1 pint of the liquid; quarts will be found more economical. There are 3 plates in each cell—2 platinized, and 1 amalgamated zinc between. They are separated at the top edges by slips of wood or ebonite, against which they are securely clamped by stout brass clamps as shown. Thus the brass clamp, being in metallic contact with the lead, with clean scraped surface, represents them both as the positive pole. To the zinc plate in the centre is soldered a common binding-screw. Very stout, soft copper wires, about No. 12, are used to connect the elements in series (zinc to platinum), with clean contacts. The sets of plates are fastened to a wooden framing, made to slide up and down the side uprights, by means of shaft, cords, and handle *a*, enabling the whole to be withdrawn from the excitant at one action. A ratchet and pawl keeps the plates in position. For quart cells the plates may be 8 in. long and 4½ in. wide. The air-distributing arrangements are as follow:—*b*, ½-in. leaden piping, fastened to the back of the framework, whence lead 6 ¼-in. rubber tubes, extending to the bottom of the cells, and running parallel with and directly under the plate edges; their ends are closed, and the horizontal portion is abundantly perforated; *c*, rubber pipe slipped over the end of *b*, its other end being made secure to the outlet *d* of a hand-pump *e* worked by the handle *f*. A valve at *d* closes the passage to *b* when the handle is drawn up, otherwise the solution would be

FIG. 31.



pumped out of the cells. The whole is screwed to the floor for steadiness. It is better to use a Fletcher's foot-blower.

If the elements are simply lowered into the solution, much greater power is obtainable from them than that given by zinc-carbon batteries. The full effect, however, can only be obtained by pumping in air by the small tubes. A great disturbance of the liquid results, and the current is so much augmented in power, that even a 6-cell battery will yield a light equal to that given by a 20-cell Bunsen or Grove. The air disturbance has no effect upon the electro-motive force of the battery, although the volume of current given off is enormously increased, and any other means of effecting the required agitation would probably answer the purpose equally well. The suggestion of Prof. Adams as to the air effecting a free circulation in the fluid, by which the metallic surfaces are kept constantly clear, is undoubtedly the correct explanation. The effects are in great part due to the low internal resistance of the cell, owing to the peculiar arrangement of negative plate, partly to the rapid flow of air upwards through the liquid, and partly to the production of heat. The action of the air-flow is principally mechanical, but by hastening the combustion of the zinc it tends to generate heat, which in turn reduces the resistance. The mechanical action of the air removes from the neighbourhood of the negative plate the chrome-alum formed there, and from the surfaces of the zinc plate the zinc sulphate, and brings a fresh supply of solution constantly to the surfaces.

With a 10-cell battery a 32-in. long platinum wire of No. 14 gauge (·080-in. diameter) was gradually brought to glowing red heat, which ebbed and flowed with the cessation or renewal of the air-flow. A brilliant electric light is maintained between 2 carbon points, which similarly varies in intensity with the flow of air, so that it is important to pump the air in regularly and when this can be done by a crank attached to a heavy fly-wheel, almost perfect regularity is secured. The effects which are ordinarily produced by 60 or 70 Grove or Bunsen cells are obtained from 10 cells of this battery. For every 15 minutes or so of electric light, the solution in the cells will be nearly exhausted. A 20-cell battery produces a very powerful current, which will be nearly constant if the air-flow is maintained continuously. (Urquhart and Webb.)

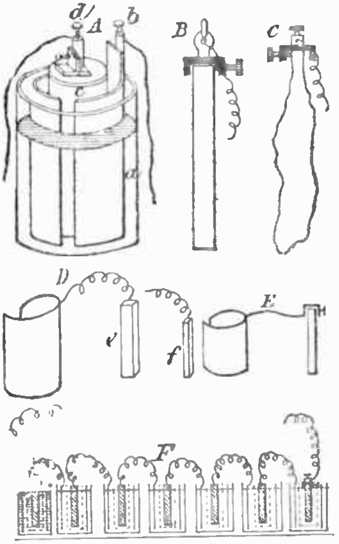
Bunsen's.—Bunsen's zinc-carbon battery is a modification of Grove's, the only difference from the latter being the substitution of carbon for platinum foil. The carbon rod or plate becomes brittle in time through the action of the battery, and should therefore not be too thin; this necessitates a much larger porous cell than in Grove's element, and makes the battery more bulky. It is, however, to be preferred to Grove's for (1) it is much less expensive, and (2) owners of Grove's battery experience that the valuable platinum plates offer a bad temptation to workmen, and at times disappear in a mysterious way.

In Fig. 32, A represents a single element of Bunsen's battery. *a* is the outer cell made of glass, earthenware, or vulcanite, the zinc-plate bent round, with a binding screw, *b*, at the top. *c*, a round porous cell, with a wooden lid at the top, through which a carbon stick or rod passes; another binding-screw *d* is attached to the top of the carbon-rod. The wooden lid at the top is not absolutely necessary; instead of it, a clamp binding-screw may be fixed at the top of the carbon (see B). Carbon is a very porous substance; if the top is not protected, the acid will rise in it by capillary attraction, and soon destroy metallic fixtures by oxidation. For this reason, the top of each carbon plate or rod should, before being first used, be soaked in hot melted paraffin wax.

If artificial carbon is used, it is put in the outer cell and shaped like Z, in Fig. 32. The carbon rod described need not be carefully squared up—it may be of very irregular shape; pieces of the hard coke obtained as scurf in gas retorts are sometimes employed, without being finished up. If a battery is fitted up with such pieces of carbon, the latter should be as nearly as possible of equal size.

Strongest nitric acid is put into the carbon cell, and acidulated water, 1 to 10, or 1 to 12, into the zinc cell. The action is similar to that in Grove's cell.

FIG. 32.



For making, at a low cost, a battery for producing electric light, buy 30 empty salt-jars at 2*d.* each, or 5*s.* the set; 30 round porous cells, 5 in. high and 2½ in. diam., at 3*s.* to 4*s.* per dozen; 30 pieces of zinc, 10 in. by 5 in. by ⅛ in. or $\frac{3}{16}$ in., ready cut, at 4*d.* to 5*d.* per lb. Bend the latter round as shown in Fig. 32, by heating them, if necessary, as described on p. 76, and amalgamate them. Cut 29 pieces of copper-wire (No. 18), each 11 in. long. Buy also 30 pieces of carbon rod, 5 in. by 1½ in. by 1 in., ready cut, and with a small hole drilled right through, ½ in. from the top. If necessary, drill the holes in a lathe, or with an archimedian drill. Two plates, each ¼ in. thick, side by side, act better than a rod of double the thickness. The end of a piece of copper-wire is then passed through the top of the carbon, and twisted as shown in D. The other end of the same wire is soldered to the top of the zinc plate *e*. The wire may be coiled round a pencil, as shown at *f*. The wire connections and the soldered joints should be warmed, and then painted with three coats of Brunswick black, applied hot. The permanent wire connection from element to element described here considerably reduces the work and time expended in charging the battery. If parts of the battery are to be used at intervals for other purposes, clamps may be preferred; in that case, a strip of zinc is riveted to the top of the zinc plate, and clamped to the carbon of the next cell. The clamps required are sold at 4*s.* per dozen, but they can easily be made by amateurs.

To make battery clamp-screws, buy 1 lb. flat brass rod, ¾ in. wide and ⅛ in. thick; ½ lb. brass wire, No. 8 gauge; and ¼ lb. stamped hexagonal nuts. Cut a thread on the wire, and cut it in pieces of ⅞ in.; tap the nuts, and either rivet or solder the threaded wire into the nuts; drill a hole at ¼ in. from one end of the brass rod, and similar holes at 2¾ in., 5¼ in., 7¾ in., &c., to the end of the rod, all holes being 2½ in. apart. Tap all the holes. Bend the brass to shape in the vice, as shown in E; cut each clamp off, and fit the screws in. You can thus make your own clamps at about 1*d.* a piece, or less. They are just as good as those made from castings, but do not look quite so well finished. The 30 elements of the battery are connected as shown in F; clamp-binding screws are used for terminals.

Cost of the Materials for a 30-Element Bunsen's Battery for producing Electric Light.

	£	s.	d.
30 salt jars, 2*d.* each ..	0	5	0
30 porous pots, 4*d.* each	0	10	0
30 carbon rods, 5*d.* each	0	12	6
30 zincs, 9*d.* each ..	1	2	6
2 clamps	0	1	4
Mercury and wire ..	0	2	6
	£2	13	10

Of course 50 elements will give a better light than 30, and 100 a better one than 50, but a 30-element battery gives a very good light. It should always be borne in mind that one cell gives as much quantity as 50 of the same size, and that doubling the size of all the plates employed doubles the quantity; also that 50 elements will give 50 times the electro-motive force of one element. To produce light requires both as much quantity and as much electro-motive force as it is possible to obtain with batteries; the more of the latter, the longer will the spark be, and the more of the former, the broader the arc. (Wiesendanger.)

"With one exception, Bunsen's is the only real producer of voltaic currents that can be cheaply applied and depended upon in the production of electric light. Its current, once started, is almost constant for about 4 hours, and a good light may, with confidence, be depended upon for 3 hours." (Urquhart.)

An improvement upon the common practice of simply clamping the carbon by a binding-clamp of brass for the connection, is to give the block a heading of lead. Dry the head, cut a notch or two around it ¼ in. from the end; melt the lead, and pour it into some square mould; before it sets, dip in the carbon end; allow to solidify before removal. While still hot, the binding-screw may be soldered on, and, before it cools, the whole should receive a coating of melted pitch; or, better, dip the head in melted paraffin, which, when cool, will defend the connection from attacks of acid. A still better way, although not so quickly accomplished, is to electrotype a heading of copper upon the rods. Partly fill a porous pot with acidulated water; place in an outer cell containing crystals of copper sulphate dissolved in warm water. Heat the rods, and give them a coating of paraffin, driven in with a hot iron, between where the liquid will reach up to and the heading will reach to. If any paraffin spreads upon the end, drive it back by heating; cut a few notches in the head as before, and drill a hole through; in it tightly place a piece of stout copper wire, having ¼ in. of the end projecting at each side. Tie a wire around the carbon block; at the end fasten a strip of zinc, and place it in the porous cell, while the carbon head dips into the copper solution. Copper will begin to deposit upon the wire and carbon; when it has attained a thickness of good brown paper, remove the block, drill 2 holes through the copper and carbon, soak a little time in warm water, dry off, and place in melted paraffin. The binding-screw may be soldered to the copper, which will be found of great utility as a heading that is not attacked by acid.

When a "charge" is worked out, the outer acid is exhausted. The nitric acid will have assumed a reddish colour, and may be used again. Next time it turns green, and the third time quite clear, when it should be replaced by fresh.

While at work, this battery gives off fumes of nitric acid, which renders it necessary that it should be placed in a draught. The fumes are poisonous; and are worse while the porous cells are being emptied into the stock bottle.

In pulling the battery to pieces after operations, all connections are first loosened; the zincs are placed in a bucket of water to wash off the acid; the carbons are similarly treated; and the porous cells are emptied into the nitric acid stock bottle, and plunged into water. The outer liquid is thrown away as useless. Porous cells, once used, are kept in water for a few hours to soak out nitric acid or zinc sulphate. All connections are washed and dried, and examined for oxidized or bad-contact points, which must be scraped bright or filed.

The force of the Bunsen increases after setting up for about an hour, and the full effect is not attained until the acid soaks through the porous cell. Carbons are not affected, and last any length of time. The zinc is slowly consumed, through the mercury coating. 25 Bunsen cells will give a very brilliant light, and 50 will produce an arc of great power. The conducting wires must be about No. 12. (Urquhart and Webb.)

Callan's. — In the Callan's or Maynooth battery, a cast-iron vessel is used as the containing cell, and forms the negative element. A zinc plate, constituting the positive element, is placed in a porous cell within the iron cell. The excitant used in the iron cell is nitric acid, and that in the porous cell is dilute sulphuric acid (1 volume of vitriol to 7 of water). For experimenting, this battery is moderately cheap to construct, exposes a large negative surface, and evolves a powerful current; but it is costly in use from consuming so much nitric acid.

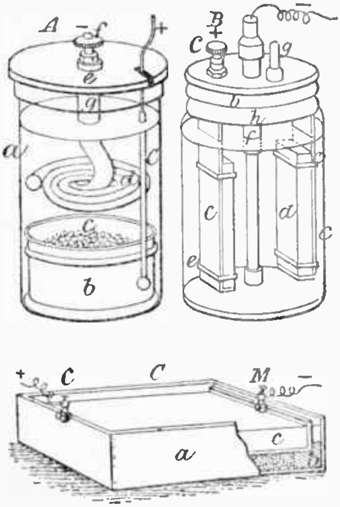
Carbon.—Mix together 15 parts powdered gas carbon, 3 of wood charcoal, and 10 of lump-sugar. Well shake down this powder, dry into paper moulds of the size and shape required, cylindrical being the most manageable. Bury the filled moulds in sand in a suitable iron or copper vessel, and gradually expose to a red heat. When cold, remove the burnt paper from the now solid cells, and soak them in a syrup made of equal parts lump-sugar and water. Well dry the cells, wrap them in paper, again bury in sand, and gradually expose them for some time to as strong a heat as practicable, but not less than a bright-red heat. For this purpose use may be made of an extempore furnace made of Fletcher's solid-flame burner, surmounted by a common unglazed earthenware drain-pipe, partially closed by an iron dome. The above described mixture, made with due care, does not crack as others do. (Symons, *Rep. Brit. Assoc.*)

Ross has an improvement in the ordinary combination of zinc and carbon, in which the carbon-rod is packed around with broken coke. In the zinc compartment, the exciting solution is a 1-per cent. solution of sulphuric acid, or a 1½-per cent. solution of hydrochloric acid; while in the carbon cell is a mixed liquid composed of 1 volume hyponitric acid, 3 of sulphuric (or 4½ of hydrochloric) acid, and 4 of water He also suggests nickel-plating, instead of amalgamating, the zincs.

André proposes carbon in the form of highly-burnt coke or wood charcoal, and in the shape of small pieces, separated from direct contact with the exciting liquid by an absorbent diaphragm. Salts of potassium, sodium, or ammonium, are used as the electrolyte. The zinc or iron electrodes are made in the form of tubes, and rest on wooden blocks surrounded by a tubular diaphragm, which allows the liquid to penetrate to the pieces of carbon in which the zinc or iron cells are imbedded. In another form, long strips of copper and zinc are coiled on a boss of wood, and separated by intervening pieces of indiarubber. The wheel or disc thus formed is revolved by an electro-motor, so that the exciting fluid does not cover more than half the disc at any one moment.

Copper Oxide.—Lalande and Chaperon have introduced a new battery with a single liquid and a solid depolarizing element, by associating copper oxide, caustic potash, and zinc. This battery possesses remarkable properties. Depolarizing electrodes are easily formed of copper oxide; it is enough to keep it in contact with a plate or cell of iron or copper constituting the positive pole of the element. Fig. 33 represents a very simple arrangement. At the bottom of a glass jar *a* is placed a box of sheet iron *b*, containing copper oxide *c*. To this box is attached a copper wire insulated from the zinc by a piece of indiarubber tube. The zinc is formed of a thick wire of this metal coiled in the form of a flat spiral *d*, and suspended from a cover *e*, which carries a terminal *f*, connected with the zinc; an indiarubber tube *g* covers the zinc at the place where it dips into the liquid, to prevent its being eaten away at this level. The jar is filled with a solution containing 30 or 40 per cent. of potash. This arrangement is similar to that of a Callan element, with this difference, that the depolarizing element is solid and insoluble. To prevent the inconveniences of the manipulation of the potash, a quantity of this substance, in the solid state necessary for an element, is enclosed in the box which receives the copper oxide, and is furnished with a cover supported by a ring of caoutchouc. It suffices then for working the battery to open the box of potash, to place it at the bottom of the jar, and to add water to dissolve the potash; then pour in the copper oxide enclosed in a bag. Also the copper oxide forms very conveniently into blocks: thus, mix the copper oxide with magnesium oxychloride in the form of paste, so as to convert the whole into a thick mass, and introduce it into metal boxes. The mass sets in a short time, or very rapidly by the action of heat, and gives porous blocks of a solidity increasing with the quantity of cement employed (5 to 10 per cent.).

FIG. 33.



B represents an arrangement with blocks. The jar *a* is provided with a copper cover *b*, screwing into the glass. This cover carries 2 vertical plates of sheet iron *c*, against which are fixed the prismatic blocks *d*, by means of indiarubber bands *e*. The terminal C, carried by the cover, constitutes the positive pole. The zinc is formed of a single pencil *f*, passing into a tube fixed to the centre of the cover. The indiarubber is folded back upon this tube so as to make an air-tight joint. The cover carries, besides, another tube *g*, covered by a split indiarubber tube, which forms a safety-valve. The closing is made hermetical by means of an indiarubber tube *h*, which presses against the glass and the cover. The potash to charge the element is in pieces, and is contained either in the glass jar itself or in a separate box of sheet iron. Applying the same arrangement, hermetically-sealed elements are formed with a single plate of very small size. The employment of cells of iron, cast iron, or copper, which are not attacked by the exciting liquid, allows the easy construction of elements exposing a large surface C.

The cell *a*, forming the positive pole of the battery, is of iron plate brazed upon vertical supports; it is 14 in. long by 7 in. wide, and about 3½ in. high. The bottom is covered with a layer of copper oxide, and in the 4 corners are porcelain insulators *b*, which support a horizontal zinc plate *c*, raised at one end and kept at a distance from the copper oxide and from the metal walls of the cell; ¾ of this is filled with a solution of potash. The terminals C and M, fixed respectively to the iron cell and to the zinc, serve to attach the leading wires. To avoid the too rapid absorption of the carbonic acid of the air by the large exposed surface, cover it with a thin layer of heavy petroleum (a substance uninflammable and without smell), or, better still, furnish the battery with a cover. These elements are easily packed so as to occupy little space.

Following are the principal properties of the battery. As a battery with a solid depolarizing element, it presents the advantages of only consuming its elements in proportion to its working; amalgamated zinc and copper are, in fact, not attacked by the alkaline solution: it is therefore durable. Its electromotive force is very nearly one volt. Its internal resistance is very low, ⅓ or ¼ ohm for polar surfaces 4 in.

square, separated by a distance of $1\frac{1}{2}$ in.; the rendering of these couples is considerable: the small cells shown in A B give about 2 ampères in short circuit, the large one gives 16 to 20 ampères. Two of these elements can replace a large Bunsen cell. They are remarkably constant. With a depolarizing surface double that of the zinc, the battery will work without notable polarization, and almost until completely exhausted, even under the most unfavourable conditions. The transformation of the products, the change of the alkali into an alkaline salt of zinc, does not perceptibly vary the internal resistance. This great constancy is chiefly due to the progressive reduction of the depolarizing electrode to the state of very conductive metal, which augments its conductivity and its depolarizing power. The manganese peroxide, which forms the base of an excellent battery for giving a small rendering, possesses at first better conductivity than copper oxide, but this property is lost by reduction and transformation into lower oxides. It follows that the copper battery will give a very large quantity of electricity working through low resistances, whilst under these conditions manganese batteries are rapidly polarized.

The energy contained in a copper oxide and potash battery is very great, and far superior to that stored by an accumulator of the same weight; but the rendering is much less rapid. Potash may be employed in concentrated solution at 30, 40, 60 per cent.; solid potash can dissolve the zinc oxide furnished by a weight of zinc more than $\frac{1}{3}$ of its own weight. The quantity of copper oxide to be employed exceeds by nearly $\frac{1}{4}$ the weight of zinc which enters into action. These data allow of the reduction of the necessary substances to a very small relative weight.

The copper oxide batteries have given interesting results in their application to telephones. For theatrical purposes, the same battery may be employed during the whole performance, instead of 4 or 5 batteries. Their durability is considerable; 3 elements will work continuously, night and day, Edison's carbon microphones for more than 4 months without sensible loss of power. The elements will work for 100 hours through low resistances, and can be worked at any moment—after several months, for example; it is only necessary to protect them by a cover from the action of the carbonic acid of the atmosphere. Potash is preferable to soda for ordinary batteries, notwithstanding its price and its higher equivalent, because it does not produce, like soda, creeping salts. Various modes of regeneration render this battery very economical. The deposited copper absorbs oxygen pretty readily by simple exposure to damp air, and can be used again. An oxidizing flame produces the same result very rapidly. Lastly, by treating the exhausted battery as an accumulator—that is to say, by passing a current through it in the opposite direction—the various products are restored to their original condition; the copper absorbs oxygen, and the alkali is restored, whilst the zinc is deposited; but the spongy state of the deposited zinc necessitates its being submitted to a process, or to its being received upon a mercury support. Again, the copper oxide employed being a waste product of brazing and plate works, unless it be reduced, loses nothing of its value by its reduction in the battery; the depolarization may therefore be considered as costing scarcely anything.

With reference to this battery, Hospitalier gives the following account of a trial made with a cell weighing 1914 *grm.* and containing 200 *grm.* of copper oxide and 800 *grm.* commercial solution of potash at 40 per cent. The E.M.F. 1 hour after setting up was 0·98 volt, and the cell was put in circuit for 6 whole days through a resistance of 0·8 ohm. The current supplied was, on an average, $\frac{1}{2}$ ampère during 6 days, or 518,400 seconds. The total quantity of electricity supplied was 259,000 coulombs, the weight of zinc consumed 88 grm., which corresponds to a theoretical production of 260,000 coulombs. This is a most important point. and very favourable to the battery, for it shows that the local action is practically nil. The energy that the battery is capable of supplying is therefore available at will, without it being necessary to disturb the elements in order to withdraw the zinc from the liquid, as in the potash bichromate batteries, for example. The useful available rendering is 0·02 kilogrammetre per second. In 6 days, therefore, the battery supplied 10,368 kilogrammetres of available electrical energy. This exceeds the results obtained up to the present with accumulators of the same weight; but the supply is much slower than from these latter. It is, however, easy to increase this rendering by increasing the surface of the elements and by diminishing the distance of the oxide from the zinc plate. The result then increases more rapidly than the weight, and tends to approach that of the accumulators. The remarkable constancy of the rendering must be attributed chiefly to the fact that the product of the reduction is metallic copper, which is a good conductor, and that the solution of an alkaline salt of zinc which is formed presents a conductivity almost equal to that of the solution of potash. For a given weight of zinc dissolved, about 3 times the amount of solid potash is required, and a quantity of copper oxide equal to 1·25 times the weight of the zinc.

Cruikshank's.—This battery consists of zinc and copper plates united in pairs, and fitting into grooves in a wooden trough, the space left between the pairs of plates accommodating the excitant. This latter is dilute sulphuric acid with a slight addition of nitric. The battery is used as a compound for medical and telegraphic purposes, but it is not very convenient.

Daniell's.—The Daniell battery consists of a copper cylinder containing another of porous earthenware, in which is placed a zinc rod; this latter forms the positive and the copper the negative element. The battery requires 2 excitants—a saturated solution of copper sulphate in the copper cylinder, and dilute sulphuric acid (1 volume oil of vitriol to 7 of water) in the porous cell. The walls of the latter keep the solutions separate, while allowing the electric current to pass through. The cathode and anode are formed by attaching binding screws to the zinc rod and copper cylinder. The battery requires no frame, is effective in use, constant, and gives a current of fair intensity. (Dyer.)

To construct a home-made Daniell cell, select a small round earthenware jar, such as is used for keeping preserves, and having lined the bottom with guttapercha, or some suitable cement, to the depth of ¾ in., fix upright in this a rod of zinc, of equal height with the jar, to which a length of copper wire has been attached by passing it through a hole drilled in the upper part of the zinc rod, or by soldering. Make a cylinder of pipeclay, or other porous clay, larger than the zinc rod, and having dried it, make it hot in the fire by degrees, till it attains a red heat. Let this cylinder cool gently, and when cold, place it in the jar round the central rod, encircling it at a little distance. By moderately heating the end of the cylinder, it will, when placed on the guttapercha, make a groove which will fix the tube, and prevent infiltration of the fluids. Line the inside of the jar with a plate of thin copper, bent into a cylindrical form, and having a few holes punched in it, through which may be threaded the extremity of another length of copper wire. On the top of this cylinder place a flat ring of copper pierced with holes, and nearly, but not quite, touching the porous cylinder. This forms the battery. To charge it, a saturated solution of copper sulphate is poured between the copper and the clay tube, and some crystals of the same salt are placed upon the perforated ring so as just to be in contact with the solution. The zinc compartment is then filled with a solution of zinc sulphate, sal-ammoniac, or common salt. (*Electrician.*)

Granule carbon.—This battery consists of an outer vessel *a* (Fig. 34), containing an inner porous cell *b*; in the outer vessel is a carbon plate *c*, packed round with broken gas-retort carbon; the zinc rod *d* is placed in the porous cell. A convenient battery may be made of 5 No. 9 jars, into which the carbon-plates with their binding screws and the porous cells are placed; the outer cells being then filled up with granulated carbon to within 1 in. of the top. As to the mixture. Make a saturated solution of potash bichromate with cold water (you will find $\frac{3}{4}$ hour sufficient to make the solution strong enough, if you give it 2 or 3 stirrings); allow it to settle, and pour off the clear solution. Take a glazed earthenware pan, and mix in it sufficient of 2 parts of the above, with 1 of muriatic acid, and fill up the outer cells. For the inner cells, break up some ammonium chloride, and put $1\frac{1}{2}$ oz. into each cell, then 1 oz. muriatic acid into each, and fill up immediately with water to the level of the granulated carbon. Couple up with stout wire, and a good light will be the result, providing you select a lamp giving low resistance. The battery requires replenishing about every 6 or 8 weeks; but this need not be if you arrange to remove the zincs from the porous cells when the light is not required. The light gets fainter after 3 hours' constant work, but regains strength if a rest is given. A layer of mercury at the bottom of the porous cell assists in keeping the zinc amalgamated and in working order. About 5 cells 8 in. by 5 in. diameter will maintain a low-resistance Swan lamp of 5 candles' power for 40 hours, but the light will not be full 5 candles. The solutions for recharging do not cost more than 3*d.* to 6*d.* in 8 or 9 months, according to use. This battery can be sealed if used for medical coils, a testing cell, or firing fuses.

FIG. 34.

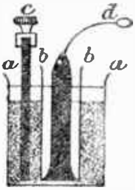
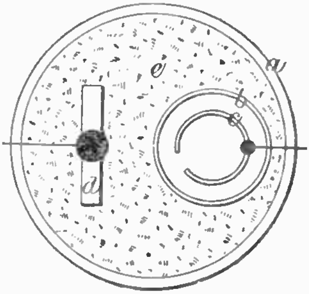


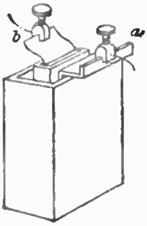
Fig. 35 shows a transverse section of a cell, which better illustrates the relative positions of the parts: *a*, outer cell; *b*, porous cell; *c*, zinc; *d*, carbon plate; *e*, granulated carbon. The black spots on the carbon-plate and zinc show the position of binding screws with wires attached. Couple up zinc of one cell to carbon of next, throughout, with stout copper wire. Place the lamp opposite a looking-glass, to economize the light. The dimensions of some parts are: outer jars, 8 in. by 6; porous cells, 9 in. by $2\frac{1}{2}$; carbon plates, $8\frac{1}{2}$ in. by $2\frac{1}{4}$ by $\frac{3}{16}$; zinc tubes, 9 in. by $1\frac{3}{4}$. The battery may be used in a well-ventilated bedroom, but the muriatic acid might then be better replaced by sulphuric.

FIG. 35.



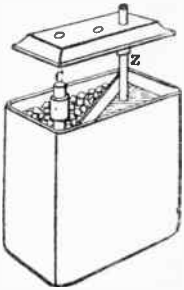
Grove's.—The elements of this battery are platinum for the negative and zinc for the positive. The battery requires a containing vessel to hold the entire arrangement, and an inner cell to hold the platinum foil only. This inner cell, like that in Daniell's battery, is of porous earthenware, which will permit the passage of the galvanic current through its sides, but will not allow the exciting fluids to mingle. When the zinc plate *a* is placed in the containing jar, the porous cell is placed between the upright portions of the zinc, and the platinum foil *b* is then put into the porous cell, as in Fig. 36. The zinc plate is usually made of a long strip bent up in the form of the letter U, by which means the zinc is brought opposite to each side of the platinum plate. But it is advantageous, instead of bending a long strip of zinc, to employ 3 shorter pieces: 1 to be put at the bottom of the containing jar, and 2 others resting on this to form the vertical sides. This is less expensive to make, and more economical to use. Binding-screws, attached to the zinc plate and the platinum, form the 2 electrodes. The excitants are strong nitric acid in the porous cell with the platinum, and acidulated water with the zinc. The form illustrated is most convenient on the score of portability, but the greatest power is obtained by arranging the battery in cylindrical vessels like a Bunsen. The ends and bottoms of porous cells may be thickened for strength. These batteries are expensive at first, owing to the high price of platinum; but the latter does not waste, and is best procured of reasonable stoutness at the outset. The connections may be soldered; but it is better to have a copper intermediary clamp-piece, and coat it with a protective against the acid fumes, e.g., Brunswick varnish, or an alcoholic solution of sealing-wax. The Grove battery costs about 3 times as much as a Bunsen of equal power; but its low resistance gives a stronger current for the same size. The connections and conductors must be of stout, soft copper; and the porous cells should have a lip at one corner. The duration of the battery about equals that of the Bunsen, with a smaller consumption of nitric acid.

Fig. 36.



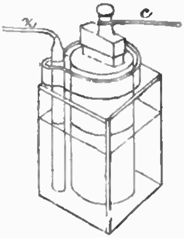
Insulite.—The British Insulite Co. have brought out a sealed cell suitable for domestic use, as shown in Fig. 37. It is an oblong vessel on plan, with a diaphragm of porous material securely cemented to opposite corners, thus dividing the cell into 2 equal compartments. In one is a carbon rod surrounded by fragments of carbon about pea size, and in the other, the familiar zinc rod, with a special excitant, non-corrosive and non-poisonous. The lid is perforated with 3 holes, into 2 of which the electrodes fit water- and air-tight, by the aid of collars formed of pieces of rubber tubing; while the third is closed by a stopper and capsule, forming a release-valve to provide for the slight variations in the pressure of the contained air. When the capsule is screwed home, the cell may be shaken about or inverted without injury or escape of the liquid; and one turn of the capsule is sufficient to leave the cell in a permanently working condition. The lid, having been fitted to the electrodes, is pressed down on the diaphragm, and autogenously soldered in position, the zinc rod lasting about 2 years with the average amount of usage of the bell, and being readily replaced when worn out. The connections are made by nickel-plated caps, split and held by pinching screws to the carbon and zinc rods, and as the latter are tightly surrounded by rubber, there is little risk of defective connections from corrosion or other effects.

Fig. 37.



Leclanché.—This form of battery, Fig. 38, is in very general use for electric bells, its great recommendation being that, once charged, it retains its power without attention for several years. 2 jars are employed in its construction: the outer one is of glass, contains a zinc rod, and is charged with a solution of ammonium chloride (sal ammoniac). The inner jar is of porous earthenware, contains a carbon plate, and is filled up with a mixture of manganese peroxide and broken gas carbon. When the carbon plate and the zinc rod are connected, a steady current of electricity is set up, the chemical reaction which takes place being as follows:—The zinc becomes oxidized by the oxygen from the manganese peroxide, and is subsequently converted into zinc chloride by the action of the sal-ammoniac. After the battery has been in continuous use for some hours, the manganese becomes exhausted of oxygen, and the force of the electrical current is greatly diminished; but if the battery be allowed to rest for a short time, the manganese obtains a fresh supply of oxygen from the atmosphere, and is again fit for use. After about 18 months' work, the glass cell will probably require recharging with sal-ammoniac, and the zinc rod may also need renewing; but should the porous cell get out of order, it is better to get a new one entirely, than to attempt to recharge it. (Dyer.)

FIG. 38.



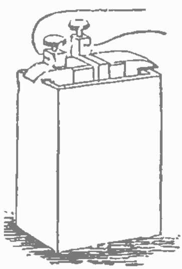
Lime Chromate.—This is a double-liquid battery devised by Fitzgerald and Molloy; it is said to be as constant as the Bunsen, almost as effective, and much cheaper. The chief point is to secure a large negative surface, and, by a soft porous cell, to reduce the internal resistance. The best form is a carbon cylinder surrounding a large porous cell containing a zinc cylinder. The carbon for the cylinder must be ground to fine powder, mixed into a stiff dough with water and sugar syrup, baked until hard, plunged, while still hot, into a strong solution of sugar or tar, heated to whiteness, and cooled slowly. Another arrangement is as follows:—In a large soft porous cell is centrally placed a thin carbon or Bunsen rod, with a screw affixed. A quantity of broken carbon, in lumps as large as hazel-nuts, is packed around the rod. Melted pitch is run over the top, and a conical hole is left for the introduction of the liquid. The outer cell contains a zinc cylinder of only just sufficient diameter to admit the porous cell freely, the object being to have the zinc near the negative element. To allow the outer liquid greater freedom of action, the zinc cylinder has a separation of about ½ in. The elements are thus carbon and zinc. The exciting solutions are:—(*a*) For porous cell: 2 oz. lime chromate, 5 oz. warm water, 5 oz. sulphuric acid. ( ) For the outer cell: 1 pint water, 3 oz. sulphuric acid. Little or no fumes are given off. The electro-motive force is slightly greater than that of the Bunsen; but the internal resistance is also greater. The same cell is available for use with another excitant, which works with even greater force, and gives no fumes for the first 2 hours:—For the porous cell: 2 oz. potash bichromate, 10 oz. nitric acid, 2 oz. sulphuric acid. The solution in the outer cell is the same as for the Bunsen. This works with greater power than the Bunsen, owing to the arrangement of the carbon; the internal resistance is less, but the cost of working is rather greater. After use, the porous cells should be emptied of their contents, and kept in water till again wanted. The same solution may be used 2 or 3 times, and on any appearance of a paucity of potash salt, more should be added. The carbon cell demands a strongly acid mixture. The battery may be advantageously used as a Bunsen, and gives a better current than common forms at little extra cost of construction. (Urquhart.)

Silver Chloride.—Skrivanow, of Paris, covers a carbon plate on both sides with silver chloride, and immerses it in a solution of potassium or sodium hydrate, the hydrate being in the proportion of 30 to 40 per cent. of the weight of the water. A zinc plate is immersed in the same solution close to the carbon, which may, however, be wrapped in asbestos cloth or placed in a porous cell. The battery may be revivified by plunging the carbon plate in a bath composed of nitric and hydrochloric acids, or sodium chloride dissolved in water, the object being to chloridize the metallic silver. The hydrates may be dissolved in glycerine if the battery is exposed to frost.

Amongst portable batteries may be noted one by Mackenzie, which is a modification of the silver chloride arrangement. A short piece of copper tube has one end stopped by a cap of the same metal, and, the interior being plated with silver, is subsequently covered with a layer of fused silver chloride; the other end of the tube is closed with a cap of some insulating material, through which passes a zinc screw, holding in the interior of the tube a zinc cylinder or tube, extending nearly to the bottom of the cell thus formed. The exciting liquid is sodium chloride (common salt) or sulphate, or zinc chloride. The wires are attached respectively to the zinc screw and to the exterior of the copper tube.

Smee's.—This form of battery is very extensively used, and consists of a platinized silver plate for the negative element, with zinc plates for the positive, as in Fig. 39. The platinized silver plate is usually attached to a wooden bar, and the zinc plates, placed one on each side of it, are kept in position by a metallic cramp passing over the top of the bar. A binding screw, passed through the wooden bar and attached to the silver plate, forms the anode, and a similar binding screw, on the cramp that holds the zincs to the bar, is the cathode. An earthenware containing-vessel is required; the battery is excited by dilute sulphuric acid (7 volumes of water to one of acid). This battery is admirably adapted for electro-depositing and general galvanic experiments; but it is not suitable for producing electric light, nor for intensity coils. It is easily managed, tolerably constant, and requires only one exciting fluid: therefore, porous cells are dispensed with. (Dyer.)

FIG. 39.



Thermo-electric.—When the junction, of 2 different metals is heated, an electric current is generated, the greatest effect being obtained with antimony and bismuth. Such generators are known as thermo-electric piles. By multiplying them, increased force is produced; 60 well-constructed couples give a current equal to that from a 1-gal. Bunsen battery, and less than 3000 of Faure's couples, with an expenditure of 80 cub. ft. of gas per hour for heating, are equivalent to 50 Bunsen's. An improved form has recently been introduced by Sudre. One of its main features is the maintenance of the necessary difference of temperature between the two solderings of each couple by placing the couples between surfaces from which they are electrically insulated. An isolated thermo-electric couple is ordinarily composed of a metallic prism casting, and a polar plate of iron, copper, or German silver, soldered to each of its extremities. The plates do not interfere with the electric force obtained, and it is the bar (such as that of antimony and zinc) which produces the effect. When using 2 metals whose effects are combined, and which are easily fusible, *e.g.* antimony and bismuth, the couple is formed of 2 bars, joined by a cross bar soldered to each. The total resistance of a couple is composed (1) of the resistance of the connecting plate; (2) of the resistance of the bar; (3) of a particular resistance at the points of contact or soldering between the plates and the bar. The plates should be of a sufficiently conductive metal, large and thick enough to present but feeble resistance, and as short as possible. The bar should have very little resistance under a small volume. Sudre takes as a datum the formula $R=k\frac{L}{S}$, in which k is a specific coefficient for the metal employed, L the length of the bar, and S its section. As the resistance depends on the ratio $\frac{L}{S}$, the volume of the couple may be diminished by lessening the length and sectional area in equal degrees, in which case the resistance will not be affected. The length given to the bar depends upon the difference of temperatures employed. For differences between 10° and 120° C. (50° and 248° F.), Sudre gives the couples a length of ½ in., whilst if the higher temperature reaches 300° C. (572° F.), the length varies from ¾ to 1⅛ in. The resistance at the points of contact or soldering is of the highest importance. The junction should be made so that the plate is in contact with the whole section of the bar. The plate should penetrate to a very little depth within the bar, so as not to diminish the electro-motive force of the couple; for the effective difference of temperature is that of the 2 solderings, and this diminishes as the plates penetrate into the bar, and thus approach one another.

Residues.—From a table compiled by Kolb, one of the secretaries in the Imperial Telegraph Department of Germany, it seems that of the 12,350*l.* spent during the year 1881-82 upon the 127,166 galvanic cells in use, 2727*l.*, or about 22 per cent., were recovered by the sale of the battery residues, consisting of copper, zinc, and lead salts. It has been customary to sell these products by auction twice a year. The Government does not guarantee any fixed percentage of metal in these salts, but the amount varies very slightly. The normal cell of the German telegraph offices is a modified Daniell of a simple and cheap kind. The zinc electrode is formed of a ring, hanging down from the edge of a glass vessel to half its depth. On the bottom lies a rectangular plate of lead, to which a vertical stout iron wire, encased in sheet lead, is soldered, making the other electrode. The glass is filled with zinc sulphate solution, and a few crystals of copper sulphate are from time to time dropped into the liquid. Of these materials the zinc ring is, of course, most subject to deterioration. Thus the above-mentioned 127,166 cells require nearly 80,000 new zinc rings, against 730 lead sheets and 910 lead plates. The copper sulphate forms the largest item in the annual expenditure, amounting to 8000*l.* During the 4 years which the table comprises, from 1878 to 1882, the number of cells had increased by nearly 20,000. (*Engineering.*)

Bells.—An ordinary electric bell is merely a vibrating contact-breaker carrying a small hammer on its spring, which hammer strikes a bell placed within its reach as long as the vibration of the spring continues. The necessary apparatus comprises a battery to supply the force, wires to conduct it, circuit-closers to apply it, and bells to give it expression.

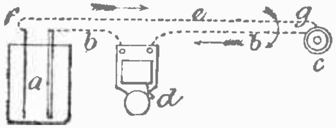
The Leclanché battery (see p. 89) is the best for all electric bell systems. On short circuits, 2 cells may suffice, increasing up to 4 or 6 as required. It is false economy to use a battery too weak to do its work properly. The battery should be placed where it will not be subject to changes of temperature, *e.g.*, in an underground cellar.

The circuit wire used in England for indoor situations is "No 20" copper wire, covered with guttapercha and cotton. In America, "No. 18, first-class, braided, cotton-covered, office wire" is recommended, though smaller and cheaper kinds are often used. The wire should be laid with great regard to keeping it from damp, and ensuring its perfect insulation. Out of doors, for carrying long distances overhead, ordinary galvanized iron wire is well adapted, the gauge running from "No. 4" to "No. 14," according to conditions. Proper insulators on poles must be provided, avoiding all contact with foreign bodies; or a rubber-covered wire encased in lead may be run underground.

The circuit-closer, or means of instantaneously completing and interrupting the circuit, is generally a simple press-button. This consists of a little cylindrical box, provided in the centre with an ivory button, which is either (1) attached to a brass spring that is brought into contact with a brass plate at the back of the box on pressing the button, or (2) is capable of pressing together 2 springs in the box. A wire from the battery is attached to the spring of the press-button, and another from the bell is secured to the brass plate. Platinum points should be provided on the spring and plate when the contact takes place. While the button is at rest, or out, the electric circuit is broken; but on being pressed in, it completes the circuit, and the bell rings.

The relative arrangement and connection of the several parts is shown in Fig. 40: *a*, Leclanché cell; *b*, wire; *c*, press-button; *d*, bell. When the distance traversed is great, say ½ mile, the return wire *e* may be dispensed with, and replaced by what is known as the "earth circuit," established by attaching the terminals at *f* and *g* to copper plates sunk in the ground.

FIG. 40.



The bells used are generally vibrating ones, and those intended for internal house use need not have a higher resistance than 2 or 3 ohms. At other times, single-stroke and continuous-ringer bells have to be provided, the latter being arranged to continue ringing until specially stopped. The bell may or may not be fitted with an annunciator system; the latter is almost a necessity when many bells have to ring to the same place, as then 1 bell only is requisite. A single-stroke bell is simply a gong fixed to a board or frame, an electro-magnet, and an armature with a hammer at the end, arranged to strike the gong when the armature is attracted by the magnet. A vibrating bell has its armature fixed to a spring which presses against a contact-screw; the wire forming the circuit, entering at one binding-screw, goes to the magnet, which in turn is connected with the armature; thence the circuit continues through the contact-screw to the other binding-screw, and out. When set in motion by electricity, the magnet attracts the armature, and the hammer strikes the bell; but in its forward motion, the spring leaves the contact-screw, and thus the circuit is broken; the hammer then falls back, closing the circuit again, and so the action is continued *ad libitum*, and a rapid vibratory motion is produced, which makes a ringing by the action of the successive blows of the hammer on the gong.

The following useful hints on electric bell systems are condensed from Lockwood's handy little volume on telephones.

With regard to the battery, he advises to keep the sal-ammoniac solution strong, yet not to put so much in that it cannot dissolve. Be extremely careful to have all battery connections clean, bright, and mechanically tight, and to have no leak or short circuit. The batteries should last a year without further attention, and the glass jars never ought to be filled more than ¾ full.

(*a*) 1 *Bell and* 1 *Press-button.*—The simplest system is 1 bell operated by 1 press-button. The arrangement of this is the same whether the line be long or short. Set up the bell in the required place, with the gong down or up as may be chosen; fix press-button where wanted, taking all advantages offered by the plan of the house; *e.g.* a wall behind which is a closet is an excellent place to attach electrical fixtures, because then it is easy to run all the wires in the closets, and out of sight. Set up the battery in a convenient place, and, if possible, in an air-tight box. Calculate how much wire will be requisite, and measure it off, giving a liberal supply: joints in inside work are very objectionable, and only admissible where absolutely necessary. Cut off insulation from ends of wire where contact is to be made to a screw. Only 3 wires are necessary, *i.e.* (1) from 1 spring of the press-button to 1 pole of the battery, say the carbon, (2) from the other spring of the button to 1 binding-screw of the bell, (3) from the other pole of the battery to the other binding-screw of the bell. In stripping wires, leave no ragged threads hanging; they get caught in the binding-screw, and interfere with the connection of the parts. After stripping the wire sufficiently, make the ends not only clean but bright. Never run 2 wires under 1 staple. A button-switch should be placed in the battery-circuit, and close to the battery, so that, to avoid leakage and accidental short circuiting when the bells are not used for some time, it may be opened.

(*b*) 1 *Bell and* 2 *Press-buttons.*—The next system is an arrangement of 2 press-buttons in different places to ring the same bell. Having fixed the bell and battery, and decided upon the positions of the 2 buttons, run the wires as follows:—1 long covered wire is run from 1 pole of the battery to 1 of the springs of the most distant press-button, and where this long wire approaches nearest to the other press-button it is stripped for about 1 in. and scraped clean; another wire, also stripped at its end, is wound carefully around the bared place, and the joint is covered with kerite tape; the other end of the piece of wire thus branched on is carried over and fastened to the spring of the second press-button. This constitutes a battery wire branching to 1 spring of each press-button. Then run a second wire from 1 of the bell binding-screws to the other spring of the most distant press-button, branching it in the same manner as the battery-wire to the other spring of the second button; connect the other pole of the battery to the second binding-screw of the bell, and the arrangement is complete—a continuous battery-circuit through the bell when either of the buttons is pressed. Before covering the joints with tape, it is well to solder them, using rosin as a flux.

(*c*) 2 *Bells and* 1 *Press-button.*—When it is required to have 2 bells in different places, to ring from 1 press-button at the same time, after erecting the bells, button, and battery, run a wire from the carbon pole of the battery and branch it in the manner described to 1 binding-screw of each bell; run a second wire from the zinc pole of the battery to 1 spring of the button, and a third wire from the other spring, branching it to the remaining binding-screw of both bells. It will not answer to connect 2 or more vibrating bells in circuit one after another, as the 2 circuit-breakers will not work in unison; they must always be branched, *i.e.* a portion of the main wire must be stripped, and another piece spliced to it, so as to make 2 ends.

(*d*) There are other methods, one of which is, if more than 1 bell is designed to ring steadily when the button is pressed, to let only 1 of the series be a vibrating bell, and the others single-strokes; these, if properly set up and adjusted, will continuously ring, because they are controlled by the rapid make and break of the 1 vibrator.

(*e*) *Annunciator system.*—To connect an indicating annunciator of any number of drops with a common bell, to be operated by press-buttons in different parts of a house, is a handy arrangement, as one drop may be operated from the front door, another from the drawing-room, a third from the dining-room, and so on. The annunciator is fastened up with the bell near it. All the electro-magnets in the annunciator are connected by 1 wire with 1 binding-screw of the bell, and the other binding-screw of the bell is connected with the zinc of the battery. It is a good plan to run a wire through the building from top to bottom, at one end connecting it with the carbon pole of the battery. It ought to be covered with a different coloured cotton from any other, so as to be readily identified as the wire from the carbon. Supposing there are 6 press-buttons, 1 in each room, run a wire from 1 of the springs of each of the press-buttons to the main wire from the carbon pole, and at the point of meeting strip the covering from both the main wire and the ends of the branch wires from the press-buttons, and fasten each branch wire to the main wire, virtually bringing the carbon pole of the battery into every press-button. Next, lead a second wire from the other spring of each press-button to the annunciator screw-post belonging to the special drop desired. This will complete the circuit when any of the press-buttons is pushed; for, as each annunciator magnet is connected on 1 side to its own press-button, and on the other side to the common bell, it follows that when any button is pressed, the line of the current is from the carbon pole of the battery, through the points of the press-button, back to the annunciator, thence through the bell to the zinc pole of the battery; and that, therefore, the right annunciator must drop and the bell must ring. In handsome houses, run the wires under the floor as much as possible, and adopt such colours for wire covering as may be harmonious with the paper and paintings. Also test each wire separately, as soon as the connection is made.

(*f*) *Double system.*—A system of bells in which the signalling is done both ways, that is, in addition to the annunciator and bell located at one point, to be signalled by pressing the button in each room, a bell is likewise placed in each room, or in a certain room, whereon a return signal may be received—transmitted from a press-button near the annunciator. This is a double system, and involves additional wires. One battery may furnish all the current. Run the main carbon through the house, as before, in such a manner as to admit of branch wires being easily attached to it. Run a branch wire from it to the spring of one of the press-buttons, a second wire from the other spring of the same button to the screw-post of the bell in room No. 2, and from the other screw-post of the said bell to the zinc pole of the battery. This completes one circuit. The other is then arranged as follows:—The main carbon, besides being led, as already described, to the spring of the press-button in room No. 1, is continued to one of the binding-screws of the bell in the same room: the other terminal of that bell is carried to one spring of the press-button in room No. 2; the complementary spring of that press-button is then connected by a special and separate wire with the zinc of the battery, and the second circuit is then also completed.

An alternative method is to run branches from the main carbon wire to all the press-buttons, and from the main zinc wire to all the bells, connecting by separate wires the remaining bell terminals with the remaining press-button springs. In the latter plan, more wires are necessary. Although the connections of but one bell either way have been described, every addition must be carried out on the same principle.

When 2 points at some distance from one another, *e.g.* the house and a stable 100 yd. distant, are to be connected, it is easy to run 1 wire, and use an earth return. If gas or water pipes are in use at both points, no difficulty will be found in accomplishing this. A strap key will in this case be found advantageous as a substitute for a press-button. The connecting wire at each end is fastened to the stem of the key; the back contact or bridge of the key, against which when at rest the key presses, is connected at each end with 1 terminal of the bell, the other terminal of each bell being connected by wire with the ground. A sufficient amount of battery is placed at each point, and 1 pole of each battery is connected with the earth, the other pole being attached to the front contact of the strap key. If impossible to get a ground, the second terminal of both bell and battery at each end must be connected by a return wire.

(*g*) *Bell and Telephone.*—It is a very easy matter to add telephones to bell signaling appliances, when constructed as here described. The only additions necessary are a branch or return circuit for the telephones, and a switch operated by hand, whereby the main wire is switched from the bell return wire to the telephone return wire. A very simple plan for a bell-call and telephone line from one room to another, can be made as follows: Apparatus required—2 bells, 2 telephones, 2 3-point switches, 2 strap-keys with back and front contacts, and 1 battery. Run 1 wire from the stem of the key in room No. 1 to the stem of the key in room No. 2. This is the main wire. Fix the bell and 3-point switch below it in each room. Connect the back contact of each key by wire to the lever of the 3-point switch, attach 1 of the points of the switch to 1 of the bell terminals, and the other bell terminal to a return wire. The return wire will now connect the second bell terminal in one room with the second bell in the other room. The other point of the switch in each room is now connected by a wire with 1 binding-screw of a telephone, and the other telephone screw is attached by another wire to the bell return. Connecting 1 pole of the battery also to the return wire, and the other pole to each of the front contacts of the keys, the system is complete. When at rest, each switch is turned on to the bell. To ring the bell in the other room, the key is pressed. The battery circuit is then from battery, front contact of the pressed key, stem of key, main wire, stem of distant key, switch, bell, and through return wire to the other pole of the battery. After bell signals are interchanged, the 3-point switches are transferred to the telephone point, and conversation can be maintained. (Lockwood.)

Making an Electric Bell.—The following description applies to 3 sizes—viz. for a 2-in. bell, hereafter called No. 1; 2¾-in., or No. 2; 4-in., or No. 3, which sizes are sufficient for most amateurs' purposes, and, if properly made, a No. 3 Leclanché cell will ring the largest 2 through over 100 yd. No. 24 (B. W. G.) wire.

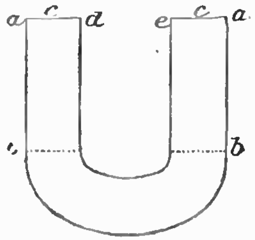
The Backboard and Cover.—This may be of any hard wood, by preference teak, oak, or mahogany, and if polished, so much the better; the size required will be—

No. 1, 5¼ in. long, 3¾ in. wide, ¼ in. thick.
No. 2, 7 in. „ 3¾ in. „ ⅜ in. „
No. 3, 8¼ in. „ 5 in. „ ½ in. „

The cover must be deep enough to cover all the work, and reach to within about ¼ in. of the top and sides of back, and allow ⅜ in. to ¾ in. between the edge of bell and cover; the making of this had better be deferred until the bell is nearly complete.

The Electro-Magnet.—This should be of good round iron, and bent into a horse-shoe shape (Fig. 41). The part *a b* must be quite straight, and not damaged by the forging; the bend should be as flat as possible, so as to make the magnet as short as may be (to save space).

FIG. 41.

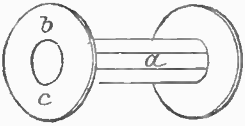


When made, the magnet is put into a clear fire, and when red hot, taken out and laid in the ashes to slowly cool; care must be taken not to burn it. Lastly, 2 small holes are drilled in the centre of the ends at *c*, about $\frac{1}{16}$ in. deep; drive a piece of brass wire tightly into the holes, and allow the wire to project sufficiently to allow a piece of thin paper between the iron and the table when the iron is standing upon it; this is to prevent the armature adhering to the magnet from residuary magnetism, which always exists more or less. The measurements are—

No. 1 size iron ¼ in., *d* to *e* ⅝ in., *a* to *b* 1¼ in.
No. 2 „ $\frac{5}{16}$ in., „ ¾ in., „ 1¾ in.
No. 3 „ $\frac{7}{16}$ in., „ ⅞ in., „ 1½ in.

The Bobbins or Coils.—These are made by bending thin sheet copper round the part *a b* of the magnet; the edges at *a* (Fig. 42) must not quite meet. The thickness of this copper must be such that 4 pieces just equal in thickness the edge of a new threepenny-piece (this is rather an original gauge, but then all can get at the thickness this way). The hole in the brass end *b* must be just large enough to push on firmly over the copper when on the iron; they must then be set true, and soldered on. The brass for the ends may be about as thick as a sixpence; a $\frac{1}{16}$-in. hole must be drilled at *c*, close to the copper. The other measurements are as follows:—

FIG. 42.

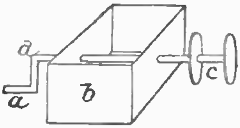


No. 1, diameter ⅝ in., length over all 1½ in.
No. 2, " ¾ in., " 1¾ in.
No. 3, " 1 in., " 1⅞ in.

The brass ends should be neatly turned true, and lacquered.

To fill the Bobbins with Wire.—For this purpose, No. 28 wire should be used, which is better if varnished or paraffined. The bobbins should be neatly covered with paper over the copper tube and inside of ends, to prevent any possibility of the wire touching the bobbin itself; the bobbin is best filled by chucking it on a mandrel in the lathe, or a primitive winding apparatus may be made by boring a hole through the sides of a small box, fit a wire crank and wooden axle to this, and push the bobbin on the projecting end—thus (Fig. 43): *a*, crank; *b*, box; *c*, bobbin; *d*, axle. The box may be loaded to keep it steady; on any account do not attempt to wind the wire on by hand—the bobbin must revolve. Leave about 1½ in. of wire projecting outside the hole *d*, in end of bobbin, and wind the wire on carefully and quite evenly, the number of layers being respectively 6, 8, and 10; the last layer must finish at the same end as the first began, and is best fastened off by a silk or thread binding, leaving about a 3-in. piece projecting. Both bobbins must be wound in the same direction, turning the crank from you, and commencing at the end nearest the box. The bobbins must now be firmly pushed on the part *a b* of the magnet, and the two pieces of wire projecting through the holes *c* soldered together.

FIG. 43.



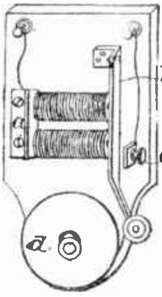
To put the Bell together.—First screw on the bell. This should be supported underneath by a piece of ¼-in. iron tube, long enough to keep the edge of the bell ⅜ to ⅝ in. above the backboard. Cut off the hammer-rod, so that when the head is on it will come nearly as low as the bell screw, and in a line with it. Make a hole in the backboard, and drive the armature post in tightly—it must be driven in so far that when the magnet is laid upon the backboard, the centre of the magnet iron and the armature are the same height. Place the magnet so that when the armature is pressed against it, the hammer-head all but touches the bell; screw it into its place by a wooden bridge across the screw passing between the bobbins. By afterwards easing this screw, any little adjustment can be made. The armature spring should tend to throw the hammer-head about ⅝ in. from the bell. The contact-post should be so placed that when the armature touches the magnet, there is a slight space between the platinum point on the screw and the platinum on the spring. In putting in the posts, a piece of copper wire must be driven in with them to attach the wire to. One post can be moved round a little either way to alter the tension of the spring; the screw in the other post can be turned in or out, to just allow the proper break to take place. By screwing it in and out, the ear will soon judge where the bell rings best. (Volk.)

Examples.—It will doubtless be of considerable assistance to many amateurs to have a few examples illustrated and explained.

(1) Trembling Bell.—Make an electro-

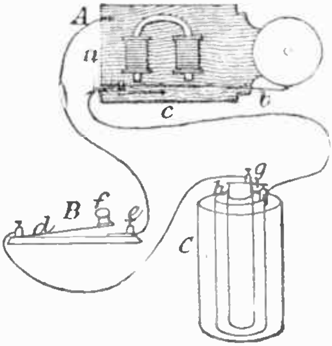
magnet, either out of $\frac{3}{8}$-in. iron bent round, or a piece of iron bent at a right angle, into which 2 cores can be screwed as at *a*, Fig. 44. On each of these cores wind 2 oz. 26 silk-covered wire; you may wind directly on to the iron, or make a bobbin; if you wind on to the iron, first cover each core with paraffin paper. The armature *b* is mounted on a spring containing the hammer at the other end. The spring is continued apart from the armature to a platinum-pointed screw *c*; this enables you to adjust the armature to a very great nicety. Lines show the connection of wires from binding-screws to electro-magnet. Of course, these wires go underneath the board. The bell *d* is suspended on a brass or iron post, with a thumb-nu on the top, screwing down on to t bell; 2 good Leclanché cells would wor this bell well.

FIG. 44.



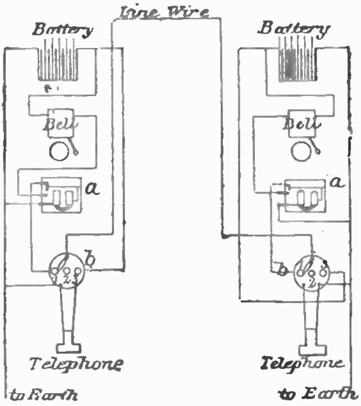
(2) A (Fig. 45) is the bell. Th consists of an electro-magnet *a*, with a vibrating armature *b*; *c* is a brass spring tipped with platinum, which keeps the circuit closed so long as the bell is not ringing. The wires are connected to the push B, and battery C. Thus, when the push B is pressed down, the circuit is closed, the iron core in electro-magnet is magnetized, and pulls the iron armature on *b* close up, thus causing the knob to strike the bell, and at the same time breaking the circuit by leaving the platinum tip on *c* The push B consists of a thin brass spring *d* and a binding-screw *e*, with a brass plate connected to it going immediately under the wooden knob *f*. The cell C is a Leclanché, with the carbon rod *g* in porous jar, well packed with an equal quantity of coke and lamp-black, oxide of manganese, and the zinc cylinder *h*. The lines show how the wires are to be connected up.

FIG. 45.



(3) Connecting Bells and Telephones by one Wire.—Use a relay, as shown in Fig. 46 at *a*. The switch *b* has 3 knobs, Nos. 1, 2, 3 The handles of both switches must be turned on No. 1 when not in use, awaiting calls, both on No. 2 for telephonic messages, and either on No. 3 for ringing bell to call attention at the other end. It would be better to have the bell single stroke (the connections make the difference), and the relay

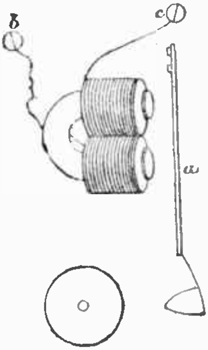
FIG. 46



will make it continuous. Make the relay of small size, and to fit in at the back of the switch. The action of the relay is thus:—When handle is turned on No. 3 right-hand switch, a current of electricity is sent through wire to the other end, through No. 1 knob to electro-magnet in relay, which draws down the spring until it touches the other wire, which sends a current through the battery, and strikes the bell. The other connections will explain themselves.

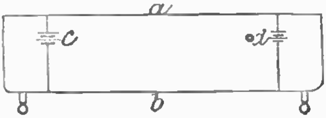
(4) Single-stroke Bell.—Fig. 47 explains its construction. Instead of having a contact-breaker fixed at *a*, the circuit only goes through the magnet, thus only ringing when the button is pressed. *b* and *c* are connected with the battery.

FIG. 47.



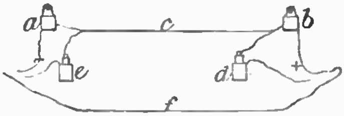
(5) It is possible to ring 2 bells with only 1 wire by having 2 series of cells: but this involves much more expense and trouble than laying a double wire and one series of cells. You can work with 1 wire if you allow both bells to ring at the same time, and have a battery at each end, or you can so arrange the batteries and bells as to throw battery of one end in circuit with the bell of the other end, and so on, as in Fig. 48, where *a* represents the gas-pipe; *b*, line wire joined up with bells in circuit; *c* and *d*, 2 wires going through cells and on to pushes in connection with line wire. Thus, when either of the pushes is closed down, the battery and distant bell are in circuit, and vice versâ.

FIG. 48.



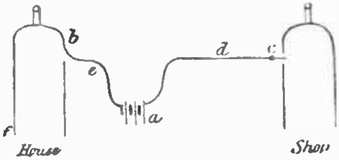
(6) The subjoined arrangement (Fig. 49) is a simple way of effecting the same object as the preceding. Let *a b* be bells at shop and house respectively; connect the line wire *c* with a binding-screw of each bell, as shown. Have a battery at shop and another at house, *d* and *e*; connect line-wire also with one pole of each battery; connect the remaining binding-screw of each bell with a metallic plate; connect the remaining poles of batteries, each with a metallic plate. Instead of the ordinary "push," arrange metallic springs at shop and house, permanently connected with gas-pipe *f*, and so placed that when at rest they are in contact with the plates.

FIG. 49.



(7) Fig. 50 shows another solution of the same difficulty. The battery *a* is placed in the house. At *b* and *c* are 2 small levers, which can be moved so as to put the line wire *d*, and the short wire *e*, which constitute the poles of the battery, in connection with the earth in 2 sets of ways. The figure shows the connection in case it is wished to ring

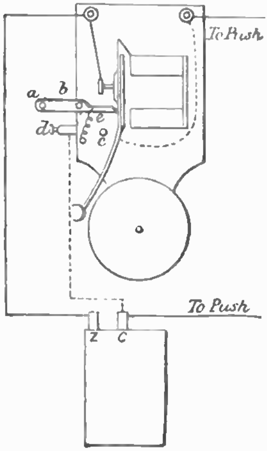
FIG. 50.



the house bell from the shop. Before leaving the house, bring the lever *b* in connection with the wire which traverses the electro-magnet of the house bell; thus *e* is brought into connection with the earth at *f*. Whenever, then, in the shop, you press down the lever *c*, you complete the circuit, and the house bell rings. Before leaving the shop, raise the lever *c* so as to bring the shop bell into the circuit, and when returning to the house you can complete the circuit, and cause the shop bell to ring every time you press down the lever *b*.

(8) Continuous-ringing Bell.—This is more complicated than the single-stroke, as will be seen by Fig. 51. A small piece of brass or iron is fixed in a suitable way (riveting is best) on to the armature of the bell upon which rests edgeways a piece of flat brass *a*, shaped as in the diagram; it is supported by a piece of brass tube, through which a screw *b* passes, securing it to the board—not too tightly, however, so as not to allow of its swinging easily; a piece of brass rod or stout wire *c* is driven into the base-board in such a way that when *a* is drawn down by the spring *e*, a good contact is formed between *a* and *c*. A wire is taken from *c* to one binding-screw of the bell, and a wire is taken from the brass tube which supports *a* to another separate binding-screw *d*. The dotted lines represent wires as well as the other lines; the dotted lines also represent the direction of the current for the continuous action, using the same wire to the zinc element. The current passes from the zinc to the contact-screw, through the coils to *c*, across *a*, down *b*, and out through the binding-screw *d* to the carbon element. The bell is stopped by pulling a cord attached to *a*, which breaks the contact, and which, if pulled hard enough, forces the armature towards the magnet by rubbing against the piece in the armature (which must be made in the shape of the diagram). When it gets above the piece in the armature, the armature springs back, and *a* rests on the piece of brass again, ready for another time.

FIG. 51.



(9) Method of producing continuous ringing from an ordinary Electric Bell.—The method works well, is inexpensive, and any one with ordinary intelligence could make and fix one for himself. Of course, the bell must have a contact breaker. In Fig. 52, *a* is the bell; *b*, hammer, in the centre of which is screwed or soldered a piece of metal projecting outwards ½ in. The head of hammer is flat, circular, with a hole in centre; *c*, piece of brass hung loosely on the screw, to which wire is attached, leading to bell as shown; *d*, screw and wire attached, leading to battery. On the bell being rung, the oblong piece of brass *c* is liberated, falling on to *d*, making a new circuit, producing continuous ringing until *c* is lifted up. (J. W. Fisher.)

(10) Connecting Telephones and Bells.—In Fig. 53, *d* is a piece of brass shaped like the shafts of a cart (only the telephone takes the place of the horse), secured to the base-board by a short piece of steel spring. The telephone, by its weight, brings *b* into contact with *c*, thereby breaking communication with the speaking instrument, and bringing the bell *e* into readiness for receiving a signal. Directly the telephone is re-

FIG. 52.

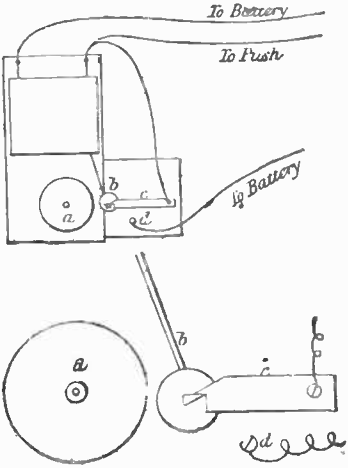
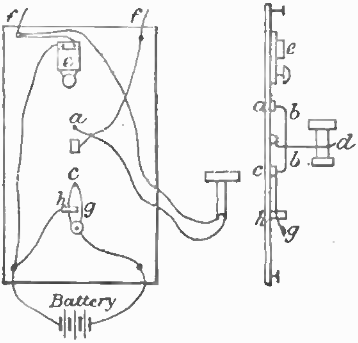


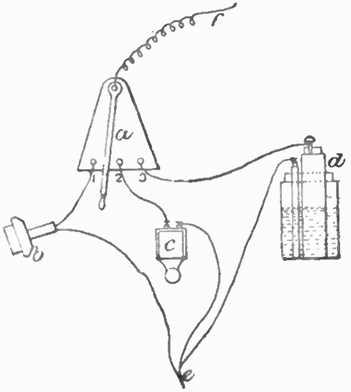
FIG. 53.



moved, *d* springs up, making contact at *b a*, so bringing the telephone into connection with the line wire *f*. As shown in the sketch, the bell is ready to receive a signal from the distant station, but by pressing down the spring *g* (similar to the key used for the Morse telegraph), you cut off connection at *h*, and bring your own battery into action, thereby ringing the bells. The board should be suspended against a wall.

(11) Another plan.—Make connections like Fig. 54 at both ends: *a*, switch; *b*, telephone; *c*, bell; *d*, battery; *e*, earth (water or gas-pipe will do); *f*, line-wire. The switch is made of a piece of wood with 3 studs at bottom, connected with the wires as shown. A strip of brass is made to slide over them so as to make contact, and communicate with line wire. When not in use, the handle must be in contact with the centre stud at both ends, to call attention at the other station. Put the switch to No. 3 stud, which will ring his bell for a few seconds, and put your switch back to stud 2. The other station now must just do the same to let you know that he is there, and as soon as the bell stops ringing, move the switch to stud 1 to connect telephones. The other station must move his switch as soon as he has rung reply to your call. You can now go on with your speaking, and as soon as finished move switch to stud 2 at both ends.

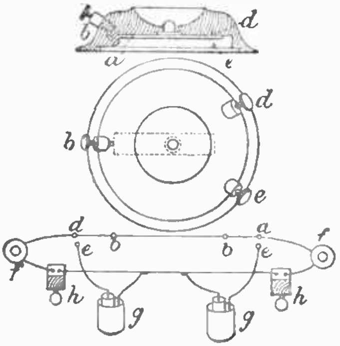
FIG. 54.



(12) Another plan.—The push in Fig. 55 is of rather peculiar construction. A spring *a* is connected, through a binding-screw *b*, with the line-wire *c*, and is fixed so that the free end plays between two contact-pieces *d* and *e*, the former of which is connected with the telephone *f*, the latter with one pole of the

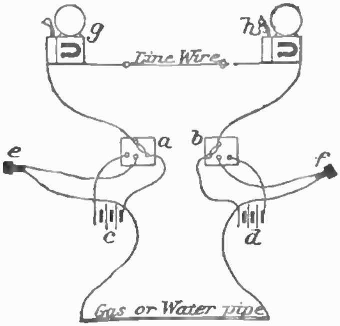
Leclanché cell *g*. The other pole of the battery is connected to the return wire, or, in the case of there being no return wire, to earth. The normal position of spring is as shown in section, pressing against *d*. The telephone *f* is thus in circuit. By pressing the stud, the spring is brought into contact with *e*, and the bell *h* at further station rings.

FIG. 55.



(13) Another plan.—The following method of connecting bells and telephones with one wire has the advantage that the telephones are thrown out of the circuit while the bells are ringing, and thus not subjected to the battery current, wherefore perhaps it is to be preferred. In Fig. 56, *a b* are 2 switch arrangements, having a movable arm fixed to the top button, capable of sliding over the lower 3, and making contact with either. *c* and *d* are the batteries, *e* and *f* the telephones, and *g* and *h* the bells. In the diagram, the switches are shown in the position in which they are always left after using. Then, by turning either of them on to the end button, both bells ring, thus letting the ringers know that the circuit is complete. The switch is then moved back for the answer. When that has been received, both switches are moved to the middle button, which brings the telephones into circuit, and conversation may be carried on. It is necessary to remember to move the switches back after the conversation is finished. This arrangement is used over 300 yd. of uninsulated copper wire, which is carried over the roofs of several houses and across 3 streets without any insulation whatever, and the gas-pipe is used for the return circuit. It employs 3 Leclanché cells of 1 pint capacity; 2 were not powerful enough. This has been in use for several weeks, and the weather does not seem to have had any bad effect on bells or telephones. A wrinkle connected with the telephone is, that the strength of the magnet makes more difference than some might suppose. A pair which were working miserably, when taken to pieces, and the magnets re-magnetized, work splendidly. Iron cores don't make any perceptible difference for ordinary purposes, and $\frac{3}{4}$ oz. of wire works perhaps rather better than $\frac{1}{4}$ oz., but there is very little difference.

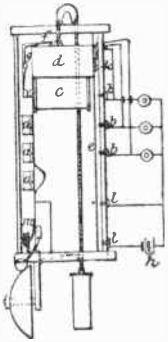
FIG. 56.



(14) In Brailsford's arrangement, Fig. 57, 1 magnet suffices to ring the bell and to indicate the place from which the signal has been sent. The electro-magnet is fixed to a block capable of sliding up and down in a vertical tubular case. When the block is at the top of the case, it is held up by a catch; the catch has an arm extending from it, which carries a soft iron armature just in front of the poles of the magnet, in order that when the armature is attracted it shall release the catch and allow the block to drop

to the bottom of the case. As the block so descends, the poles of the magnet are carried past a series of other soft iron armatures, situated at distances apart one below the other. If a current is passed through the coils of the magnet when it is opposite to any of these armatures, the armature is attracted, and moves a distance towards the magnet, and in doing so shifts a signal or indicator *a* connected to it, and so indicates which armature has been moved. When the block reaches the bottom of the case, the poles of the magnet come opposite another armature, by means of which the bell is to be rung, and an electric current being then caused to pass through the coils of the magnet, the bell is rung, and (in the event of a continuous signal being desired) does not cease to ring until the block is lifted up again to the top of the case. In some instances, the falling of the block might be made to complete a circuit through the magnet coils of a separate bell apparatus, instead of the magnet on the block being made to ring the bell.

FIG. 57.



From each room an insulated wire is led to the part of a building in which the apparatus is placed. In each room is, as usual, a contact apparatus by which such wire can be coupled to a main wire from one pole of a battery. The ends of all the wires are led into the top of the casing of the apparatus. When the block is at the top of the case, a metallic contact mechanism carried by the block is in contact with each of the wires; the contact is also coupled to one end of the coils of the electro-magnet; this end of the coils of the magnet is also coupled to a metallic contact spring, which, when the block falls, comes in succession against a series of metallic contact plates *b*, fixed at distances apart one below the other. There are as many contact plates as wires from the several rooms, and each plate is coupled to one wire. The other end of the coil of the magnet is coupled to another contact spring carried by the block, and this spring always rests against a metallic rod which extends from top to bottom of the case, and is coupled to the other pole of the battery. In this way, whenever one of the wires leading from any room is, by the pushing in of a press-button or other contact apparatus, coupled up with the main wire from the battery, a current will pass through the coils of the magnet; the magnet will attract the armature attached to the catch, and will release the catch; the block will drop, and when the contact spring it carries passes over the contact plate, which is in connection with a branch of the same wire through which the current previously passed, the current again passes, the armature, which is then opposite to the poles of the magnet, is attracted, and the signal in connection with that armature is moved. The speed at which the block is allowed to descend can be controlled by suspending the block by a cord passed over a pulley, and having a counterbalance weight attached to it. The electro-magnet might be arranged to move in a circular course.

Alternately the armatures may be made to travel in front of the fixed electro-magnet, and operated by a hanging weight. The successive completion of the different circuits will be made as specified, the relative movements of the magnet to the indicative armature and to the bell being the same. In the figure, *c* is the electro-magnet, fixed to a carrier or block *d*, which slides up and down the tube *e*. The block and magnet are suspended by the notched rod *f*, held by the lever detent *g*, which is provided with a soft iron armature, and is thus attracted to the magnet when the circuit is completed, releasing the magnet and block, and allowing them to fall; *h* represents any suitable galvanic battery, with different room circuits and bell pushes *i*. When the magnet reaches the bottom of the case, spring *k* is in contact with the stud *l*, the termination of a permanently closed circuit. The recovered magnetism of the electro-magnet will then operate, by the vibration in the usual way of the spring armature *m*, an ordinary electric bell, which will continue to give warning until the attendant raises the electro-magnet to its former position, thereby also tilting back any displaced indicator label.

General Hints.—(1) The amounts and sizes of silk-covered wire to be used for making coils for electric bells are as follows, the number of inches indicating the diameters of the respective gongs:—For a 2-in. gong, 8 yd. of No. 26; 2½-in., 9 yd. No. 25; 3-in., 10 yd. No. 25; 3½-in., 10 yd. No. 25; 4-in., 11 yd. No. 24; 5-in., 12 yd. No. 22; 6-in., 13 yd. No. 20. (2) The bells after being turned and polished receive an electro deposit of nickel or silver, or they may be warmed and lacquered with gold-lacquer in the lathe; screws and other brass fittings are done the same way. (3) It is immaterial whether the bell support be of iron or brass. (4) For winding the bobbins quickly and neatly, have a steel spindle, about ¼ in. diameter, fixed in 2 bearings on uprights on a stand. Cut 2 pieces of stout brass tube (¾-in. common tube) each 1 in. long; turn each down taper to one end, and put a set-screw in each; then slide them over the ¼-in. spindle, so that their thin ends are nearest together. Reels with holes of many different sizes can thus easily be fixed true and wound very easily, either in the lathe, or by hand by means of a small crank.

(5) A difficulty with the Leclanché battery is that the sal-ammoniac solution rises by capillarity, and attacks the leaden taps, brass binding-screws, and wires. The following suggestions relate to batteries:—(*a*) Take your battery to pieces, well wash in hot water to remove the chloride of lead, dry, and give a good coating of Brunswick-black; after setting up, give another, so as to thoroughly protect the leaden caps. (*b*) Try a few drops of sweet-oil on the surface of solution, to prevent verdigris on binding-screws. Try a chloride of zinc battery instead of a Leclanché. A 4-cell bichromate form battery, with sal-ammoniac solution, can be used for bells with great success and no trouble. (*c*) Avoid brass-work on Leclanché cells; prefer lead connections covered with Brunswick-black or black Japan varnish, which prevents salts from creeping up and destroying the connections. Prefer wires (blacked over) to lead outside battery-box, having the terminals for connecting the cells outside the box. A Leclanché set of 6 cells will work for nearly 3 years on a bell circuit by simply refilling with water occasionally. (*d*) Take out the carbons, well soak the heads in melted paraffin for say 2 in. down, then, by reheating carbons, drive back the paraffin for sufficient space for binding-screws to take on. If you have time, you might electrotype the heads and solder the binders to this. But in any case, you will find the paraffin wax prevent the creeping action of the excitant. (*e*) When you put the zinc rod into the solution (which should be only half up the outer jar), see that it is well amalgamated, and do not let it touch the porous cell. (*f*) To prevent the salt and water creeping up, grease the upper portions of the carbon, zinc, and jars; to check evaporation, place your cells in a wooden case, and screw on the front so as to be air-tight. When so fitted, if the insulation is good, Leclanché batteries of the best make will work well without any attention for several years; one working house-bells has been in daily use for 9½ years, during which time it has been filled up with cold water 5 times, and been recharged once. Neat's-foot-oil is the best kind of grease for this purpose. (*g*) Get new carbons, made out of gas-retort "scurfing," as it is called, then prepare the ends that are out of the solution, thus:—Thoroughly scrape the top of the carbon, fit nicely on a piece of sheet platinum like an inverted V, fix the binding-screw on tightly, and then coat the carbon and connection (previously well warming both) with

shellac varnish or Brunswick-black. As to the zinc connection, do not use a binding-screw at all near the cell, drill the zinc, and insert a tinned iron wire, or twist it round the rod and well solder it, then warm, as you do the carbon, and coat with the Brunswick-black. Do all connections with binding-screws fixed to a frame, say 10 or 12 in. away from the cells, where the fumes cannot well reach them. Do not wet the carbons or zincs when putting the solution in—*i.e.* that portion which is not intended to be in—and do not fill the jars above ⅔ full.

Carbons.—The rods first used for the electric light were of wood charcoal, quenched in water or mercury; they burnt with brilliancy and regularity, but too rapidly. Next, the carbon which is deposited in gas-retorts was employed; its chief faults are found to be want of homogeneity and purity, causing variations in brilliancy; liability to split; and hardness, entailing considerable cost for cutting it into "pencils" of the required size. With the sudden impetus given to electric lighting, much ingenuity has been devoted to the production of a more suitable carbon for this purpose. In some instances this has been attempted by purifying gas-retort carbon. The first plan of this kind was as follows:—The retort carbon is fused with caustic potash or soda, and the carbon rods are digested in this bath at a red heat for 15 minutes. In this way, the silica present is converted into a soluble silicate; the rods are then washed in boiling water, and are submitted for several hours to the action of chlorine at red heat, to change the earthy matters into volatile chlorides. These rods give a regular light, but the purification is costly and inefficient. From a number of experiments on retort carbons impregnated with different salts, it seems that potash and soda double the length of the voltaic arc, render it more silent, combine with the silica, and eliminate it from the carbons during the action of the current; they also augment the light in the proportion of 1·25 to 1. Lime, magnesia, and strontia increase the light as 1·40 is to 1; iron and antimony, as 1·60 or 1·70; boracic acid is said to lengthen the durability of the carbons by coating them with a vitreous layer, but it does not increase the light.

On the other hand, experiments have been made with a view to manufacturing a carbon from other sources. In one instance, it was endeavoured to imitate the process of formation of retort carbon with pure materials. Tars resulting from true distillation, therefore free from all non-volatile impurities, were decomposed in a tube of refractory earth in a furnace, and yielded plates of carbon which, when cut into "pencils," gave a light that was steadier, whiter, and 25 per cent. more powerful than that obtained with ordinary carbons. The hardness of the material, however, entailed great cost for cutting, and caused much waste. Another plan consisted in mixing 2 parts of pulverized retort carbon, 2 of pulverized wood charcoal or coke, and 1 of tar, rendering the mass a stiff paste, and subjecting it to great pressure. The moulded pieces were covered with a coating of syrup of sugar, placed beside each other in a vessel of retort carbon, and submitted to great heat for 20 or 30 hours. At an early date, a mixture of pulverized coke and sugar was proposed. To powdered coke a small quantity of syrup was added, and the compound was pugged, moulded, and strongly pressed. Next it was heated moderately, thrust into a concentrated solution of sugar, and finally heated to whiteness. Carmer's carbon consists of lampblack, benzine, and oil of turpentine, calcined together, and moulded into cylinders of porous carbon, which is soaked with resins or saccharine matters, and again calcined. The objections to this are the high price of lampblack, and the difficulty of managing it. Peyret's carbon is prepared by soaking pieces of elder-tree pith, or other porous materials, in liquefied sugar, and decomposing the sugar by heat. By repeating this process, a dense carbon is obtained; it is then submitted to a current of carbon bisulphide vapour. In Archereau's carbon, the addition of magnesia makes the light steadier and increases its power. Carré adopts the following mixture:—15 parts coke powder, 5 of calcined lampblack, and 7 to 8 of a syrup (composed of 30 parts cane-sugar and 12 gum). The whole is thoroughly triturated, and receives an addition of 1 to 3 parts water to compensate for that lost by evaporation. The paste is pressed, and passed through a draw-plate. The carbons are next arranged in horizontal layers in a crucible, the lowest tier lying on a bed of coke-dust, and the upper ones separated by paper to prevent adherence. Between the top and the cover of the crucible is placed a stratum of coal-dust; and upon the joint of the cover is spread siliceous sand. In this position, the carbons are strongly heated, and are then placed for 2 or 3 hours in a concentrated boiling syrup of cane-sugar or caramel, 2 or 3 intervals of cooling being admitted in order that atmospheric pressure may force the syrup into all the pores of the carbons. These are then allowed to drain by opening a tap in the bottom of the vessel; after this, they are well washed with boiling water, to remove the sugar adhering to their surface. When dry, they are subjected to a second heating, and are passed through a repetition of the process till the requisite density is obtained. In many respects they resemble retort carbons, but are harder, more tenacious, and better conductors.

Upon the introduction of foreign substances into the carbon rods, a number of experiments have been made. The materials chosen have been lime phosphate, lime borate, lime silicate, calcium chloride, magnesia phosphate, magnesia borate, magnesia, alumina silicate, and pure precipitated silica, with the following observed results:—

Lime phosphate is completely decomposed, reduced calcium goes to the negative carbon, and in contact with the air it burns with a reddish flame. Lime and phosphoric acid are abundantly diffused in fumes. The light, as measured by a photometer, is double that produced by similar-sized rods of retort carbon.

Lime borate and silicate, and calcium chloride are all decomposed; the boracic and silicic acids are volatilized, and escape electric action. The light does not equal that from lime phosphate.

Magnesia salts are decomposed; the magnesium burns with a white flame, while the acids are vaporized. The light is less than from lime salts.

Alumina silicate and alumina require a very strong current to effect their decomposition, and burn with a blue flame of small illuminating power.

Silica melts and volatilizes without undergoing decomposition.

Gaudoin has proposed 2 distinct methods of preparing carbon for electric rods. According to the first, he decomposes, by heat, organic matters capable of yielding pure carbon after decomposition, *e.g.* pitches, fats, &c. The decomposition is effected in closed retorts, or in graphite crucibles, at bright red heat. In the bottoms of the latter, are provided a tube for the liberation of volatile matters, and a second tube for feeding purposes. The gaseous products of decomposition are led into a condensing chamber, for recovery and utilization. The more or less compact carbon remaining in the retort is finely pulverized, and with it are mixed certain proportions of lampblack, and of the carbides of hydrogen previously produced by the decomposition process. These, being quite free from iron, are much superior to commercial hydrocarbons. The draw-plate or moulding apparatus employed by Gaudoin differs from that commonly used in the following important particulars:—The carbon is made to issue horizontally, at a descending angle of about 50°, guided by tubes, and supported so that the mould can be emptied without interruption and the carbon does not break under its own weight. Gaudoin's second plan is to take dried wood, shaped in the form of the rod, and to carbonize and soak it in carbonaceous liquids. The wood is subjected to a slow distillation process, in order to drive off the volatile matters; then washed in acids or alkalies, to remove impurities; and finally desiccated in a reducing atmosphere at very high temperature. The pores of the wood are closed by submitting it to the action of carbon chloride and various hydrocarbons under heat. This process promises to afford carbons which will burn at a slow rate, and give a steady light.

The advantage derived from closing the pores of carbons has been further attested by the success of the Sawyer and Mann rods, which are prepared in the following manner:—The carbon rod is immersed in olive-oil until it has become thoroughly saturated; while in this condition, it is included in a powerful electric current, the effect of which is to carbonize the oil in the pores and on the surface. Rods thus prepared are extremely hard, of steel grey colour on the surface, and give very constant light.

Bad carbons are undoubtedly rendered more uniform conductors by covering them with a coating of metal. A great increase of light is also secured by a slight coating of metallic bismuth, or by saturating with a solution of bismuth nitrate. It has been proposed to attain the same end by incorporating powdered copper or iron with the carbon; also by inserting a wire core in the rod, and by winding a thin strip of metal around it.

Jacquelain has pointed out that carbon for the electric light should be purer than that obtained by calcining wood; and, if not free from hydrogen, should at any rate contain no mineral impurities. He gives 3 methods for accomplishing this result: (1) By the action of a jet of dry chlorine gas directed on the carbon, raised to a light red heat; (2) by the action of potash and caustic soda in fusion; and (3) by the action of hydrofluoric acid on the finished carbons. Jacquelain has prepared carbons by all 3 methods, and has summed up in a table the photometric results of his experiments. He comes to the conclusion that the luminous power and regularity of the voltaic arc increase in direct ratio to the density, hardness, and purity of the carbons. He remarks, incidentally, that the natural graphitoïd of Siberia possesses the singular and unexpected property of acquiring by purification a luminous capacity double that which it has in the natural state, and which exceeds by 4 that of pure artificial carbons. In passing dry chlorine gas over pulverized coal or coke heated to bright redness, all the silica, alumina, and magnesia, as well as alkalies and metallic oxides, are converted into volatile chlorides and expelled; even the hydrogen is driven off as hydrochloric acid. The easiest method of carrying out the process on a large scale is to allow the dry chlorine gas to act upon gas carbon—from the retorts—cut into thin prisms, for 30 hours, and then raise the temperature to a bright white heat. This makes the carbon porous; in order to convert into a dense, heavy carbon, which is a good conductor and not easily combustible, the vapours of heavy tar-oils are passed slowly over the pieces of glowing carbon, when a deposition of carbon will take place within the pores of the coke. If the carbon rods are treated with fused sodic hydrate (caustic soda), the silica and alumina will be dissolved as soda silicate and aluminate, and can be removed by washing with hot water. Oxide of iron and other constituents of the ash are removed with hydrochloric acid followed by pure water. The simplest process recommended by Jacquelain, is to leave the carbons for 2 or 3 days in dilute hydrofluoric acid, at ordinary temperature, then wash well, and expose for a few hours to a slow current of tar vapours at a high temperature. (*Comptes Rendus.*)

With direct currents, the positive carbon burns away at double the rate of the negative, owing to the much higher temperature which it undergoes, amounting to whiteness as compared with dull redness. With alternating currents, the carbons are consumed equally. This consumption is also completely avoided by producing the voltaic arc *in vacuo*.

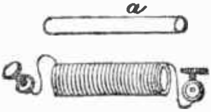
Carbons of ½ in. diameter burned with a current of 75 ampères give a light equal to 400 gas-burners, each using 500 cub. ft. per hour. The weight of carbon burned is 0·79 oz. per hour, requiring 2·11 oz. or 1·57 cub. ft. of oxygen. A ¼-in. crater in the positive carbon will necessitate a deduction of 15 per cent., giving 1·32 cub. ft. of oxygen per hour employed in the formation of carbonic acid.

Varley has devised an electric lamp in which he uses fine filaments in a rope-like bundle as the poles of the arc. It is said that the space between the two points is so heavily charged with incandescent carbonaceous matter that the resistance is considerably reduced, and the "light" is of much greater area, for the luminosity comes from the arc itself and not so much from the carbons, which no longer present the cup and cone formation, although possibly the filaments individually preserve the distinctive shape. An advantage is that the carbons are flexible, can be wound on a reel, and be payed out by means of clockwork. The carbons are made of pieces of rope soaked in paraffin or ozokerit, and carbonized in a crucible kept constantly filled with a hydrocarbon atmosphere.

Coils, Induction.—An electrified wire is capable of exciting a current in another wire placed near it, but not in contact, and such a current is termed an induced current. Induced currents generally have a very high electromotive force, and are capable of sparking across far greater spaces than can be accomplished by ordinary battery currents. An induction coil consists of a cylindrical bobbin with an iron core, surrounded first by a primary coil of stout wire, and then by a secondary coil of very fine wire, carefully insulated between the different parts. The primary coil is joined to the terminals of some Bunsen or Grove cells, and includes an interruptor (contact breaker) and a commutator. The object of the former is to repeatedly and rapidly make and break the primary circuit. The primary coil, destined to carry strong currents, and produce a powerful magnetic field at the centre, is made in few turns, so as to lessen resistance and avoid self-induction of the primary current. The iron core, whose value depends upon its great co-efficient of magnetic induction, is best made of a bundle of fine wires to avoid induction currents. The secondary coil is made in many turns that the co-efficient of mutual induction may be large, its increased resistance being immaterial in the presence of such great electro-motive force. With these general explanations, the construction of induction coils may be entered upon, the information being mainly condensed from Dyer's practical little book.

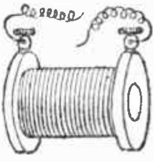
Primary Coil.—Prepare a paper tube, about 4 in. long and ¾ in. diameter, and wind on it 2 or 3 layers of copper wire covered with cotton, and of the size of ordinary bell wire. A binding-screw is attached to each end of the wire, as shown in Fig. 58, by which means it can be united to a battery. The paper tube upon which the wire is wound is filled up with a bundle of iron wire *a*.

FIG. 58.



Secondary Coil.—Prepare a second paper tube of similar length to that in the centre of the primary coil, but large enough in diameter to slide over it. Fit 2 discs of wood on the ends of this tube, and then wind on 5 or 6 layers of cotton-covered copper wire about the size of stout packthread, and attach binding-screws to its beginning and end (Fig. 59). If the primary coil be attached to a battery, and contact be broken rapidly, distinct shocks may be felt from the induction coil. Thus are constructed the coils of electro-magnetic

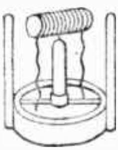
FIG. 59.



machines for medical and experimental purposes. But such are not intensity coils, for their mode of construction involves the loss of nearly all the electrical current excited in the wires of which they are composed.

Contact-breakers, or Interrupters.—Fig. 60 represents the apparatus devised by Dr. Ritchie as a mode of obtaining rotary motion by the temporary magnetization of an iron bar, which is extensively employed as a contact-breaker. It consists of a circular wooden disc placed between the poles of a horse-shoe magnet, having a deep channel turned in it so as to form a cup. This cup is divided into 2 parts by a wooden bridge, the ends of which come opposite to the poles of the magnet. A brass pillar rises up the centre of the bridge, supporting on its top an iron bar wound with insulated wire, the ends of which come down into the cup, and are of such a length, that when the iron bar is rotated, they will just pass over the bridge without touching it. This bar, or electro-magnet, as it really is, has a pointed pin projecting from its underside, which fits into the brass pillar, allowing the bar to rotate with very little impediment from friction. The 2 semi-cups are filled with mercury, which will stand up above the top of the bridge, the latter thus causing a sort of trough between them.*

FIG. 60.

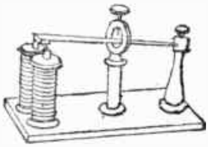


The 2 wires from the electrodes of a battery are put into the mercury, and the rotating bar is moved round so that it may stand across instead of in the line of the bridge. As soon as this is done, the wires from the iron bar will touch the mercury, and the battery current will circulate round the bar and convert it into an electro-magnet. The N. and S. poles of the horse-shoe magnet will attract dissimilar poles, produced in the iron bar by the action of the battery current, and draw them round until they are opposite the 2 poles of the horse-shoe magnet. This operation will also carry the wires out of the mercury, communication with the battery will be interrupted, and consequently the electro-magnet will lose all its properties. But the impetus it acquired by its partial rotation will carry it a little beyond the line of the bridge, and this will bring the points of the wires again into the mercury, though not in the same semi-cups as before; the battery current therefore flows through the wire on the iron bar in the opposite direction, consequently the polarity acquired by the bar is opposite to that which it had before. The end of the electro-magnetized bar that is now N. is thus near the N. pole of the horse-shoe magnet, and these 2 mutually repel each other, and by this force the rotating bar is driven to a position at right angles to the bridge, and where its N. can be attracted by the S. of the horse-shoe magnet. By this alternative magnetization and demagnetization, an attractive and repulsive action is obtained, by means of which a rapid rotation is produced, and a contact made and broken twice in each revolution.

Though convenient for some purposes, this is not suitable for large batteries or coils. Every time the wires leave the mercury, a vivid spark occurs, and the surface of the mercury soon becomes covered with a coating of oxide. This being a non-conductor, prevents the battery current from flowing into the wire, and so interrupts the action.

Fig. 61 shows the general form of the vibrating contact-breaker. It consists of a base-board having an outer brass pillar, a central brass pillar, and an electro-magnet. The electro-magnet is

FIG. 61.



fixed to the board with its poles upwards, and of the ends of the wire wound on it, one is left open, so that the battery may be connected with it, and the other passes under the board to the base of the central pillar. The outer pillar, at its upper part, holds the end of a metallic spring which passes through the ring of the central pillar to the poles of the electro-magnet. Here the end of the spring is armed with an iron plate or clapper, which should stand, when the spring is at rest, about $\frac{1}{15}$ in. above the poles of the electro-magnet. A screw passes through the ring at the top of the central pillar, and comes just into contact with the spring. The spring at this point and at the end of the screw is of platinum. When one electrode of a battery is attached to the open end of the wire of the electro-magnet and the other to the outer brass pillar, the circuit is complete. If the anode of the battery be connected with the electro-magnet, the current will enter there, circulate round it, communicate magnetic properties to it, pass under the board to the central pillar, rise up here to the ring, descend through the screw to the spring, and thence by the outer pillar to the cathode of the battery. The electro-magnet will now attract the iron clapper at the end of the spring down to itself, and by this means a separation takes place between the end of the screw and the spring, and the battery circuit is interrupted. The electro-magnet can no longer hold the clapper down; the spring thus liberated rises to the position it formerly occupied, and again comes into contact with the end of the screw that passes through the ring. As soon as this takes place, the current again flows, and the electro-magnet draws down the clapper. Thus a rapid vibration is kept up, every oscillation of the spring being associated with making and breaking contact with the battery. When applied to intensity coils, it is usual to employ the iron bundle forming the core of the coil as the electro-magnet, and to place the vibrating spring vertical instead of horizontal.

Foucault's contact-breaker consists of a brass arm, which dips a platinum wire into a cup of mercury, whence it draws the point out, so breaking circuit, in consequence of its other end being attracted towards the core of the coil whenever it is magnetized; the arm is drawn back by a spring when, on the breaking of the circuit, the core ceases to be a magnet.

A common contact-breaker on small coils is constructed of a piece of thin steel which makes contact with a platinum point, and which is drawn back by the attraction of the core on the passing of a current, and so makes and breaks circuit by vibrating to and fro like the hammer of an electric bell.

Coils, Intensity.—The parts of an intensity coil are: reel, primary coil, secondary coil, iron bundle or core, contact-breaker, condenser, pedestal or base, and commutator. The dimensions given may be considerably varied without impairing the efficiency of the apparatus.

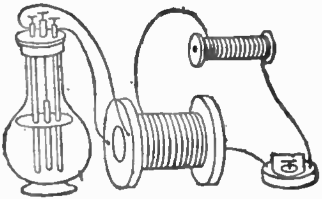
Reel.—The reel consists of a hollow cylinder or tube, with a square or circular plate firmly fixed on each end. The cylinder is formed of paper, and the plates or reel-ends of guttapercha or ebonite. The reel-ends are flat, and not less than $\frac{3}{8}$ in. thick; if circular, a facet is made on the edge of each, so that when the reel is complete it may stand steadily on the pedestal. The hole through the centre of the reel-ends is turned perfectly true, so as to fit the outside of the cylinder; and a shoulder is left on the outer face sufficient to prevent the paper cylinder from being pushed through the ends when being fastened on. The reel-ends may be 4½ in. in diameter if circular, or 4 in. by 4 in. if square. They can be glued to the paper cylinder. The cylinder is formed of cartridge-paper cut into a long strip, and when gummed or pasted on one side, wound round a rod $\frac{7}{8}$ in. diameter. When properly done, a firm tube, 7 in. long, 1 in. diameter, and about $\frac{1}{1}$ in. thick, is obtained. This is allowed to dry thoroughly, and the ends are cut at right angles to the axis. The ends are firmly fastened to the cylinder; in order to effect this, the holes through the discs are slightly tapered, the larger dimensions being towards the shoulder. Before fixing the paper cylinder, a slightly conical plug is provided, fitting the inside of the cylinder. When the parts are ready and carefully coated with the glue, they are put together, and the conical plug is gradually pressed into the end of the cylinder, which will expand it a little, and force it into close contact with the sides of the hole in the disc; it remains in this position until the glue is thoroughly set, when the plug can be removed. The reel is provided with a hollow groove in the edges of the discs, if circular, to receive the pieces of catgut cord that are to fasten it to the base; if square, they can be fastened by screws; 2 holes are drilled through one end of the reel, to allow the primary wire to be passed through; these should be about ⅛ in. diameter, and somewhat oblique in direction, so that the wire, where passed through the reel-end, may not be at right angles with the axis of the reel.

Primary Coil.—The primary coil consists of No. 16 cotton-covered copper wire, averaging about 18 yd. to the lb. One end of the wire is passed from the inside through one hole in the reel-end, so as to project 6 or 8 in., and the wire is then carefully wound over the cylinder up to the other end, and back again, so as to form 2 layers, one over the other. When completed, the remaining end of the wire is passed through the second hole in the reel-end. Before putting on the wire, fit a wooden or metallic rod inside the paper cylinder of the reel, or the cylinder is likely to be damaged by the force required to wind the wire round it. When the primary wire is on, it is varnished with 2 or 3 successive coats of shellac dissolved in spirits of wine, care being taken that one coat is thoroughly dry before another is put on. The first coat should be thin, so as to be readily absorbed by the covering of the wire and conveyed to the nether layer. When the varnish is dry and hard, the primary wire is covered with a strip of cartridge-paper passed 2 or 3 times over the wire, and fastened by gum or glue. This paper must be cut exactly to the width between the inside faces of the ends of the reel, and drawn tightly when put on, but not so tightly as to show on its surface the interstices between the rows of wire. This paper covering, when dry, is varnished to present a smooth cylindrical surface, having no space between it and the inside face of the reel ends. Shellac varnish forms a good insulator, but is not so effective as ordinary black rosin and beeswax. This preparation is rather more difficult to apply, but greatly superior to the varnish when done. The rosin is melted in an earthen vessel, and a small quantity of beeswax is added to it, the proportion to be determined by experiment, the use of the wax being to diminish the friability of the rosin without interfering with its hardness: usually about ⅓ by weight will be found suitable. The rosin and wax, fully melted and heated almost to boiling, are poured over the wire from a ladle, turning the coil round, and repeating the application until the mixture has completely permeated the strands and filled up all the interstices between the wires. If this be done neatly, the paper covering may not be required. When the rosin mixture is employed as the insulating material, it is convenient to wind the wires on the cylinder, and insulate before the reel-ends are fixed on.

Secondary Coil.—This is formed of No. 38 copper wire, covered with silk, and averaging 180 yd. to the oz.; the quantity required is about 6 oz. In winding on the reel, scrupulous care is needed, to avoid any break in the wire, and any kink or bend in it. The diameter of this wire is ·0067 in. The layers of the secondary wire should not be carried close up to the end of the primary coil, thus avoiding the possibility of the wire of one layer sinking down to the level of that below it. When a layer of wire is finished and insulated, it is next to impossible to take it off again; consequently every care must be taken to prevent any failure in winding it on. One layer of the secondary wire is wound on at a time, and then coated with the shellac varnish or rosin mixture. When done, the layer is further insulated by wrapping round several thicknesses of guttapercha tissue, or thin white demy paper soaked in the rosin mixture, and allowed to become hard. Whichever material be used, it is cut in strips a little wider than the length of the layer of wire it is to cover, and wound on tightly but smoothly. The length of the strip should be such as to wrap 3 or 4 times round the coil; it is fastened with the varnish or rosin mixture. When the requisite quantity of wire is put on, 8 or 10 folds of the insulating paper or tissue are wrapped round the coil before the ornamental covering of silk velvet is applied. If the wires forming the coil have been put on before the reel-ends have been fixed to the inner paper cylinder, the reel-ends must now be put in place, and, when firmly set, the spaces between the ends of the layers of wire and the inside of the reel-ends are filled up with the rosin mixture so that the insulation may be perfect. The winding of the secondary wire begins at the opposite end of the coil to that at which the winding of the primary coil commenced, and finishes at the end where it began. The 2 ends of the wire are wound into helices, and these can be passed through 2 holes in the reel-ends, in order that they may be connected with the other part of the apparatus.

Before winding the secondary wire, it is tested in the following way:—Attach one end of the wire on the bobbin (as it comes from the covers) to one electrode of a battery, and the other end to one of the binding screws of a galvanometer. The circuit is completed by uniting the other electrode of the battery with the other binding screw of the galvanometer, and if there be no break in the wire, a deflection of the needle will ensue. Should no deflection take place, the wire must be unwound from the bobbin, carefully examined, and the break detected and soldered. When the continuity of the wire has been effected, winding it on to the reel can be commenced. Each layer, as wound on, and before insulated, should be tested by the galvanometer. For this operation a different course is adopted. The beginning of the secondary wire on the reel is connected with one of the binding-screws of the galvanometer, and the end of the wire that still remains on the bobbin is attached to the other binding screw, as in Fig. 62.

FIG. 62.



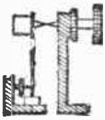
The 2 ends of the primary coil are connected with the battery, and if there be no fault, the needle of the galvanometer will be deflected; the layer can then be insulated, and the same course adopted with each layer. To solder 2 ends of the secondary wire together, the silk coating must be removed from each end—the ends brightened by rubbing with fine glass paper, put side by side in contact with each other, a small piece of tinfoil wrapped round both wires, moistened with a solution of zinc chloride, and moved over the flame of a very small spirit-lamp; in a few seconds, the tinfoil melts and unites the wires. Should it be necessary to apply the wires again to the lamp, they are first moistened with a fresh portion of zinc chloride. The wires should overlap each other about ½ in.; when the soldering is complete, the silk covering is carefully replaced.

Iron Bundle.—This is a bundle of uncovered iron wires, about No. 18 gauge, quite straight, of exactly equal lengths, and about ½ in. longer than the outside measurement of the coil. The centre of the coil is filled with these wires;

and then a short piece of larger wire, carrying on one end an iron disc about $\frac{1}{4}$ in. thick and $\frac{5}{8}$ in. diameter, is pushed into the centre of the coil at each end, so as to secure the bundle in place.

Contact-breaker.—The form used for intensity coils is the vibrating contact-breaker. It is not desirable to use a separate electro-magnet for intensity coils, as a resistance is offered by it to the passage of the battery current; therefore the iron bundle in the coil, which becomes an electro-magnet, is used instead. This necessitates an alteration in the position of the spring and iron clapper, which, as shown in Fig. 63, are placed vertically. The spring is fixed to a brass block attached to the pedestal, having a vertical plate rising on one side. A screw passes through this plate and comes into contact with the spring a little way above its point of fixation to the block; the use of this screw is to regulate the tension of the spring and its distance from the end of the iron bundle. At the top end of the spring is an iron cylinder or clapper about $\frac{1}{2}$ in. long, and of similar diameter; the spring is adjusted so that the face of this cylinder may, when the spring is at rest, be about $\frac{1}{4}$ in. from the end of the bundle. A strong brass pillar rises up also from the pedestal, and reaches a little above the centre of the coil. Through the top of this pillar a strong screw (the platinum screw) passes, carrying on its end a piece of platinum, which comes into contact with the spring where the iron cylinder is attached to it. The spring at this part is armed with platinum, and it is here that the contact is made and broken. The platinum screw is provided with a running boss, so that, when the screw is adjusted, the boss can be brought up tightly against the pillar, and thus prevent the screw from shifting. The surfaces of the platinum require to be smoothed and scraped from time to time, in order to maintain complete contact.

Fig.



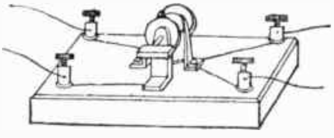
Condenser.—This is usually shut up in the cavity of the pedestal, though it can be separate. Its purport is to add to the energy of the current that traverses the primary wire, and consequently to increase the force of the secondary discharge. It consists of a number of tinfoil plates, separated by sheets of carefully varnished or rosinized paper, the alternate tinfoil plates being joined, thus forming 2 separate insulated series. One is connected with the pillar of the contact-breaker that carries the platinum screw, and the other with the block that holds the vibrating spring: these plates do not form part of the battery circuit, but are, as it were, lateral expansions of that circuit, on each side of the contact-breaker. The insulating sheets between the tinfoil plates thus have their electrical condition disturbed; when the battery circuit is interrupted, the plates return to their normal state, and in so doing, increase the action of the current circulating in the primary wire. The paper for separating the plates should be moderately thin, not too heavily sized, cut into pieces rather larger than is required, dipped into a solution of 1 oz. shellac dissolved in 6 oz. methylated spirit, hung up to dry for some hours, and examined; if the minutest pinhole be observed in any sheet, it must be rejected. A second coating of shellac varnish is applied, and when thoroughly dry, the paper is cut to the proper size, and preserved in a portfolio for use. For rosinized paper, ordinary tissue-paper does well, but white demy is better.

The condenser is made thus:—Prepare 50 sheets of tinfoil 5 in. long and wide, 60 pieces of insulating paper 7 in. by 5 in., and 2 thin mahogany boards of rather smaller size, varnished on each side. One board is laid down, and upon it 5 insulating papers are placed, then 1 tin-foil plate, taking care that 1 in. of the latter projects over one side of the varnished paper. Another paper is laid on this, coinciding in position with the first; on this comes a second tinfoil plate, but with the overhanging part at the opposite side. This is covered with an insulating paper, and followed by the other plates in similar order. When done, 5 more papers are laid on, then the second mahogany board, and the whole is tied up with guttapercha string. All the projecting tinfoils at one side are pressed together, also those at the other side; the condenser is then ready to be placed in the cavity of the pedestal.

Pedestal.—This is made 13 in. long, 8 in. wide, and 2 in. deep. The bottom is movable, and fixed by screws or buttons. The coil is placed horizontally in the centre; holes are made in the top, in order to fix the coil in position. Other holes allow the ends of the primary wires, together with the pillars and binding screws, to be passed through, in order to attach them underneath. The contact-breaker is fixed at one end of the coil, and 2 binding-screws are fitted to the same end of the pedestal; at the other end are 2 ebonite pillars, 6 in. high and about ½ in. diameter. If the ebonite be cut off about 1 in. longer than required, the extra can be turned down to a pin ¼ in. diameter, and a screw cut on its end. The holes in the pedestal are made sufficiently large to allow these pins to pass through, and the pillars can be firmly fixed by putting a nut on the under side. On top of each pillar is a binding-screw with 2 holes and separate screws to each; one for the reception of an end of the secondary wire of the coil, and the other for attaching any apparatus to be employed in conjunction with the coil.

Commutator.—This is shown in Fig. 64; its use is to change the direction of the currents through the primary and secondary circuits. It consists of an ivory or ebonite cylinder, 1 in. long and 1 in. diameter. Metallic axes project from each end in separate pieces, 2 brass plates ¾ in. wide are fixed to opposite sides of the cylinder, one connected with each axis. The cylinder is supported horizontally on 2 brass blocks or pillars fixed to the base-board; and 2 brass springs rise up from the board and press on the brass plates on the face of the cylinder. Of the 4 binding-screws on the board, 2 are connected with the 2 springs by wires passing underneath or over the base-board, and the other 2 with the blocks carrying the axes of the cylinder. One axis projects through the block in which it rests, and on it is fitted an ivory or ebonite plate, to enable the cylinder to turn round. Two of the binding-screws on the board are connected with the battery, and the other 2 with the apparatus to be operated with.

Fig. 64.

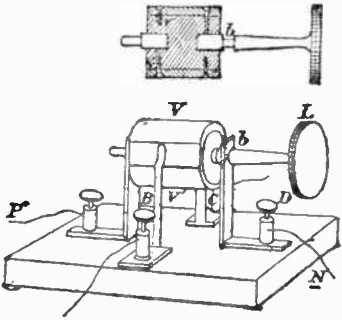


The current passes from the anode of the battery, through one binding-screw of the commutator, under or over the board, to one of the springs, up this to the plate on the cylinder it is in contact with, to the first axis, through the block in which the axis rests, and out by the binding-screw connected with that block to the apparatus, returning by the other spring plate and axis to the battery. When the cylinder is turned half round, without any other change in the arrangement, the current will pass in the opposite direction, still from the anode of the battery to the first spring, but thence to the second axis.

If the commutator be mounted on the pedestal, separate stand and binding-screws will not be required. It is capable of being used also as a current suspender: if the cylinder be turned only ¼ revolution, the springs rest upon the interspace between the 2 brass plates, and contact is broken. This should be done while the arrangements for the secondary current are being made, to avoid receiving a shock.

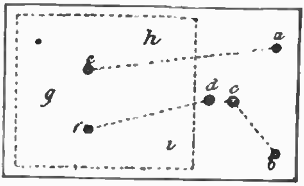
Fig. 65 shows Ruhmkorff's commutator. The battery poles are connected through the ends of the axis of a small ebonite or ivory cylinder to 2 brass cheeks, V V′, which can be turned so as to place them either way in contact with 2 vertical springs B C, which are joined to the ends of the primary coil.

FIG. 65.



Connections.—As to the way of making the connections beneath the base-board, it will be assumed that the commutator is not fixed on it. Then on turning the pedestal of the coil upside down, the under side will present the appearance shown in Fig. 66: *a b* are the ends of the binding screws to which the battery is attached; *c*, pillar of the contact-breaker that carries the platinum screw; *d*, end of block that carries the spring forming the other part of the contact-breaker; *e f*, beginning and end of primary coil. A loose board *g* fits into the pedestal, as shown by the dotted lines, and is fixed about half-way up from the bottom. This is required to lay the condenser on, and to afford convenient means for attaching it. On it, at *h i*, 2 flat brass plates, about 1 in. square, are fixed, having a screwed pin in the centre of each. These are for connecting the condenser with the contact-breaker. The various screws project through the top of the pedestal fully ⅜ in. to enable nuts to be screwed over them. Strips of sheet copper, about ½ in. wide, are prepared, 2 having a hole at one end and binding-screw at the other, and the third having a hole at each end. This latter is long enough to connect *b* and *c*, by dropping it over their projecting screws, and screwing a nut down tightly on the copper, securing the strip, and making the contact. The strips with binding-screws are used to connect *a e* and *d f*, the binding-screws securing the wires *e f*, and the holes in the copper strips enabling them to pass over the projecting screws *d a*, where they are fixed by nuts. When the anode of the battery is attached to the binding-screw at *a*, and the cathode to that at *b*, the current will flow through the coil. The circuit is complete in the direction of the dotted line *a e*, through the primary coil, out at *f*, then from *f* to *d*, through the contact-breaker to *c*, and from *c* to *b*.

FIG. 66.



The condenser is laid on the loose board *g*, with the projecting tinfoils resting on the brass plates *h i*, a hole being punched through each set of tinfoils to admit the screw-pin; a brass plate is then laid on the top of the tinfoils, and by means of a nut on the screw-pin they are pressed closely together. When the condenser has been fitted in place, the nuts are loosened, the top brass plate is taken off, and 2 copper strips with holes at each end are fitted over the pins. These copper strips must be long enough to connect the pin *h* of the condenser with *c* of the contact-breaker and the pin *i* with *d*; this done, the nut is screwed up again. If the condenser is not thick enough to fill the space between the loose board and the bottom, the latter is padded, so that it will press on the former, and prevent it from shifting.

Coils, Resistance.—These consist of coils of wire (German silver or silver-iridium alloy), wound with great care, and of a length to have a resistance of a definite number of ohms.

The following instructions for making

a set of resistance coils, simple yet reliable, are easily within the reach of any one possessing the few requisite tools. The coils themselves consist of wooden frames (preferably oak), as shown in Fig. 67: *a b* are 6 in. long, ½ in. deep, and rather over ¼ in. thick; joining them are *c d*, also of oak, ½ in. deep, and rather thinner than *a b*, so that they do not come up flush with *e f*. The tops of *a b* are grooved, as shown at *e f*; and at intervals (varying with the size of wire used) are cut notches as shown along *a*, for the wire to be wound into. If the wires are not larger than 24 or 26 BWG, they may be about ⅛ in. apart. The number of frames is regulated by the number of ohms resistance required to be made up. Upon the frames is wound uninsulated German silver wire, such as may be bought at any metal warehouse. One end is fixed by a screw to a point on *c*, and winding is commenced, keeping the wire tight, and taking care that it goes to the bottom of the notches cut for it. When the coils are not likely to be subjected to very powerful currents, No. 28 wire may be commenced with for the smaller resistances, gradually progressing to No. 40 as the resistances increase. When the frames are wound, they are soaked in hot paraffin wax till thoroughly saturated, and the excess is drained off. The next step is to give the coils their true value, according to some available standard. For this is required a simple form of Wheatstone bridge, such as that shown in Fig. 68, and made in the following way:—On a board about 5 ft. long fix a piece of wood about ½ in. thick at each end. From the tops of these pieces of wood tightly stretch a piece of German silver wire, and firmly fix it by screws. To 2 points *x y* near the ends of the German silver wire, solder 2 stout copper wires, leading to 2 binding-screws *g h*; at *i*, between them, is another screw. Make 2 clips of stout brass, as shown in elevation and section in Fig. 69; to one of these solder any piece of copper wire, and to the other a stout piece. Place the clip with the thin wire so that it clips the wire *x y* at any point; let the wire connected with it go to one terminal of an astatic galvanometer, whilst the other terminal of the galvanometer is connected with *i*. Let the standard, which may be a piece of wire having a resistance of 1 ohm, be placed between *g i*, and to *h* connect the end of the wire on one of the coils just wound. Connect a battery to *xy*, about 6 Daniell cells, though less may do. Supposing it is wished to find what point of the wire on the coils gives 5 ohms: divide the wire *xy* into 6 parts, and set the clip so that 5 parts are on one side and 1 on the other; then *xk* : *ky* : : 1 : 5, and the 1 ohm standard is between *g* and *i*. Now, having *h* connected to one end of a coil, connect the end of the stout wire on the other clip to *i*, and put the clip on different points of the wire wound on the coil till no deflection is got on the galvanometer: this point shows the ends of the 5 ohms, and to it a stout copper

FIG. 67.

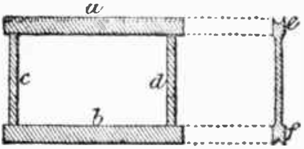


FIG. 68

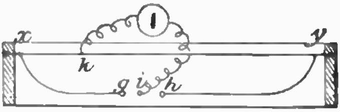
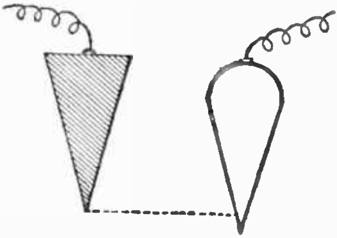


FIG. 69.



wire is soldered. Similar trials, altering the ratio of xk to ky, will enable any number of ohms' resistance to be accurately marked out. This done, a box is made rather larger than the frames of the coils, and into it the coils are put, first fixing pieces of cork at the corners, so that no contact takes place between the coils. On the top of the box, as shown at *a*, Fig. 70, is placed a piece of stout brass, ½ in. by ¼ in.; holes are bored at intervals of about 1 in., made tapering with a reamer, and fitted with tapering brass plugs. Binding-screws are fixed at *ab*; underneath, between every 2 holes, a small hole is bored, and a short piece of wire is screwed in and fitted with a brass nut and washer; these serve both to bolt down the piece of brass and for fixing the resistance coil wire to. Finally, across the centre of each hole, the brass is sawn right through. Fig. 71 shows a section through the plug *a*, piece of brass *b*, top of the box *c*, the pieces of wire *d* screwed into *b*, the nut *e* and washer *f*, the wire *g* being clipped between them. Between each pair of brass pieces is clipped some resistance: when all the plugs are in, the current will go from *ab* (Fig. 70) round by the thick brass at the top; if a plug is drawn, the current has to pass through the resistance that connects the 2 brass pieces thus left without a plug. It is convenient to have plugs putting in the following resistances:—1, 2, 2, 5, 10, 10, 20, 50, 100, 100, 200, 500, thus giving any integer between 1 and 1000.

FIG. 70.

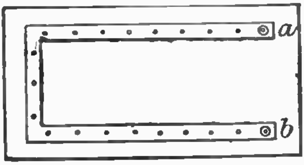
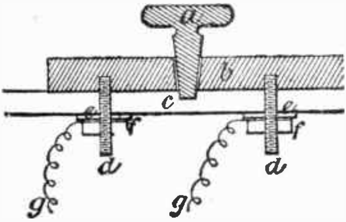


FIG. 71.



Dynamo-electric Machines.—The following description of dynamo-electric machinery is mainly derived from a series of Cantor Lectures by Prof. Silvanus Thompson, delivered before the Society of Arts in December, 1882.

A dynamo-electric machine is an apparatus for converting energy in the form of dynamical power into energy in the form of electric currents, by the operation of setting conductors, usually in the form of copper wire coils, to rotate in a magnetic field. From a consideration of the principles underlying dynamo-electric machines, Prof. Thompson formulates the following summary:—

(1) A part at least of the energy of an electric current exists in the form of magnetic whirls in the space surrounding the conductor.

(2) Currents can be generated in conductors by setting up magnetic whirls round them.

(3) Magnetic whirls can be set up in conductors by moving magnets near them, or moving them near magnets.

(4) To set up and maintain such magnetic whirls requires a continuous expenditure of energy; *i.e.* consumes power.

(5) To induce currents in a conductor, there must be relative motion between conductor and magnet of such kind as to alter the number of lines of force embraced in the circuit.

(6) Increase in the number of lines of force embraced by the circuit produces a current in the opposite sense to decrease.

(7) Approach induces an electromotive force in the opposite direction to that induced by recession.

(8) The more powerful the magnet-pole or magnetic field, the stronger will be the current generated (other things being equal).

(9) The more rapid the motion, the stronger will be the currents.

(10) The greater the length of the moving conductor thus employed in cutting lines of force (*i. e.* the longer the bars, or the more numerous the turns of the coil), the stronger will be the currents generated.

(11) The shorter the length of those parts of the conductor not so employed, the stronger will be the current.

(12) Approach being a finite process, the method of approach and recession (of a coil towards and from a magnet pole) must necessarily yield currents alternating in direction.

(13) By using a suitable commutator, all the currents, direct or inverse, produced during recession or approach, can be turned into the same direction in the wire that goes to supply currents to the external circuits, thereby yielding an almost uniform current.

(14) In a circuit where the flow of currents is steady, it makes no difference what kind of magnet is used to procure the requisite magnetic field, whether permanent steel magnets or electro-magnets, self-excited or otherwise.

(15) Hence the current of the generator may be itself utilized to excite the magnetism of the field-magnets, by being caused, wholly or partially, to flow round the field-magnet coils.

Many varieties of dynamo-electric machine have been constructed upon the foregoing principles. Prof. Thompson distinguishes 3 main classes:—

I.—Dynamos in which there is rotation of a coil in a uniform field of force, such rotation being effected round an axis in the plane of the coil, or one parallel to such an axis. Examples: Gramme, Siemens (Alteneck), Edison, Lontin, Bürgin, Fein, Schückert, Jürgensen (Thomson's Mousemill-dynamo), [Brush].

II.—Dynamos in which there is translation of coils to different parts of a complex field of varying strength or of opposite sign. Most machines of this class furnish alternate currents. Examples: Pixii, Clarke, Niaudet, Wallace, Farmer, Wilde (alternate), Siemens (alternate), Hopkinson and Muirhead, Thomson (alternate), Gordon (alternate), Siemens-Alteneck (Disk Dynamo), Edison (Disk Dynamo), De Meritens.

III.—Dynamos having a conductor rotating so as to produce a continuous increase in the number of lines of force cut, by the device of sliding one part of the conductor on or round the magnet, or on some other part of the circuit. Examples: Faraday's Disk-machine, Siemens's ("Unipolar" Dynamo), Voice's Dynamo.

One machine does not fall exactly within any of these classes, and that is the extraordinary tentative dynamo of Edison, in which the coils are waved to and fro at the ends of a gigantic tuning-fork, instead of being rotated on a spindle.

A dynamo of any one of these plans must be constructed upon the following guiding lines:—

(*a*) The field-magnets as strong as possible, and their poles as near together as possible.

(*b*) The armature having the greatest possible length of wire upon its coils.

(*c*) The wire of the armature coils as thick as possible, so as to offer little resistance.

(*d*) A very powerful steam-engine to turn the armature, because,

(*e*) The speed of rotation should be as great as possible.

It is impossible to realize all these conditions at once, as they are incompatible with one another; and there are many additional conditions to be observed. Prof. Thompson deals with the various matters in order, beginning with the speed of the machine.

Relation of Speed to Power.—Theory shows that, if the intensity of the magnetic field be constant, the electromotive force should be proportional to the speed of the machine. This is true within certain limits, for machines in which the field magnets are independent of the main circuit, *i.e.* for magneto and separately-excited dynamos. It is not, however, quite exact, unless the resistance of the circuit be increased proportionately to the speed, because the current in the coils itself reacts on the magnetic field, and alters the distribution of the lines of force. The consequence of this reaction is that (1) the position of the "diameter of commutation" is altered, and (2) the effective number of lines of force is reduced. So that, with a constant resistance in circuit, the electromotive force, and therefore the current, are slightly less at high speeds than the proportion of the velocities would lead one to expect. Since the product of current into electromotive force gives a number proportional to the electric work of the machine, it follows that, for "independently excited" machines, the electric work done in given time is nearly proportional to the square of the speed, and the work drawn from the steam-engine will be similarly proportional to the square of the speed. In self-exciting machines, whether "series" or "shunt" in their arrangements, a wholly different law obtains. If the iron of the field-magnets be not magnetized near to saturation, then, since the increase of current consequent on increase of speed produces a nearly proportional increase in the strength of the magnetic field, this increase will react on the electromotive force, and cause it to be proportional more nearly to the square of the velocity, which again will cause the current to increase in like proportion. But since the magnetization of the iron is, even when far from saturation point, something less than the magnetizing force, it is in practice found that the electric work of the machine is proportional only to something slightly less than the third power of the speed. As mechanical considerations limit the velocity of the moving parts, it is clear that, at the limiting speed at which it is safe to run any given armature, the greatest amount of work will be done by using the most powerful magnets possible—electro-magnets rather than steel. Deprez has found that for every dynamo there is a certain "critical" speed, at which, no matter what the current is which circulates in the coils of the field magnets, the electromotive force is proportional to the strength of that current; and he bases upon it 2 methods for obtaining, automatically, either a constant electromotive force or a constant current, at will, in a circuit in which the resistances are varied to any degree. In all these combinations, however, everything depends upon the condition that the driving speed shall be uniform. Gas engines are out of the question as a source of power; even with the best steam-engines a specially sensitive valve is required, and probably such valves will, in future, be operated electrically by self acting electromagnet gearing. Where the driving is at all liable to be uneven, the precaution should be taken of placing a heavy fly-wheel on the axis of the dynamo.

Field-magnets.—The coils of the field-magnets cannot be constructed of no resistance; thus they always waste some of the energy of the currents in heat. It has been argued that it cannot be economical to use electro-magnets in comparison with permanent magnets of steel, which have only to be magnetized once for all; but certain considerations tell in favour of electro-magnets. For equal power, their prime cost is less than that of steel magnets, which require remagnetizing at intervals. Moreover, as there is a limiting velocity at which it is safe to run a machine, it is important, in order not to have machines of needlessly great size, to use the most powerful field-magnets possible. But if it is more convenient to spend part of the current upon the electro-magnets, economy dictates that they should be so constructed that their magnetism may cost as little as possible. To magnetize a piece of iron requires the expenditure of energy; but when once it is magnetized, it requires no further expenditure of energy (save the slight loss by heating in the coils, which may be reduced by making the resistance of the coils as little as possible) to keep it so magnetized, provided the magnet is doing no work. Even if it be doing no work, if the current flowing round it be not steady, there will be loss. If it do work, say, in attracting a piece of iron to it, then there is an immediate and corresponding call upon the strength of the current in the coils to provide the needful energy. In a dynamo, where, in many cases, are revolving parts containing iron, it is of importance that the approach of a recession of the iron parts should not produce such reactions as these in the magnetism of the magnet. Large slow-acting field-magnets are therefore advisable. The following points embody the conditions for attaining the end desired:—

(*a*) The body of the field-magnets should be solid. Even in the iron itself currents are induced, and circulate whenever the strength of the magnetism is altered. These self-induced currents tend to retard all changes in the degree of magnetization. They are stronger in proportion to the square of the diameter of the magnet, if cylindrical, or to its area of cross-section. A thick magnet will therefore be a slow-acting one, and will steady the current induced in its field.

(*b*) Use magnets having in them plenty of iron. It is important to have a sufficient mass, that saturation may not be too soon attained.

(*c*) Use the softest possible iron for field-magnets, not because soft iron magnetizes and demagnetizes quicker than other iron (that is here no advantage); but because soft iron has a higher magnetic susceptibility than other iron—is not so soon saturated.

(*d*) Use long magnets to steady the magnetism, and therefore the current. A long magnet takes a longer time than a short to magnetize and demagnetize. It costs more and requires more copper wire in the exterior coil; but the copper wire may be made thicker in proportion, and will offer less resistance. The magnetism so obtained should be utilized as directly as possible, therefore

(*e*) Place the field-magnets, or their pole-pieces, as close to the rotating armature as is compatible with safety in running.

(*f*) If the field-magnets or their pole-pieces have sharp edges, the field cannot be uniform, and some of the lines of force will run uselessly through the space outside the armature instead of going through it. Theoretically, the best external form to give to a magnet is that of the curves of the magnetic lines of force.

(*g*) Reinforce the magnetic field by placing iron, or, better still, electro-magnets, within the rotating armature. This is done by giving the armature coils iron cores which rotate with them; or the iron cores or internal masses may be stationary. In the former case, is loss by heating; in the latter, are structural difficulties to be overcome.

(*h*) In cases where a uniform magnetic field is not desired, but where, as in dynamos of the second class, the field must have varying intensity at different points, it may be advisable specially to use field-magnets with edges or points, so as to concentrate the field at certain regions.

Pole-pieces.—(*a*) The pole-pieces should be heavy, with plenty of iron in them, for reasons similar to those urged above.

(*b*) They should be of shapes adapted to their functions. If intended to form a single approximately uniform field, they should not extend too far on each side. The distribution of the electromotive force in the various sections of the coils on the armature depends very greatly on the shape of the pole-pieces.

(*c*) Pole-pieces should be constructed so as to avoid, if possible, the generation in them of useless Foucault currents. The only way of diminishing loss from this source is to construct them of laminæ, built up so that the mass of iron is divided by planes in a direction perpendicular to that of the currents, or of the electromotive forces tending to start such currents.

(*d*) If the bed-plates of dynamos are of cast-iron, care should be taken that these do not short-circuit the magnetic lines of force from pole to pole of the field-magnets. Masses of brass, zinc, or other non-magnetic metal may be interposed; but are at best a poor resource. In a well-designed dynamo there should be no need of such devices.

Field-magnet Coils.—(*a*) To be of the greatest possible service, the coils of field-magnets should be wound on most thickly at the middle of the magnet, not distributed uniformly along its length, nor yet crowded about its poles. The reason for this is two-fold. Many of the lines of force of a magnet "leak out" from the sides of the magnet before reaching its poles, where they should all emerge if the mass of the magnet were perfectly equally magnetized throughout its whole length. Internally, the magnetization of the magnet is greatest at its centre. At or near the centre, therefore, place the magnetizing coils, that the lines of force due to them may run through as much iron as possible. The second reason for not placing the coils at the end is this: any external influence which may disturb the magnetism of a magnet, or affect the distribution of its lines of force, affects the lines of force in the neighbourhood of the pole far more than those in any other region.

(*b*) The proper resistances to give to the field-magnet coils of dynamos have been calculated by Sir Wm. Thomson, who has given the following results:—

For series dynamos, make the resistance of the field-magnets a little less than that of the armature. Both should be small compared with the resistance of the external circuit. The ratio of the waste by heating in the machine to the total electric work of the machine will be—

$$\frac{\text{waste:}}{\text{total work}} = \frac{R_M + R_A}{R_M + R_A + R_X}$$

and

$$\frac{\text{useful work}}{\text{total work}} = \frac{R_X}{R_M + R_A + R_X}$$

where R_M is the resistance of the magnets,

R_A is the resistance of the armature,

R_X is the resistance of the external circuit.

For a shunt dynamo the rule is different. The best proportions are when such that

$$R_X = \sqrt{R_M R_A}, \text{ or that}$$

$$R_M = \frac{R_X^2}{R_A}$$

also the ratio of useful work is—

$$\frac{\text{useful work}}{\text{total work}} = \frac{1}{1 + 2\sqrt{\frac{R_A}{R_M}}}$$

As an example of the latter, suppose it was wished that the waste should not be more than 10 per cent. of the useful work, the ratio of the formula must equal $\frac{10}{11}$, or $1 \div 1\frac{1}{10}$. Hence

$$\sqrt{\frac{R_A}{R_M}} \text{ must equal } \tfrac{1}{20};$$

or R_M the resistance of the field-magnets must be 400 times R_A that of the armature.

Armature Cores.—(*a*) Theory dictates that if iron is employed in armatures, it must be slit or laminated, so as to prevent the generation of Foucault currents. Such iron cores should be structurally divided in planes normal to the circuits round which electromotive force is induced; or should be divided in planes parallel to the lines of force and to the direction of the motion. Cores built up of varnished iron wire, or of thin disks of sheet-iron separated by varnish, asbestos paper, or mica, partially realize the required condition.

(*b*) Armature cores should be so arranged that the direction of polarity of their magnetization is never abruptly reversed during their rotation. If this precaution is neglected, the cores will be heated.

Armature Coils.—(*a*) All needless resistance should be avoided in armature coils, as hurtful to the efficiency of the machine. The wires should be as short and thick as is consistent with obtaining the requisite electromotive force, without requiring an undue speed of driving.

(*b*) The wire should be of the best electric conductivity. The conductivity of good copper is so nearly equal to that of silver (over 96 per cent.), that it is not worth while to use silver wires in the armature coils of dynamos.

(*c*) In cases where copper rods or strips are used instead of wires, care must be taken to avoid Foucault currents by laminating such conductors, or slitting them in planes parallel to the electromotive force; *i.e.* in planes perpendicular to the lines of force and to the direction of the rotation.

(*d*) In dynamos of the first class, when used to generate currents in one direction, since the currents generated in the coils are doing half their motion inverse to those generated during the other half of their motion, a commutator or collector of some kind must be used. In any single coil without a commutator, the alternate currents would be generated in successive revolutions, if the coil were destitute of self-induction currents. But if by the addition of a simple split-tube commutator, the alternate halves of these currents are reversed, so as to rectify their direction through the rest of the circuit, the resultant currents will not be continuous, but will be of one sign only, there being 2 currents generated during each revolution of the coil. If 2 coils are used at right angles to each other's planes, so that one comes into the position of best action, while the other is in the position of least action (one being normal to the lines of force when the other is parallel to them), and their actions be superposed, the result will be to give a current which is continuous but not steady, having 4 slight undulations per revolution. If any larger number of separate coils is used, and their effects, occurring at regular intervals, be superposed, a similar curve will be obtained, but with summits proportionately more numerous and less elevated. When the number of coils used is very great, and the overlappings of the curves are still more complete, the row of summits will form practically a straight line, or the whole current will be practically constant.

(*e*) The rotating armature coils ought to be divided into a large number of sections, each coming in regular succession into the position of best action.

(*f*) If these sections, or coils, are independent of each other, each coil, or diametrical pair of coils, must have its own commutator. If they are not independent, but are wound on in continuous connection all round the armature, a collector is needed, consisting of parallel metallic bars as numerous as the sections, each bar communicating with the end of one section and the beginning of the next.

(*g*) In any case, the connections of such sections and of the commutators or collectors should be symmetrical round the axis; if not, the induction will be unequal in the parts that successively occupy the same positions with respect to the field-magnets, giving rise to inequalities in the electromotive force, sparking at the commutator or collector, and other irregularities.

(*h*) Where the coils are working in series, it is advantageous to arrange the commutator to cut out the coil that is in the position of least action, as the circuit is thereby relieved of the resistance of an idle coil. But no such coil should be short-circuited to cut it out. Where the coils are working in parallel, cutting out an idle coil increases the resistance, but may be advisable to prevent heating from waste currents traversing it from the active coils.

(*i*) In the case of pole-armatures, the coils should be wound on the poles rather than on the middles of the projecting cores; since the variations in the induced magnetism are most effective at or near the poles.

(*j*) Since it is impossible to reduce the resistance of the armature coils to zero, it is impossible to prevent heat being developed in those coils during their rotation; hence it is advisable that the coils should be wound with air spaces in some way between them, that they may be cooled by ventilation.

(*k*) The insulation of the armature coils should be ensured with particular care, and should be carried out as far as possible with mica and asbestos, or other materials not liable to be melted, if the armature coils become heated.

Commutators, Collectors, and Brushes.—(*a*) Commutators and collectors, being liable to be heated through imperfect contact, and liable to be corroded by sparking, should be made of very substantial pieces of copper.

(*b*) In the case of a collector made of parallel bars of copper, ranged upon the periphery of a cylinder, the separate bars should be removable singly, to admit of repairs and examination.

(*c*) The brushes should touch the commutator or collector at the 2 points, the potentials of which are respectively the highest and the lowest of all the circumference. In a properly and symmetrically built dynamo, these points will be at opposite ends of a diameter.

(*d*) In consequence of the armature itself, when traversed by the currents, acting as a magnet, the magnetic lines of force of the field will not run straight across from pole to pole of the field-magnets, but will take, on the whole, an angular position, being twisted a considerable number of degrees in the direction of the rotation. Hence the diameter of commutation (which is at right angles to the resultant lines of force in machines of the Siemens and Gramme type, and parallel to the resultant lines of force in machines of the Brush type), will be shifted forward. In other words, the brushes will have a certain angular lead. The amount of this lead depends upon the relation between the intensity of the magnetic field and the strength of the current in the armature. This relation varies in the 4 different types of field-magnets. In the series dynamo, where the one depends directly on the other, the angle of lead is nearly constant, whatever the external resistance. In other forms of dynamo, the lead will not be the same, because the variations of resistance in the external circuit do not produce a proportionate variation between the 2 variables which determine the angle of lead.

(*e*) Hence in all dynamos it is advisable to have an adjustment enabling the brushes to be rotated round the commutator or collector, to the position of the diameter of commutation for the time being. Otherwise there will be sparking at the brushes, and in part of the coils at least the current will be wasting itself by running against an opposing electromotive force.

(*f*) The arrangements of the collector or commutator should be such that, as the brushes slip from one part to the next, no coil or section in which there is an electromotive force should be short-circuited, otherwise work will be lost in heating that coil. For this reason, it is well so to arrange the pole-pieces that the several sections or coils on either side of the neutral position should differ but very slightly in potential from one another.

(*g*) The contact points between the brushes and the collector, or commutator, should be as numerous as possible, for, by increasing the number of contacts, the energy wasted in sparks will be diminished inversely as the square of that number. The brushes might with advantage be laminated, or made of parallel loose strips of copper, each bearing edgeways on the collector.

Relation of Size to Efficiency.—The efficiency of a dynamo is the ratio of the useful electrical work done by the machine to the total mechanical work applied in driving it. Every circumstance which contributes to wasting the energy of the current reduces the efficiency of the machine. It has been shown what the chief electric sources of waste are, and how they may be avoided. Mechanical friction of the moving parts can be minimized also by due mechanical arrangements. But even the best conductors have a certain resistance, and it is impossible to prevent the heating of the conducting coils; the more powerful the current generated by the machine, the more important does this source of waste become. The one way to reduce this is by increasing the size of the machines. For some years, Prof. Thompson has advocated large dynamo machines, because the larger machines may be made more efficient than the small, in proportion to their cost. In discussing the relation of size to efficiency, he assumes, for the sake of argument, that the size of any machine can be increased n times in every dimension, and that, though the dimensions are increased, the velocity of rotation remains the same, and that the intensity of the magnetic field per square centimetre remains also constant. If the linear dimensions be n times as great in the larger as in the smaller, the area it stands on will be increased n^2 times, and its volume and weight n^3 times. The cost will be less than n^3 times, but greater than n times. If the same increase of dimensions in the coils be observed (the number of layers and of turns remaining the same as before), there will be in the armature coils a length n times as great, and the area of cross section of the wire will be n^2 times as great as before. The resistance of these coils will therefore be but $\frac{1}{n}$ part of the original resistance of the smaller machine. If the field-magnet coils are increased similarly, they will offer only $\frac{1}{n}$ of the resistance of those of the smaller machine. Moreover, seeing that while the speed of the machine is the same, the area cut through by the rotating coils is increased n^2 times, these coils will in the same time cut n^2 times as many lines of force, or the electromotive force will be increased n^2 times. Supposing the whole of the circuit to be similarly magnified, its resistance will also be but $\frac{1}{n}$ of the previous value.

If the machine is a "series-wound" dynamo, an electromotive force n^2, working through $\frac{1}{n}$ resistance, will give a current n^3 times as great as before. Such a current will, as a matter of fact, much more than suffice to bring up the magnetic field to the required strength, viz., n_2 times the area of surface magnetized to the same average intensity per square centimetre, as stipulated; for the mass of iron being n^3 times as great, it need not be so much saturated as before to give the required field. Here an economy may be effected, therefore, by further reducing the number of coils, and therefore the wasteful resistance of the field-magnet coils, in the proportion of n^3 to n^2, or to $\frac{1}{n}$ of its already diminished value. Even if this were not done, by the formula given above for the electrical efficiency of a "series" dynamo, the waste, when working through a constant external resistance, will be n-fold less than with the smaller machine. Now, if the current be increased n^3 times, and the electromotive force n^2 times, the total electric work which is the product of these will be n^5 times greater than in the small machine, and it will consume n^5 times as much power to drive it. It is clearly an important economy, if a machine costing less than n^3 times as much, will do n^5 times as much work (to say nothing of the increased ratio of efficiency). A machine doubled in all its linear dimensions will not cost 8 times as much, and will be electrically 32 times as powerful.

Suppose the machine to be "shunt" wound, then to produce the field of force of n^2 times as many square centimetres area, will require (if the electromotive force be n^2 times as great) that the absolute strength of the current remain the same as before in the field magnet coils. This can be done by using the same sized wire as before, and increasing its length n^2 times, to allow for n times as many turns, of n times as great a diameter each, in the same number of layers of coils as before. In this case the work done in the shunt, being equal to the product of the n^2-fold electromotive force into the unaltered current, will be only n^3 times as great, while the whole work of the machine is augmented n^5 times. If, while augmenting the total work n^5 times, the waste work is increased only n^2 times, it is clear that the ratio of waste to the total effect is diminished n^3-fold. There is, therefore, every reason to construct large machines, from the advantage of economy both in relative prime cost and relative efficiency.

Methods of exciting Field-Magnetism.—There are certain theoretical considerations respecting the method of exciting the magnetism of the field in which the armatures are to revolve. The main methods are 4 in number.

Magneto - Dynamos.—Magneto-dynamos have the advantage in theory that their electromotive force is very nearly exactly proportional to the velocity of rotation; though, of course, the variable difference of potential between the terminals of the machine depends on the relation of the resistance of the external circuit to the internal resistance of the armature coils. They possess the disadvantage that, since steel cannot be permanently magnetized to the same degree as that which soft iron can temporarily attain, they are not so powerful as other dynamos of equal size.

Separately - excited Dynamos. — The separately-excited dynamo has the same advantage as the magneto-machine, in its electromotive force being independent of accidental changes of resistance in the working circuit, but is more powerful. It has, moreover, the further advantage that the strength of the field is under control, for, by varying either the electromotive force or the resistance in the exciting circuit, the strength of the magnetic field is varied at will. It has the disadvantage of requiring a separate exciting machine.

Series Dynamos.—The ordinary or series dynamo is usually a cheaper machine, for equal power, than any other form, as its coils are simpler to make than those of a shunt machine, and it wants no auxiliary exciter. It has the disadvantages of not starting action until a certain speed has been attained, or unless the resistance of the circuit is below a certain minimum. It is also liable to become reversed in polarity, a serious disadvantage when this machine is applied for electroplating or for charging accumulators. From its arrangements, any increase of the resistance in the circuit lessens its power by diminishing the strength of its magnetic field. Hence it is better adapted for use with lamps arranged in parallel arc than for lamps arranged in series. An additional lamp switched in, in series, adds to the resistance of the circuit, and diminishes the power of the machine to supply current; while, on the other hand, an additional lamp in parallel reduces the total resistance offered by the network of the circuit, and adds to the power of the machine to provide the needed current. It is easy to regulate the currents given by a series dynamo, by introducing a shunt of variable resistance across the field-magnet, thus altering the magnetizing influence of the current.

Shunt Dynamos.—The shunt dynamo has several advantages over other forms. It is less liable to reverse its polarity than the series dynamo, and it is commonly considered as providing the magnetizing power to the magnets with less waste of current. Moreover, for a set of lamps in series, its power to supply the needful current increases with the demands of the circuit, since any added resistance sends additional current round the shunt in which the field-magnets are placed, and so makes the magnetic field more intense. On the other hand, there is greater sensitiveness to inequalities of driving, in consequence of the self-induction in the shunt. The shunt part of the circuit in the present case consists of a fine wire of many turns, wound upon iron cores. It therefore has a much higher co-efficient of self-induction than the rest of the circuit; and consequently any sudden variations in the speed of driving can but affect the current in the main circuit more than in the shunt. Briefly, the shunt-winding, though it steadies the current against perturbations due to changes of resistance in the circuit, does not steady the current against perturbations due to changes in driving speed. In the series-wound dynamo, the converse holds good.

Any of these systems may be applied either in direct current or in alternate current machines. Each has its own merits for special cases, but none is perfect. Not one will ensure that, with uniform driving speed, either the electromotive force of the current shall be constant, however the resistances of the circuit are altered.

There is no such thing yet as a best dynamo. One gives steadier currents, another is less liable to heat, a third is more compact, a fourth is cheaper, a fifth is less likely to reverse its currents, a sixth gives a greater volume of current, while a seventh evokes a higher electromotive force.

Combination Methods.—A method of rendering a dynamo automatically self-adjusting, so that either its electromotive force or its current (according to circumstances) shall be constant, is due to Deprez. If a dynamo be wound with a double set of coils, one of which can be traversed by an independent current, whilst the other is traversed by the current of the machine itself, there can always be found a certain critical velocity of driving, for which, provided the field-magnets are far from attaining their saturation point, the desired condition is fulfilled. Other combination methods have been suggested, and a summary of them follows.

(1) Series and Separate (for Constant E.M.F.), Deprez.—This method can be applied to any ordinary dynamo, provided the coils are such that a separate current from an independent source can be passed through a part of them, so that there shall be an initial magnetic field, independent of the main-circuit current of the dynamo. When the machine is running, the electromotive force producing the current will depend partly on this independent excitement, partly on the current's own excitement of the field-magnets. If the machine be run at such a speed that the quotient of the part of the electromotive force due to the self-excitement, divided by the strength of the current, is numerically equal to the internal resistance of the machinery, then the electromotive force in the circuit will be constant, however the external resistances are varied. This velocity can be deduced from experiment, and when the critical velocity has once been determined, the machine can be adjusted to work at any desired electromotive force, by varying the strength of the separately-exciting current to the desired degree.

(2) Shunt and Separate (for Constant Current), Deprez.—When cases arise, as for a set of arc lamps in series, that it is desired to maintain the current in the circuit at one constant strength, the previous arrangement must be modified by combining a shunt-winding with coils for a separately-exciting current. This arrangement is, in fact, that of a shunt-dynamo, with an initial magnetic field independent of the strength of the current in the circuit. Seeing that the only object in providing the coils for separate excitement is to secure an initial and independent magnetic field, it is clear that other means may be employed to bring about a similar result.

(3) Series and Magneto (Constant E.M.F.), Perry.—The initial electromotive force in the circuit, required by Deprez's theory, need not necessarily consist in there being an initial magnetic field of independent origin. It is true that the addition of a permanent magnet, to give an initial partial magnetization to the pole-pieces of the field magnets, would meet the case to a certain extent; but Prof. Perry has adopted the more general solution of introducing into the circuit of a series-dynamo a separate magneto machine, also driven at a uniform speed, such that it produces in the circuit a constant electromotive force equal to that which it is desired should exist between the leading and return mains This arrangement may be varied by using a shunt-wound dynamo, the magnets being, as before, included in the part of the circuit outside the machines.

(4) Shunt and Magneto (Constant Current), Perry.—Perry's arrangement for constant current consists in combining a shunt-dynamo with a magneto machine of independent electromotive force, this magneto machine being inserted either in the armature part or in the magnet-shunt part of the machine. As before, a certain critical speed must be found from experiment and calculation,

(5) Series and Shunt.—A dynamo having its coils wound so that the field-magnets are excited partly by the main current, partly by a current shunted across the brushes of the machine, is not so perfect as either of the preceding, being more limited in operation. If the shunt coils be comparatively few and of high resistance, so that their magnetizing power is small, the machine will give approximately a uniform electromotive force; whereas, if the shunt be relatively a powerful magnetizer, as compared with the few coils of the main circuit, the machine will be better adapted for giving a constant current; but, as before, each case will correspond to a certain critical speed, depending on the arrangements of the machine.

(6) Series and Long Shunt.—Prof. Thompson gives this name to a combination closely resembling the preceding. If the magnets are excited partly in series, but also partly by coils of finer wire, connected as a shunt *across the whole external circuit*, then the combination should be more applicable than the preceding to the case of a constant electromotive force, since any variation in the resistance of the external circuit will produce a greater effect in the "long shunt" than would be produced if the resistance of the field-magnets were included in the part of the main circuit external to the shunt. Although the last 2 combinations are not such perfect solutions of the problem as those which precede, they are more likely to find immediate application, since they can be put into practice upon any ordinary machine, and do not require, as in the first 4 combinations, the use of separate exciters, or of independent magneto-machines.

All these arrangements presuppose a constant velocity of driving; but they are not the only ones consistent with this condition. An ordinary series dynamo may be made to yield a constant current, by introducing across the field-magnets a shunt of variable resistance, the resistance of the shunt being adjusted automatically by an electro-magnet whose coils form part of the circuit. This is actually done in the automatic regulator attached to Brush dynamos, as used in supplying a series of arc lights. A shunt-dynamo may similarly be controlled, so as to yield a uniform electro-motive force, by introducing a variable resistance into the shunt-magnet circuit as is done in some of Edison's dynamos. To make the arrangement perfect, this variable resistance should be automatically adjusted by an electro-magnet whose coils are an independent shunt across the mains of the external circuit. Yet another way of accomplishing the regulation of dynamos is possible in practice, without the condition of a constant speed of driving. Let the ordinary centrifugal governor of the steam-engine be abandoned, and let the supply of steam be regulated, not by the condition of the velocity of driving, but by means of an electric governor, such as an electro-magnet working against an opposing spring. If this electro-magnetic governor is to maintain a constant electromotive force, its coils must be a shunt to the mains of the circuit. If it is to maintain a constant current, its coils must be part of the main circuit. Such a governor ought to be more reliable and rapid than any centrifugal governor intended to secure a uniform speed of driving.

Organs of Dynamos as constructed in practice.—Field-Magnets.—In the classification of dynamos, those of the first class required a single approximately uniform field of force, whilst those of the second required a complex field of force differing in intensity and sign at different parts. Hence a corresponding general demarcation between the field-magnets in the 2 classes of machine. In the first, are usually 2 pole-pieces on opposite sides of a rotating armature; in the second, a couple of series of poles set alternately round a circumference or crown, the coils which rotate being set upon a frame between 2 such crowns of poles.

Confining attention to the first class of machines, in practice their magnets differ widely in construction and design.

In very few of the existing patterns is much trouble taken to secure steady magnets, by making them long, heavy, and solid, or with very heavy pole-pieces. Repeatedly an unnecessary amount of wire has been wound upon field-magnets; and the usual excuse is that, with less wire, the machine does not work so well. If, however, it is found necessary to wind on so many coils upon the magnets as to bring these practically to saturation long before the machine is doing its maximum work, it is clear that either the iron is insufficient in quantity or it is deficient in quality. In the Bürgin machines, where cast-iron field-magnets are employed, the smaller magnetic susceptibility of this metal is made up for by employing a great weight of it. In Siemens's smaller dynamos, the amount of iron employed in the field-magnets would be quite insufficient if it were not of high quality; as it is, Prof. Thompson is of opinion that the mass of it (especially in the polar parts) might with advantage be increased. In some of the early machines of Wilde, and in Edison's well-known dynamos, long field-magnets, with heavy pole-pieces, are found. Edison's dynamos, indeed, are all remarkable in this feature; the pole-pieces and the yoke connecting the iron cores of the coils are made abnormally heavy. This is not more noticeable in the giant dynamos used at the Holborn Viaduct, than in the smaller machines used in isolated installations for 60 and for 15 lights.

The principle of shaping the magnets, so that their external form approximates to that of the magnetic curves of the lines of force, is to some extent carried out in such widely differing types of machine as the Gramme with "Jamin" magnet, the Jürgensen dynamo, and Thomson's "mousemill" dynamo. The 2 machines last named exhibit several curious contrasts. In the Jürgensen, the field-magnets have heavy pole-pieces; in the Thomson, are none; and in the Thomson, the iron core is thicker at the middle than at the ends. In both, are auxiliary internal electro-magnets, fixed within the rotating armature, to concentrate and augment the intensity of the field, according to the device patented by Elphinstone and Vincent. In the Thomson machine, the coils are heaped on more thickly at the middle of the field-magnets; in the Jürgensen, the coils are crowded up around the poles. Judging from a report on this machine by Professors Ayrton and Perry, the arrangement is not satisfactory in practice, as there are more coils than suffice to magnetize the magnets.

Another suggestion, indicated from theoretical considerations, was that of laminating the pole-pieces, to prevent the production in them of wasteful Foucault currents. But one machine has been designed in which this precaution is carried into effect. This is the disk-dynamo of Drs. Hopkinson and Muirhead, the field-magnets of which are made up of laminæ of iron, cast into a solid iron backing.

Another matter is the form to be given to pole-pieces, in order to produce the best effect. These present such singular divergence in practice as to suggest the thought that little importance has been attached to them. Yet upon the form and extent given to the pole-pieces depend the reduction of idle wire in the armature, the reduction of sparking at the commutator, and the avoidance of counter-electromotive forces in the armature. If the pole-pieces are badly shaped for their work, or approach one another too far round the armature, they may completely perturb the approximate uniformity of the field, and may cause the central portion of the field to be of much weaker intensity than the two lateral regions between the edges of the pole-pieces. When this is the case, the rotating coils are virtually moving in a double field, and it is even possible that, in consequence, the direction of the currents induced in the individual coils may be reversed 4 or 6 times as they make one rotation. In such a case, the distribution of potential round the separate bars of the commutator will be abnormal.

Armatures.—The armatures of dynamos of the first class may be roughly classified in 3 groups, according to the manner of arranging the coils; these are—

(1) Ring armatures, in which the coils are grouped upon a ring, whose principal axis of symmetry is its axis of rotation also.

(2) Drum armatures, in which the coils are wound longitudinally over the surface of a drum or cylinder.

(3) Pole armatures, having coils wound on separate poles, projecting radially all round the periphery of a disk or central hub.

To these will be added a fourth form, disk armatures, when dealing with dynamos of the second class.

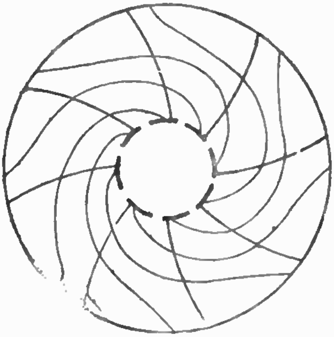
The object of all these combinations is to obtain practical continuity of current. Some of the individual coils should be moving through the position of maximum action, whilst others are passing the neutral point, and are temporarily idle. Hence a symmetrical arrangement around an axis is needed. Ring armatures are adopted in practice in the dynamos of Pacinotti, Gramme, Schückert, Gülcher, Fein, Heinrichs, De Meritens, Brush, Jürgensen, and others. Drum armatures are found in the Siemens (Alteneck), Edison, Elphinstone-Vincent, Laing, and other machines. Pole-armatures are used in the dynamos of Allen, Elmore, and of Lontin. There are several intermediate forms. The Bürgin armature consists of 8 or 10 rings, side by side, so as to form a drum. The Lontin (continuous-current dynamo) has the radial poles affixed upon the surface of a cylinder. The Maxim armature is a hollow drum wound like a Gramme ring, and has therefore a great quantity of idle wire on the inner surface of the drum. The Weston armature has the drum surface cut up into longitudinal poles; there is a similar armature by Jablochkoff, in which the poles are oblique.

Ring armatures are found in many machines, but the ingenuity of inventors has been exercised chiefly in 3 directions:—The securing of practical continuity; the avoidance of Foucault currents in the cores; and the reduction o useless resistance. In the greater par of these machines, the coils that for the sections of the ring are connected i series, the end of one to the beginnin of the next, so that there is a continuou circuit all round, an attachment bein made between each pair to a bar or segment of the collector. Most inventor have been content to secure approximat continuity by making the number o sections numerous. Prof. Perry ha built up a ring with coils wound obliquely, so that the one coil reaches th neutral point before the preceding on has passed it; this arrangement presents mechanical difficulties in construction. Pacinotti's early dynamo had th coils wound between projecting teet upon an iron ring. Gramme rejecte these cogs, preferring that the coil should be wound round the entire sur face of the endless core. To preven wasteful currents in the cores, Gramm employed for that portion a coil of varnished iron wire of many turns. I Gülcher's latest dynamo, the ring-cor is made up of thin flat rings cut out o sheet iron, furnished with projectin cogs, and laid upon one another. Th parts of the coils which pass throug the interior of the ring are comparatively idle. They cut very few line of force as they rotate, and therefor offer a wasteful resistance. Inventor have essayed to reduce this source o loss, by either fitting projecting flange to the pole-pieces (as in Fein's dynamo) or by using internal magnets (as i Jürgensen's), or by flattening the ring into a disk-form, so as to reduce th interior parts of the ring-coils to a insignificant amount. This is done i the dynamos of Schückert and Gülcher In the latest form of Gülcher's dynamo the field-magnets, at front and back of the ring, are united on the right and left sides in a pair of hollow pole-pieces, which form cases over the ring covering a considerable part of it. The collector is identical with that o Gramme, but very substantial.

Drum-armatures may all be regarded

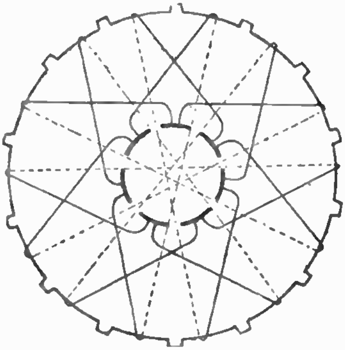
as modifications of Siemens's longitudinal shuttle-form armature of 1856, the multiplicity of sections of the coils affording practical continuity in the currents. In some of Siemens's machines, the cores are of wood, overspun with iron wire circumferentially, before receiving the longitudinal windings; in another, is a stationary iron core, outside which the hollow drum revolves; in others is no iron in the armature beyond the driving-spindle. In all the Siemens armatures, the individual coils occupy a diametral position with respect to the cylindrical core, but the mode of connecting up the separate diametral sections is not the same in all. In the older of the Alteneck-Siemens windings, the sections were not connected together symmetrically, but in more recent machines, a symmetrical plan has been adhered to, as shown in Fig. 72.

FIG. 72.



In this system, as in the Gramme ring, the successive sections of coils ranged round the armature are connected together continuously, the end of one section and the beginning of the next being united to one segment or bar of the collector. A symmetrical arrangement is of course preferable, not only for ease of construction, but because it is important that there should never be any great difference of potential between one segment of the collector and its next neighbour; otherwise there will be increased liability to spark, and form arcs across the intervening gap. In Edison's modification of the drum-armature, the winding, though symmetrical in one sense, is singular, inasmuch as the number of sections is an odd number. In the first machines were 7 paths, as shown in Fig. 73; in his latest giant machines, the number of sections is 49. One consequence of this peculiarity of structure is that, if the brushes are set diametrically opposite to one another, they will not pass at the same instant from section to section of the collector; one of them will be short-circuiting one of the sections, whilst the other is at the middle of the opposite collector. The armature of the latest of Edison's dynamos is not wound up with wire, but, like some of Siemens's electro-plated dynamos, is constructed of solid bars of copper, arranged around the periphery of a drum. The ends are connected across by washers or disks of copper, insulated from each other, and having projecting lugs, to which the copper bars are attached. Such disks present much less resistance than mere strips would do. The connections are in the following order:—Each of the 49 bars of the collector is connected to a corresponding one of the 49 disks at the anterior end of the drum, which is connected, by a lug-piece on one side,

FIG. 73.



to one of the 98 copper bars. The current generated in this bar runs to the farther end of the machine, enters a disk at that end, crosses the disk, and returns along a bar diametrically opposite that along which it started. The anterior end of this bar is attached to a lug-piece of the next disk to that from which we began to trace the connections; it crosses this disk to the bar next but one to that first considered, and so round again. The 2 lug-pieces of the individual disks at the anterior end are therefore not exactly opposite each other, diametrically, as the connections advance through $\frac{1}{49}$ of the circumference at each of the 49 paths. The collector is very substantially built, and a screen is fixed between the collector and the rest of the armature, to prevent any copper-dust from flying back or clogging the insulation between the bars or disks. There are 5 pairs of brushes, the tendency to sparking being thereby greatly reduced. The core of the armature is made of very thin iron disks, separated by mica or asbestos paper from each other, and clamped together. Some exception may be taken to the use of such stout copper bars, as being more likely to heat from local currents than would be the case if bundles of straps or laminæ of copper were substituted. And, indeed, the presence of a 4 h.-p. fan to cool the armature is suggestive that continuous running is liable to heat it.

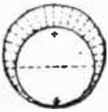
It is worth while to mention the peculiarity of form of the Bürgin armature, consisting of 8, or, in the newest machines constructed by Crompton, of 10 rings, set side by side. Each ring is made of a hexagonal coil of iron wire, mounted upon light metallic spokes, which meet the corners of the hexagon. Over this hexagonal frame, 6 coils of covered copper wire are wound, being thickest at the 6 points intermediate between the spokes, thus making up the form of each ring to nearly a circle. Each of the 6 coils is separated from its neighbour, and each of the 10 rings is fixed to the axis $\frac{1}{60}$ of the circumference in advance of its neighbour, so that the 60 separate coils are in fact arranged equidistantly (and symmetrically, as viewed from the end) around the axis. There is a 60-part collector, each bar of which is connected to the end of one coil and to the beginning of the coil that is $\frac{1}{6}$ in advance; that is, to the corresponding coil of the next ring. This armature has the great practical advantages of being easy in construction, light, and with plenty of ventilation.

In the Elphinstone-Vincent dynamo is a drum-armature of a somewhat distinct order, the separate coils being made of a rectangular form, and then laid upon the sides of a hollow papier-maché drum in an overlapping manner, and curved to fit it. The field is complex, with 6 external and 6 internal poles, and is very intense, owing to the proximity of these poles. The parallelogram-shaped coils are connected together so as to work as 3 machines, and feed 3 pairs of brushes; which may again be united, either in series or in parallel, or may be used to feed 3 separate circuits.

Collectors.—On p. 123 the main points to be observed in the construction of collectors are enumerated. Collectors of such a type are common to all dynamos of the first class, except the Brush, in which there is a multiple commutator, instead of a collector. The collector of Pacinotti's early machine differed only in having the separate bars alternately a little displaced longitudinally along the cylinder, but still so that the same brush could slip from bar to bar. Niaudet's modification, in which the bars are radially attached to a disk, is a mere variety in detail, and is not justified by successful adoption. In the collector used in Weston's dynamo, and in some forms of Schückert's, the bars are oblique or curved, without any other effect than that of prolonging the moment during which the brush, while slipping from contact with one bar to contact with the next, short-circuits one section of the coil.

In a well-arranged dynamo of the first class, the sections of the collector are traversed by currents, which run from the negative brush in 2 directions round the successive coils, and meet at that bar of the collector which touches the positive brush. Each section of the coil thus traversed adds its own electromotive force to the current passing through it. Consequently, on measuring the difference of potential between the negative brush and the successive bars of the collector, it is seen that the potential increases regularly all the way round the collecting cylinder. in both directions, becoming a maximum at the opposite side where the positive brush is. This can be verified by connecting one terminal of a voltmeter to the negative brush, and touching the rotating collector at different points of its circumference with a small metallic brush or spring attached by a wire to the other terminal of the voltmeter. If the indications thus obtained are plotted out round a circle corresponding to the circumference of the collector, the values give a curve like that shown in Fig. 74, from observations upon a Gramme dynamo.

Fig. 74.



It can be seen that, taking the negative brush as the lowest point of the circle, the potential rises regularly to a maximum at the positive brush. The same values are also plotted out as ordinates upon a horizontal line in Fig. 75. This form of diagram shows very clearly that the rise of potential is not equal between each pair of bars, otherwise the curve would consist merely of 2 oblique straight lines, sloping right and left from the central point. On the contrary, there is very little difference of potential between the collector bars close to the + brush on its right and left respectively. The greatest difference of potential occurs where the curve is steepest, at a position nearly 95° from the brushes; in fact, at that part of the circumference of the collector which is in connection with the coils that are passing through the position of best action. Were the field perfectly uniform, the number of lines of force that pass through a coil ought to be proportional to the sine of the angle which the plane of that coil makes with the resultant direction of the lines of force in the field, and the rate of cutting the lines of force should be proportional to the cosine of this angle. Now, the cosine is a maximum when this angle = 0°; hence, when the coil is parallel to the lines of force, or at 90° from the brushes, the rate of increase of potential should be at its greatest—as is very nearly realized in the diagram of Fig. 75, which, indeed, is very nearly a true "sinusoidal" curve. Such curves, plotted out from measurements of the distribution of potential at the collector, show not only where to place the brushes to get the best effect, but enable us to judge of the relative "idleness" or "activity" of coils in different parts of the field, and to gauge their actual intensity while the machine is running. If the brushes are badly set, or if the pole-pieces are not judiciously shaped, the rise of potential will be irregular, and there will be maxima and minima of potential at other points. An actual diagram, taken from a dynamo in which these arrangements were faulty, is shown in Fig. 76, and plotted horizontally in Fig. 77; from these it will be seen, not only that the rise of potential was irregular, but that one part of the collector was more positive than the positive brush, and another part more negative than the negative. The brushes, therefore, were not getting their proper difference of potential; and in part of

Fig 75.

Fig. 76.

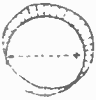


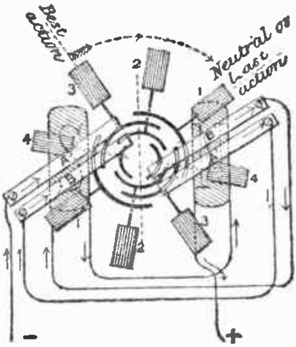
Fig. 77.

the coils the currents were actually being forced against an opposing electromotive force. In a badly-arranged dynamo giving such a diagram as Fig. 76, a second pair of brushes, applied at the points, showing maximum and minimum potential, could draw a good current without interfering greatly with the current flowing through the existing brushes.

Curves similar to those given can be obtained from the collectors of any dynamo of the first class—Gramme, Siemens, Edison, &c.—saving only from the Brush machine, which, having no such collector, gives diagrams of a different kind. It is not needful, in taking such diagrams, that the actual brushes of the machine should be in contact, or that there should be any circuit between them, though in such cases the field-magnets must be separately excited. Also, the presence of brushes, drawing a current at any point of the collector, will alter the distribution of potential in the collector; and the manner and amount of such alteration will depend on the position of the brushes, and the resistance of the circuit between them.

Brush Dynamo.—Its armature—a ring in form, not entirely overwound with coils, but having projecting teeth between the coils like the Pacinotti ring—is unique. Though it resembles Pacinotti's ring, it differs more from the Pacinotti armature than that differs from those of Siemens, Gramme, Edison, Bürgin, &c; for in all those, the successive sections are united in series all the way round, and constitute, in one sense, a continuous bobbin. But in the Brush armature is no such continuity. The coils are connected in pairs, each to that diametrically opposite it, and carefully isolated from those adjacent to them. For each pair of coils is a separate commutator, so that for the ordinary ring of 8 coils are 4 distinct commutators side by side upon the axis—one for each pair of coils. The brushes are arranged so as to touch at the same time the commutators of 2 pairs of coils, but never of 2 adjacent pairs; the adjacent commutators being always connected to 2 pairs of coils that lie at right angles to one another in the ring. The arrangement is given in Fig. 78.

FIG. 78.



In this figure, the 8 coils are numbered as 4 pairs, and each pair has its own commutator, to which pass the outer ends of the wire of each coil, the inner ends of the 2 coils being united across to each other (not shown). In the actual machine, each pair of coils, as it passes through the position of least action (*i.e.*, when its plane is at right angles to the direction of the lines of force in the field, and when the number of lines of force passing through it is a *maximum*, and the rate of change of these lines of force a *minimum*) is cut out of connexion. This is accomplished by causing the 2 halves of the commutator to be separated from one another by about $\frac{1}{8}$ of the circumference at each side. In the figure, the coils marked 1, 1, are "cut out." Neither of the 2 halves of the commutator touches the brushes. In this position, however, the coils 3, at right angles to 1, are in the position of best action, and the current powerfully induced in them flows out of the brush A (which is therefore the negative brush) into A′. This brush is connected across to brush B, where the current re-enters the armature. Now, the coils 2 have just left the position of best action, and the coils 4 are beginning to approach that position.

Through both these pairs of coils, therefore, a partial induction will be going on. Accordingly, it is arranged that the current on passing into B, splits, part going through coils 2 and part through 4, and re-uniting at the brush B′, whence the current flows round the coils of the field magnets to excite them, and then round the external circuit, and back to the brush A. (In some machines it is arranged that the current shall go round the field-magnets after leaving brush A′, and before entering brush B; in which case the action of the machine is sometimes, though not correctly, described as causing its coils, as they rotate, to feed the field-magnets and the external circuit alternately.) The rotation of the armature will then bring coils 2 into the position of least action, when they will be cut out, and the same action is renewed with only a slight change in the order of operation. The following table summarizes the successive order of connexions during a half-revolution:—

First position. (Coils 1 cut out.)

$A—3—A'$; $B < \substack{4\\2} > B'$;

Field-magnets—External circuit—A.

Second position. (Coils 2 cut out.)

$A < \substack{1\\3} > A'$; $B—4—B'$;

Field-magnets—External circuit—A.

Third position. (Coils 3 cut out.)

$A—1—A'$; $B < \substack{2\\4} > B'$;

Field-magnets—External circuit—A.

Fourth position. (Coils 4 cut out.)

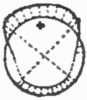
$A < \substack{3\\1} > A'$; $B—2—B'$;

Field-magnets—External circuit—A.

Whichever pair of coils is in the position of best action is delivering its current direct into the circuit; whilst the 2 pairs of coils which occupy the secondary positions are always joined in parallel, the same pair of brushes touching the respective commutators of both.

One consequence of the peculiar arrangement thus adopted is, that measuring the potentials round one of the commutators with a voltmeter, gives a wholly different result from that obtained with other machines. For $\frac{1}{8}$ of the circumference on either side of the positive brush, there is no sensible difference of potential. Then comes a region in which the potential appears to fall off; but the falling-off is here partly due to the shorter time during which the adjustable brush connected with the voltmeter and the fixed positive brush are both in contact with the same part of the commutator. Farther on is a region in which the voltmeter gives no indications corresponding to the cut-out position; and again, on each side of the negative brush, is a region where the polarity is the same as that of the negative brush. Fig. 79 is a diagram of a 6-light Brush taken at one commutator, the main + brush being, however, allowed to rest (as in its usual position), in contact with both this commutator and the adjacent one.

FIG. 79.

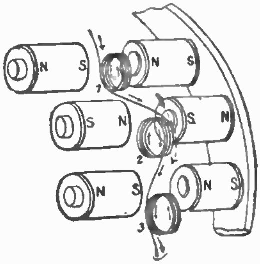


From the foregoing considerations, it is clear that the 4 pairs of coils of the Brush machine really constitute 4 separate machines, each delivering alternate currents to a commutator, which commutes them to intermittent uni-directional currents in the brushes; and that these independent machines are ingeniously united in pairs by the device of letting one pair of brushes press against the commutators of 2 pairs of coils. Further, that these paired machines are then connected in series by bringing a connection round from brush A′ to brush B.

Dynamos of Second Class.—In these, coils are carried round to different parts of a magnetic field, whose intensity differs in different regions; or one, in different parts of which the lines of force run in opposite directions. In the early machine of Pixii, a single pair of coils was mounted so as to pass in this fashion through parts of the field where the magnetic induction was oppositely directed. Such a machine gives alternate currents, unless a commutator be affixed to the rotating axis. Niaudet's dynamo, which may be regarded as a compound Pixii machine, having the separate armature coils united as those of Gramme and Siemens into one continuous circuit, is furnished with a radial collector mentioned above. In the Wallace-Farmer dynamo is a pair of poles at the top arranged so that the N. faces the S. pole, and another pair at the bottom where the S. faces the N. pole. The coils are carried round, their axis being always parallel to the axis of rotation upon a disk; there being 2 sets of coils on opposite faces of 2 iron disks set back to back. They are united precisely as in Niaudet's dynamo, and each disk has its own collector. Each bar of the collector is, moreover, connected, as in the Pacinotti, Gramme, Siemens, &c., with the end of one coil and the beginning of the next. In fact, the Wallace-Farmer is merely a double Niaudet with cylindrical collectors. There is a serious objection to the employment of solid iron disks such as these: in a very short time they grow hot from the eddying Foucault currents engendered in them as they rotate. This waste reduces the efficiency. In the Hopkinson and Muirhead dynamo, the disk-armature takes a more reasonable shape. Instead of a solid iron disk to support the coils, is a disk built up of a thin iron strip wound spirally round a wooden centre. The coils, of approximately quadrangular shape and flat form, are wound upon the sides of this compound disk. The Ball dynamo (so-called "Arago-disk") is similar in many respects, but has no iron cores to the armature coils.

Alternate-current Dynamos.—By far the most important of the dynamos of this second class are those usually known as "alternate-current machines." This type of dynamo was originally created by Wilde, in 1867. The field-magnets consist of 2 crowns of fixed coils, with iron cores, arranged so that their free poles are opposite one another, with a space between them sufficiently wide to admit the armature. The poles taken in order round each crown are alternately of N. and S. polarity, and opposite a N. pole of one crown faces a S. pole of the other. This applies to the magnets of the alternate-current machines of Wilde and Siemens, the Ferranti machine, and, with certain reservations, to the Lachaussée and the Gordon. The armatures in almost all machines of this type consist of a disk, bearing at its periphery a number of coils, whose axes are parallel to the axis of rotation. The principle is shown in Fig. 80, which gives a general view of the arrangement. Since the lines of force run in opposite directions between the fixed coils, which are alternately S.—N., N.—S., the moving coils will be traversed by alternating currents; and as the alternate coils of the armature will be traversed by currents in opposite senses, it is needful to connect them up so that they shall not oppose one another's action.

FIG. 80.



In Wilde's dynamo, the armature coils have iron cores, and the machine is provided with a commutator on the same principle as that used by Jacobi in his motor of 1838, consisting of 2 metallic cylinders, cut like crown wheels, having the teeth of one projecting between those of the other, so that the brushes make contact against them alternately as they rotate. The brushes are fixed so that they do not both touch the same part. This commutator Wilde usually applied to a few, or only one, of the rotating coils, and utilized the current thus obtained to magnetize the field-magnets. The main current was not so commuted, but was led away from a simple collector, consisting of 2 rings connected to the 2 ends of the armature circuit, each being pressed by one brush.

Siemens prefers to use a separate

direct current machine to excite the field-magnets of alternate-current dynamos. In the armature of the latter, the coils are wound, usually without iron, upon wooden cores. In some forms of the machine, the individual coils are enclosed between perforated disks of thin German silver. When currents of great strength are required, but not of great electromotive force, the coils are coupled up in parallel arc, instead of being united in series.

In a dynamo by Lachaussée, which very strikingly resembles the preceding one, there is iron in the cores of the rotating coils. But the main difference is that the rotating coils are the field-magnets, excited by a separate Gramme dynamo, whilst the coils, which are fixed in 2 crowns on either side, act as armature coils in which currents are induced.

Gordon's dynamo is constructed on the same lines as the Lachaussée, but with many important improvements. In the first place, there are twice as many coils in the fixed armatures as in the rotating magnets, there being 32 on each side of the rotating disk, or, in all, 64 moving coils; while there are 64 on each ot the fixed circles, or 128 stationary coils in all. The latter are of an elongated shape, wound upon a bit of iron boiler-plate, bent up to an acute V form, with cheeks of perforated German silver as flanges. The object of thus arranging the coils, so that the moving ones shall have twice the angular breadth of the fixed ones, is to prevent adjacent coils of the fixed series from acting detrimentally, by induction, upon one another. The alternate coils of the fixed series are united together in parallel arcs, so that there are 2 distinct circuits, in either or both of which lamps can be placed; or they can be coupled up together. Great care appears to have been taken, in the construction of this large machine, to guard against the appearance of Foucault currents, by arranging the cores, frames, and coils, so that all metallic parts of any size shall be slit, or otherwise structurally divided at right angles to the direction of the induced electromotive forces.

Another alternate-current dynamo, identical in many respects with the Siemens, is the Ferranti. As in the machines of Wilde and Siemens, the electro-magnets form 2 crowns with opposing poles. The point of difference is the armature, which, like that of Siemens, has no iron cores in its coils; but which, unlike that of Siemens, is not made up of coils wound round cores, but consists of zigzags of strip copper folded upon one another. There are 8 loops in the zigzag (as shown in Fig. 81), which depicts half only of the arrangement, and on each side are 16 magnet poles; so that, as in Gordon's dynamo, the moving parts are twice the angular breadth of the fixed parts. The advantage of the armature of zigzag copper lies in its simplicity of construction. Sir W. Thomson, who is the real inventor of this armature, proposed originally that the copper strips should be wound between projecting teeth on a wooden wheel, as indicated in Fig 82. He also proposed to use as field-magnets a form of electro-magnet of the kind known as Roberts's, also used by Joule, in which

FIG. 81.

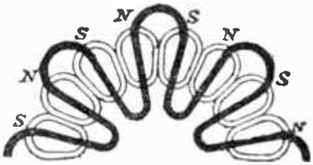
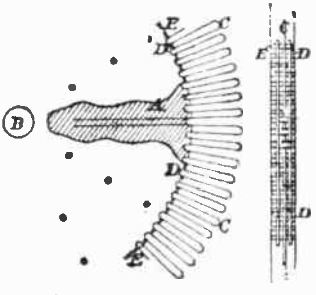


FIG. 82.

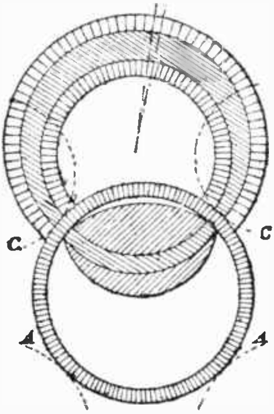


the wires that bring the exciting current are passed up and down, in a zigzag form, between iron blocks projecting from an iron frame.

Prof. Thompson is not at all convinced that this type of machine, though at present fashionable, is destined to prove of very great value, because he doubts whether any dynamo that yields alternate currents can compete with continuous-current machines. For the purposes of a general system of distribution, where more than one dynamo must be available, and for the purpose of supplying motors, alternate-current machines are quite out of the question. Besides the disk armatures described, pole armatures have been employed in alternate-current machines by Gramme, Jablochkoff, and Lontin. Hefner Alteneck has gone a stage farther, and, by the device of employing a disk armature in which the number of coils differed by 2, or some other even number, from those of the field, and by the employment of a multiple-bar collector with complicated cross connections, has succeeded in converting this type of dynamo into a continuous-current machine.

Thomson's "Mouse-mill."—This dynamo is shown in Fig. 83 in diagram. The armature is a hollow cylinder S, made up of parallel copper bars, arranged like the bars of a mouse-mill (whence the name of the machine). These bars are insulated from each other, but are connected all together at one end. At the other, they serve as collector-bars, and deliver up the currents generated in them to the "brushes," which here are rotating disks of springy copper shown as dotted circles at C. As the armature is a hollow barrel, with fixed electro-magnets within, it cannot be rotated on a spindle, but runs on friction rollers AA′, by one or more of which it is driven.

FIG. 83.



Dynamos of Third Class.—The earliest machine which has any right to be called a dynamo was of this class. Barlow and Sturgeon had shown that a copper disk, placed between the poles of a magnet, rotates in the magnetic field when traversed by an electric current from its axis to its periphery, where there is a sliding contact. Faraday, in 1831, showed that by rotating a similar disk mechanically between the poles of a magnet, continuous currents were obtained. These he drew off by collecting springs of copper or lead, one of which touched the axis whilst the other pressed against the amalgamated periphery. Here was demonstrated the production of a permanent (*i.e.* continuous) current of electricity by ordinary magnets. He went on to employ the principle of separate excitement of his field-magnets. Effects were obtained from *electro-magnetic poles*, resulting from the use of copper helices or spirals, either alone or with iron cores. The directions of the motions were precisely the same; but the action was much greater when the iron cores were used than without. Such a machine as Faraday's is impracticable for several reasons: the peripheral friction is inadmissible on any but a small scale; and the disposition of the field-magnets necessarily evokes wasteful eddy-currents in the disk, which, even if slit radially, would not be an appropriate form of armature for such a limited magnetic field.

Another method of obtaining a continuous cutting of the lines of force, is where a sliding conductor travels round the pole of a magnet. Faraday even generated continuous currents by rotating a magnet with a sliding connection at its centre, from which a conductor ran round outside, and made contact with the end-pivots which supported the magnet.

A similar arrangement was devised by Varley about 1862. He rotated an iron magnet in a vertical frame, having a mercurial connection at the centre. The current which flowed from both ends of the magnet toward the centre was made to return to the machine, and to pass through coils surrounding the poles of the rotating magnet; thus anticipating the self-exciting principle of later date. Varley also proposed to use an external electro-magnet to increase the action.

Quite recently, the same fundamental idea has been worked upon by Siemens and Halske, who have produced a so-called "unipolar" machine. In this remarkable dynamo are 2 copper cylinders, both slit longitudinally to obviate eddy-currents, each of which rotates round one pole of a U-shaped electro-magnet. A second electro-magnet, placed between the rotating cylinders, has protruding pole-pieces of arching form, which embrace the cylinders above and below. Each cylinder, therefore, rotates between an internal and external pole of opposite polarity, and consequently cuts the lines of force continuously by sliding upon the internal pole. The currents from this machine are of very great strength, but of only a few volts of electromotive force. To keep down the resistance, many collecting brushes press on each end of each cylinder. This dynamo is actually at work for electro-plating.

In Voice's dynamo, a coil armature, wound upon an iron ring, is so placed that the iron ring is itself one pole of a magnet, a projecting pole-piece from the other pole being fixed near it, so that the coils fixed upon one pole glide round and cut the lines of force proceeding from the other pole. Whether this machine will be a practical one remains to be seen.

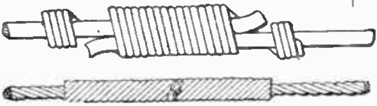
Fire Risks.—The following rules and regulations are drawn up by a committee of the Society of Telegraph Engineers and Electricians for the reduction to a minimum, in the case of electric lighting, of those risks of fire which are inherent in every system of artificial illumination, and also for the guidance and instruction of those who have, or who contemplate having, electric lighting apparatus installed in their premises. The difficulties that beset the electrical engineer are chiefly internal and invisible, and they can only be effectually guarded against by "testing," or probing with electric currents. They depend chiefly on leakage, undue resistance in the conductor, and bad joints, which lead to waste of energy and the dangerous production of heat. These defects can only be detected by measuring, by means of special apparatus, the currents that are, either ordinarily or for the purpose of testing, passed through the circuit. Should wires become perceptibly warmed by the ordinary current, it is an indication that they are too small for the work they have to do, and that they should be replaced by larger wires. Bare or exposed conductors should always be within visual inspection, and as far out of reach as possible, since the accidental falling on to, or the thoughtless placing of other conducting bodies upon, such conductors, would lead to "short circuiting," and the consequent sudden generation of heat due to an increased current in conductors not adapted to carry it with safety.

The necessity cannot be too strongly urged for guarding against the presence of moisture and the use of "earth" as part of the circuit. Moisture leads to loss of current and to the destruction of the conductor by electrolytic corrosion, and the injudicious use of "earth" as a part of the circuit tends to magnify every other source of difficulty and danger. The chief dangers of every new application of electricity arise from ignorance and inexperience on the part of those who supply and fit up the requisite plant. The greatest element of safety is therefore the employment of skilled and experienced electricians to supervise the work.

(a) *The Dynamo Machine.*—(1) The dynamo machine should be fixed in a dry place. (2) It should not be exposed to dust or flyings. (3) It should be kept perfectly clean and its bearings well oiled. (4) The insulation of its coils and conductors should be practically perfect. (5) All conductors in the dynamo room should be firmly supported, well insulated, conveniently arranged for inspection, and marked or numbered.

(b) *The Wires.*—(6) Every switch or commutator used for turning the current on or off should be constructed so that when it is moved and left it cannot permit of a permanent arc or of heating. (7) Every part of the circuit should be so determined that the gauge of wire to be used is properly porportioned to the currents it will have to carry, and all junctions with a smaller conductor should be fitted with a suitable safety fuse or protector, so that no portion of the conductor should ever be allowed to attain a temperature exceeding 150° F. (65½° C.). (8) Under ordinary circumstances, complete metallic circuits should be used; the employment of gas or water pipes as conductors for the purpose of completing the circuit should not in any case be allowed. (9) Bare wires passing over the tops of houses should never be less than 7 ft. clear of any part of the roof, and all wires crossing thoroughfares should invariably be high enough to allow fire escapes to pass under them. (10) It is most essential that joints should be electrically and mechanically perfect, and united by solder. The form of joint recommended is shown in Fig. 84.

FIG. 84.



(11) The position of wires when underground should be clearly indicated, and they should be laid down so as to be easily inspected and repaired. (12) All wires used for indoor purposes should be efficiently insulated, either by being covered throughout with some insulating medium, or, if bare, by resting on insulated supports. (13) When these wires pass through roofs, floors, walls, or partitions, or where they cross or are liable to touch metallic masses, like iron girders or pipes, they should be thoroughly protected by suitable additional covering; and where they are liable to abrasion from any cause, or to the depredations of rats or mice, they should be efficiently encased in some hard material. (14) Where indoor wires are put out of sight, as beneath flooring, they should be thoroughly protected from mechanical injury, and their position should be indicated. N.B.—The value of frequently testing the apparatus and circuits cannot be too strongly urged. The escape of electricity cannot be detected by the sense of smell, as can gas, but it can be detected by apparatus far more certain and delicate. Leakage not only means waste, but in the presence of moisture it means destruction of the conductor and its insulating covering, by electric action.

(c) *Lamps.*—(15) Arc lamps should always be guarded by proper lanterns to prevent danger from falling incandescent pieces of carbon, and from ascending sparks. Their globes should be protected with wire netting. (16) The lanterns, and all parts which are to be handled, should be insulated from the circuit.

(d) *Danger to Person.*—(17) Where bare wire out of doors rests on insulating supports, it should be coated with insulating material, such as indiarubber tape or tube, for at least 2 ft. on each side of the support. (18) To secure persons from danger inside buildings, it is essential so to arrange and protect the conductors and fittings, that no one can be exposed to the shocks of alternating currents of a mean electromotive force exceeding 100 volts, or to continuous currents of 200 volts. (19) If the difference of potential within any house exceeds 200 volts, the house should be provided with a "switch," so arranged that the supply of electricity can be at once cut off.

With reference to par. (10). Bolas says that the best way to make an electrical joint is, first to thoroughly tin the wires, and then wipe them carefully while they are still hot; any chloride of zinc which may have been used being next removed by a damp cloth. The wires are then bound, and subsequently well grouted with solder, rosin only being used as a flux.

Killingworth Hedges, in a paper recently read before the British Association, alludes to some sources of danger not previously mentioned. Thus, in reference to the development of heat caused by an increased resistance, he recalls Matthiessen's experiment showing that the conducting power of "commercial" copper wire is only 13·6 as against 99·95 for pure copper: hence the wire used must be pure throughout. An absolute essential is a cut-out or fusible plug in the circuit, arranged to melt if the current is more than 10 to 15 per cent. in excess of the working strength.

Measuring.—The following observations on the measurement of electric currents are condensed from J. N. Shoolbred's paper on the "Measurement of Electricity" ('Jl. Soc. Arts,' Ap. 6. 1885), and one by Professors Ayrton and Perry on "Measuring Instruments used in Electric Lighting and Transmission of Power."

The measurement of all physical quantities rests upon 3 fundamental units—length, mass, and time. All others can be deduced from these. The fundamental units chosen for electrical measuring are: length, 1 centimetre; mass, 1 gramme; time, 1 second; and the term "C.G.S." was applied to the whole system.

As, with the use of a scale common to all quantities, both very large and very small numbers must often be represented, it is advocated in the C.G.S. system to express each number as the product of 2 factors, 1 of them being a power of 10; also to effect this in such a way that the exponent of the power of 10 shall be the characteristic of the logarithm of the number. Thus, 1.280.000 would be written as $1·28 \times 10^6$. and $·000128$ as $1·28 \times 10^4$.

The following table contains some of the units based upon the C. G. S. system:—

C.G.S. UNITS OF MEASUREMENT.

Fundamental Units.

Length, 1 centimetre; mass, 1 gramme; time, 1 second.

Derived Units.—Mechanical.

Velocity.—Unit length in unit time

$$\frac{\text{Centimetre}}{\text{Second.}}$$

Acceleration.—Rate of increase of velocity per second: In gravitation measure = g. g. in latitude of London = 981 C. G. S. units.

Momentum.—Momentum of 1 gramme with a velocity of 1 centimetre per second.

Force or Power—*Dyne.*—Force which, acting upon 1 gramme for a second, generates a velocity of 1 centimetre per second.

Work—*Erg.*—Amount of work done by 1 dyne working through 1 centimetre of distance.

Electro-magnetic.

Magnetic Pole.—A pole which, at 1 centimetre distance from a similar pole, gives a force of 1 dyne.

Magnetic Field.—The intensity of a field which acts on unit magnetic pole with a force of 1 dyne.

Current.—A current flowing along 1 centimetre of a circuit in form of a circular arc, of 1 centimetre radius; and exerting a force of 1 dyne on a unit pole placed at the centre.

Quantity.—The quantity conveyed by unit current in 1 second.

Potential or Electromotive Force.—The difference of the electric condition between 2 conductors, or 2 points of a conductor, when the transference of electricity from one to the other is proceeding at the rate of 1 erg of work per unit of electricity transferred.

Resistance.—A resistance such that, with unit of difference of potential between the ends of conductor, 1 unit of current is conveyed along it.

N.B.—The estimation of resistance actually resolves itself into a question of velocity, *i.e.* $\frac{\text{Length}}{\text{Time}}$

Some of the above C. G. S. electro-magnetic units being found to be inconveniently large, and others to be far too small, the following "practical" units, for general use, have been deduced from them, and are now being universally adopted.

"*Practical*" *Electrical Units.*

The *ohm* (10^9 C. G. S. units of resistance), as the unit of resistance, is that of a column of mercury having 1 sq. millimetre of section, and of a length hereafter to be determined by a commission specially appointed for the purpose. *Note.*—The length is supposed, however, to be between 104 and 105 centimetres.

The *volt* (10^8 C. G. S. units of electromotive force), as the unit of electromotive force. *Note.*—This corresponds nearly to that of a Daniell's cell.

The *ampère* (10^{-1} C. G. S. units of current), as the unit of current; which is the current produced by 1 volt through 1 ohm.

The *coulomb* (10^{-1} C. G. S. units of quantity), as the unit of quantity of electricity; which is defined by the condition that an ampère yields 1 coulomb per second.

The *farad* (10^{-9} C. G. S. units of capacity), as the unit of capacity; which is such that 1 coulomb in a farad shall give 1 volt.

Or, to quote the words of Sir Wm. Thomson, "The volt acting through an ohm gives a current of 1 ampère, that is to say, 1 coulomb per second; and the farad is the capacity of a condenser, which holds 1 coulomb, when the difference of potential of its 2 plates is 1 volt."

The following was suggested by Dr. C. W. Siemens to be added to the above units :—

The *watt* (10^7 C. G. S. units o power), as the unit of power; being th power conveyed by a current of 1 ampère in 1 second through a conductor whose ends differ in potential by 1 volt.

The *joule* (10^7 C. G. S. units of work), as the unit of work, or heat, being th heat generated by a watt in a second.

In the construction of instruments for the generation and measurement of electric currents, great advantage is taken of the inducting action of magnets upon coils; of the effect of the passage of the electric current through a coil upon a magnetic needle in its vicinity; and of the result of electric currents of different intensities upon each other, in their passage through conductors in the form of coils.

The evaluation of the electrical energy of a supply depends upon the exact measurement of 2 factors—the amount of the supply and the pressure under which it is given; or the quantity of the current and the electromotive force. The product of the current expended, in ampère seconds, or of this amount of quantity expressed in coulombs, by the electrical pressure of the same, expressed in volts, gives the electrical energy expended, or the power of the supply. The electrical energy is therefore represented by the product of volts × ampères × time; or by the product of volts × coulombs; or, expressed algebraically, $W = ECt = EQ$.

Following are equivalent expressions for the same amount of power, expressed in other terms, some of which may be more familiar :—

Rate of expending Energy.

$$1 \text{ volt-ampère} = \left\{ \begin{array}{l} 10^7 \text{ ergs per second.} \\ 1 \text{ watt.} \\ \frac{1}{1\cdot 35} \text{ foot-pounds per second.} \\ \frac{1}{9\cdot 81} \text{ kilogrammetres per second.} \\ \frac{1}{736} \text{ force-cheval (French horse-power).} \\ \frac{1}{746} \text{ horse-power.} \end{array} \right.$$

The Board of Trade suggest that the unit of price to be charged should be based on "the energy contained in a current of 1000 ampères flowing under an electromotive force of 1 volt during 1 hour;" or, in other words, the unit might be put as 1000 volt-ampère hours. The ampère hour is another way of saying 3600 coulombs of quantity of electricity supplied. It may be of interest to state in other more conventional terms the equivalent of the amount of work implied in the above unit:—

Work done, or Energy expended.

1000 volt-ampère hours =
10^{10} erg hours.
3,600,000 volt-coulombs.
3,600,000 joules.
1000 watt-hours.
2,645,000 foot-pounds.
366,840 kilogrammetres.
1·35 force-cheval heures.
1·34 horse-power hours.

Put in terms more in accordance with actual practice, the above unit might mean the supply for 1 hour of a current of 10 ampères with an electromotive force of 100 volts; or a 5-ampère current with an E. M. F. of 200 volts; or a 10 ampère current at 200 volts for only ½ hour; and so on, provided that the product of the 3 factors is always 1000.

To arrive at an evaluation of the supply of electric energy, the measurement of each of these 2 factors (in volts and ampères respectively), must be effected either separately or combined, and a continuous and cumulative record must be kept of the supply as it proceeds. To measure with completeness, for commercial purposes, a supply of electricity, entails a continuous record of current and pressure, either separately or combined. In the supply of towns, the question for the consumer will probably be much simplified by causing one element, pressure, to remain constant. If so, it becomes the duty of suppliers to keep up that pressure under penalty; and instruments for recording such pressure will have to be installed where required, and placed under proper supervision. For the customer, it will then generally suffice to have an exact record of the quantity of his individual consumption of electric supply.

Some of the non-recording instruments in more general use, by the addition of recording apparatus, by which the element of time can be integrated, may be made into registering meters. Thus, any current or ampère measurer may be converted into a record of quantity; or a coulomb-meter, by the integration of the time during which the current has flowed; and, similarly, any power or volt-ampère measurer may become a register of work done by means of the addition of the elements of time. Again, volt or pressure measurers will always be required in any case where a check is needed upon the actual difference of potential or electromotive force of the supply; and this may arise from a variety of causes.

NON-REGISTERING INSTRUMENTS.—(*a*) *Current Measurers.*—(1) Siemens's Electro-dynamometer consists of a fixed coil, and of a movable coil suspended by a thread and a spiral spring, the normal position of the latter being at right angles to that of the former. When a current is sent through the 2 coils in series, the movable coil is deflected; this deflection is counteracted by torsion of the spiral spring, the amount of such torsion (indicated by a pointer on an index-dial) being proportioned to the square of the current strength.

(2) Obach's Tangent Galvanometer has a movable ring round a horizontal axis. If the ring is vertical, the needle tends to turn on a vertical axis, as in the ordinary tangent galvanometer (the opposing force being the horizontal component of the earth's magnetism); if, however, the ring is placed horizontally, the needle turns round a horizontal axis, or dips (the opposing force being the vertical component of the earth's magnetism). The effect of the intensity of the current upon the needle may therefore be varied with the inclination of the ring. With the ring in

any fixed position, the current strength is proportional to the tangent of the deflection (as in an ordinary tangent galvanometer).

(3) Cardew's Low-resistance Galvanometer is based on the principle of finding the intensity of an unknown current by balancing it against one of known strength, and thus ascertaining the relation between the two. It consists of 2 coils, a thick wire one (for the unknown current), and a thin wire one (for the standard one); both are wound on the same bobbin, but are insulated from each other. A magnet, with needle-pointer, is pivoted in the centre of the bobbin, and its deflections are counteracted by the insertion of known resistance.

(4) Ayrton and Perry's Am-meter.—This instrument is made in several forms. In its original shape, it consists of a permanent magnet of horse-shoe pattern, with a needle-armature fixed between its pole-pieces. These are made of such a shape as to ensure that the deflections of the needle shall be directly proportional to the intensity of the current causing them; hence a knowledge only of the constant of each instrument is required when using it. Furthermore, the coil of wire through which the current passes, is in some instruments divided up into 10 strands, which may, by means of a cylindrical commutator, be coupled up in "parallel" or in "series," as it is desired or not to magnify the deflection 10-fold for small currents. In cases where loss of magnetism in the permanent magnet is to be feared, a spiral spring is made to take the place of the horse-shoe magnet as the controlling force. Again, where extreme delicacy is required, the deflections of the needle may be magnified 10-fold or more, by attaching to the shaft of the needle a wheel and pinion. This form of instrument is adapted for use with strong currents.

(5) Deprez's Galvanometer consists of a horse-shoe permanent magnet, with a solid armature-needle of peculiar "fish-bone" form, and index-pointer, pivoted vertically, placed between its poles, and a coil of the wire, which carries the current to be measured, laid within the horse-shoe. A table indicating the value of the several deflections of the needle has to be used.

(6) Thomson's Current Galvanometer.—This instrument, together with its fellow one, for the measurement of the difference of potential, have been termed "graded galvanometers." They are designed to permit of a very wide range being obtained with each respectively; this being effected by varying the intensity of the magnetic field in a known ratio, and comparing with it the unknown current. The present instrument consists essentially of 2 parts; a coil of thick wire, through which the current to be measured is allowed to pass, it being fixed upright at the end of a wooden platform, with about ½ only of the coil projecting above it; and a "magnetometer." This last consists of 4 short steel magnets (constituting the "needle") mounted in a frame on a vertical axis, with a long aluminium pointer attached, and enclosed in a quadrant-shaped box, with a glass cover and a silvered glass mirror bottom (in order to counteract any effect of parallax while reading the scale of tangents, to which the instrument is graduated). To increase the directive force of the needle, when required, a semicircular permanent magnet of hard steel, and of known intensity, may be fixed upright on 2 arms projecting from the magnetometer, behind the apex of the quadrant. The magnet stands over the needle, with its magnetic axis in the horizontal plane through that of the needle. The magnetometer is made to slide along a groove in the wooden platform in front of the fixed coil, and in a direction at right angles to it, the axis of the magnet and of the needle (when at rest) being parallel to that of the coil; while the aluminium pointer, when at zero, which is the centre of the scale, lies in the same direction as the groove, or at right angles to the coil. The range of sensibility obtained by varying the extreme distance along the groove of the magnetometer from the coil is about

50-fold; while by removing the magnet, and leaving the needle under the influence of the earth's force alone, a further sensibility 50 times greater can be obtained.

(*b*) *Pressure Measurers.*—(1) Ayrton and Perry's Volt-meter is in principle and form like their am-meter, and has, like it, several similar modifications. The essential difference between the 2 instruments is that the thick wire coil of the am-meter is here replaced by a thin wire coil, with the connections to its ends so arranged as to measure the difference of potential between the points desired.

(2) Thomson's Potential Galvanometer differs only from his "current" instrument, already described, in the use of a thin wire coil (of German silver of about 6000 ohms resistance), instead of a thick wire coil; and in the change in the connections to suit the present object.

(3) Siemens's Torsion Galvanometer consists of a bell-magnet suspended between 2 coils of fine wire by means of a thread and a spiral spring. The deflections of the magnet under the current are counteracted by means of the spring, as in the electro-dynamometer, only that the angles of torsion are here proportional simply to the intensity. Certain resistances can also be added by which the sensitiveness can, by means of the insertion of a plug, be increased 10-fold.

(*c*) *Power or Energy Measurers.*—(1) Ayrton and Perry's Power-meter consists of a thick wire coil through which the main current passes, and of a fine wire coil on a shunt, which is suspended within it. The axes of the 2 coils are parallel, and the passage of a current tends to deflect the suspended one. Since the thick wire coil measures the intensity of the current, and the thin wire one its electromotive force, and as the deflection of the latter is the product of the two, therefore the amount of that deflection is the measure of the power, or energy, of the current. Modifications of this instrument, with or without a commutator, or with a wheel and pinion arrangement, are also made.

(2) Siemens's Watt-meter is constructed on the same principle as the electro-dynamometer. The 2 coils are, however, kept distinct, with separate terminals to each. The fixed one, of thin wire on a shunt, measures the electromotive force; while the movable one has the main current passing through it. The resulting position of the latter coil is due directly to the intensities of the 2 currents; that is, to the power developed. This product, of volts × ampères, is watts; hence the name of the instrument. The angle of torsion of the index-pointer gives the watts directly, and with the knowledge of the particular constant.

(*d*) *Resistance Measurers.*—Measurements of this class are generally carried out by means of a galvanometer, a set of resistance coils, and a Wheatstone bridge (therewith balancing the unknown resistance by means of one of a known amount).

Ayrton and Perry's Ohm-meter consists of 2 coils: a thick wire one for the main current, and a thin wire one on a shunt for the electromotive force. Both are fixed with their axes at right angles to each other. A needle is acted upon by the currents flowing through each, and as these are at right angles to each other, the resulting deflection represents the ratio $\frac{\text{E. M. F.}}{\text{current}}$, *i.e.* resistance; while in the power-meter the deflection is caused by the product of current × E.M.F. In all the instruments devised by Professors Ayrton and Perry, the deflections are caused, by duly proportioning the parts, to be directly proportional to the measurements sought for in each case.

(B) REGISTERING INSTRUMENTS.—These may be divided into 2 classes —(*a*) Quantity or coulomb meters; (*b*) energy or work meters.

(*a*) *Quantity or Coulomb Meters.*—These are separated into those based upon electrolytic action, and those which are mechanical in principle.

(1) Electrolytic.—Edison's current-meters are based upon electro-deposition of metal, due to the action of a known

fractional part of the total current. The weight of the increments is ascertained periodically, and from it the total quantity of the current which has passed through the interval is deduced. The metal used consists of plates of amalgamated zinc, immersed in a solution of 90 parts zinc sulphate and 100 of pure water. In the form of meter for commercial use, 2 cells are placed as a check against each other; one, termed the "monthly cell," receiving 4 times the current of the other, which is known as the "quarterly cell." To prevent the temperature of the liquid in the cells falling so low as to freeze, a connection is made, by means of a long thin strip of brass and steel riveted together, to an incandescent lamp, which is thereby lighted, and raises the temperature as required. It is only when the temperature falls to 42° F. (5½° C.) that this tongue is sufficiently depressed to form contact, and so to light the lamp. On the temperature rising, the tongue rises, and the lamp is extinguished. Experience shows that electro-deposition, to give a true and reliable record, should not be forced or overworked in its action; and that the plates should not in their daily duty be required to do more work, or be longer in action, than they are intended for by their superficial area. In practice, about 75 per cent. only of the nominal work should be required of them. It appears to be the custom to design the duty of a meter for 3 hours' burning of each lamp per night. Thus, a 25-light meter would have its plates designed for 75 lamp-hours per night. As just stated, it is not advisable in practice to exceed 75 per cent. of this amount. However, it is seldom found that the whole of the lights are used for the entirety of the time allotted to each; and if this were so, it would merely require a larger meter to meet the case. It is said that over 300 meters on this principle are in use in New York.

Sprague's meters are based upon electro-deposit up to a certain point; *i.e.* when the intended quantity of metal, whether copper or zinc, has been deposited on the plate. The current is then reversed, and the metal is gradually dissolved again until the primary condition of the plate is reached; when, by another reversal of the current, deposition again commences. Each reversal of the current is recorded by a mechanical counter and a train and wheels. Not much practical experience has been obtained with these meters; but what has been done tends to point out that the mechanical operations involved in the reversals of the current, and in their registration, absorb a large amount of power.

(2) Mechanical.—Hopkinson's current-meter consists of a thick wire coil, in the form of a solenoid, through which the current passes to be measured. The iron core of this solenoid revolves with its central shaft by the action of the armature of a small dynamo machine placed at one end of the shaft. The core of the solenoid is in 2 parts; the lower is fixed to the shaft, while the upper is movable, being attached to a governor-ball arrangement, and sliding up and down the shaft in accordance with the variations in the rotation speed of the shaft. A shunt current passes through the dynamo and its armature, up through the lower or fixed portion of the core, (by contact only) to the sliding part, and thence to the framework of the apparatus. If the movable core be lifted, owing to the speed of rotation, by the action of the governor-balls, this circuit is broken, and the shunt current through the dynamo is interrupted. Whenever a current to be measured passes through the coil, attraction, by means of its casing, takes place between the fixed and the movable parts of the iron core. This magnetic action, which is proportional to the square of the current, tends to keep the 2 parts of the core together and in contact; while the centrifugal force of the governor-balls, which is proportional to the square of the speed of revolution, tends to break the contact by lifting the movable part. These opposite forces will, in working, balance one another, and the result is that the

system revolves with a velocity proportional to the current through the coil. As the revolutions of the shaft are transmitted continuously by a train of wheels to a set of index dials, a record is kept of the quantity of the current that has passed.

Boys's Quantity or Vibrating Meter is based upon 2 well-known principles: (1) The force acting on the armature of an electro-magnet, in any position, is proportional to the square of the current; (2) the square of the number of vibrations, say, of a pendulum, is a measure of the controlling force. Therefore, if the controlling force under which a body vibrates is due to the action of an electro-magnet on its armature, the square of the number of vibrations in a given time is a measure of the square of the electric current. In other words, the rate of vibrating is a measure of the strength of the current; and the number of vibrations is a measure of its quantity. The exact form and nature of the meter may vary in many details. One form consists, primarily, of an electro-magnet (the upper one), through the coils of which passes a portion of the main current to be measured. This magnet is placed horizontally, and a vertical rocking shaft stands between its poles. This shaft has fixed on it a soft iron armature, rounded at the ends, and free to move in the horizontal plane between the poles of the electro-magnet. The intensity of the attraction between the poles and this armature determines the rate of vibration, which, as above stated, is a measure of the strength of the current. Each vibration is itself recorded by means of an escapement, a train of wheels, and a set of index dials: and the number of vibrations thus registered becomes a measure of the quantity of the current. To add to the momentum of the vibrating body, 2 long arms, weighted at the end, are attached to the lower part of the vertical shaft. To prevent the vibrating armature from gradually coming to rest, it is arranged that, when the vibrations fall below a certain limit, by making contact, a portion of the current is sent round the coils of a second or "impulse" electro-magnet (placed underneath the "controlling" magnet), and which has an armature of a suitable form fixed on to the same shaft that carries the armature of the upper magnet. The extra motion thus given to the shaft by the attraction of the lower armature, affords the necessary impulse to the vibrating armature when required.

In Lane-Fox's quantity meter the entire current of supply is passed through the coils of a solenoid; the movable core, or plunger (the degree of insertion of which within the solenoid depends upon the intensity of the current), is made pendant from one end of a beam or balance. From the other extremity of the beam hangs a plunger, in the form of an inverted cone, which in its position of rest fills up completely, with the base of the cone, a small vertical water-pipe, the water being constantly supplied from a small cistern above. The result of the passage of an electric current through the coils of the solenoid is to suck the core or plunger deeper in, and in doing so the conical water-plug is lifted, and its diameter at the orifice of the pipe being diminished in consequence, water escapes down the pipe. The amount of this water, being directly dependent upon the intensity of the current, becomes a measure of its quantity. A cistern is provided for this overflow; and when it becomes full, it is automatically emptied. These successive operations of emptying are recorded mechanically by a train of wheels. By this means, a record is kept of the quantity of the supply.

F. H. Varley's meter is based partly upon electric and partly upon mechanical principles, the successive increments of depositions being made visible by a pointer on a curved index; and the several reversals are understood to be alterations in the mechanical direction, and not in that of the current (as in Sprague's meters).

(c) *Energy or Work Meters.* — (1) Boys's.—This consists of 2 parts—the indicator of energy, and the integrating apparatus. In the indicator of energy, a balanced beam has from one end suspended a counter-weight, and from the other a hollow solenoid, free to work up and down into 2 other solenoids. The movable solenoid is wound with a considerable length of fine wire, in the upper half in one direction, in the lower in the opposite (this is to render it independent of any magnet which may be placed near it). This solenoid constitutes the high resistance shunt which measures the E.M.F. The 2 fixed solenoids are wound with thick wire, and convey the main current. The result of the action of the fixed and movable solenoids on each other is a force proportional to the product of the 2 currents, that is, to the energy expended: but the external evidence of this is the inclination of the beam, and this inclination, or rather the tangent of the inclination, is proportional to the energy being expended. The recording apparatus consists of a cylinder, which, by means of a mangle-motion, is made to reciprocate backwards and forwards by clockwork, and during its passage in each direction the cylinder is made to bear alternately against one of 2 tangent wheels, each free to be inclined in its direction of travel: both are fixed on the same swivelling frame, but only one of them bears at the same time against the cylinder. This frame is free to be inclined from the vertical in correspondence with the inclinations of the beam. The effect of this inclination of the tangent wheel is to cause the reciprocating cylinder to rotate, the speed of such rotation being proportional to the tangent of the inclination of the wheel, which is likewise proportional to the tangent of the inclination of the beam, *i.e.* to the amount of energy expended. The path of the tangent wheel on the reciprocating cylinder, when not inclined, is simply a straight line lengthways along the cylinder, and no rotation is caused; but when, owing to the inclination of the wheel, the cylinder rotates, the wheel-path becomes a spiral. The rotations of the cylinder are transmitted to a train of wheels, and registered, thus giving a record of the amount of energy expended during a given time.

(2) Deprez's instrument consists of a thick wire coil, movable upon its axis, which passes through its centre of gravity. This axis-shaft is set upon 2 knife-edges, insulated from each other, and communicating respectively with the coil; and with a metallic bar having a curved, quadrant-shaped head, which dips into a mercury cup, and thus forms connection with the main current. The shaft also carries, projecting downwards, a pendulum rod, the bob of which is intended to cause an antagonistic force; while the extension upwards of the rod forms a pointer, with a scale fixed on the frame of the apparatus. On the frame there is also a fine wire coil, on a shunt, fixed so as to surround the movable coil. The deflections on the pointer are therefore due to the product of the intensity of the current and its electro-motive force; that is, to the power developed. The readings of this instrument may be integrated either by a Deprez rotating disc and ball integrator, or by one designed by Abdank (of Cracow), having a travelling cylinder and tangent-wheel arrangement, somewhat similar to that of Boys.

(3) Ayrton and Perry's erg-meter is but a further development or sequel to their power-meter, by the addition of apparatus which integrate and record continuously the time during which the electrical energy has been imparted, as well as the variations in its amount. By this means is preserved a record of the entire work done, or of the total electrical energy supplied. As in the power-meter, 2 coils are here made use of. There is a thick wire one on the main circuit, to measure the amount of current; and a thin wire one on a shunt, joining the ends of the main circuit, to measure the difference of potential, or electromotive force, of the main circuit. The thin wire coil, of say 1000 ohms resistance, simply replaces the pendulum bob of a clock. The wires from each end of the coils pass up the sides of the pendulum rod,

and on to binding-screws, which can be joined to the supply and return cables of a house, or machine, or a system receiving electrical energy. In the immediate vicinity of the fine wire coil, fastened to the clock-case and parallel with the plane of the pendulum path, is fixed the thick wire coil, which forms part of the main circuit and has a very small resistance. The effect upon the thin wire coil of its repeated passages in front of the thick wire coil is to cause a certain pull or attraction upon its motion—either of acceleration or of retardation, according to the direction of the coiling. This action, in addition to the ordinary action of gravity upon the pendulum, will keep constantly adding to or taking from its rate of motion, in proportion to the electrical power of the circuit. This pull is the product of the magnetic moments of the 2 coils, and therefore is proportional to the product of the current and the electromotive force. The effects of these repeated accelerations or retardations upon the progress of the clock keep constantly accumulating, and their total amount can at any time be detected and ascertained by observing the amount of loss or gain which the clock has experienced. As the rate of loss or gain in the clock due to different amounts of electrical power has been previously ascertained, this knowledge of the total retardation or acceleration upon the clock is, in fact, a record of the total amount of electrical energy which has been expended, or of the work done, since the last observation of the clock.

Prof. W. Grylls Adams observes that before much can be said about these various instruments, they require further trial and comparison with one another. One important point is economy; a simple instrument will have the preference over another which may be equally effective but more complicated. If these instruments are to be used by every consumer, it is a matter of great importance that they shall not be unnecessarily expensive.

Preece advocates the adoption of a mode by which lighting may be paid for, not by measuring the quantity of electricity consumed, but by the measurement of the amount of light given as compared with that given by 1000 cub. ft. of gas. What is supplied and used is light, and what people want to pay for is light; 1000 cub. ft. of gas give a very convenient standard, and if the electric light companies could only formulate some plan by which they would charge accounts for the light supplied, he believes the public would be more ready to use it than if they were charged per volt-ampère, or any other measurement which a few understood but the majority did not. The most interesting subject is, not how electricity is to be measured, but how it is to be paid for. Boys's instruments are perfect of their kind, and Dr. Hopkinson's instrument for measuring the quantity of electricity passed into a house, though very little known, is one of the most perfect things he has ever seen. Why he objects to pay for electricity is because he believes we do not know how much light it will produce. If we agreed to pay 7*d.* per 1000 volt-ampère hours this year, the probability is that next year such improvements would be made, that the same energy which now produced 200-candle power, would then produce 2000.

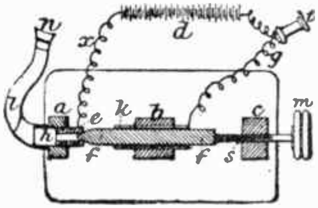
Microphones.—The microphone has been so named from its power of increasing sounds resulting from mechanical vibrations transmitted by solid substances, and thus rendering audible such ordinarily inaudible sounds as a fly's footsteps on the stand of the instrument. Its action is thus described by Prof. James Blyth.

Action.—In the microphone transmitter, as usually employed in circuit with a battery and a bell telephone, are essentially 2 pieces of carbon resting lightly against each other, through which the current passes. That the instrument may work effectively, 2 things are requisite: first, that the carbons be always in contact, or at least sufficiently near for the current to pass between them; and secondly, that they may not be pressed together so tightly as to prevent any motion of the one relatively to the other. This state of things is sufficiently well described by the term "loose contact." To understand the action of the microphone, it is necessary to find out what effects are taking place at the loose contact when the instrument is acted upon by sonorous waves. These are twofold: first, the effect produced by the sound waves (that is, the variations of density due to the condensations and rarefactions of the air), which pass directly through the air when they arrive at the loose contact; and secondly, the effect produced by tremors set up in the entire instrument, wooden supports, and carbons together, by the sound waves which strike against it and are thereby stopped.

For distinction, the first of these may be called the air effect, and the second the tremor effect. To isolate the air effect, it is obviously necessary either to fix the carbons rigidly in their supports, so as to avoid any motion of the one relatively to the other, or to use a strong current and place them just clear of contact with each other.

Fig. 85 illustrates how this may be done: *a*, *b*, *c* are 3 blocks of brass firmly fixed to a heavy wooden sole-plate. To the top of *a* is soldered a piece of brass tube *h*, about 2 in. long and ⅝ in. bore To the top of *b* is soldered a piece of similar tube *k*, about 4 in. long. Through *c* passes a fine screw *s* worked by a milled head *m*. A piece of carbon-rod *e* is fixed firmly into *h*, and has a hole ¼ in. in diameter drilled through its centre. A long piece of carbon *f*, pointed at one end, passes tightly through the tube *k*, and can be moved backwards and forwards by the screw *s*. A piece of indiarubber tube *l* is passed over the left end of the tube *h*. and to this is attached a mouthpiece *n*. By means of the wires *x* and *y* soldered to the carbon rods, they are put in circuit with the battery *d* (20 Grove's cells) and the telephone *t*, which must either have a small resistance, or be placed in a separate circuit from that containing the battery, so as to be acted upon inductively.

Fig. 85.



When the carbon *f* is screwed tightly into the hollow of *e*, the circuit is completely closed, and no sound uttered into *n* is heard at *t*. But when *f* is drawn gradually back until small electric arcs are seen to pass between *f* and *e*, every sound uttered into *n* is loudly and distinctly reproduced in the telephone *t*. Here is clearly only the air effect acting, and that solely upon the small electric arcs passing the carbons. It is somewhat difficult to get the sounds to last for any length of time, in consequence of the arc distance soon getting too great for the current to pass, and requiring re-adjustment. When the arc begins and ends, a sharp click is heard in the telephone; but in the interval during which the arc lasts, the sounds are distinct.

As far as the tremor effect is concerned, it is obvious that the microphone action must depend either (1) upon the variation of resistance due to variation of pressure, or (2) to variation in the extent of surface contact due to the elastic yielding of the carbons under pressure.

To test the first of these causes, Prof. Blyth made experiments on the effect of pressure upon the specific resistance of carbon. For this purpose he took a short length of carbon rod, and soldered wires to it at a short distance from each end. By means of these wires the resistance of the carbon rod was balanced in the Wheatstone bridge. Pressure was then applied by means of a lever to the carbon in a longitudinal direction. No appreciable variation in the resistance was observed even under considerable pressure; and it only be came manifest when the pressure was sufficient to bend or crush the carbon. Similar experiments, with the same result, have been made by Prof. Thompson. Hence it can hardly be believed that variation of specific resistance due to pressure can have the slightest effect in producing the microphone action.

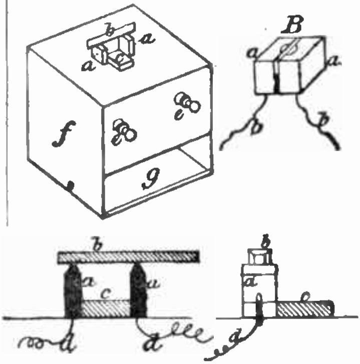
To test the second cause above mentioned - that is, the variation of resistance due to variation in the extent of surface contact due to elastic yielding under pressure—Prof. Blyth experimented as follows:—In the apparatus already described, he replaced the tubular carbon by a finely-pointed piece, so as to have 2 fine points exactly opposite each other. The resistance of the points was balanced in the bridge in the usual way. Pressure was then applied by a known number of turns or parts of a turn of the fine screw, and the change of resistance was noted. The screw was then brought back to former position, and the pressure relieved so as to allow the elasticity of the carbon to act and restore the points to their first condition. It is obvious that if the change of resistance were due merely to elastic yielding, it should now be the same as before. This was found not to be the case. From the gritty nature of the carbon, the points of contact were perpetually changing, and hence the variation of resistance produced in this way obeyed no regular law. From this irregularity it is impossible to conclude that this cause could explain the transmission of musical sounds, far less articulate speech.

As far as Blyth's experiments go, the following appears to be something like the true explanation of the microphone action. What he has termed the air and the tremor effects take place simultaneously. The tremor effect produces a jolting of the carbons sufficient to allow momentary minute electric arcs to take place between the points which are just clear of contact with each other. Simultaneously with this, the air effect comes in, and on account of the variations of density due to the condensations and rarefactions of the air, acts upon the minute electric arcs so as to vary their resistance. The tremor effect explains merely production of the musical pitch of the sounds heard in the telephone, whereas it is to the air effect that we must look for the transmission of the quality of the sounds uttered into the microphone transmitter. The microphone is thus so far a delicate make and break analogous to the old Reiss transmitter, with the important addition, however, of minute momentary gaps filled with a material which is sensitive to the minute harmonic variations of the atmospheric density which constitute sonorous vibrations. (Prof. Blyth.)

Construction.—Instructions will now be given for the construction of microphones of various forms and patterns.

(1) Simple Microphone, capable of making the tramping of a fly, &c., audible (Fig. 86).—All the battery it requires is a piece of carbon and zinc or copper and zinc, about 3 in. square, with a piece of blotting-paper between, damped with vinegar. It answers equally as well as an expensive battery. *f* is a box, size immaterial, say 4 in. square; over the top is stretched a piece of vegetable parchment; *a*, pieces of carbon filed to a knife-edge at top, to support small stick of carbon, *b*; *c*, piece of wood glued to *a* and to parchment top; *d*, wires connecting *a* with

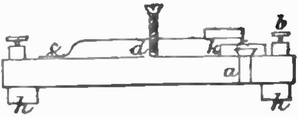
FIG. 86.



binding-screws *c*. An old sewing machine needle makes a good drill for drilling the holes into which the wires are wedged tight with the point of a pin. B is another form, scarcely so sensitive, but less liable to accident from flies walking over it. *a* are 2 pieces of carbon about ¼ in. square, fastened together by being glued to a thin piece of card which reaches about half-way up. The top of the carbon, in the centre, is cupped so as to hold a small pellet of carbon, ranging in size from a mustard-seed to a pea; *b*, wires to binding-screws. When all the connections are made, place a watch at the bottom of the box at *g*, and gently push the carbon piece *b* till it is almost falling over. A little practice will soon enable any one to get a very fine balance. The finer the balance, the better the result. When the ticking of the watch can be heard distinctly, take it out and place it on the top of box, resting the ring on the piece of wood *c*. With a moderately good telephone, the ticking will be sufficiently loud to be heard across a good-sized room. For flies, cover the top with a bell glass, or put them in the box and close up the opening. When using a common pin instead of *b*, flies may be heard running about almost as distinctly as with the carbon. A human hair drawn across the parchment is heard as a rustling sound in the telephone. The experiments should be conducted in a quiet room, as the slightest conversation or movement affects the microphone, and produces a jarring noise in the telephone. (T. Cuttriss).

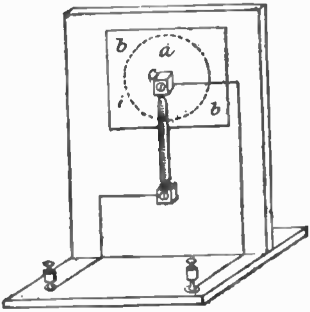
(2) Adjustable Microphone.—Get a piece of ⅛-in. deal, about 4 in. by 3 in., polish it up, and ebonize it. Underneath put 4 corner pieces, 2 of which are shown at *h*, Fig. 87. Next fix one of the carbon pieces on the board. In one corner of the board cut a square hole through, as at *a*, then get your carbon block and bore a hole half-way through it, making the hole wider inside (*k*). The carbon block is sunk slightly into the hole at *a*, a piece of copper wire is inserted, and melted lead is poured into the hole, binding the carbon block on and making a good connection between it and the wire, which is then connected underneath to the binding screw at *b*. Then get a slip of thin "latten" brass about 2 in. long by $\frac{3}{16}$ in. broad, and punch two small holes in it, one at one end *c*, the other in the middle *d*. At the other end a piece of gas carbon, about ¼ in. by ¼ in. by ⅛ in., is fastened by means of melted lead. The end *c* is then fastened down with a screw and washer, the carbon end in this position being about ⅛ in. from the carbon block. A small spiral is made with No. 32 copper wire—this is put on a taper wood screw, which is screwed through *d* till the 2 carbon surfaces touch. If small sounds are intended to be shut out, the screw is tightened. It may, of course, be used with a soundboard if desired. (*Eng. Mech.*).

FIG. 87.



(3) Gives excellent results in transmitting the human voice and musical notes (Fig. 88). The upright board has a circular hole *a* cut through it, about 2½ in. in diameter. Over this is gummed some vegetable parchment *b*,

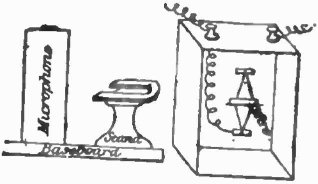
FIG. 88.



which, when the gum has well dried, is wetted and dried several times till quite taut. To the centre of this is fixed the upper carbon block *c* by means of a screw and a small wooden nut, and the wires are connected with battery and telephone in usual manner. I have only tried a 2½ in. hole, but am inclined to think that an improvement may be made by varying the size of the hole and the position of the carbon block on it. (T. J. Mercer.)

(4) Will transmit distinctly the loudest voice and the lowest whisper, when such are spoken 10 ft. or 12 ft. distant, without the smallest jar, and in the same tone as the speaker's voice. (Fig. 89.) Take a piece of very thin deal, 5 in. by 2½ in., smoothly planed; fix to it the sides 1½ in. deep, equally thin; now add ends ⅛ in. thick. You will then have a lidless box whose bottom and sides are very thin and smooth, but with ends much thicker. Hold a stick of cask-wax in the flame of a spirit lamp, and run it in the seams where the sides and ends join—of course having previously glued them; screw this firmly through its end, to a stout base-board 3 in. by 7 in. In this box fix an ordinary microphone; to the centre of the vibrator cement a piece of iron wire. It is only necessary now to make a stand upon which to place a horse-shoe magnet; the stand, with the magnet upon it, must be in height so that when placed upon the base-board the feet of the magnet will stand parallel to the iron wire. The magnet may be fixed to the stand, but the stand must be free, so that it can be moved backwards or forwards on the base-board, nearer to or farther from the vibrator. Having connected your batteries and telephones, bring the feet of the magnet within ⅛ in. of the iron wire (the wire must not touch the magnet). Now speak, standing 3 or 4 ft. away—your friend will then report to you through the telephone the result; if not satisfactory, move the magnet farther away, until the voice is clearly heard, and in its natural tone. The results are equally as satisfactory as wonderful, the magnet merely acting as an easily adjustable spring in controlling superfluous vibration, which is the cause of that peculiar and annoying jarring sound. (R. Blakeborough.)

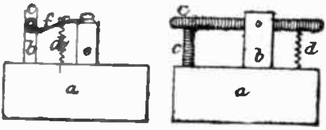
FIG. 89.



(5) Get a thin bit of board about 6 in. by 3 in., supported at each corner by little feet, also 2 small blocks of carbon with a hole through the middle and a notch at the side of each; screw them into the board about 1½ in. apart by binding-screws, and across them, resting in the notches, put a bar of carbon; it will much improve it if the carbon is heated red-hot and plunged into mercury. The microphone is now complete. To connect it, join one terminal of microphone with one pole of the battery and the other with one pole of the telephone; the second terminal of the telephone is joined with the other of the battery. (E. H. Hills.)

(6) The following arrangement of microphone transmits speech clearly. The sketches are sectional (Fig. 90).

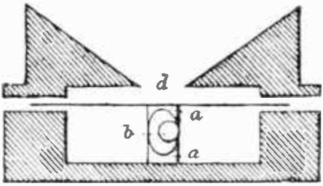
FIG. 90.



a, side of box; *b*, one of 2 pieces of copper between which the horizontal piece of pencil carbon *c* is spindled so that one end rests lightly on the other piece of pencil carbon *c*, which is fixed upright; *b*, the 2 pieces of copper mentioned before; *c*, end of the horizontal piece of carbon, under which a fine watch-spring *f* passes. One end of the spring *f* is screwed on to a wooden block *e*. The pressure of the spring *f* against the end of the carbon *c* is regulated by the screw *d*, which passes through it. Use a Bell's telephone as the receiving instrument. Speak in a low clear tone quite close to the microphone, and if the voice cannot be heard well at the other end of the line, tighten the screw *d*, thereby easing the pressure of the spring *f* against the carbon *c*. On the other hand, if too much vibration is heard, loosen *d* a little. Use either a small bichromate battery, or a single No. 2 Leclanché cell. (*Eng. Mech.*)

(7) Cup-and-ball microphone (Fig. 91). To construct the cup-and-ball microphone, take the case of an ordinary Bell telephone, remove the magnet and coil, cut off the long end or handle which contained the magnet, and plug up the hole in the case; turn the 2 cups out of a piece of a round carbon rod $\frac{3}{8}$ in. in diameter, and make the ball out of a piece of round carbon rod $\frac{3}{16}$ in. diameter. Secure one of the cups to the centre of the wooden case of the telephone by a small screw, and the other cup to the centre of the diaphragm of the telephone by a leaden rivet; place the carbon ball in the cup which is secured to the case, and place the diaphragm with the cup attached to it in its former position in the telephone case, having of course first carried a wire from each carbon cup to a terminal screw; see that the 2 cups are concentric; screw in the mouthpiece, and the microphone is complete. The microphone must be mounted in gimbals like a looking-glass, and slightly inclined backward or forward, until it speaks quite clearly, when it may be clamped. Each microphone has one position in which it speaks best, and this position must be found by actual trial. If the microphone is intended for ordinary use, the diaphragm should be made of thin deal, straight-grained and about $\frac{1}{8}$ in. thick; after the carbon cup is attached, the wooden diaphragm should receive, in the side against which you speak, a coat of thin white hard varnish, put on in a dry room with a wide brush.

FIG. 91.



In the sketch, *a* are the carbon cups, *b* is the carbon pea, *d* is the diaphragm, and the shaded parts represent the telephone case, which, as drawn, is not closely screwed up. The open interior part of the case, *i.e.* the part which determines the area of the free vibrating portion of the diaphragm, should be $2\frac{1}{4}$ in. in diameter; the other dimensions may be varied according to fancy, but the carbon cup attached to the diaphragm should not be more than about $\frac{1}{4}$ in. in length. There is no difficulty in turning the carbon cups, the only tools required being a brad-awl, which makes a capital drill for carbon; an old file to smooth down the back and face of the cup, which can, however, be done with emery-paper; the stump of any old small chisel ground to a long cutting slope; and a fret-saw. It is desirable to turn a small piece of boxwood to such a shape as will fit into the cup when completed, and by pushing this lightly into the cup whilst it is running in the lathe, the interior of the cup will be smoothed, and in many cases polished. To make the ball, chuck a piece of $\frac{3}{16}$ in. round carbon rod, and at the end turn a round head, like the head of a pawn in a set of chessmen; get it as nearly round as possible—a file is the best tool for this—and then cut it off; rub off any projections on emery-paper. The remainder of the process may be done in 2 ways. (1) Tack a sheet of emery-paper on a board, secure another piece of emery-paper to a conveniently-shaped piece of wood with a flat face; put the carbon pea on the emery-paper tacked on the board, and, with the other piece of emery-paper-covered wood, rub the pea about in every direction between the two, and with a little care the pea will become nearly a true sphere. (2) The other way, advised by Yeates, of King Street, Covent Garden, is—take a piece of sheet-steel about as thick as a screw-blade, and about 2 in. long by ¾ in. wide, soften it, chuck it by means of sealing-wax; drill a hole, about ⅛ in. in diameter, through the centre—the exact centre is not required; then with a *very keen-edged* tool enlarge this hole to about $\frac{5}{32}$ in. diameter, and take care that the edges of this hole are left sharp and not rounded; then harden the plate as hard as you can make it. Take the carbon pea which you have roughed down in the lathe, put it in the hole in the steel plate, rub it round in every direction between the finger and thumb, and after a while it will pass through the hole and be almost a true sphere. I have made the carbon balls by both these processes, and though the latter is by far the more accurate, the former has answered very well. One plate will make a great many balls. In all microphones, the points actually in contact, or which regulate the current, oxidize and when this is complete, the current will not pass. In this cup-and-ball microphone, fresh surfaces are constantly coming into contact, and a shake will always ensure this. If the microphone is properly constructed, the ball should rattle loudly when the microphone is shaken. In screwing up the microphone, the diaphragm should not be pinched too tightly. The best way is to screw it up a little too tight, and then slacken it slightly. This microphone need not be round in shape; it can easily be made square, in which case the dimensions should not be less than 4 in. by 3 in., and a mouthpiece may be dispensed with. I have made a microphone with 4 sets of cups and balls, the diaphragm being about 7 in. in diameter, and the cups arranged with 3 pairs equidistant in a circle 3 in. in diameter, and the fourth pair in the centre; the cups in the diaphragm being connected together, and the cups on the back or case also connected; with this arrangement, a very strong battery may be used, when the articulation is a little louder, but scarcely so distinct as with one pair of cups only. If a multiple microphone is made up, the cups should not be less than 1½ in. nor more than 2 in. apart.

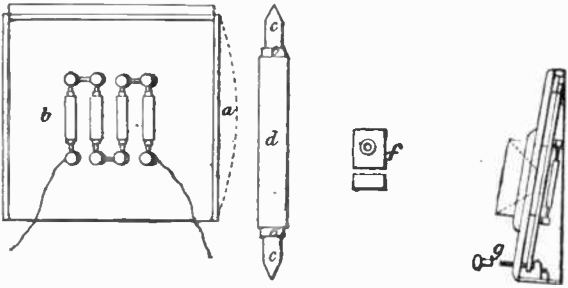
The receiver is made as follows:—Take a round piece of mahogany, or other dry wood, 2 in. in diameter and ½ in. thick; in the centre make a circular hole the size of a sixpence to take the electro-magnet: on one face mark a circle the size of a bronze penny; just outside this circle, and touching it, make 3 holes equidistant from one another, and the size of No. 9 B.W.G. iron wire; in each hole put a piece of this iron wire, long enough to project a little from the wood on each side; the electro-magnet is made of a piece of the same No. 9 B.W.G. iron wire, slightly less than ⅝ in. long, and the reel is the size of a sixpence, ½ in. long, and wound with No. 36 silk-covered copper wire; the electro-magnet is placed in the hole in the wood, the end of the wire is carried out to connect with the terminals, and the whole is boiled in paraffin. Two pieces of thin wood, about $\frac{3}{16}$ in. thick and 2 in. in diameter, are also required. In one a recess is made the size of a penny and rather less than $\frac{1}{16}$ in. deep; in the other a similar recess, but with a central aperture about ½ in. in diameter, to permit the sound to escape; 2 discs of thin iron, 5 mil. thick, or ferrotype plate, are also required. Take the disc of wood containing the electro-magnet, the wires of which have of course been led to convenient terminals, file down the ends of the 3 iron wires on one side of the disc, until one of the thin iron discs, when laid upon these 3 iron wires, will *almost* touch the core of the magnet; let this plate remain on these 3 wires, put on the recessed disc of wood, which is without the central aperture, and secure it by 3 screws. The setting of the other thin iron plate requires more care, but is done in the same way, the projecting ends of the thin wires being filed down until the other thin iron plates, when placed upon them, and the whole put in circuit with an articulating microphone, speaks distinctly: the recessed disc of wood with the central aperture is then placed upon the iron plate, and secured by 3 screws, which must not be tightened too much, or the plate will not speak clearly. We have now an electro-magnet between 2 thin iron plates, which plates are in metallic connection with one another by the 3 iron wires; one plate being adjusted at the best speaking distance from the core of the magnet, and the other plate as near to the core of the magnet as it can go without touching it at any time.

The above directions will enable any one to make both the cup-and-ball microphone and the electro-magnet receivers; but remember that a good receiver is of no use with a bad transmitter, nor a good transmitter with a bad receiver. I have had these instruments in use for 2 years: they work admirably and give no trouble. For telephone work, I prefer the gravity Daniell battery to any other, but I intend to try the iron perchloride battery. (H. B. T. Strangways.)

(8) Fig. 92. — The diaphragm is constructed of white or yellow pine, $\frac{1}{12}$ in. thick and 5 in. square; on the edges are glued 2 strips of wood *a*, about $\frac{3}{16}$ in. thick, shaped like a bridge, about $\frac{1}{2}$ in. at the middle, and tapering gradually at the ends; these are glued across the grain, and prevent the sound-board *b* from twisting. The carbon pencils *c* are made from electric-light pencils No. 2, obtained from E. Paterson, 76 Little Britain, and the pencil-holders from No. 5 pencil. The pencils are 2 in. long, neatly filed to a point, and fitted into a small leaden tube *d*. The tube used for pneumatic bells answers well. Round the carbon is glued a leather collar *e*, which secures the lead in place, and acts as a damper in preventing the sound given by the carbon itself. This is heard if a small piece of carbon is struck, and is the cause of the metallic noise so often heard in microphones. The length of the leaden tube should be 1$\frac{3}{16}$ in.

The pencil-holders are cut about $\frac{7}{16}$ in. long, a hole is drilled half-way through, and a groove is cut round, as at *f*; 4 holders are glued to the sound-board, and, when dry, the pencils are put in place loosely by placing the remaining 4 holders. Connections of copper wire, cleaned well, about No. 30, are placed in the grooves in the carbon holders, twisted up, and a touch with soldering-iron afterwards makes all secure. On the opposite side of diaphragm is lightly glued a rubber-ring, about 2½ in. in diameter, which rests when in box against the front, and the pressure is regulated by a screw *g*, filed to a square, and moved by a key. This rubber-ring acts as a damper, and prevents noise and rattling.

FIG. 92.

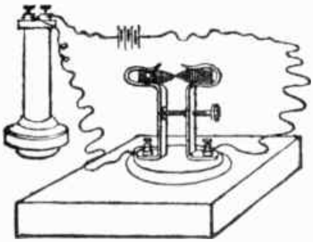


The sound-board is fastened to the inside of the box by a leather hinge glued along the upper edge; and on a slip of wood, the thickness of rubber-ring, a small spring presses at the lower edge of board, which keeps it close to the screw *g*.

The sound-hole in mouthpiece is 1 in. in diameter, and the box is made of well-seasoned mahogany, ½ or ¾ in. thick, solidity being essential; the internal diameter of box is about 5½ in., leaving a space of about ¼ in. all round the board, except at the upper edge, where the leather hinge is glued on.

When the adjusting screw allows the diaphragm to press lightly on front of box, the instrument is in order for speaking, and 8 to 10 in. distance gives first-rate results. The voice should be just as in ordinary conversation; music, such as violin, is beautifully heard through a telephone-receiver. Two or three Leclanché cells are sufficient for ordinary purposes. The microphone can be used well without induction-coil, and can be fixed to any of the existing arrangements with switch and bell. The angle of microphone box is 10° to 12°.

Fig. 93.

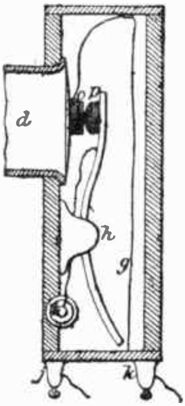


(9) Fig. 93.—The instrument consists essentially of 2 springs secured to a small base-piece, and each supporting at its upper end a piece of ordinary battery carbon. These 2 pieces of carbon are placed in light contact, and the 2 springs are placed in an electrical circuit in which there is also a receiving telephone of the Bell form. The instrument is represented secured to a small sounding-board. The 2 carbon-supporting springs are fastened to a single base by the binding-posts which receive the battery wires. An adjusting screw passes through one of the springs at or near its centre, and bears against a rubber button projecting from the other spring. This simple device, when placed on a table, indicates in the receiving telephone the slightest touch of the finger on the table or on the instrument. Blowing on it makes in the receiving instrument a deafening roar; drawing a hair or a bit of cotton across the carbon is distinctly audible in the receiving instrument. When the device is placed on a small sounding-board, every sound in the room is received and transmitted. An ant running across the sounding-board can be plainly heard, and a touch upon the instrument or the table which supports it, which without the microphone would be entirely inaudible, can be distinctly heard in the receiving telephone by aid of the instrument, even though miles intervene. When it is placed on a violin, blowing lightly upon the strings produces æolian harp tones in the receiver, and a song sung to the violin is rendered in the receiving instrument with an æolian harp accompaniment. When mounted on a violin or sounding-board, it will transmit articulate speech, uttered in any portion of a room of ordinary size; it will receive and transmit the music of a piano, and even the sounds of turning the sheets of music may be heard. Whistling, flute music, and other sounds are transmitted with their characteristics of volume, pitch, and timbre. This instrument, although so very simple, is capable of doing all that has been done by other instruments of an analogous character, and it will be determined by further experiment whether it will do more. Although carbon contact points are preferable, they are not absolutely essential to the operation of the instrument, as metallic points will do the same things, but not so satisfactorily. (G. M. Hopkins.)

(10) Microphone for reproducing Speech (Fig. 94).—It consists of a box of thin wood, the front of which is perforated with a hole large enough to receive the tube of a common string telephone, the parchment membrane *d*, stretched over the inner end of which, is kept level with the surface of the board on the side at which the microphone is placed. The membrane *d* carries in its centre a small piece of metallized pine charcoal *c*, which is connected by the

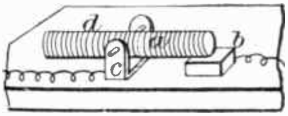
wire *g* and binding-screw *k* to the battery wire. A vertical lever, delicately pivoted on 2 points at *h*, carries at its upper end another piece of similar charcoal *p*, which is ligntly pressed against the piece *c*. The lever is connected with the circuit by means of the wire and binding-screw *j*, and the pressure with which it bears on the charcoal, carried by the membrane *d*, is regulated by a light spring and silk thread actuated by the tension screw *t*. With a battery of 6 or 7 Leclanché cells, words can be transmitted and received; but they are always much less accentuated than with the Bell telephone. The apparatus, however, appears to be a neat and handy form of microphone to employ for speaking purposes, and can be made very cheaply. (Th. du Moncel.)

Fig. 94.



(11) Hughes's Microphone.—In order to hear the tramp of a fly, the microphone is constructed as in Fig. 95; *a*, stick of carbon (preferably the round compressed pencils used for electric light), pivoted on its brass support at *c*, and resting by the slight pressure of its weight upon a small block of metallized charcoal (blow-pipe, box-wood, or any hard conducting charcoal will serve); the wires are connected to the pivot support at *c*, and charcoal *b*. This structure is fastened to any small board *d* of pine, ¼ in. thick, and 3 in. or 4 in. square. This will also perfectly transmit articulate speech, if spoken to not closer than 1 ft.; if louder tones are desired, put a small weight on *a*, and speak within a few inches of the microphone.

Fig. 95.



(12) Making Plates for Microphones.—The following process for making very thin plates for microphonic purposes, is given by Trichasson, of Mourmelon-le-Grand. A sheet of ordinary tinned iron of any thickness is cut into plates, and rubbed vigorously on both faces with a dry linen cloth. This operation is to clean away all grease. A plate is then taken and plunged vertically in a bath of nitric acid until it is entirely immersed. Acid which has already served in Bunsen batteries will answer very well, or better still, the nitric acid of commerce, diluted with ¼ water. It is necessary to remove the plates from the bath from time to time, in order to see whether the required thickness has been reached. When this is attained, the plate is washed several times in water to remove the black layer of oxide. The plate is then allowed to dry, and afterwards varnished on both sides with Japan varnish, to prevent oxidation. This process permits of making microphone and telephone diaphragms as thin as may be desired, and at little cost.

Motors.—This section may be divided into 2 parts: (1) the principles and practice of the construction of electro-motors, and (2) their application. The first may be best studied from Prof. Thompson's Cantor Lecture, before alluded to.

Construction.—An electro-motor, or electro-magnetic engine, is one which does mechanical work at the expense of electric energy, whether the magnets which form the fixed part of the machine be permanent magnets of steel or electro-magnets. Any of the 4 kinds of dynamo can be used as a motor, though some more appropriately than others. All are electro-magnetic in principle; *i.e.* there is some part, fixed or moving, which is an electro-magnet, and which attracts and is attracted magnetically. A magnet will attract the opposite pole of another magnet, and pull it round; also, every magnet placed in a magnetic field tends to turn round and set itself along the lines of force. Supposing a small magnetic needle to be confined at right angles to the lines of force in a simple magnetic field, produced between the poles of 2 strong magnets, one on the right, the other on the left, then shortening the lines of force has the effect of rotating the magnetic needle upon its centre, through an angle of 90°. Very soon after the invention of the electro-magnet, many perceived that it would be possible to construct an electro-magnetic engine, in which an electro-magnet, placed in a magnetic field, should be pulled round; and further, that the rotation should be kept up continuously by reversing the current at an appropriate moment.

A mere coil of wire, carrying a current, is acted upon when placed in the magnetic field, and is pulled round as a magnet is. On this principle was constructed the earliest electric motor of Ritchie, well known in many forms, but little better in reality than a toy.

Jacobi constructed a multipolar machine for his electric boat. It had 2 strong wooden frames, in each of which 12 electro-magnets were fixed, their poles being set alternately. Between them, upon a wooden disk, were placed another set of electro-magnets, which, by the alternate attraction and repulsion of the fixed poles, were kept in rotation, the current which traversed the rotating magnets being regularly reversed at the moment of passing the poles of the fixed magnets, by means of a commutator consisting of 4 brass-toothed wheels, having pieces of ivory or wood let in between the teeth for insulation. Jacobi's motor is, in fact, a very advanced type of dynamo.

An earlier rotating apparatus, and, like Ritchie's motor, a mere toy, was Sturgeon's wheel, described in 1823. This instrument, interesting as being the forerunner of Faraday's disk dynamo, is the representative of an important class of machines, namely, those which have a sliding contact merely, and need no commutator.

A fourth class may be named, wherein the moving part, instead of rotating upon an axis, is caused to oscillate backwards and forwards. Prof. Henry constructed, in 1831, a motor with an oscillating beam, alternately drawn backwards and forwards by the intermittent action of an electro-magnet. Dal Negro's motor of 1833 was of this class; in it a steel rod was caused to oscillate between the poles of an electro-magnet, and caused a crank, to which it was geared, to rotate in consequence. A distinct improvement in this type of machine was introduced by Page, who employed hollow coils or bobbins as electro-magnets, which, by their alternate action, sucked down iron cores into the coils, and caused them to oscillate to and fro. Motors of this kind form an admirable illustration of one of the laws of electro-magnetics, to the effect that a circuit acts on a magnetic pole in such a way as to make the number of magnetic lines of force that pass through the circuit a maximum.

Page's suggestion was further developed by Bourbouze, who constructed a motor which looks like an old type of steam-engine. It has a beam, crank, fly-wheel, connecting-rod, eccentric valve-gear, and slide-valve; but for cylinders, 4 hollow electro-magnets; for pistons, iron cores, that are alternately sucked in and repelled out; and for slide valve, a commutator, which, by dragging a pair of platinum-tipped springs over a flat surface made of 3 pieces of brass separated by 2 insulating strips of ivory, reverses at every stroke the direction of the currents in the coils of the electro-magnets. It is a very ingenious machine, but in point of efficiency far behind many other electric motors.

A fifth class of electric motors owes its existence to Froment, who, fixing a series of parallel iron bars upon the periphery of a drum, caused them to be attracted, one after the other, by electro-magnets, and thus procured a continuous rotation.

Last of the various types of motor may be enumerated a class in which the rotating portion is enclosed in an eccentric frame of iron, so that as it rotates it gradually approaches. Little motors, working on this principle of "oblique approach," were invented by Wheatstone, and have long been used for spinning Geissler tubes, and other light experimental work. More recently, Trouvé and Wiesendanger have sought to embody this principle in motors of more ambitious proportions, but without securing any great advantage.

All the early attempts came to nothing, for 2 reasons: there was no known economical method of generating electric currents, and the great physical law of the conservation of energy was not recognised. While voltaic batteries were the only available sources of electric currents, economical working of electric motors was hopeless; for a voltaic battery, wherein electric currents are generated by dissolving zinc in sulphuric acid, is a very expensive source of power. To say nothing of the cost of the acid, the zinc—the very fuel of the battery—costs more than 20 times as much as coal, and is a far worse fuel; for whilst 1 oz. of zinc will evolve heat to an amount equivalent to 113,000 foot-lb. of work, 1 oz. of coal will furnish the equivalent of 695,000 foot-lb.

Now, if a galvanometer is placed in circuit with the electric-motor and the battery, it is found that when the motor is running it is impossible to force so strong a current through the wires as that which flows when the motor is standing still. There are only 2 causes that can stop such a current flowing in a circuit; either an obstructive resistance, or a counter-electromotive force. At first, the common idea was that, when the motor was spinning round, it offered a greater resistance to the passage of the electric current than when it stood still. Jacobi, however, discerned that the observed diminution of current was really due to the fact that the motor, by the act of spinning round, began to work as a dynamo on its own account, and tended to set up a current in the circuit in the opposite direction to that which was driving it. The faster it rotated, the greater was the counter-electromotive force (or "electromotive force of reaction") developed. In fact, the theory of the conservation of energy requires that such a reaction should exist. In the converse case, when employing mechanical power to generate currents by rotating a dynamo, directly we begin to generate currents—*i.e.* to do electric *work*—it requires much more power to turn the dynamo than when no electric work is being done. In other words, there is an opposing reaction to the mechanical force applied in order to do electric work. An opposing reaction to a mechanical force may be termed a "counter-force." When, on the other hand, we apply (by means of a voltaic battery, for example) an electromotive force to do mechanical work, there is an opposing reaction to an electromotive force, or a "counter-electromotive force."

The existence of this counter-electromotive force is of the utmost importance, in considering the action of the dynamo as a motor, because upon its existence and magnitude depends the degree to which a motor enables us to utilize energy supplied to it in the form of an electric current. In discussing the dynamo as a generator, were pointed out some considerations whose observance would improve their efficiency; many of these—*e.g.* the avoidance of useless resistances, unnecessary iron masses in cores—apply to motors. The freer a motor is from such objections, the more efficient will it be; but its efficiency in utilizing the energy of a current depends not only on its efficiency in itself, but on the relation between the electromotive force which it generates when rotating, and the electromotive force (or "electric pressure") at which the current is supplied to it. A motor which itself in running generates only a *low* electromotive force, cannot, however well designed, be an *efficient* or economical motor when supplied with currents at a *high* electromotive force. Dynamos used as motors must be supplied with currents at electromotive forces adapted to them. Even a perfect motor—one without friction or resistance of a kind—cannot give an "efficient" or economical result, if the law of efficiency is not observed in the conditions under which the electric current is supplied to it.

The efficiency with which a perfect motor utilizes the electric energy of the current depends upon the ratio between this counter-electromotive force and the electro-motive force of the current that is supplied by the battery. No motor ever turns into useful work the whole of the currents that feed it, for it is impossible to construct machines without resistance, and whenever resistance is offered to a current, part of the energy of the current is wasted in heating the resisting wire. Let the symbol W stand for the whole electric energy of a current, and let w stand for that part of the energy which the motor takes up as useful work from the circuit. All the rest of the energy of the current, or $W-w$, will be wasted in useless heating of the resistances. But to work a motor under the conditions of greatest economy, there must be as little heat-waste as possible; or, in symbols, w must be as nearly as possible equal to W. The ratio between the useful energy thus appropriated and the total energy spent, is equal to the ratio between the counter-electromotive force of the motor, and the whole electromotive force of the battery that feeds the motor. Let this whole electromotive force with which the battery feeds the motor be E, and let the counter-electromotive force be e: then the rule is

$$w : W = e : E;$$

or, expressed as a fraction,

$$\frac{w}{W} = \frac{e}{E}$$

If the resistances of the circuit are constant, the current c, observed when the motor is running, will be less than C, the current while the motor is standing still. But from Ohm's law we know that

$$c = \frac{E - e}{R}.$$

Hence $\frac{C - c}{C} = \frac{e}{E} = \frac{w}{W}$. From which, it appears that we can calculate the efficiency at which the motor is working by observing the ratio between the fall in the strength of the current and the original strength. This mathematical law of efficiency has been strangely mis-apprehended. Another law, discovered by Jacobi, not a law of efficiency at all, but a law of maximum work in a given time, has usually been given instead. Jacobi's law is as follows:—The mechanical work given out by a motor is a maximum when the motor is geared to run at such a speed that the current is reduced to half the strength that it would have if the mŏtor was stopped. This implies that the counter-electromotive force of the motor is equal to half of the electromotive force furnished by the battery or generator. Under these circumstances, only half the energy furnished by the external source is utilized, the other half being wasted in heating the circuit. If Jacobi's law were indeed the law of efficiency, no motor, however perfect in itself, could convert more than 50 per cent. of the electric energy supplied to it into actual work. Siemens has shown that a dynamo can be, in practice, so used as to give out more than 50 per cent. of the energy of the current. It can, in fact, work more efficiently if it be not expected to do its work so quickly. Siemens has, in fact, proved that if the motor be arranged so as to do its work at less than the maximum rate, by being geared so as to do much less work per revolution, but yet so as to run at a higher speed, it will be more efficient; that is to say, though it does less work, there will also be still less electric energy expended, and the ratio of the useful work done to the energy expended will be nearer unity than before.

The algebraic reasoning is as follows:—If E be the electromotive force of the generator when the motor is at rest, and c be the current which flows at any time, the electric energy W, expended in unit time, will be (as expressed in watts) given by the equation,

$$W = Ec = E\frac{(E - e)}{R}. \quad . \quad . \quad (1)$$

When the motor is running, part of this electric energy is being spent in doing work, and the remainder is wasting itself in heating the wires of the circuit. We have already used the symbol w for the useful work (per second) done by the motor. All the energy which is not thus utilized is wasted in heating the resistances. Let H represent this heat. Its mechanical value will be HJ, where J stands for Joule's equivalent. Then we shall have

$$W = w + HJ.$$

But by Joule's law the heat-waste of the current, whose strength is c, running through resistance R, is expressed by the equation

$$HJ = c^2R.$$

Substituting this value above, we get

$$W = w + c^2R, \quad . \quad . \quad . \quad (2)$$

which we may also write

$$w = W - c^2R.$$

But by equation (1) $W = Ec$, whence

$$w \quad Ec - c^2R, \quad . \quad . \quad . \quad (3)$$

and writing for c its value, $\frac{E-e}{R}$, we get

$$w = \frac{(E-e) \quad (E - \{E-e\})}{R}$$

or, $w = e\frac{E-e}{R} \quad . \quad . \quad . \quad . \quad (4)$

Comparing equation (5) with equation (1), we get the following:—

$$\frac{w}{W} = \frac{e\,(E-e)}{E\,(E-e)};$$

or, finally, $\frac{w}{W} = \frac{e}{E}$

This is, in fact, the mathematical law of efficiency, so long misunderstood until Siemens showed its significance. It may appropriately be called the law of Siemens. Here the ratio $\frac{w}{W}$ is the measure of the efficiency of the motor, and the equation shows that we may make this efficiency as nearly equal to unity as we please, by letting the motor run so fast that e is very nearly equal to E: which is the true law of efficiency of a perfect motor supplied with electric energy, under the condition of constant external electromotive force.

Now go back to equation (3), which is—

$$w = Ec - c^2R.$$

In order to find what value of c will give us the maximum value for w (which is the work done by the motor in unit time) we must take the differential coefficient and equate it to zero.

$$\frac{dw}{dc} = E - 2cR = o;$$

whence we have

$$c = \tfrac{1}{2}\frac{E}{R}.$$

But by Ohm's law, $\frac{E}{R}$ is the value of the current when the motor stands still. So we see that, to get maximum work per second out of our motor, the motor must run at such a speed as to bring down the current to half the value which it would have if the motor were at rest. In fact, we here prove the law of Jacobi for the maximum rate of doing work. But here, since—

$$c = \frac{E-e}{R} = \tfrac{1}{2}\frac{E}{R}$$

it follows that—

$$E - e = \tfrac{1}{2}E;$$

or $\frac{e}{E} = \tfrac{1}{2}$,

whence it follows also that—

$$\frac{w}{W} = \tfrac{1}{2}.$$

That is to say, the efficiency is but 50 per cent. when the motor does its work at the maximum rate.

Throughout it has been supposed that the motor is to be worked with a supply of current furnished at a fixed electromotive force. It is convenient and wise to make such a condition the basis of the argument, because this is probably the condition under which electric power will be distributed over large areas. It is true that this is not the only condition of supply, for a generator or system of generators may be worked so as to yield a constant current. And it would be quite possible to formulate a set of rules for the efficiency and maximum duty of motors under this condition. But this method of distributing electric power is far less likely to be of importance in the near future. than distribution with constant electr motive force; though for transmission of power to an isolated station, the case becomes of importance. One simple problem is worthy of mention. Suppose that one is desirous of working a motor so as to do work at the rate of a specified number of horse-power, and that the wire available to bring the current cannot safely stand more than a certain current without being in danger of becoming heated unduly; it might be desirable to know what electromotive force such a motor ought to be capable of giving back, and what electromotive force must be applied at the transmitting end of the wire. Let N stand for the number of horse-power to be transmitted, and c for the maximum strength of current that the wire will stand (expressed in ampères). Then, by the known rule for the work of a current, since—

$$\frac{ec}{746} = N, \quad e = \frac{746\,N}{c}$$

gives the condition as to what electromotive force (in volts) the machine must be capable of giving, when run at the speed it is eventually to run at as a motor. Moreover, the primary electromotive force E must be such that

$$\frac{E-e}{\Sigma R} = c$$

where ΣR is the sum of all the resistances in the circuit. Whence,

$$E = e + c\Sigma R.$$

Which is the required condition.

Another problem in the application of motors to transmission of power, which vitally affects their construction, is the determination of the relation of the heat-waste to the electromotive force at which the current is supplied to the motor.

If, as before, ΣR stands for the sum of all the resistances in the circuit, then by Joule's law the heat-waste is (in mechanical measure)

$$HJ = C^2\Sigma R.$$

And since $c = \frac{E-e}{\Sigma R}$, we may write the heat-waste as

$$HJ = \frac{(E-e)^2}{\Sigma R}.$$

Suppose that, without changing the resistances of the circuit, we can increase E, and also increase e, while keeping $E-e$ the same as before, it is clear that the heat-loss will be precisely the same as before. But how about the work done? Let the two new values be respectively E' and e'. Then the electric energy expended is—

$$W' = \frac{E'(E'-e')}{\Sigma R}$$

and the useful work done is—

$$w' = \frac{e'(E'-e')}{\Sigma R}$$

That is to say, with no greater loss in heating, more energy is transmitted and more work done. Also the efficiency is greater, for

$$\frac{w'}{W'} = \frac{e'}{E};$$

and this ratio is more nearly equal to unity than $\frac{e}{E}$, because both E and e have received an increment arithmetically equal. Clearly, then, it is an economy to work at high electromotive force. The importance of this matter, first pointed out by Siemens and later by Marcel Deprez, cannot be overrated. But how to obtain this higher electromotive force. One very simple expedient is that of driving both generator and motor at higher speeds. Another way is to wind the armatures of both machines with many coils of wire having many turns. This expedient has, however, the effect of putting great resistances into the circuit. This circumstance may, nevertheless, be no great drawback, if there is already a great resistance in the circuit—as, for example, the resistance of many miles of wire through which the power is to be transmitted. In this case, doubling the electromotive force will not double the resistance. Even in the case where the line resistance is insignificant, an economy is effected by raising the electromotive force. For, as may be deduced from the equations, when $E-e$ is kept constant, the effect of doubling the electromotive force is to double the efficiency when the resistance of the line is very small as compared with that of the machines, and to quadruple it when the resistance of the line is very great as compared with that of the machines. It is, in fact, worth while to put up with the extra resistance, which we cannot avoid, if we try to secure high electromotive force by the use of coils of fine wire of many turns. It is true that the useful effect falls off, *cœteris paribus*, as the resistance increases; but this is much more than counterbalanced by the fact that the useful effect increases in proportion to the square of the electromotive force.

In the recent attempt of Marcel Deprez to realize these conditions in the transmission of power from Miesbach to Munich, through a double line of telegraph wire over a distance of 34 miles, very high electromotive forces were actually employed. The machines were 2 ordinary Gramme dynamos, the magnets being series-wound, similar to one another, but their usual low-resistance coils had been replaced by coils of very many turns of fine wire. The resistance of each machine was consequently 470 ohms, whilst that of the line was 950 ohms. The velocity of the generator was 2100 revolutions per minute; that of the motor, 1400. The difference of potential at the terminals of the generator was 2400 volts; at that of the motor, 1600 volts. According to Prof. von Beetz, the mechanical efficiency was found to be 32 per cent. Deprez has given the rule that the efficiency $\frac{w}{W}$ is obtained, in the case where 2 identical machines are employed, by comparing the 2 velocities at the 2 stations. Or

$$\frac{W}{w} = \frac{N}{n},$$

where N is the speed of the generator, *n* that of the motor. There is, however, the objection to this formula, that the electromotive forces are not proportional to the speeds, unless the magnetic fields of the 2 machines are also equally intense, and the current running through each machine is the same. This is not the case if there is leakage along the line. Moreover, when there are resistances in the line, the ratio of the 2 electromotive forces of the machines is not the same as the ratio of the 2 differences of potentials, as measured between the terminals of the machines.

Turning back to consider some points in the design and construction of motors, it will be found that many of the rules already suggested (pp. 118–24) are applicable also to motors.

In the dynamo used as a generator, the capacity for doing work increases as the fifth power of the linear dimensions; by doubling a dynamo in length, breadth, and thickness, we have a machine weighing 8 times as much, costing less than 8 times as much, but capable of doing 32 times the work, and that with a great gain in economy in working. The same thing is true of motors.

In the prospect of an immediate field of usefulness opening out for motors, so soon as we have such a thing as regular town supplies of electric currents laid on, it is most important that motors should be designed, not simply to work with the constant electromotive force supplied at the electric mains, but designed also to work at uniform speeds. It is highly important, in driving many kinds of machinery, that the speed should be regular, and that the motor should not "run away" as soon as the stress of the cutting tool is removed. Deprez and Perry have solved a converse problem to this, namely, that of getting a dynamo to feed a circuit with currents, at a constant electromotive force, when driven with uniform speed, the solution consisting in using certain combinations for the field magnets, which give an initial magnetic field, independently of the actual current furnished by the dynamo itself. This problem may be applied conversely, and motors may be built with a combination of arrangements for their field-magnets, such that, when supplied with currents at a certain constant electromotive force, their speed shall be constant, whatever the work or no work whi they may be doing. The difficulty in the problem—a mere matter for experiment and calculation—is to find the critical number of volts of electromotive force at which this will hold good. It is, in fact, the converse to the operation of finding the critical velocity at which one of Deprez's or Perry's combination dynamos must be driven, in order that it may give a constant electromotive force. Deprez has constructed motors upon this plan, which run at a perfectly uniform speed, quite irrespective of the work being done: whether lifting a load from the ground, or letting this load run down to the ground, or without any load at all. Ayrton and Perry have a motor weighing only 350 lb., which will give an effective power equal to 8 h.-p.; and without any mechanical governor, without anything, in fact, in the nature of a moving governor, it always goes at the same speed, whatever work it has to do.

It is possible to use as a motor any direct-current dynamo, whether the field-magnets be series-wound, shunt-wound, separately excited, or permanently magnetized. There is this curious point of difference. Suppose the dynamo to be arranged so as to work as a generator, and then to be supplied with currents from an exterior source, to make it work as a motor. If the dynamo is series-wound, it will run the reverse way (or against its brushes), no matter which way the currents run through it. If shunt-wound, it will run with its brushes, whichever direction the current runs through it. The direction of rotation taken by the separately-excited and the magneto-machine will also be with the brushes, if the current is in the right direction, through the armature. These points have to be taken into account in any attempt to combine the different systems.

In applying to motors rules and suggestions such as were applied to generators, it will be found that, whilst some of them apply directly, others are singularly in contrast. For example, it is advisable, for the sake of steadying the currents in generators, to use large and long field-magnets with plenty of iron, and with heavy pole-pieces. In the case of motors there is no such necessity, for we want here to produce a uniform steady rotation. Even if the impulses be intermittent, the mechanical inertia of the moving parts will steady the motion. Electric currents have no such inertia (except in so far as the self-induction in a circuit exerts an influence like that of inertia), and hence the precautions for generators. In the case of generators, to produce steady currents, we had to multiply coils on the armature in many separate paths, grouped round a ring or a drum, involving a complicated winding, and a collecting apparatus consisting of many segments. In motors, no such necessity exists, provided only we arrange the coils that there shall be no dead-points. For large motors, it may be advisable to multiply the paths and segments for other reasons (as, for example, to obviate sparking at the collectors), but for securing steady running, the inertia of the moving parts spares us (at any rate, in small machines) the complication of parts which was expedient in the generator. Some of the most successful of the little motors that have recently appeared—those, for example, of Deprez, Trouvé, and Griscom—have for their armatures the simple old shuttle-wound Siemens armature of 1856, and in these is the disadvantage of dead-points to take into account. Deprez, in his first motors, placed this armature longitudinally between the poles of a horse-shoe magnet, with the axis parallel to the limbs. He has also constructed motors with 2 such armatures on one spindle, one of the coils being 90° in advance of the other, so that while one was at the dead-point, the other should be in full action. The same suggestion has been carried out in Akester's motor. Trouvé has tried to get over the dead-points by utilizing the method of oblique approach. The Griscom motor, which has little copper rollers as commutator brushes, has for field-magnets a compact tubular electro-magnet wound in series with the armature. It has the disadvantage of dead-points. There is, in all these motors, the disadvantage that at every half-revolution the magnetism of the armature core is reversed; and as in all these forms this core is of solid iron, there must be waste by heating in the cores. In fact, to the rotating armatures of motors, as to those of generators, apply all the rules about slitting to get rid of induced eddy-currents, avoiding idle coils and useless resistances. The rules about proper pole-pieces, adjustable brushes, and multiplication of contacts, are mostly applicable to motors also as well as to generators.

In order to meet the case of a handy and reliable motor, Prof. Thompson designed a machine in which the field-magnets, which also constitute the bed-plate of the motor, are of malleable cast-iron, of a form that can be cast in one, or at most two, pieces. Their form is that of a Joule's magnet, with large pole-pieces, and wound with coils, are ranged partly in series, partly as a shunt, in certain proportions, so as to give a constant velocity when worked with an external electromotive force of a certain number of volts. As an armature, he employs a form which unites simplicity with efficiency for the end desired; he modifies the old Siemens armature by embedding, as it were, one of these shuttle-shaped coils within another, at right angles to one another. And having duplicated the coils, he duplicates the segments of the commutator, which therefore becomes either a 4-part collector or else a double collar, according to circumstances. There are no solid iron parts in the armature, but the cores are made of thin pieces of sheet iron, stamped out and strung together.

Reckenzaun's motor is interesting, because its armature, though a drum-armature in form, in reality consists of independent coils, connected, like those of the Brush dynamo, to separate commutators. There are, in fact, 4 commutators, grouped as 2 twos, and 2 pairs of brushes in contact with them.

De Meritens employs a ring armature very like that of Gramme, but places it between very compact and light field-magnets, which form a framework to the machine. There is one point about this machine of great interest, which is, however, a later addition. It is provided with a reversing gear. In it are 2 pairs of brushes; the 2 upper are fixed to a common brush-holder, which turns on a pivot, and can be tilted by pressing a lever handle to right or to left. The 2 lower brushes are also fixed to a holder. Against each brush-holder presses a little ebonite roller, at the end of a bent steel spring, fixed at its middle to the handle. The result of this arrangement is that, by moving the lever, the brushes can be made to give a lead in either direction, and so start the motor rotating in either direction. Such a reversing gear is obviously a most essential adjunct for industrial applications of motors, and if the difficulties of sparking at the brushes, caused by the sudden removals of them from the collector, be obviated, must prove much better than any mechanical device to reverse the motion, by transferring it from the axle of the motor through a train of gearing to some other axle. One great advantage of electric motors is, that they can be so easily fixed directly on the spindle of the machine which they are to drive; an advantage not lightly to be thrown away.

Application.—When once we have electrical mains of sufficient capacity carried from central stations to our houses, how simple a matter it will be to combine lighting with domestic operations, and even the larger operations required for purposes of trade; for each motor of a series, placed in parallel circuit, performs the work required of it independently of all the others, and independently of the generating machine, provided only that the generator is capable of producing the power it is called upon to furnish.

Three conclusions are to be drawn, which are the fundamental principles of the theory of the electrical transmission of power.

I. The motor, as a machine, is entirely independent of the generator, and must be designed for the particular work it has to do without reference to the generator.

II. The current depends upon the load on the motor, and upon no other thing whatever.

III. The speed depends upon the E.M.F. of the generator, and the total resistance in the circuit of the machines. If the mains which supply the current to the motor be maintained at a constant potential, and the motor be separately excited, or have permanent magnets, the speed is proportional to the potential of the main, less the loss of potential due to the resistance of the armature.

As a practical corollary, the generator must be designed to give the current required of it by the motor, and E.M.F. sufficient after allowing for fall of potential through the resistance of the mains, to give the requisite speed. Keeping these points in view, it is easy to design a combination of machines for performing any particular work, to calculate exactly the efficiency of the combination, and to account for the various losses that occur.

To put these considerations in a mathematical form:—The first problem is, given a main with a constant E.M.F., denoted by E, to construct a dynamo machine, drawing its current from the main, to work with a given load L, and at a given number of revolutions n per minute.

FIG. 96.

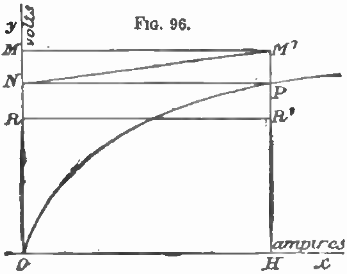
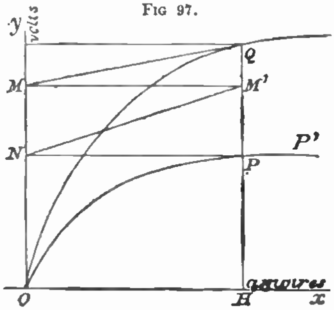


FIG 97.



Take Ox Oy (Figs. 96, 97) as axes of coordinates; along Oy cut off OM, representing the E.M.F. of the main in volts. The makers of each type of dynamo machine know approximately the percentage of energy their machines absorb in producing the necessary magnetic field. Take a point N in OM, such that the ratio $\frac{ON}{OM}$ is equal to this percentage. Again, it is known that a dynamo is not an absolutely perfect machine, but that a certain amount of energy is wasted in the friction of the bearings, of the brushes against the commutator, and in induced currents in the core of the armature. Take OR, such that $\frac{OR}{ON}$ represents the efficiency of the machine. This, in the case of the Siemens machine, is at least 90 per cent. From Ox cut off OH, such that the rectangle OHR'R represents the power required from the motor expressed in watts. Then OH is the current passing through the motor, measured in ampères, and HP is the inverse E.M.F. The proper motor, therefore, is that dynamo which, when running at the given number of revolutions n per minute, has a characteristic curve passing through the point P. The total efficiency is evidently the ratio of the rectangle OHR'R to the rectangles OHM'M, which is equal to $\frac{HR'}{HM'}$; the electrical efficiency is $\frac{HP}{HM'} = \frac{E'}{E}$, the ratio of the inverse E.M.F. of the motor to the E.M.F. of the main. The energy spent in magnetization is measured by

PNMM′, and the tangent of the angle PNM′ represents the resistance of the armature and magnets.

The second problem is:—Given a motor requiring a certain current and E.M.F. for the work it has to do, to construct a suitable generator, the distance between the machines being represented by an electrical resistance R measured in ohms. Let OPP′ be the characteristic curve of the motor, when running at the required speed; ON the E.M.F. in volts, and OH the current in ampères. Let R′ be the sum of the resistances of the motor and conductor. Draw PN perpendicular to OH, and make the angle PNM′ having its tangent equal to R′; then M′H represents the difference of potential between the terminals of the generator. Produce HM′ to Q, so that $\frac{QM'}{QH}$ is the ratio of the energy expended in producing the magnetic field to the total energy of the machine; then the generator is that dynamo which, when running at its proper speed, has a characteristic curve passing through the point Q.

The electrical efficiency of the combination is the ratio $\frac{PH}{QH}$, *i.e.* the ratio of the E.M.F. of the motor to the E.M.F. of the generator, which, if the machines are similar, is equal to the ratio of their speeds. The energy converted into heat in the wires of the machine, and in the conductor, is NPQS; and the total efficiency of the combination is the ratio of the electromotive forces, multiplied by the product of the efficiencies of the 2 machines, considered separately. The conductor connecting the 2 machines has been assumed to be perfectly insulated, though this is not practically attained. (A. Siemens.)

Railways. — The Portrush electric railway extends from Portrush a distance of 6 miles. The line is single, and has a gauge of 3 ft. The gradients are exceedingly heavy, being in parts as steep as 1 in 35. The curves are also in many cases very sharp, having necessarily to follow the existing road. There are 5 passing places, in addition to the sidings at the termini and at the carriage depôt. About 1500 yd. from the end of the line is a waterfall on the river Bush, with an available head of 24 ft., and an abundant supply of water at all seasons of the year. Turbines are being erected for employing the fall for working the generating dynamo machines, and the current will be conveyed by means of an underground cable to the end of the line. At present the line is worked by a small steam engine.

The system employed may be described as that of the separate conductor. A rail of T-iron, weighing 19 lb. to the yd., is carried on wooden posts, boiled in pitch and placed 10 ft. apart, at a distance of 22 in. from the inside rail and 17 in. above ground. The conductor is connected by an underground cable to a single shunt-wound dynamo machine, worked by a small agricultural steam-engine of about 25 I.H.P. The current is conveyed from the conductor by means of 2 steel springs, rigidly held by 2 steel bars placed one at each end of the car, and projecting about 6 in. from the side. Since the conducting rail is iron while the brushes are steel, the wear of the latter is exceedingly small. In dry weather, they require the rail to be slightly lubricated; in wet weather, the water on the surface of the iron provides all the lubrication required. The double brushes, placed at the extremities of the car, enable it to bridge over the numerous gaps, which necessarily interrupt the conductor to allow cartways into the fields and commons adjoining the shore. On the car passing one of these gaps, the front brush breaks contact, but since the back brush still touches the rail, the current is not broken. Before the back brush leaves the conductor, the front brush will have again risen upon it, so that the current is never interrupted. When gaps are too broad to be bridged in this way, the driver breaks the current before reaching the gap, the momentum of the car carrying it the 10 or 12 yd. it must travel without power.

The current is conveyed under the gaps by means of an insulated copper cable carried in wrought-iron pipes, placed at a depth of 18 in. At the passing places, which are situated on inclines, the conductor takes the inside, and the car ascending the hill also runs on the inside, while the car descending the hill proceeds by gravity on the outside lines.

From the brushes the current is taken to a commutator worked by a lever, which switches resistance-frames placed under the car, in or out, as may be desired. The same lever alters the position of the brushes on the commutator of the dynamo machine, reversing the direction of rotation. The current is not, as it were, turned full on suddenly, but passes through the resistances, which are afterwards cut out in part or altogether, according as the driver desires to run at part speed or full speed.

From the dynamo the current is conveyed through the axle-boxes to the axles, thence to the tyres of the wheels, and finally back by the rails, which are uninsulated, to the generating machine. The conductor is laid in lengths of about 21 ft., the lengths being connected by fish-plates and by a double copper loop securely soldered to the iron. It is also necessary that the rails of the permanent way should be connected in a similar manner, as the ordinary fish-plates give a very uncertain electrical contact, and the earth for large currents is altogether untrustworthy as a conductor, though no doubt materially reducing the total resistance of the circuit.

The dynamo is placed in the centre of the car beneath the floor, and through intermediate spur-gear drives by a steel chain on to one axle only. The reversing levers, and the levers working the mechanical brakes, are connected to both ends of the car, so that the driver can always stand in front and have uninterrupted view of the rails, which is of course essential in the case of a line laid by the side of the public road.

For calculation, let L be the couple, measured in foot-lb., which the dynamo must exert in order to drive the car, and w the necessary angular velocity. Taking the tare of the car as 50 cwt., including the weight of the machinery it carries, and a load of 20 people as 30 cwt., we have a gross weight of 4 tons. Assume that the maximum required is that the car should carry this load at a speed of 7 miles an hour on an incline of 1 in 40; the resistance due to gravity may be taken as 56 lb. per ton, and the frictional resistance and that due to other causes, say, 14 lb. per ton; giving a total resistance of 280 lb., at a radius of 14 in. The angular velocity of the axle, corresponding to a speed of 7 miles an hour, is 84 rev. per minute. Hence

$$L = 327 \text{ foot-lb., and } w = \frac{2\pi \times 84}{60}.$$

If the dynamo be wound directly on the axle, it must be designed to exert the couple L, corresponding to the maximum load, when revolving at an angular velocity w, the difference of potential between the terminals being the available E.M.F. of the conductor, and the current the maximum the armature will safely stand. But when the dynamo is connected by intermediate gear to the driving wheels only, the product of L and w remains constant, and the 2 factors may be varied. In the present case, L is diminished in the ratio of 7 to 1, and w consequently increased in the same ratio. Hence the dynamo, with its maximum load, must make 588 rev. per minute, and exert a couple of 47 foot-lb. Let E be the potential of the conductor from which the current is drawn, measured in volts, C the current in ampères, and E_1 the E.M.F. of the dynamo. Then E_1 is proportional to the product of the angular velocity, and a certain function of the current. For a velocity Ω, let this function be denoted by $f(C)$. If the characteristic of the dynamo can be drawn, then $f(C)$ is known.

We have then

$$E_1 = \frac{w}{\Omega} f \quad . \quad . \quad (1)$$

If R be the resistance in circuit by Ohm's law,

$$C = \frac{E - E_1}{R}$$

$$= \frac{E - \frac{w}{\Omega} f(C);}{R}$$

and therefore

$$w = \frac{\Omega (E - CR)}{f(C)} \quad . \quad (2)$$

Let a be the efficiency with which the motor transforms electrical into mechanical energy, then—

$$\text{Power required} = Lw = aE_1C$$

$$= aC \frac{w}{\Omega} f(C)$$

Dividing by w,

$$L = \frac{aCf(C)}{\Omega} \qquad (3)$$

It must be noted that L is here measured in electrical measure, or, adopting the unit given by Dr. Siemens, 1 Joule equals approximately 0·74 foot-lb. Equation (3) gives at once an analytical proof of the second principle stated above, that for a given motor the current depends upon the couple, and upon it alone. Equation (2) shows that with a given load the speed depends upon E the electromotive force of the main, and R the resistance in circuit. It shows also the effect of putting into the circuit the resistance-frames placed beneath the car. If R be increased until CR is equal to E, then w vanishes, and the car remains at rest. If R be still further increased, Ohm's law applies, and the current diminishes. Hence, suitable resistances are, first, a high resistance for diminishing the current, and consequently the sparking at making and breaking of the circuit: and secondly, one or more low resistances for varying the speed of the car. If the form of $f(C)$ be known, as is the case with a Siemens machine, equations (2) and (3) can be completely solved for w and C, giving the current and speed in terms of L, E, and R. The expressions so obtained are not without interest, and agree with the results of experiment.

It has often been pointed out that reversal of the motor on the car would be a most effective brake. This is certainly true; but at the same time it is a brake that should not be used except in cases of emergency. For the dynamo revolving at a high speed, the momentum of the current is considerable; hence, owing to the self-induction of the machine, a sudden reversal will tend to break down the insulation at any weak point of the machine. The action is analogous to the spark produced by a Ruhmkorff coil. This was illustrated at Portrush: when the car was running perhaps 15 miles an hour, the current was suddenly reversed. The car came to a standstill in little more than its own length, but at the expense of breaking down the insulation of one of the wires of the magnet coils. The way out of the difficulty is at the moment of reversal to insert a high resistance to diminish the momentum of the current.

In determining the proper dimensions of a conductor for railway purposes, Sir William Thomson's law should properly apply. But on a line where the gradients and traffic are very irregular, it is difficult to estimate the average current, and the desirability of having the rail mechanically strong, and of such low resistance that the potential shall not vary very materially throughout its length, becomes more important than the economic considerations involved in Sir William Thomson's law. At Portrush the resistance of a mile, including the return by earth and the ground rails, is actually about 0·23 ohm. If calculated from the section of the iron, it would be 0·15 ohm, the difference being accounted for by the resistance of the copper loops, and occasional imperfect contacts. The E.M.F. at which the conductor is maintained, is about 225 volts, which is well within the limit of perfect safety assigned by Sir William Thomson and Dr. Siemens. At the same time the shock received by touching the iron is sufficient to be unpleasant, and hence is some protection against the conductor being tampered with.

Consider a car requiring a given constant current, evidently the maximum loss due to resistance will occur when the car is at the middle point of the line, and will then be one-fourth of the total resistance of the line, provided the 2 extremities are maintained by the generators at the same potential. Again, by integration, the mean resistance can be shown to be one-sixth of the resistance of the line. Applying these figures, and assuming 4 cars are running, requiring 4 h.-p. each, the loss due to resistance does not exceed 4 per cent. of the power developed on the cars; or if 1 car only be running, the loss is less than 1 per cent. But in actual practice at Portrush even these estimates are too high, as the generators are placed at the bottom of the hills, and the middle portion of the line is more or less level; hence the minimum current is required when the resistance is at its maximum value.

The insulation of the conductor has been a matter of considerable difficulty, chiefly on account of the moistness of the climate. An insulation has now, however, been obtained of 500 to 1000 ohms per mile, according to the state of the weather, by placing a cap of insulite between the wooden posts and Γ-iron. Hence the total leakage cannot exceed 2·5 ampères, representing a loss of ¾ h.-p., or under 5 per cent., when 4 cars are running.

Apart from these figures, we have materials for an actual comparison of the cost of working the line by electricity and steam. The steam tramway engines, temporarily employed at Portrush, are generally considered as satisfactory as any of the various tramway engines. They have a pair of vertical cylinders, 8 in. diameter and 1 ft. stroke, and work at a boiler pressure of 120 lb., the total weight of the engine being 7 tons. The electrical car with which the comparison is made, has a dynamo weighing 13 cwt., and the tare of the car is 52 cwt. The steam-engines are capable of drawing a total load of about 12 tons up the hill, excluding the weight of the engine; the dynamo over 6 tons, excluding its own weight; hence, weight for weight, the dynamo will draw 5 times as much as the steam-engine. Finally, compare the following estimates of cost. From actual experience, the steam-engine, taking an average over a week, costs—

	£	s.	d.
Driver's wages	1	10	0
Cleaner's do.	0	12	0
Coke, 58½ cwt. at 25*s.* per ton	3	13	1½
Oil, 1 gal. at 3*s.* 1*d.* . . .	0	3	1
Tallow, 4 lb. at 6*d.* . . .	0	2	0
Waste, 8 lb. at 2*d.* . . .	0	1	4
Depreciation, 15 per cent. on £750	2	3	3
Total . .	£8	4	9½

The distance run was 312 miles. Also, from actual experience, the electrical car, drawing a second behind it, and hence providing for the same number of passengers, consumed 18 lb. of coke per mile run. Hence, calculating the cost in the same way, for a distance run of 312 miles in a week—

	£	s.	d.
Wages of stoker of stationary engine	1	0	0
Coke, 52 cwt. at 25*s.* per ton	2	15	0
Oil, 1 gal. at 3*s.* 1*d.* . . .	0	3	1
Waste, 4 lb. at 2*d.* . . .	0	0	8
Depreciation on stationary engine, 10 per cent. on £300, 11*s.* 6*d.* Depreciation of electrical apparatus, 15 per cent. on £500, £1 8*s.* 10*d.*	2	0	4
Total . .	£5	19	1

A saving of over 25 per cent.

The total mileage run is very small, on account of the light traffic early in the year. Heavier traffic will tell very much in favour of the electric car, as the loss due to leakage will be a much smaller proportion of the total power developed.

It will be observed that the cost of the tramway engines is very much in excess of what is usual on other lines, but this is entirely accounted for by the high price of coke, and the exceedingly difficult nature of the line to work, on account of the curves and gradients. These causes send up the cost of electrical working in the same ratio, hence the comparison is valid as between the steam and electricity, but it would be unsafe to compare the cost of either with horse traction or wire-rope traction on other lines. The same fuel was burnt in the stationary steam-engine and in the tramway engines, and the same rolling stock used in both cases; but otherwise the comparison was made under circumstances in favour of the tramway engine, as the stationary steam-engine is by no means economical, consuming at least 5 lb. of coke per horse-power hour, and the experiments were made, in the case of the electrical car, over a portion of line 3 miles long, which included the worst hills and curves, and one-half of the conductor was not provided with the insulite caps, the leakage consequently being considerably larger than it will be eventually.

Finally, as regards the speed of the electrical car, it is capable of running on the level at the rate of 12 miles per hour.

Taking these data as to cost, and remembering how this will be reduced when the water-power is made available added to such considerations as be freedom from smoke and steam, the diminished wear and tear of the permanent way, and the advantage of having each car independent, it may be said that there is a future for electrical railways. (Dr. Hopkinson.)

Machinery.—Electric engines may be used with advantage in cases where the importance of utilizing power at a distance from an original motor is sufficient to compensate for the loss in converting the power into electric energy, and again in reconverting it into mechanical force at the place where it is to be applied, the total loss in these 2 processes being about $\frac{2}{3}$ of the original force. The dynamo-electric machines employed are the same as those for electric lighting. A machine requiring 2 h.-p. to work it costs about 50*l*., one requiring 4 h.-p about 80*l*., and one 10 h.-p. about 200*l*. The machine for giving out the force is the same as the one that receives it. There is also to be taken into account the wear and tear of the apparatus, and the interest on the capital expenditure.

The principal advantage which ma
be expected from electric transmissio
is in the utilization of natural force
such as water-power or cheap fuel, a
distant places. At present, howeve
(1882), copper conductors for transmi
ting considerable power become costl
and inconvenient for distances abo
2 miles, and the system is practicall
limited, as it is seldom that the adva
tages so obtained compensate for th
expense. The most favourable oppo
tunity for using electric engines aris
when the generator and conductor a
already established for electric lightin
A small conductor $\frac{1}{8}$ in. diameter will n
only suffice for numerous lights, b
would afford 1 or 2 h.-p. for a moto
and smaller motors suitable for a sewin
machine or other domestic purpose ca
be purchased for 3*l*. to 10*l*. Electr
science is advancing so rapidly that t
present difficulties are likely to be ove
come, and the cheapness with whi
large motors can be worked as compar
with numerous small ones will co
pensate for considerable loss in distr
bution and reconversion, if the dif
culties and expenses of long conducto
be removed. A motor of $\frac{1}{2}$ h.-p. weig
less than 40 lb., and occupies very sma
space. Forms suitable for driving tr
cycles can be attached beneath the sea
At the Agricultural Show at Bar-
Duc, France, in May 1880, an electr
motive machine was exhibited, sui
able for agricultural use. A large fie
was successfully ploughed with one
Howard's double-furrow ploughs work
by it.

The experiment of Deprez at Muni
gives much information for future us
With machines of the type described
him, 2000 volts is too high an electr
motive force to employ. The reason
that it is impossible to prevent t
contact of the brushes from being som
times accidentally broken. In such
case it was found that the electromoti
force developed by the extra current
sufficient to ruin the insulation. Anoth
matter deserving of attention is t
relative size of the generator and mot
Deprez employed 2 machines of equ

size. This slightly simplifies the theory, but it is certainly not the most advantageous arrangement, and we are much in want of accurate measurements on this head. The Deprez experiment at Munich was, commercially, a failure. Since then Deprez has been occupied with experiments of a far more practical nature, with a line of 160 ohms resistance. In the latest experiments, where the effects of friction were deducted, a return of 47½ per cent. was obtained, and 4·4 h.-p. of work was actually given off by the motor. If a fall of water be used as the motive power, we can install a turbine and dynamos which shall transmit 6 h.-p. through a resistance of 12 ohms, at a cost of 200*l*., omitting the unknown cost of the conductor. If this power were used in a place where coal costs 20*s*. per ton, the cost of fuel for 6 h.-p. would be about 60*l*. per annum. The interest and depreciation on the boiler and steam-engine would be about 30*l*. per annum, making in all 90*l*. per annum, exclusive of wages. Electrically transmitted, the interest on plant, at 15 per cent., would be 30*l*. per annum, exclusive of wages. This difference of 60*l*. per annum, after deducting from it the interest and depreciation of the conductor, is so enormous, that it is easy to see what a large saving would be effected in any installation where there is a large consumption of power. There are many factories where it is essential to use a high-priced coal, but if the power could be conveyed electrically from a distance of a few miles, an immense saving would be effected by employing a cheaper kind of coal. When water-power is used, it often happens that the cables can be conveyed along the bed of the river. This preserves the insulation, and keeps the conductor cool, so preventing the usual increase of resistance by heating. In some towns, notably Sheffield, the whole of the water supplying the town comes from reservoirs at a great height. The very large quantity of energy of this water is at present absolutely wasted. At the site of the Severn Tunnel is a width of river of 2½ miles, where the average rise of tide is 50 ft. If the average rate of flow across this section were 1 mile per hour, we could utilize 100,000 horse-power, and the market value of that power is something like 1,000,000*l*. per annum, which is now allowed to be wasted. It is worthy of the most serious consideration whether it would not be worth while to erect the enormous engineering works which would be required to utilize this wasted energy, or rather a portion of it, even assuming the interest and depreciation on the turbines and dynamos to be at the rate of 2*l*. per annum per horse-power (and it would be far less than this for a large installation). (Prof. Forbes.)

Phonographs.—The phonograph is an instrument by which sounds can be imprinted on soft metal, such as tinfoil, and reproduced with distinctness and accuracy of tone any number of times. It consists of 3 parts: a receiver, a recorder, and a reproducer.

The receiver consists of a curved tube, one end of which is fitted with a mouthpiece, and the other end closed by an exceedingly thin metallic plate or diaphragm, which vibrates with the least sound. On the centre of the outer side of this metallic diaphragm is a small blunt steel pin. The recorder is a brass cylinder 4 in. long and 4 in. in diameter, with a continuous V-shaped groove cut into it from end to end, like a large screw; 2 pins 4 in. long are fixed in the ends of the cylinder, one of which is cut with a screw thread, corresponding to that of the V-groove in the cylinder, and these pins are fitted into appropriate bearings, 8 in. apart. By turning a handle fixed on to one of the pins just referred to, the cylinder is not only rotated, but traverses from one support to the other. In using this instrument, the recorder is covered with a sheet of tinfoil, and is placed in front of the vibrating diaphragm of the receiver, the blunt pin of which just touches the surface of the tinfoil, and is opposite the commencement of the groove of the brass cylinder. If now a person speaks into the mouth piece of the receiver, and the handle of the recorder be turned, a spiral series of indentations will be made on the tinfoil by the pin of the vibrating diaphragm, these indentations corresponding to the groove in the brass cylinder under the tinfoil. The sounds that have been uttered are now recorded on the tinfoil. The reproducer, which forms the third part, consists of a conical metallic drum, having its larger end open; the smaller, which is about 2 in. in diameter, being covered by a sheet of paper stretched tight like a drum. In front of this paper diaphragm is a light, flat steel spring, held in a vertical position, and from the end of which a blunt steel point projects. The spring is connected with the paper diaphragm by means of a silken thread, which is placed just sufficiently in tension to cause the outer face of the diaphragm to assume a slightly convex form. In order to reproduce the sounds received on the tinfoil, the receiver is placed in front of the "reproducer," so that the blunt pin is just over the first indentation; the handle of the receiver is turned in a reverse direction to what it was before, and this causes the spring of the reproducer to vibrate. The movements of the spring are communicated to the paper diaphragm by the silken thread, and the words spoken into the receiver are heard issuing from the open end of the reproducer. (Dyer.)

It must not be supposed that all the tinfoil used for phonographic registration is equally good. The foil must be of a definite thickness, and combined with a certain amount of lead. That which is used for wrapping chocolate, and indeed all foil of French manufacture, is too thin and too exclusively made of tin to produce good results. The relative proportion of lead and tin has not yet been defined, and the selection of foil has been made empirically; but as the use of the phonograph becomes more general, this proportion must be ascertained, and it may easily be done by analysing the composition of the foil which gives the best results. The arrangement of the tracing-point is also of much importance for the successful action of the phonograph. It must be very slender and very short (not exceeding 1 millimètre in length), so as to register distinctly the smallest vibrations of the vibrating disk without deviating from the normal direction of the cylinder, which might be the case, if it were long, on account of the unequal friction exerted on the tinfoil. It must also be made of a metal which has no tendency to tear the metallic sheet. Iron appears to combine most of the conditions demanded. (Hedges.)

Shelford Bidwell gives the following description of how to construct a phonograph. He says the most important part of it is the cylinder. This, in his phonograph, is a hollow brass casting, 4½ in. long and 4½ in. in diameter. It is mounted upon an iron spindle ¾ in. in diameter and 16 in. long, at one end of which is a winch handle. Upon that part of the spindle which lies between the handle and the cylinder, a screw is cut, having 8 threads to the inch. The other end of the spindle is left plain. The cylinder having been turned perfectly true, a screw is cut upon its surface of exactly the same pitch as the screw upon the spindle—*i.e.* 8 threads to the inch. The depth of the spiral groove thus formed is $\frac{1}{16}$ in., and its breadth is $\frac{1}{16}$ in. It is better to cut it square, and not V-shaped. Two brass bearings for the spindle are made of the following dimensions—length, 2¼ in.; thickness, 1⅛ in.; height, 1½ in. One of these has an inside screw corresponding to the screw upon the spindle. Each bearing has 2 holes for screwing it to the support. The cylinder, spindle, and bearings being completed, 10 pieces of wood must be prepared as follows:—

A is 12 in. × 9½ in. × 1⅛ in.

B is 3 in. × 3 in. × 1⅛ in.

C is similar to B.

D is 5½ in. × 5½ in. × ½ in., and has a circular hole, 2¾ in. in diameter, cut in its centre.

E is similar to D.

F is 5½ in. × 5½ in. × ½ in., and has a hole, 1 in. in diameter, in its centre.

G is 5½ in. × 2½ in. × ½ in.
H is similar to G.
I is 8 in. × 2½ in. × ½ in.
K is similar to I.

FIG. 98.

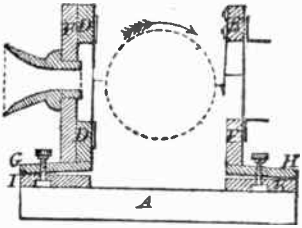
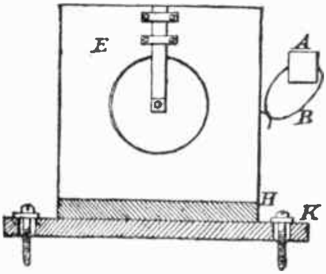


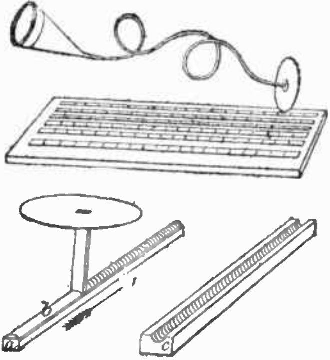
FIG. 99.



There are 2 upright supports for the bearings. The position is indicated by the letters corresponding to them in Figs. 98, 99. The uprights are fixed near the ends of the base-board A by means of 2½ in. screws. D and F are screwed together, and the 2 are then fixed perpendicularly upon G. G is joined to I by a pair of hinges. The 2 ends of I are screwed to the base-board, but the holes in I are ⅛ in. larger in diameter than the screws which pass through them. The heads of the screws are effectively enlarged by iron washers ¾ in. in outside diameter. The object in this arrangement is to allow a certain amount of play in the board I for purposes of adjustment. When properly adjusted, the screws may be tightened, and the board firmly fixed in position. E is attached perpendicularly to H, and made rigid with 2 small triangular pieces, not shown. H is hinged to K, and K is fixed to the base in exactly the same manner as I. Through the middle of I is passed a brass screw-bolt, the square head of which is fixed in I. The screw goes through an elongated hole in G, and is fitted with a round milled brass nut. It is well to place a washer under the nut. Screw-bolts of this description are used for fixing the expanding bodies of ordinary photographic cameras, and may be had of any optician. H and K are fitted with a similar bolt. Two rather stiff pieces of steel spring are attached to the ends of I, and extend for a little distance underneath G. These springs tend to separate G and I, or rather to cause G to turn backwards, like the lid of a box when opened. The nut, of course, works against the springs. When the nut is screwed up tight, G and I approach, and may be made almost to touch each other. When the nut is loosened, the spring causes G to rise. Very delicate adjustment is thus rendered possible. H and K are fitted with similar springs for a similar purpose. The diaphragm which receives the voice is fixed over the circular hole in D, as shown in Fig. 98. It consists of a circular plate of very thin iron 4 in. in diameter. Ferrotype plate will answer the purpose very well, but thin charcoal iron is better. It is, however, possible to have the iron too thin. About two-thirds the thickness of an ordinary ferrotype plate is the best. The point is made from a knitting-needle about $\frac{1}{20}$ in. in diameter, which must be very hard—one which can be bent is of no use. The original point had better be broken off, and a new one ground upon an oilstone. For this purpose, the needle is held at an angle of about 30° with the stone, and is constantly turned round. The point, having been made tolerably sharp, is polished and cut off with a file. The part so cut off is $\frac{3}{16}$ in. long. This has now to be attached perpendicularly to the centre of the diaphragm, and the method of doing so is as follows:—The diaphragm is laid upon a sheet of glass, and a little spot in its centre—about ⅛ in. in diameter—is scraped clean with a knife. This must be done carefully and gently, or a bulge will be produced. The fragment of knitting-needle is then taken up with pliers, and its blunt end, having been moistened with soldering fluid, is held above the flame of a spirit-lamp, and touched with a piece of tin-foil. With a little manipulation, a small bead or globule of tin may thus be made to adhere to the end. The scraped spot on the diaphragm is now moistened with soldering fluid, and the diaphragm is supported at some distance above a small spirit flame. The ring of a retort stand forms a convenient support. The butt end of the point, with tin globule attached, is then applied to the scraped spot with pliers. In a few seconds the globule melts, when the lamp is instantly removed, and the point manipulated with the pliers, so as to be perfectly upright when the tin hardens, which will take place in a few seconds more. The point will then be found to be firmly attached. The diaphragm and point must, after this operation, be thoroughly washed with soap and water, and slightly oiled—otherwise they will rust. The only precaution to be observed is to apply no more heat than is just necessary for melting the tin. Too much heat will warp the disc, and, if it is a ferrotype, blister the japan. The soldering fluid consists of equal parts of hydrochloric acid and water, in which is dissolved as much zinc as possible. A pile of books will be found useful for steadying the arm while manipulating the point. The diaphragm is fixed in its place by means of a brass flange (like a camera flange), 4 in. in outside diameter, with a 2¾ in. opening. Four screws are used. The second diaphragm is made of parchment paper, like that used for covering jam-pots. It is 4 in. in diameter, and is gummed over the hole in E on the side remote from the cylinder (see Fig. 98). When the gum is dry, the diaphragm is moistened, and again allowed to dry, when it will be found to be as tight as a drum. The second point is exactly like the first, though it may with advantage be a trifle sharper. It is not attached directly to the paper diaphragm, but to a steel spring, which may be seen in Figs. 98 and 99. This is a piece of mainspring 5/16 in. wide and 2⅞ in. long. It is fixed above the hole in E by means of 2 strips of brass, as shown in Fig. 99, and is just so much bent that the end of it, when free, is ⅝ in. distant from the plane of E. The power of this spring may, however, be varied within considerable limits without appreciable difference in its performance. The point is fixed to the spring in the same manner as to the iron disc, but the same care as to over-heating is not requisite, and the operation is consequently easier. Before the spring is screwed in its place, a loop of sewing silk is attached to the centre of the paper diaphragm by means of a piece of court plaister ¼ in. square (see Fig. 99, where A is the piece of plaister, B the loop). The length of the loop must be such that when it is drawn over the spring just above the point, the end of the spring may be nearly in the plane of E. The spring is thus caused to draw the paper drum even tighter than before, and its inner surface is rendered slightly convex. Another flange carrying a short rim or spout is now screwed round the paper drum. A paper resonator is made to slip over the short rim or spout. It is a cone made of 2 or 3 thicknesses of stout drawing-paper. Its length is 18 in.; diameter at small end, 2⅞ in., and at large end, 7 in. The resonator greatly reinforces the sound when the phonograph is speaking. A wooden mouthpiece like those used for speaking-tubes is inserted into the hole F. The instrument is now complete, but it will require careful adjustment before it can be used. In the first place, the screws which attach I to the base must be loosened, the milled nut on G screwed up tight, and the piece I shifted about until the point on the iron disc is exactly in the middle of one of the grooves on the cylinder, and barely touches the bottom of it. Then the screws must be tightened, and this part of the apparatus is finally adjusted. The same process is repeated on the other side, but in this case the adjustment is not quite final. as will hereafter be seen. The next thing is to procure suitable tinfoil. This should be rather stout—about 15 sq. ft. to the lb.—and should be cut into pieces 14½ in. by 4½ in. Before putting a tinfoil upon the cylinder, the 2 nuts are removed, and the diaphragms turned back out of the way. A little gum brushed along one end of the tinfoil will be sufficient to keep it firmly in its place; the join must be carefully smoothed. The diaphragms are then turned back to their places, and the nuts screwed on. The nut on G is screwed up just far enough to cause the point on the iron diaphragm to touch the tinfoil very lightly. The handle is then turned about ¼ rev., causing the point to make a short scratch on the tinfoil. The nut on G is thereupon loosened, withdrawing the point from the tinfoil, and the nut on H being screwed up, another turn is given to the handle. If the scratch thus produced exactly coincides with the former one, well and good; if not, the screws attaching K to the base must be loosened, and K shifted about until absolute coincidence is attained. The utmost accuracy on this point is essential. The instrument may now be considered fit for use. Loosen the nut on H, so that the point on the spring may be well away from the tinfoil, and screw up the nut on G, so far that the point on the iron diaphragm may score a well-defined furrow on the tinfoil when the handle is turned. Turn the handle with as great regularity as possible, at the rate of about 1 turn per second, or a little slower. Speak loudly and distinctly into the mouthpiece. putting the mouth as near as possible to it, without actually touching. When you have finished, withdraw the point by loosening the nut, turn the handle backwards until the cylinder is in its original position, and screw up the second nut until the second point presses lightly but steadily upon the bottom of the furrow. Then put on the paper resonator, and turn the handle at the same speed as before. If the adjustments are perfect, the result will be astonishing. It will be observed that this instrument has 2 diaphragms, whereas Edison's latest has only 1, which does both the receiving and the speaking. Bidwell made many experiments with the object of dispensing with 1 of the diaphragms, but never, under any circumstances, obtained so good results with 1 as with 2. Preece told the Physical Society that the employment of only 1 was a "retrograde step." Bidwell does not believe that iron and parchment-paper are the best possible materials for the diaphragms, though they are better than any others tried. The great fault in the iron appears to lie in its tendency to resound forcibly to certain overtones in certain vowel sounds. Bidwell tried to overcome this by coating the diaphragm with indiarubber, but with no great success. He thinks, however, that a ring of indiarubber between the diaphragm and the flange has an undoubted effect in diminishing the nuisance. The steel spring is subject to independent vibrations of a similar nature. These may be damped by causing a piece of soft indiarubber to press lightly upon it at a point about ½ in. below the lower strip of brass. He also found it an advantage to wrap indiarubber round the top of the spring before screwing it on. He believes that the mouthpiece of a telephone would give better results than that of a speaking tube. A long resonating mouthpiece like that which Edison first used is worse than useless. The point on the steel spring should be made to turn very slightly upwards instead of being perpendicular. In the latter case, it is liable to produce a squeak something like that of a slate-pencil when drawn upright across a slate. If the points are too sharp, they will cut and scrape the tinfoil; if too blunt, the articulation will be muffled. After the points have traversed the cylinder 200 or 300 times, they will require sharpening. This can be done with a small oil-stone, without removing them. (*Eng. Mech.*)

The very simple apparatus illustrated in Fig. 100 is a speaking phonograph that can be made and sold for 6*d*., or even less, and yet leave a profit to the manufacturer. It is the invention of Lambrigot, an inspector of telegraphs at Albi, in the Department of Tarn, in the south of France. The whole apparatus consists, first, of a hollow cone of pasteboard about 1½ in. in diameter, whose apex is connected to the centre of a similar-sized pasteboard disc by means of a leaden wire about 16 in. long; and second, of a small board or tablet, on which is fixed 1, or a larger number of short lengths of leaden wire, each of which bears upon its upper surface a phonographic embossed record corresponding to a certain word or sentence, by which it was originally produced by a process to be described further on.

FIG. 100.



To those who are familiar with the construction of the phonograph in the form in which it was first shown in this country, it would appear necessary, in order to reproduce the sounds recorded on the tablet, for the edge of the disc to be held in an annular frame so as to convert it into a diaphragm, and for its centre to be thrown into vibration by means of a point or style projecting from it and drawn over the undulatory surface of the record. But the method of using the apparatus is far simpler than that; all that is necessary is to hold the paper cone against the ear with one hand, and with the other to take hold of the cardboard disc, drawing its edge along the record with a steady scraping motion, and the mechanical vibrations thus set up in the disc being communicated by the wire to the conical earpiece which serves as a resonator and concentrator, produce in the organs of hearing the sensation of the articulate sound by which the markings on the leaden record were originally produced. We should have thought that a stout thread or a lighter wire would have formed a more efficient as well as a cheaper connection for the purpose than the leaden wire, but we are informed that Lambrigot has found the lead to answer the purpose better than anything else; it does not require to be kept stretched between the cone and the disc, and being of a very inelastic nature, it does not spring about and produce disturbing sounds by clashing against itself or against neighbouring objects. Again, it would naturally be expected that the earpiece would be more perfectly adapted to its purpose if it were in the form of that used in the ordinary thread telephone; that is to say, if it consisted of a cylindrical cardboard box closed at one end with a stretched paper diaphragm, to the centre of which the connecting wire was attached; but simple as it is, this would undoubtedly be a more complex form of construction than the cardboard cones, and would be far more liable to be destroyed by the weight of the connecting wire. The employment of cardboard as the material of which the principal parts of the apparatus are constructed, is, in the case of the cone, for cheapness, and in that of the disc, partly for cheapness, but chiefly to protect the markings on the leaden record from being destroyed, as they soon would be if a harder material than card were employed.

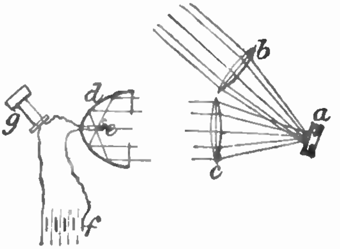
The most interesting point connected with this very simple apparatus is the method by which the leaden records are produced, which is as follows:—The upper surface of a rectangular prism of glass, or other hard and rigid material, is thickly coated with stearine wax, which is then scraped into a convex form, as shown in the diagram, in which *a* represents the glass bar and *b* the convex coating of stearine. This bar is then fixed into a simple phonographic instrument, which, by means of a screw or other mechanical contrivance, traverses it at a suitable speed below a diaphragm. This diaphragm is rigidly held around its circumference by an annular framework (not shown in the diagram), and is in every respect exactly similar to the diaphragm of an ordinary phonograph. To the centre of this diaphragm is attached a thin flat plate, whose lower end is cut out to a concave curve, to fit the convex surface of the stearine *b*. When all is properly adjusted, and the temperature is so arranged as to give to the stearine surface the proper degree of hardness to ensure the best results, the handle of the instrument is turned, and at the same time words are spoken against the diaphragm, which immediately set up in it vibrations, which are communicated to the plate or style. While this is moving up and down, following the vibrations of the diaphragm caused by the voice, the stearine coating of the bar *ab* is steadily drawn in the direction of the arrow below the vibrating bar, receiving from it a phonogram similar to that produced on the tinfoil of an ordinary phonograph.

The stearine bar is then coated with a fine surface of graphite, so as to give to it an electrically conducting surface, and it is then electro-plated with copper by the ordinary process. Out of the copper coating so formed the stearine is removed, and a rigid backing of lead or other metal having been run over the outside convex surface of the copper, a firm copper-lined matrix or mould is formed, the whole presenting the appearance shown, and consisting of a rectangular block having along the middle of one of its faces a semi-cylindrical groove c of copper, which bears upon its surface certain raised striations corresponding to the depressions which were made by the diaphragm on the surface of the stearine. Into this groove is laid a piece of lead wire about 3 or 4 millimetres in diameter, and the two being put into a press and squeezed together, the surface of the lead wire receives a permanent impression which is an exact reproduction of the original impression made upon the stearine bar. From one copper matrix a very large number of lead impressions may be made, and we are told that the whole process can be gone through, and lead wires, each containing the record of a short sentence, can be made and sold with a profit for ½d. each.

It is an interesting fact that if a small stick of wood, such as the stem of a common match, be substituted for the disc, and its end be drawn along the copper groove of one of the matrix moulds, articulate speech is communicated equally well to the earpiece, although the motion of the point is the reverse of that of the disc; and this bears a very close analogy to the fact that in the ordinary Bell telephone a message is transmitted with equal distinctness, whether the poles of the receiving instrument be reversed or not. (*Eng. Mech.*)

Photophones.—Fig. 101 illustrates the principle of Bell's photophone, and shows one of the most successful arrangements. A beam of light from any source is concentrated on the diaphragm *a* by the lens *b*, and the diaphragm of silvered mica or glass capable of reflecting the light is placed in such a position in relation to the lens c

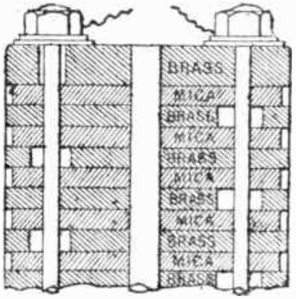
FIG. 101.



as to project the light along a line joining the axes of the lens *c* and of the parabolic reflector *d*. The lens *c* renders the divergent rays of light parallel, and the parabolic reflector concentrates the light upon the selenium cell *e*. The selenium forms a part of an electric circuit, which includes the battery *f* and receiving telephone *g*. A sound made in the vicinity of the transmitting instrument vibrates the diaphragm *a*, and undulates the beam of light projected through the lens *c*, and the consequent variations in the intensity of the light concentrated on the selenium by the parabolic reflector, changes the electrical conductivity of the selenium, and renders the electric current undulatory. This current affects the receiving telephone in the same way as it would be affected in an ordinary telephonic circuit, and the sounds made in the transmitting instrument are reproduced in the telephone.

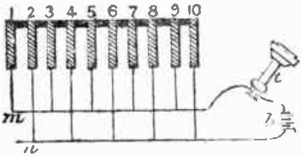
Fig. 102 shows the cylindrical form of selenium cell adopted, the rays of undulatory light being thrown upon its cylindrical face by a paraboloid reflector, in whose focus it is placed. This beautiful little instrument consists of a number of circular discs of brass, about 2 in. in diameter, strung upon a rod passing through their common centre, and separated from one another by a similar series of discs of mica, whose diameter is slightly smaller than that of the brass discs, so as to form with the latter (when the whole is built together as a cylinder) a number of grooves around its cylindrical surface. The discs are held firmly together by nuts and bolts passing through them, 2 of which are shown in the diagram, and which form the connecting screws for placing the instrument in circuit with a pair of telephones and a battery. Upon reference to Fig. 102 (which is only a diagram explanatory of the arrangement of circuits, and does not represent the construction of the instrument or the proportion of its parts), it will be seen that every alternate disc of brass is in metallic connection with the upper bolt, but is insulated from the lower bolt, and *vice versa*. In other words, if all the brass discs were numbered consecutively from one end of the series to the other, all the discs marked with even numbers are connected to the lower bolt and insulated from the upper, and all the uneven-numbered discs are in contact with the upper bolt, but insulated from the lower. The grooves formed around the cylindrical surface are filled in with selenium by the following simple process: the cylinder is first heated to a temperature somewhat above that of the fusing-point of selenium, and, while hot, a stick of selenium is rubbed over its surface, filling up the grooves and covering the edges of the brass discs. The cylinder is then put in a lathe, and the selenium is turned off until the edges of the brass discs are bared. Before being sensitive to light, however, the selenium has to be annealed by first heating it until signs of fusion begin to show themselves; when the heat is removed, the fused portions recrystallize, and the selenium is thereby rendered both sensitive to light and a conductor of electricity. Prof. Bell states that the whole process of annealing occupies only a few minutes. Fig. 103 is a diagram in which the connection of the brass discs with the external or telephonic current is more clearly shown. Here it will be seen that the discs numbered 1, 3, 5, 7, and so on, are connected to one terminal of the telephone *t* by the wire *m*, while

FIG. 102.



the even discs 2, 4, 6, 8, &c., are in connection with the other terminal through the wire *n* and battery *b*. Upon examination of the diagrams, it will be seen that while the surfaces of contact between the selenium rings and the brass discs are increased to a maximum by reason of their large diameter, which also ensures a maximum of sensitive surface, the resistance of the whole photopile is reduced to a minimum, not only by the method of making the circuits as shown, but by the large sectional area of conducting material presented by the annular form of the selenium.

Fig. 103.



The transmitting instrument of the photophone is shown in Fig. 104, and consists of a long board mounted upon a firm support (with suitable adjustments for directing it, within certain limits, in both altitude and azimuth), to which are attached the various parts of the apparatus: *o* is the mouthpiece with its reflecting diaphragm *d* of silvered glass or mica, and *m* is the mirror by which a ray of light from the sun or any other powerful source may be projected on to the diaphragm *d* by the condensing lens *l*, below which is fixed another lens for the purpose of parallelizing the beam after reflection from the silvered diaphragm, and projecting it to the distant station, where it is received by the paraboloidal reflector of the receiving instrument, in the focus of which is placed one of the cylindrical photopiles such as described, and in circuit with the latter is placed a pair of telephones and a voltaic battery, which in Prof. Bell's experiments consisted of 9 Leclanché cells.

Fig. 104

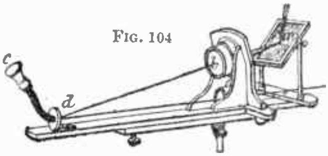
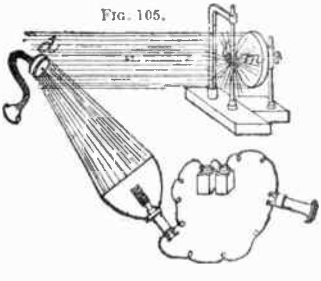


Fig. 105.



Prof. Bell made a series of photophonic experiments in Paris, using the electric light as his source of illumination, and it is an interesting fact—although one which might have been expected from the results obtained in his earlier experiments—that the irregularities and vibrations, which are well-nigh inseparable from the light emitted by the electric arc, produce their effect in the telephone as an unceasing murmur, while at the same time articulate speech is heard superposed, as it were, upon the "voice" of the arc.

Fig. 105 is a diagram illustrating the arrangement of apparatus with which Prof. Bell worked in Paris. *l* is the electric lamp, the arc of which is in the focus of a paraboloidal silvered reflector *m*, by which the divergent rays emanating from the arc are condensed and projected as a parallel beam to the reflecting diaphragm *d*, by which a certain small proportion of them is reflected to the receiving instrument through a distance of nearly 50 ft., as shown in the figure. From this diagram it will be seen that a very large proportion of the light projected by the lamp reflector does not fall upon the diaphragm at all, but notwithstanding this loss, highly satisfactory results were obtained in the transmission of articulate speech, and Prof. Bell is of opinion that effects equal to those obtained with sunlight would be produced by means of an electric lamp suitably arranged so as to utilize the whole of the light radiating from the arc. (*Engineering.*)

Storage.—The following observations on the electrical storage of energy are gathered from Prof. Oliver Lodge's Cantor lecture on "Secondary Batteries and the Electrical Storage of Energy."

Methods of storing energy are very numerous, and may be divided into 2 classes, mechanical and chemical. Under the first class come the raising of weights, as by the pumping of water into a reservoir; and that is a very efficient method of storing energy for future use, as a large proportion of the energy can be made available. Another mechanical method is by the coiling of springs, or producing strain in an elastic body by twisting—a form of storage familiarly exemplified in winding up a watch. A third form of mechanical storage is by charging a Leyden jar. The old idea of the action of a Leyden jar was that it was a chemical action; but that is not the case. What is being done in charging a jar is producing a strain on the molecules of the glass vessel. If the strain be carried too far, the glass will burst under the internal tension, producing a disruptive discharge, and overcoming the molecular resistance. There are also various chemical methods of storing energy. One class is represented by gunpowder, dynamite, and other explosives, though it must be confessed that this use of the term chemical storage is somewhat questionable in the case of gunpowder, for in it are combined substances not in themselves explosive, which in combination yield great energy when a light is applied to them. The smelting of metals is a better example of chemical storage. By the melting of zinc is produced a material which can be employed for evolving energy in a common battery. Then we have the energy of sunlight stored on a gigantic scale by radiation upon vegetable substances, and this stored solar energy can be reproduced by the burning of coal either directly or as gas. This form of energy is utilized as a mechanical power in the well-known gas-engine, in which a mixture of coal gas and common air produces a mild form of explosion which furnishes an available energy. The amount of energy obtained for a given quantity of gas by this electro-chemical decomposition is not very great; other gases are known which have far more explosive power in small quantities than a mixture of coal gas and air. Thus a mixture of oxygen and hydrogen, if brought together, will decompose and explode with far greater violence than coal-gas and air, and thus can be made to store and reproduce a larger amount of energy. Many persons are directing attention to the second example of decomposition of gases as a possibly practicable method of storing and reproducing energy, and Prof. Lodge is not quite sure but that it will be rendered useful in the future: whether it ever will be found an economical manner of utilizing energy remains to be seen; most probably not. Even in a test-tube the gas is too much confined to evolve much energy. These forms of storage by mechanical and chemical means may be distinguished as proper or improper, and in more exact language, as homotropic and heterotropic.

Passing next to consider the direct storage and reproduction of electric energy, Dr. Lodge points out that this can only be effected by the use of 2 conducting surfaces or plates, one of which must be different either in material or in action from the other. One of these plates must be attackable by electric energy, and the other not so attackable. Any difference in the attackability of the 2 plates will cause them to act as a battery—and the action may be produced either by using plates of different metals, or by acting in a different manner on 2 plates of the same material. In a platinum cell, one plate is oxygenized and the other hydrogenized. The hydrogenized plate is the one attacked, and the oxygenized plate is not attacked; the current passes through the cell from one plate to the other till the gas stored on the plates, *i.e.* the energy, is consumed, an event which happens very soon. A secondary battery or store of electric energy consists of a reservoir connected by wires on the one side with a plate of source, and on the other with a plate of use, and some switch arrangement is needed to connect or disconnect it as required with the plates of source and use. A simple example of a secondary battery consists of a store or glass cell containing dilute sulphuric acid, in which 2 plates of lead are partially immersed, and these are connected by wires at will by a switch, either with a bell or a galvanometer, or with both. After the plates have been immersed a few seconds, it is found that they are saturated with electricity, as shown by the escape of gas in bubbles, and any attempt to store energy by continuing the current beyond that point is sheer waste. By switching it on to a bell and galvanometer, it can be seen how transient the energy in such a cell is, as it only rings the bell or deflects the needle for a few seconds, and the current is then exhausted, the cell needing a few minutes' rest to recover its energy. This is because the 2 plates cannot retain the gas; what is wanted is a plate to hold the oxygen, and become oxidized. This is the principle of Grove's gas battery. In Ritter's secondary piles, oxidized metals are employed; but it is necessary that the oxide of the metal used for plates shall not be soluble. Lead fulfils this condition, not being soluble, and is therefore a good material for plates, but it absorbs more than it ought. Silver and manganese, like lead, have a peroxide; but lead is better suited for use as plates than other metals, because its peroxide is less soluble in dilute sulphuric acid, and hence one can store in leaden plates the largest quantity of electric energy.

In defining the positive and negative poles, Dr. Lodge calls that the positive plate which is oxidized, and from which the current enters the store; and that the negative which is hydrogenized, and by which the current leaves. In other words, the oxide plate is plus or positive, and the hydrogenized plate minus or negative. Whether tested by duration of ringing or deflection of needle, the negative plate is the first to fail. This was the condition of the Ritter secondary pile before the days of Planté. The improvement introduced by the latter worker consisted in providing a reducible plate. The lead in itself is irreducible. Planté achieved his object by the simple process of reversing the action in the cell, converting the positive into the negative plate, and *vice versâ*, so that the hydrogenized plate became oxidized. The peroxide penetrates deeper and deeper into the plates as they are successively used as positives, and by repeated reversals their surfaces ultimately come to have a porous spongy condition—a state which takes a month or two to attain. Returning to a consideration of the failure of the negative plate: on taking a piece of amalgamated lead and withdrawing it upon exhaustion, the mercurized surface of the plate is seen to be dimmed over by a glaze. This glaze, it can be further shown, is sulphur, and the early failure of the negative plate is due to the formation of a coat of sulphate of lead. The film is extremely thin, imperceptible on ordinary lead, yet is sufficient to stop the current. That this is the correct explanation is shown by wiping off the film by rubbing the plate on a cloth, when the current again passes till the sulphate has been redeposited. At first sight it would seem best to employ a metal for the plates, of which the sulphate was soluble; but that would not answer, for the positive plate, when the current was reversed for the peroxide, would also be dissolved, and the peroxide deposited on the positive plate conducts electricity, whereas the sulphate of the negative plate does not.

The improvement introduced by Faure, was to get reducible plates without the great number of preliminary reversals necessary under Planté's system. Planté provided oxidizable plates, but their oxidizability did not extend to any great depth, and most of the force escaped. Faure decided to coat his plates with some porous peroxide, and found that minium, red-lead, and litharge were suitable for the purpose. By this means a large absorbent surface was provided, and the waste occasioned by the giving off of gas from the cell was delayed, thus increasing the storage capacity of the cell by that interval. The peroxide coat sponged out till all was peroxidized, and so there was no discharge till the plate was full. For the positive plate it was found best to use minium, and for the negative red-lead as a coat. If the quantities of coats and liquid were properly adjusted, both plates would be filled together; but, as a matter of fact, this was not attained. That was the Faure principle, in which there were no reversals of current, and the economy in time over the Planté or reversing system could be estimated from the fact that a Faure cell was prepared in a week, whereas the Planté cell took 2 or 3 months to fill, while there was no essential difference in the results of the 2 forms of storage. The time and expense of production were thus greatly diminished under the Faure system. But in practice it was not found easy in the Faure cells to make the coating adhere to the plates for any length of time. The red-lead or minium had no affinity for the lead steeped in the liquid, and speedily peeled off, and the difficulty arose, how could the 2 substances be kept together. The first attempt at a solution was to place porous material between the plates, and then the composition was literally tied on to the plates by bands of cloth. But this did not give a good chemical contact with the plate, and another difficulty was that the cloth was rapidly attacked and decomposed by the dilute sulphuric acid. To prolong its life, the best trousering cloth was used, and this proved very expensive, and did not last long nor give a good contact; besides this, the coats and plates would not bear such shaking as they would sustain in transit by railway.

A further improvement was devised, and consisted in putting the oxidizing coating into perforations or interstices of the metallic plates themselves. This was hit upon by Swan and Sellon almost simultaneously, Swan being actually the first in point of time. In the perfected battery known as the Faure-Sellon-Volckmar, the lead becomes a grid filled with an oxidizable composition. First of all, cast-iron moulds are prepared, scored all over like a gridiron with a network of straight channels. Two of these matrices are put together, and the molten lead is poured into them; rectangular pierced sheets of lead are cast as the result. These framed grids are then filled with composition litharge for the positive and red-lead for the negative plate, the composition being made into a pulp with diluted sulphuric acid, and run in. Though the plates may be somewhat dusty, the composition adheres well to them, and can only be removed by bending the plates back. The next stage is to form cells. A large number of plates are put together in a trough, the positives and negatives being kept apart, and each plate is separated from the next by a frame of india-rubber. The dilute sulphuric acid is then poured in, and the plates are slowly peroxidized. They gradually become blackened upon the lines of the lead-work, the centres of the holes being the last portions to change colour, and the whole surfaces are in a spongy condition, accessible to the liquid. A peroxidized plate has a soft crystalline appearance of a deep brown colour. The plates are then stored in Faure cells ready for use, being carefully isolated by the india-rubber bands. Another plan is now being tried by Thornton, of pushing out the composition from certain holes, and filling them up with projecting india-rubber plugs; but if the plugs are not bent, no contact is possible under the present plan. The state of saturation in the liquid is ascertained by an ingenious copper balance and hygrometer. The plates are made in 2 sizes, one double of the other, and are packed together, 9 positives and 9 negatives, in a box. The small sizes of cell are known as ½ h.-p., and the large ones as 1 h.-p. cells, the term signifying, of course, such a power "per hour," and combinations of cells are manufactured up to 5 h.-p., the only difference being in the number of plates per cell. About 16 ampères per hour can be stored in a small pair of plates, and such a pair will discharge a current for 6 to 8 hours, giving forth 160 ampères. Having explained the process of charging and discharging the cells, Dr. Lodge mentions that the reduction of the sulphate is rather troublesome. and it is desirable that no more sulphate should accumulate than is absolutely necessary. It grows more rapidly during idleness than in action. Indeed, if kept in action, these cells are very efficient; but if suffered to be idle, they rapidly degenerate. Much of the difference found in cells is due to their comparative use and idleness. The sulphate on the positive plate is less important than that on the negative, because the oxide attacks the former far more readily. The secret of the most economical use of a secondary battery lies in charging it slowly, never filling the cell beyond its capacity, and in never completely draining it; it should be discharged as slowly as practicable. The electromotive force in a small or ½ h.-p. cell is about 2 to 2·1 volts per hour, or about 20 ampères for 6 or 8 hours. The amount of energy is nearly uniform for this period, and then rapidly falls—a far more satisfactory condition than one in which the cell regularly diminishes in power from the commencement.

Prof. Lodge points out the extreme value of peroxide of lead, it acting better than any other known electro-negative. In an experimental cell he used 2 plates of lead. If he substituted a clean piece of platinum for the negative lead plate, the platinum acted as plus to the peroxide of lead, though whether it was really attacked by the dilute sulphuric acid he could not tell. But by substituting for the platinum a piece of copper, the latter metal was more strongly plus, and its action, as tested by the ringing of an electric bell, was not only stronger, but of longer duration. The copper was dissolved, and formed a sulphate of copper. This would proceed either until the dilute acid was saturated, and could take up no more copper, or, if the copper plate was relatively small, until it was completely dissolved. This is the principle of a Sutton cell, but with the action reversed. As tested by its ability to ring a bell, such a cell shows for some time no signs of falling of. It is not very clear why the Sutton cell is not in more general use, although possibly it is liable to run down during the night or when idle. Lead is not strongly plus to peroxide, and hence the use of a lead plate as a support for the peroxide. Gladstone and Tribe have said that a thin coat of varnish formed on the plate. On removing the peroxidized or positive plate from the cell, and substituting for it a hydrogenized plate, a very slight, almost infinitesimal action, is perceptible. This film or scum on the lead is therefore resistance; and the result of the experiments is not due to electromotive force, and this scum is of very great value in preventing local action on the plus plate. Using a piece of spongy lead, the scum or film takes longer to form, and the electric bell will ring for a considerable period. Lead can be rendered spongy or porous in various ways—electrically, chemically, or mechanically; and by any of these means one can obtain an almost indefinite extension of the surface of the negative or minus plate, thus postponing the period at which the scum formed on its surface renders it effective, and enabling it to outlast the positive or plus plate. In passing, he refers to the great advantage derived from the inactivity of lead in its use as a support for the peroxide. When he took a piece of clean lead for the peroxide plate, it refused to pass a current after the first instant, and if this were not the case, they would be unable to use it as a support on account of the local action, for the plate and its peroxide coat would act as a miniature cell. Thus, if a piece of copper fell into a cell of this class, a primary battery would be formed, and holes would be eaten into the lead. The reason for this protection was the thin but insoluble film of sulphate of lead which protected the plate, and was vital to the life of the cell, for if it were soluble, a violent effervescing action would be set up. Experiments have shown that manganese is not so good as lead. It has been attempted to meet some of the defects of lead by using carbon with it, but the coat is non-adherent and troublesome. Lead is therefore, on the whole, the most suitable material at present known. The minus plates can be improved by being made spongy, or perforating or folding them. The plan adopted by Watt, of Liverpool, is to force a jet of steam under high pressure against a stream of molten lead, which is thereby deflected against a board, from which it is removed in a spongy condition. In the Sellon-Volckmar cell, the lead is perforated, and in the process of Kabath the metal is bent or folded. The plates may again be coated with salt of lead, either electrically, as in the Planté cell; chemically, as in Schultzer's, who prepares his plate incrusted with a thick sulphate; or mechanically, as in Faure's process. In all the varieties of coated plates tried, Lodge had not found anything much better than the Planté cell; but several other considerations had to be borne in mind in selecting secondary batteries, such as internal resistance, weight, and compactness of the cells. The ½ h.-p. Sellon-Volckmar-Faure cell is equivalent to 20 ampéres, 2 volts in 9 hours, and the h.-p. cell is just double that power, and equals the raising of nearly 2 million foot-lb. The percentage of quantity of available work is very good in these cells—from 80 to 90 per cent., and even more, of the charge being utilized; and it is well established that the more slowly a cell is charged the less waste is apparent, and were it practicable, the discharge should be equally slow. The next point is as to the use of the secondary battery; and the first, because most obvious, is for lighting purposes, for which the cells have many advantages. As stores for electric power for use in lighting conveyances making short journeys, they will be highly useful. Small vessels, cabs, and tricycles can carry with them boxes giving sufficient power for some hours' lighting; and it is well known that the Pulman train between London and Brighton has for some time been lighted by secondary batteries. Another advantage is that by this means you can use for a short time a higher power than an engine can give. It is not economical to run an engine for a few hours only, and by the cells the engine can be kept going all day, and a larger horse-power can be expended in lighting energy during the evening. There is less danger of sudden extinction, for a cell is not liable to give out suddenly, as is a belt to slip from an engine. Greater steadiness of light is attainable, the secondary battery acting as a governor, and it will also be utilized as a governor, performing the function of a cistern or so-called gasometer. Any fluctuation in the dynamo is not communicated to the lamps. If used for electric installations, the reservoir will probably be in a central place; but there are advantages in having separate boxes in each house. This is the cistern as opposed to the constant supply system, and it is probable that, as in water services, the latter, by which a central store supplies the force, will be most popular. The central supply of electromotive force will be equally available for incandescent, arc, and other forms of lamp at the same time. The excellence of the result is due to the remarkably low internal electrical resistance of the cells, and in this respect they differ from any batteries. In these cells the internal resistance is as small as ·0016 of an ohm, rising to ·002 of an ohm when nearly exhausted. Where a gas-engine is employed it is not important, as with a steam-engine, to keep it continuously at work, and with this motor the secondary battery should be used as a regulator rather than a store. A waterfall is an instance of a motor where economy demands that it shall be employed continuously; by the use of secondary batteries, a 70 h.-p. fall would provide a 100 h.-p. light at night. For domestic lighting, the problem is how to reduce the electromotive force so as to render it perfectly safe for household purposes. Dynamos have a high internal resistance: secondary batteries will give the same amount of electromotive force with far less resistance. For an energy of 2000 h.-p., the resistance would, with the cells, be less than 2 ohms, but would rise to about 400 ohms with a dynamo. A high electromotive force is most economical; but to obtain this directly from a dynamo, the rate of revolution must be enormous, and the friction is correspondingly great.

On the formation and construction of lead batteries, some valuable notes have been contributed by J. T. Sprague to the *English Mechanic*, mainly as follows.

Planté's directions for charging are to effect 6 or 8 reversals of current the first day, prolonging the successive charges; this is continued next day till the duration of useful charging becomes a couple of hours; at this limit it becomes necessary to give intervals of rest between the charges, during which a local action takes place: these rests require gradual prolongation to several days, and even weeks; after the cell approaches the capacity of storage intended, the current should not be reversed, but the cell should simply be charged and discharged as if in actual work. The process of this forming, therefore, occupies some months, except with very thin plates, and if pushed too far, the whole substance of the plate may be converted into peroxide, which would render it liable to break up, and would increase its resistance.

Heat assists the formation and reduces the time required for the process; therefore during the process of charging the temperature may be advantageously raised to 100° to 160° F. (38° to 71° C.), and allowed to fall as soon as the charge is effected. But heat is objectionable in actual working, because it facilitates the oxygen and hydrogen assuming the gaseous state and going off to waste.

Alcohol added to the extent of 5 per cent. to the acid solution is said to assist the formation. Berliner states that it requires but an hour to develop a heavy oxide surface capable of taking a large charge.

Nitric acid is recommended by Planté, who says that by soaking the plates for some hours in nitric acid mixed with an equal volume of water, he has greatly reduced the time of formation. The effect is to produce a porous surface more quickly acted upon; but it is evident that for this treatment the plates should be thicker.

Electro-deposited lead has been tried for the same object. But lead is a very troublesome metal to deposit; unlike other metals, it does not spread as an even film, but will dart out in fine arrows from points on the surface, which either fall off as they lengthen, or close the circuit to the other plate; for this reason the presence of lead salts in solution, or the use of acids, &c., which will dissolve lead, is very objectionable.

Amalgamation of the lead has been employed by Paget Higgs. It is by no means clear that it is an advantage on the whole: it must tend to weaken the lead, and therefore to fracture of the plates. It is not desirable or useful at the peroxide plate, because it resists the formation of PbO_2, and tends to form oxide or salts of mercury; the mercury also prevents the molecular union of the lead and peroxide, which latter therefore tends to separate from the plate. It is probable that mercury facilitates the absorption of hydrogen at the leaden plate; but even there the advantage is very doubtful, because in regular working the real action which goes on is the reduction of the lead sulphate which has been formed during discharge.

The plates may be either flat plates interleaved like those of a condenser, or they may be large plates rolled up as cylinders, or folded up together. Flat plates give a simpler construction, and have the great advantage that they can be "formed" in a separate vessel and combined as desired; each can also be removed singly in case of injury, and easily replaced. They have a serious disadvantage, however. It is evident that the molecular volume of lead salts exceeds that of lead, so that there is constant expansion and contraction going on, which tend to produce bulging surfaces. and this much more readily upon flat parallel plates. It is therefore desirable to introduce slips of glass or other insulating material to resist this, and prevent the plates coming in contact. The cylindrical form is made by laying a long sheet of lead on a table, placing upon it a number of strips of soft vulcanized rubber arranged diagonally upon the lead, then another sheet of lead with similar diagonal strips; the sheets are then rolled up firmly so as to form 2 parallel spirals separated from each other. The insulating strips can be inserted as the rolling up proceeds. The thickness of the lead must be sufficient to bear its own weight and the strains put upon it after use; the peroxide plate should therefore be about double as thick as the other. In large batteries, lead 1 millimetre (·03937 in.) thick is used, or about 24 sheets to the inch; 1 sq. ft. of lead 1 in. thick weighs 59·1 lb.; therefore this would be about 2¼ lb. lead. The smaller cells are made of lead little thicker than that prepared for damp walls, which is about 4 to 5 oz. per ft. For ordinary purposes, it is probable that sheets of 1½ lb. and 1 lb. would be most advantageous, with the formation carried so far as to convert ½ lb. of the lead to peroxide on the one plate.

Connections must be provided to the sheets in either form, and the best is made by strips of lead attached carefully to the sheets by soldering, which should be well protected by good cement; copper wire should not be used, as it is sure to be acted upon, and form salts, which will exert a very mischievous action.

Containing vessels may be of any suitable material, but glass has the great advantage of permitting the action to be watched; if leaden, or wood lined with cement, or other opaque vessels are used, they should be covered with sheet glass for this reason. They must not be entirely closed, because gases are generated, and must be allowed to escape; they should not be uncovered, in order to resist evaporation, and also for prevention of dirt, which would be likely to result in short-circuiting the plates—a thing very likely to occur, and obviously injurious to the working.

Space for acid must be allowed, sufficient to effect the action; therefore the distance of the plates must be so adjusted. Circulation cannot be depended on, but it is desirable to raise the bottom of the plates above that of the vessel, and to allow the liquid to rise above them, in order that the heat and escape of gas may tend to produce a current, and to draw the external acid between the plates; 1 lb. of lead requires ½ lb. of acid to convert it into sulphate, and as by the foregoing proportions there would be ½ lb. of lead to be converted on the 2 faces of lead opposing per sq. ft., this requires space for ¼ lb. of acid, which, diluted as 1 to 10, would be contained in a space of ⅓ in. between the plates.

The strength of the acid varies during the action, becoming strongest when the charge is complete, and one plate is converted into spongy lead and the other into peroxide; when discharge is completed, a great part of the acid is absorbed in the formation of sulphate of lead. Several consequences result: (1) the resistance of the battery is lowest just when its electromotive force is highest, and *vice versâ*, which introduces a variation in the current generated at different periods of discharge; (2) when the material consists of a porous mass containing liquid confined among its interstices, the acid may be entirely removed at an early period of the discharge, and consequently much material remains unacted upon; also, the residuary liquid being highly resistant at the next act of charge, the current cannot reach the material. As a consequence, a cell containing a large mass of active material may be able to do but little work. This defect is also an accumulative one: portions of the mass become practically non-conducting, and insulate other portions to which the acid has access, because in very dilute acid, instead of the normal sulphate $PbSO_4$, there is a tendency to produce the basic sulphate $PbSO_4 + PbO$, which is not readily reduced by hydrogen.

To charge a secondary battery it is necessary to employ an E.M.F. greater than its own, and greater in proportion to the rate of charge desired. All such excess of E.M.F. is energy lost in overcoming resistance; therefore slow charge is most economical under this head, though other practical considerations have to be taken into account, *i.e.* against energy lost at the rate of the square of the current generated, must be reckoned time and interest on plant. But in addition to the loss of energy involved, a small charging current is desirable for 2 good reasons: (1) the product is in better condition, the particles being in closer contact and better electrical connection; (2) there is less loss by uncombined gases escaping.

Throughout the charging there is a constant escape of gases going on, chiefly oxygen; and the loss of either gas means total loss of the equivalent of electricity involved in the decomposition from which it arises. If O is wasted, H is lost too, or the total power of the cell is reduced by its incapacity to take up the O. But the escape of H indicates either that the rate of charging current is too great, or that the limit of the economical charge is approached. The rate at which a unit area of surface can act properly, in the case of a secondary receiving charge, is a lowering capacity, because it is related to the diminishing quantity of lead sulphate remaining unconverted. The increase of free acid tends to increase the current, and the combination of these 2 causes results in a growing loss of gases as the charge proceeds. Obviously, therefore, it is bad economy to press the charge to the full capacity.

The electromotive force is about 2·25 volts immediately after charging, but falls spontaneously to 2 volts. This high initial force cannot be due to the free H and O, because their force of combination is only 1·5, but it is easily accounted for by the presence of ozone, which is oxygen charged with a higher energy in order to force the third atom of O into the molecule. The normal E.M.F. of 2 volts is subject in working to a fall such as occurs in ordinary batteries to an extent increasing with the rate of current, and due probably to the change in the liquid particles adjoining the plates: therefore the E.M.F. rises again after a short rest has allowed fresh liquid surfaces to reach the plates by diffusion. The average rate of working E.M.F. is probably 1·9 to 2 volts.

Metallic solutions, while promising in appearance, do not answer in practice. The action, unless very slow, alters the layer of liquid in contact with the metal, which then refuses to act; in charging, after the first action, there is no metallic salt present to decompose, but only acid which gives off gas, and so the metallic deposit becomes noncoherent; in discharge, the metallic salt forms too rapidly to dissolve, and crystallizes on the plate.

Acid solutions other than sulphuric might be used, and no doubt will; but hydrochloric acid when electrolysed does not give up H and Cl simply—it is always accompanied with oxygen, and the result is the formation, not of chlorides, but of oxychlorides, which are exceedingly refractory in reduction; for this reason, the silver chloride battery fails in reversal, or it would constitute an admirable storage battery.

Alkaline solutions cannot be used with lead, because they dissolve it; but they may be employed with some other metals, as iron, which would absorb H at one plate and form peroxide at the other, producing a battery of rather low E.M.F.

In charging a number of cells, it is necessary so to arrange them in series and in arc as to distribute them on the same principles as ordinary battery cells when a number are used together. So many must be ranged in series that the number multiplied by the E.M.F. is so much below the charging E.M.F. as allows the required rate of current to pass; that is to say, E (or 2·25) × n × 1·25 = E.M.F. of source, assuming that this is to exceed the counterforce of the battery by ¼. So many must be ranged in multiple arc as brings the united resistance to such a ratio to the available E.M.F. as will permit the intended rate of current to pass; such rate being well below the proper working density suited to the area of the plates.

It is of the utmost importance that all cells to be worked together shall be fairly equal, for, as in a chain, the capacity of a combination is that of the weakest link; if some cells become inactive in discharge, they are not merely useless, they begin to take charge in the opposite direction and oppose their E.M.F. If several sets in multiple arc differ in E.M.F., which will occur if their conditions differ, some of the sets will not get charged, or if left so connected when the source is not acting, they will be reversed, and the charge be wasted.

The charge should not be carried to more than ¾ of the capacity. The discharge should not be carried farther than ¾ of the charge actually stored; and the battery should not be charged, if avoidable, long before it is intended to be used.

Each cell should be occasionally tested as to its condition, in order to discover any derangement or accidental short circuit, and any cell showing unusual evolution of gas should receive immediate attention.

Galvanometers should always be kept in circuit, to give warning as to what is going on: and automatic cut-outs are very useful in case of a failure of the source, or other accident. Such appliances are easily made with an electro-magnet inserted in the circuit, or in a shunt circuit, with a permanent steel magnet for the armature, mounted on a spring, and completing the circuit only when held down: the attraction of the armature for the core will hold it down ordinarily; but if a reverse current arises, the armature leaves the magnet, breaks the circuit, and can be made to ring a bell to call attention.

It is asserted by some that secondary batteries will return 90 per cent. of the energy stored. It is quite likely that 90 per cent. of the electricity, reckoned in coulombs, might be obtained, provided the battery were used not long after charge. But what is really important is, the energy depends upon the E.M.F. as well as the current; and as the E.M.F. of charge must exceed that of discharge, and may probably exceed it by ⅓, here is an inevitable loss, which cannot be defined for all cases, because it will depend upon the ratio of the external and internal resistances. This only gives the loss upon actual storage; there is to be added that lost in the act of charge, and that carried away in the escaping gases. When all these are considered, it is almost certain that, on the average, the use of storage batteries means the loss of 50 per cent. of the energy as compared with direct working. This means doubling the cost, irrespective of the value and expense of the battery itself. (J. T. Sprague, *Eng. Mech.*)

Henry Greer, of New York, gives a good detailed account of the construction of the various secondary batteries before the public, in his pamphlet on the 'Storage of Electricity.'

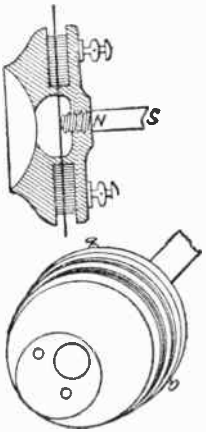
Telephones. — Before describing the construction of various forms of telephone, it is necessary to explain the principles underlying its mode of action. The sensation felt in the organ of hearing, and known as a "sound," is due to waves or vibrations in the air acting upon the tympanum of the ear. In this transmission of sound, the particles of air or other conductor are not transported, but the vibration of one particle is communicated to the next, and so on, the intensity becoming less as the distance increases. This constitutes the main fault of the so-called "string telephone," the earliest and simplest form of apparatus for communicating speech —its range is limited. The telephone proper differs from other instruments of a like class, in that it reproduces instead of merely conveying vibrations, and has thus a practically unlimited range.

Forms.—Various forms of telephonic apparatus may now be discussed.

(1) String Telephone.—This is formed of 2 metallic or cardboard tubes, in the shape of a cylindrical cone; one end is closed by a tightly-stretched parchment membrane, in whose centre the string intended to connect the 2 cylinders is fastened by a knot. When 2 such tubes are thus united, and the cord is tightly stretched, words may be conveyed along it by the speaker placing the opening of one tube to his mouth, and the listener putting his in the same way to his ear. The distance which may thus be traversed does not exceed 170 yd. The best results are said to be got from silken cord and the worst from hempen; cords of plaited cotton are generally used for economy. Some preference is given to nickel silver as the material for the mouth-pieces. Several modifications have been proposed. Millar ascertained that by means of a telegraphic wire, stretched and connected by 2 copper wires with 2 vibrating disks, musical sounds might be conveyed to a distance exceeding 160 yd., and that by stretching these wires through a house, and connecting them with mouth-and-ear holes in different rooms, communication between them became perfectly easy. For the vibrating disks he employed wood, metal, or gutta-percha, in the form of a drum, with wires fixed in the centre. The sound seems to become more intense in proportion to the thickness of the wire. Heaviside and Nixon ascertained that the most effective wire was No. 4 B.W.G. They employed wooden disks $\frac{1}{8}$ in. thick, and these may be placed in any part of the length of the wire. When the wire was well stretched and motionless, it was possible to hear what was said at a distance of 230 yd., and it seems that Huntley, by using very thin iron diaphragms, and by insulating the line wire on glass supports, was able to transmit speech for 2450 ft., in spite of the zigzags made by the line on its supports.

(2) Kennedy's Telephone (Figs. 106, 107) is of the "Bell" type, but differs in its principle of action and in construction. No coils of wire are used on the magnets; but 2 coils are used, one on each side of the ferrotype plate, the wooden case being turned out so as to form 2 spaces for the wire, also to grip the plate, leaving 2 in. of the centre of the plate for vibrating; the plate is 4 in. to 6 in. diameter; 2 to 4 oz. of No. 30 wire may be used in each space. The action of the telephone is this:—On current passing through the coils, the plate is magnetized, with its centre a S pole, say; the plate is therefore drawn inwards. On a reverse current passing, the centre of the plate is magnetized as a N. pole; the centre of the plate is therefore repelled outwards—that is the action when it is used as a receiver of alternately reversed currents, such as produced in the Bell telephone or in the carbon telephone used with an induction coil as a transmitter. It may be used as receiver or transmitter just the same as Bell's telephone. A pair of them tried on the same circuit with a pair of Bell's, spoke much louder, and, what is of more importance, the articulation was much more distinct.

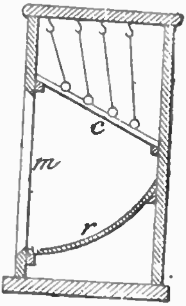
FIGS. 106, 107.



(3) Thompson's.—Prof. S. P. Thompson's improvements relate to telephonic transmitters based upon the principle discovered by Reis, of employing current-regulators actuated, directly or indirectly, by the sound-waves produced by the voice. By "current-regulator" is meant a device similar to that employed by

Reis, wherein a loose contact between 2 parts of a circuit (in which are included a battery and a telephonic receiver) offers greater or less resistance to the flow of the electric current, the degree of intimacy of contact between the conducting pieces being altered by the vibrations of the voice. In Reis's transmitter, in Edison's, and in other well-known forms of this instrument, the action is indirect, a tympanum of stretched membrane or other equivalent organ, such as a diaphragm of mica, being used to collect, magnify, or concentrate the vibrations of the voice, and to convey them to the points of loose contact that regulate the current. In other forms of transmitter (for example, some of Hughes's microphones), the mode of action is direct, the air-waves beating directly upon the conductors or electrodes which are in loose contact, without the intermediation of a tympanum or diaphragm. Of these 2 classes of telephone transmitters—viz. those in which the current-regulator is combined with a tympanum or diaphragm, and those in which the current-regulator is acted upon directly by the air-waves of the voice—the improvements relate to the latter only, as Prof. Thompson dispenses with the membrane tympanum used by Reis, the tympanic diaphragm of mica used by Edison, and does not even employ any diaphragm in the sense of a partition between the current-regulator and the air-waves of the voice, as in Theiler's transmitter. In Thompson's transmitters the air-waves act directly upon the current-regulator itself. As a result, the articulation is clearer for some of the consonantal sounds, which are only imperfectly or difficultly transmitted by telephones in which the current-regulator is affected indirectly through a tympanum, diaphragm, or partition. Transmitters of the class to which the improvements relate are ordinarily liable to 2 defects. Firstly, they do not articulate so loudly as transmitters in which there is a tympanum or diaphragm to collect or magnify the vibrations. Secondly, when, to obviate this difficulty, the speaker speaks with his mouth very close to the current-regulator, the moisture of his breath condenses upon the contact points or adjacent parts of the regulator, interfering with its action and spoiling the articulation. The improvements relate chiefly to means for remedying or obviating these defects. Prof. Thompson proposes to employ mirrors, sound-reflectors or reverberators (one form of which is shown in Fig. 108 in transverse section), consisting of glass, metal, wood, or other material, by which the sound-waves are turned aside from their direct path, and are made to converge upon the current-regulator, precisely as rays of light may be turned by a mirror. If actual mirrors of polished metal or silvered glass are employed for this purpose, they have the additional advantage of revealing to the speaker the presence of moisture. But in any case the mirror serves to collect the sound-waves as they come from the speaker's mouth, and to direct them on to the current-regulator while intercepting moisture from the speaker's breath: *m* is the mouthpiece or tube; *c*, the current-regulator; *r*, the reverberator. An adjusting screw and an outlet cock for the water which collects in the mouth-tube are also provided where necessary. The mouthpieces hitherto used on ordinary transmitters are not intended to serve either as reverberators or as protectors from moisture, and Prof. Thompson finds that mouth-pieces for this purpose must, as shown in Fig. 109, be deep and of conical or paraboloidal form. Another part of the invention consists in employing for the current-regulator such materials as are at once neither hygroscopic, nor liable, by their properties with respect to heat, to condense films of moisture, while at the

FIG 108.



same time they are good conductors of electricity. Prof. Thompson prefers to use as materials for the current regulator, either spongy platinum, carbide of platinum, boron, coke, carbon, or elastic carbon specially prepared, having first deprived such materials of their hygroscopic properties by treatment with petroleum. or other suitable hydrocarbon. In some cases. and especially where the contact surfaces of the current-regulator are of metal, he finds it convenient to keep their surfaces constantly moistened with petroleum or other hydrocarbon by supplying them through a cotton filament in communication with a small lubricator. The improvements also consist in so arranging the parts of the current-regulator that the points of loose contact can be actuated by the sound-waves, whilst they are protected from the moisture of the breath by some portion of the conductors or electrodes projecting between the contact points and the breath of the speaker. An example of such an arrangement is given in Fig. 110, wherein the contact-points *c* are protected from the breath by making one of the electrodes in the form of a cup, against the concave face of which the contact-point on the other electrode is directed. The improvements relate further to the form of the conductors or electrodes combined to serve as the current-regulator. The current-regulator of Reis, consisting of one piece of platinum resting lightly against another, is imperfect, except when, as in some forms of Reis's instrument, one or both the pieces of metal are fixed upon springs or some equivalent elastic support; otherwise, the current is liable to very abrupt interruptions. In Fig. 111 is shown a current-regulator, wherein the two contact pieces are held upon springs *s*; one of these springs is fixed to an adjusting frame *b*, and the other to an insulating block *k*, for it is found that when there are many points of contact instead of but a single pair of such points, there is less liability to such abruptness. Multiple contacts, therefore, are advantageous. One of the improved forms of current regulator consists of a framework of prepared carbon or metallic tongues, so connected that the current cannot pass from one to the next except through pieces of good conducting carbon or metal, suspended or resting in loose contact against the tongues. In the instrument shown in Fig. 108, the current-regulator *c* consists of an inclined grating of carbon strips, against which the voice-waves

FIG. 109.

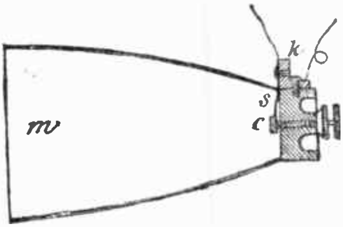


FIG. 110.

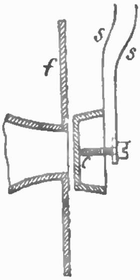
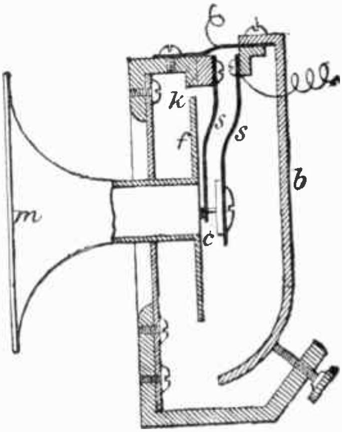
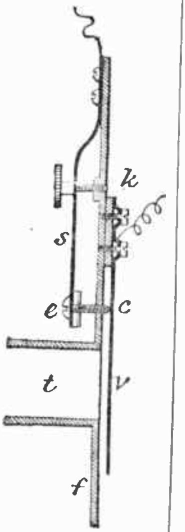


FIG. 111.



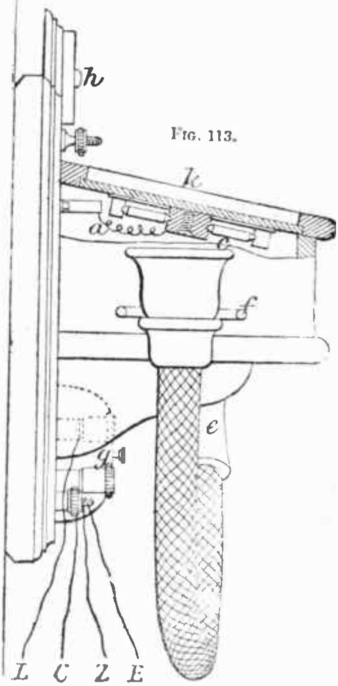
are reflected by the reverberator *r*, and upon which rest light balls of carbon or metal suspended from hooks by silken strings. In some cases, where a highly powerful action is desired, the air-waves are caused to act first on a vibrating tongue, which then transfers the vibrations indirectly to the current-regulator or contact points *c*. Such a vibrating tongue is shown at *v* in Fig. 112, where it is attached behind a flanged tube *t*, the contact-points or current-regulator *c* being on the same face of the tongue *v* as that against which the voice-waves impinge. This tongue may be itself an electrode, and serve as part of the current-regulator, in which case it is formed of metal, carbon, or elastic conductor, whether anhygroscopic or not. (*Eng. Mech.*)

FIG. 112.



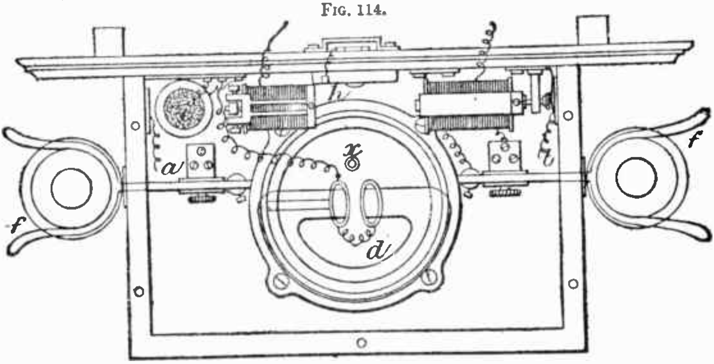
(4) Gower's Telephone is a combination of a telephone and microphone in the same case, which arrangement affords all the advantages obtained by the employment of a battery for communication, without its accompanying objections, and without destroying the effect of the telephone when it is employed as a transmitter in the case of a battery failing. Fig. 113 is a side elevation of the apparatus partly in section, a portion of the side of the box being removed in order to show the communication between the microphone and the principal circuit. Fig. 114 is a plan, the microphone being removed in order to show clearly the arrangement of all the parts on the interior of the box. Fig. 115 is a plan of the underside of the microphone shown in Fig. 113. This microphone is connected with the principal circuit by means of wires, which are broken off in the figures.

FIG. 113.



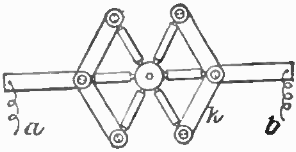
When the plate of the microphone is in the position shown in Fig. 113, so as to close the box, the wire *a*, Fig. 115, is joined to the wire *a*, Fig. 114, and the wire *b*, Fig. 115, is joined to the wire *b*, Fig. 114. In constructing the apparatus, a microphone *c* of any suitable construction (but by preference having at least 6 contact-points) is attached to the upper part *k* of a box, the lower part of which box is provided with a Gower telephone *d*, constructed in the form known as the chronometer telephone. This telephone is provided with a bifurcated acoustic or speaking tube *e*, having 2 branches, in order to enable the operator to listen with both ears if required. Commutators *f* are provided at the side of the box, for the purpose of interrupting the passage of the current from the battery, and opening the circuit of the call-bells. After working the apparatus, the extremities of the acoustic tubes *e* are placed in holders connected with the commutators *f*, and the circuit is thereby interrupted. An electric call-bell *g* is provided underneath the box, and a knob *h* for working the call-bells is placed at the upper part of the apparatus. An induction-coil *i* is situated inside the box, and the microphone *c* and the battery are connected to the primary circuit, whilst the Gower telephone and the line are connected with the secondary circuit. In speaking against the upper part *k* of the box, which may be of wood, iron, brass, or other suitable material, and near or upon the under surface of which the microphone is placed either with or without attaching the microphone to the box top directly, the sound-waves from the voice form electrical undulations in the primary circuit through the action of the microphone, and these undulations are reproduced in the secondary circuit by induction, and are thus repeated in the Gower telephone at the receiving station. Especial attention is directed to the fact that the microphone in this combination is not necessarily attached to the box top, but that it may be carried upon a framework attached at any point to the combined apparatus. The undulations, however, when so reproduced, are intensified to such an extent by the great power of the magnet in the Gower telephone, that they act upon the microphone in the same case with such effect as to set up corresponding undulations in the primary circuit at the receiving station, and these undulations are again reproduced in the Gower telephone with increased intensity.

FIG. 114.



Moreover, when the diaphragm of the telephone is provided with a vibrating reed *x*, Fig. 115, as is usual in the Gower telephone, it is simply necessary to close one of the branches of the acoustic tube, and blow into the other branch, in order to cause the reed to vibrate, and thus produce powerful vibrations of the plate before the magnet. These vibrations not only produce currents in the coils or the poles of the magnet, but also act with great power upon the microphone, the sound being produced in the interior of

FIG. 115.

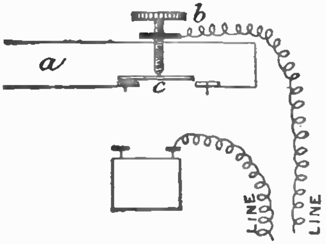


the same box, and thus double the effect of the signal current on the line wire without exhausting the battery to any greater extent than when speaking in the usual manner through the apparatus.

By employing this combination of magneto-electric and electro-magnetic currents, it is possible to act with great power upon what is known as the "Ader" disc, or upon any other suitable receiving instrument at the distant station, as well as in the case of a system worked with a central office, and any suitable arrangement of the mechanical parts may thus be employed at the receiving station. It also results from the employment of this combination that a failure of the battery will not stop the communication, the Gower telephone being always capable of working the apparatus, whether employed as a receiver or as a transmitter, provided that the wire is not broken, whilst it is also possible, when the Ader signalling apparatus is employed at the central office or other receiving station, to transmit a signal without employing a battery, as in the case of the ordinary Gower telephone. The employment of bifurcated or double acoustic tubes obviates the necessity for having a separate instrument as receiver, and thus enables the flexible conducting wire to be dispensed with, which wire constitutes one of the principal objections to the use of telephones in practice.

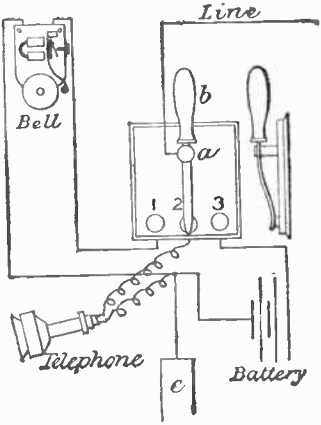
(5) Calls.—(*a*) This is not so noisy as bells, yet sufficient for the purpose. Fig. 116: *a*, tube; *b*, brass screw, platinum-pointed; *c*, brass block and platinum reed. On blowing into the mouth of the tube at *a*, a musical note is produced by the vibration of the reed *c*, and the circuit is interrupted at the point *c*, the effect of which is that the note is produced at the distant station with nearly the same force. The effect would be augmented if a small induction-coil were placed with its primary terminals, connected across at zinc line, and the ends of secondary coil joined to zinc proper. The point of the screw may be nearer the end of the reed than is shown.

FIG. 116.



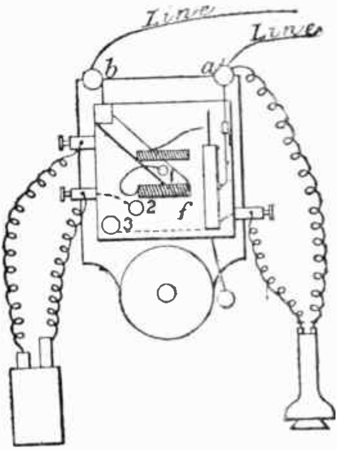
(b) Fig. 117: *a*, board; *b*, brass spring fitted with a handle for convenience of shifting; 1, 2, and 3 are the studs, connected as shown. It will be observed that one of the wires from telephone bell and battery is connected to the earth-plate *c*, or return wire. In the position shown, the telephone is in use; if the spring is moved to No. 3, the bell at the other end of the line (the apparatus is supposed to be in duplicate) will ring, provided the switch is on No. 1 stud. Keep the switch on No. 1 to let the home bell be rung. (Cory.)

FIG. 117



(*c*) Fig. 118, making the bell-case act as switch-board. *a b* are the line terminals; *a* is in connection with one terminal of bell, battery, and telephone respectively; *b* is connected with switch-

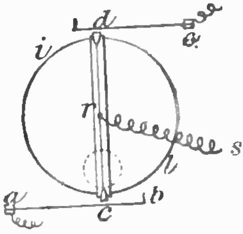
FIG. 118.



arm *f*, moving over studs 1, 2, 3, which are the other terminals of bell, battery, and telephone. Dotted lines on the box show the connections inside, which can be easily made out if each circuit be followed separately. The action has been most satisfactory.

(*d*) Fig. 119: *idl* is a brass wheel, the edge of which is milled, and which

FIG. 119.

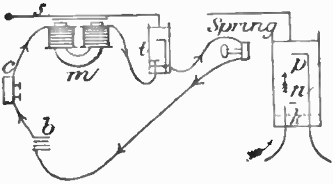


runs on the axle *r*, connected with the wire *rs*. The end of the wire *s* is connected with one of the poles of an electric battery, the other pole of which is connected with the earth-plate or return wire; *ed* and *ab* are springs, *a* being connected with the earth-plate through the telephone. and *e* with the line wire; *crd* is a flat piece of ebonite (or wood steeped in paraffin), with two brass studs *d c* fixed into each end, and in metallic connection with one another by a wire: this ebonite is firmly fixed on the wheel, so as to insulate the studs *d c* from it. The dotted circle at the bottom of the wheel represents a lump of lead, fixed behind, so as to keep the wheel in the above position when not being turned by a handle fastened in front. It will be seen that when the wheel is turned out of the above position, the spring *ed* will press upon the milled edge of the wheel, and thus establish electrical communication between the wire *e* and the wire *s*, which is connected with a battery. But when the stud at *d* is moved round, the stud at *c* will also move, and the spring *ab* will then be released, and tend to press on the edge of the wheel, from doing which it is restrained by a small pin in front of the spring at *b*. In the position shown in the figure, a current entering at *e* from the line wire would take the course *edca*, and then go back through the telephone and earth. When the wheel is turned, however, any connection between the spring *ab* and the wheel is impossible, on account of the pin at *b*, but the spring *ed* presses on the milled edge of the wheel, which is connected with the battery, and thus, while the wheel is being turned, numerous small currents are sent along the line, which generate a loud musical note in the telephone at the other end, and thus call attention. No bells are used, and when attention is to be called at the other end of the line, a handle has merely to be turned; the trouble is thus extremely slight. (T. A. Garrett.)

(6) Augmenting Sound (Fig. 120).—A simple contrivance for augmenting the sound of the telephone, by increasing the variations of current by pressure on a tube filled with powdered carbon, caused by an electro-magnet. The current from the battery *b* flows through carbon telephone *c*, where it meets with varying resistance; from this it goes to

the electro-magnet *m*, which it magnetizes and causes to attract a small piece of soft iron attached to the spring *s*, and produces pressure in the glass tube *t*, which is filled with powdered carbon. From the magnet the current passes to a wire introduced into the lower part of *t*, the bottom of which is stopped with a cork; from this wire it passes through the powdered carbon to another wire higher up in the tube. When the current is strongest, there will be the greatest pressure on the carbon, and so the least resistance; when it is weakest, there will be least resistance. The tube by itself is shown on the right. The bottom is stopped by a piece of cork *k*, through which are introduced the wires *p* and *n*, of which *p* is covered with an insulating substance as far as the bent part. In the top of the tube is fitted a piece of thin iron, against which the spring is caused to press.

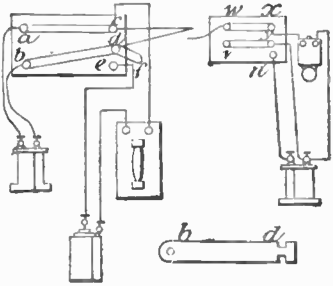
FIG. 120.



(7) Cheap Magnets.—Procure from a saw-sharpener 2 old 6-in. 3-square files, worth not more than 1*d*. each. Put one in a vice and knock the shank end off (that which fits in the handle) to within ¾ in. of main part of file; take out, measure off 5 in. from shank, put the file in the vice the reverse of what it was, and knock the other end off, as near as you can so that it will be 5 in. in total length, and you will have (when magnetized) a magnet with an iron pole-piece, the shank being much softer than any other part of the file. Grind the shank round as near as you can, for your coils to go on; with such magnets you can lift a ¼-lb. iron weight. They also work through greater resistances than the roll steel commonly used. They speak very plainly. Magnetize them with 3 horse-shoe magnets, putting 2 on the table with their opposite poles 4 in. apart. Bridge the spaces with 2 files, and use the third for magnetizing. Commencing at the centre of the file, rub it to one end of the file, then return to the centre and pass to the other end, and so on, finishing at the centre, and slide the magnet off; then proceed with the other one.

(8) Circuits.—(*a*) Switches for telephone, microphone, and bell (Fig. 121).

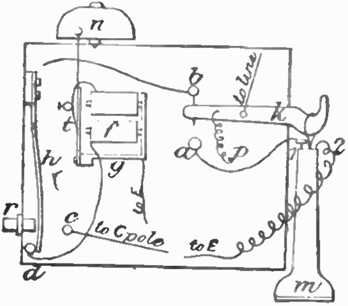
FIG. 121.



To ring bell, move the brass slip *ac*, working on *a*, to form *ad*; and upon moving *bd*, working on *b*, to form *be*, the bell will ring if your battery is strong enough; if not, place a piece of copper wire to join your telephone terminals, which will take out the *r* of the coil within, as shown. The receiver hearing the bell, turns *vy*, working on *v*, to form *vz*, and then *wx*, working on *w*, to form *vy*, and answers. The transmitter now may speak by the microphone, or by replacing strips as shown by telephone alone. *df* is to cut out the telephone and use microphone alone. The message ended, all strips are replaced as shown; the battery circuit is then broken until you require to "telephone" again, proceeding as before. Telephone wire is usually small; consequently, the resistance through it, the telephone coil, and coil bell, is considerable. (Hannen.)

(*b*) Telephone Circuits and Call (Fig. 122).—When the button *r* is pressed, the spring *h* makes contact with support *c*.

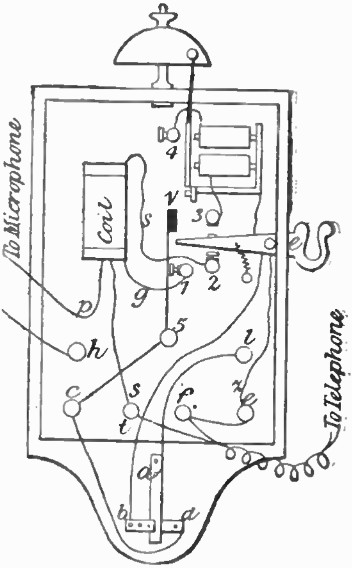
Fig. 122.



A current then flows from battery to *c* through spring *h* by means of a wire to *b*, thence through *k* to the line. Through the line it enters the other end through *kbh* to *d*; from *d* through coil *f* to terminal *t*, through the keep and frame *g* to earth, ringing the bell *n* as it does so. On taking the telephones off the hooks at both ends, the currents produced by speaking into them are sent through *a* to *k*, and then to line entering *k* at the other end through *a* to the telephone there, and from end 2 of bobbin to earth or return wire. These connections can be made out of any old pieces of brass, screws, &c., and fitted up in a box. So long as the contacts are clean and firm, it will work as well as if better made. *k*, automatic switch arrangement, brass hook pivoted so that a spring fastened to it and point *p* would keep it down firm on *a* if telephone *m* were taken off; *a* is connected with one end of telephone bobbin; *b*, brass post so placed that *k* presses firmly against it when *m* is on the hook; *h*, brass spring normally pressing firmly upon *d*, and capable of being pushed hard against *c* by means of ebony button *r*—it is connected by a wire to *b*; *c*, brass post connected with positive pole of battery; *d*, brass post connected to one end of coil of bell movement *f*; 2, an end of telephone bobbin connected to earth or return wire.

(*c*) Ditto (Fig. 123).—This is the same as supplied with the Blake's Transmitter, and is as simple as any. The hook *e* has the telephone off; the spring *f* has drawn the hook contact down on contact 2; *s* is the secondary wire of the coil; a current coming from *s* passes through contact 2 into hook to *b*, through contact to *a* to terminal *l*, this being line. The other end of secondary *s* is fixed to terminal *t*; *f* is connected to terminal *ze*; zinc of battery and earth is connected to terminal *ze*—hence the two letters; the telephone cord is connected to *tf*; the primary wire of coil, one end *p* to microphone, the other end *g* to contact 1; *h* is terminal of transmitter zinc; *c* is terminal for copper or carbon end of battery. When the telephone is on the hook, it draws it down and places hook contact in contact with bell contact 3. A current now being sent from the other end to ring up, passes through *lab* to 3 through bell coils, regulating screw 4, through keeper and frame to *ze*. The act of taking off the telephone allows the hook to slide

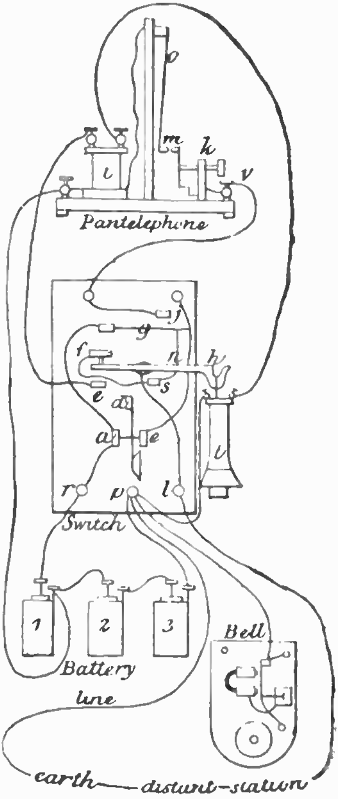
Fig. 123.



off the vulcanite *v*, and lets the ring 5 come in contact with contact 1; this puts *c* in connection with one end of primary *p*; the other end *g* was already in connection with *h* through the microphone. The instrument is now ready for speaking to. A current coming through line passes through *ab*, hook 2, secondary wire to *t*, through telephone cords, coil, *f* to *zc*. To ring up, *a* is pressed on *d*; this does not affect your own instrument, as *a* leaves *b* before it touches *d*, so cut your own instrument out. (Tolman.)

(*d*) Transmitter and Switch (Fig. 124). —The pantelephone is a good transmitter when combined with an induction-coil, not without. The hanging plate may be made of pasteboard, also of thin wood, with like results, but the best effects are got when the contacts are of carbon only. The figure shows a very useful switch suitable for working the 4 instruments required in successful telephony—viz., the telephone, microphone, bell, and battery. To call attention at the distant station, where it is assumed the same kind of instruments are in use, press the button *b* on switch for a second or two; this breaks contact with *c*, and makes contact with *a*. The current now flows from the battery, cell No. 1, through *a* to *d*, on to *f*, then along lever *h* to its centre, and down to post *l*, thence to line, and on to distant station, where it rings a bell; then to earth, and back again to central post *p* on switch, then to cell No. 3, and so completes the circuit. The "call" will be answered by the home bell ringing, produced by the same operation of pressing the button *b* at the distant station. This sends a current into the line to the home station, which, entering the switch at *l*, passes upwards to the lever *h*, along this to *f*, then to *d* and *c*, and upwards to one of the top parts, then out to bell, which it rings in passing, and on to centre post *p*, and back through earth to distant station, and so again the round is completed. Now remove telephone *t* from the hook *h*; the spring *s* at once lifts up this lever, and through the insulated connection (a silk thread) *n* allows the spring *g* to make contact with *j*. Contact is also at the same time made by the lever with *e*, and broken at *f*. This operation brings the microphone or pantelephone into action.

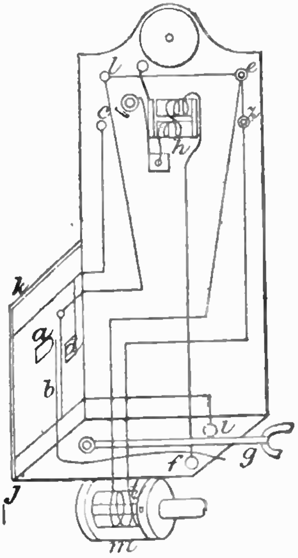
FIG. 124.



The current now flows from No. 1 cell only, this being sufficient to work the local circuit through the microphone. Its course is through *agj* to pantelephone, then passing by *k* through the loose carbons *m* to *o*; up this it passes by a wire, then down on the other side to the induction-coil *i*, where it flows through the primary wire and back to the same cell No. 1. The secondary wire terminates in 2 binding posts on the top of the coil. This wire furnishes the current necessary to work the telephones. It starts, say, from the left-hand post and passes to *z* on switch, then along lever *h*, now in contact with *e*, and down to post *l*, thence through line to distant station, and through its telephone to earth, then back again it hastens to centre post *p* on home switch, and on through telephone to induction-coil, whence it started. The microphone bell and switch are best combined in one instrument. (Frank.)

(*e*) Switch for simplex Telephone (Fig. 125).—It is manipulated as follows:—

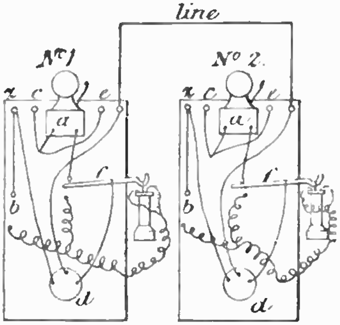
FIG. 125.



To call the distant station, press the button *a*, which breaks contact at *b*, and puts the line *l* and carbon of battery *c* in contact at *d*. The circuit is completed by putting the zinc of battery to *z*, whence the current passes through the receiver *m*, and out at *e*—either to earth or return wire. By this arrangement, the ringing at the distant station is repeated or made known at the sending station. The contacts at *b* are made with two strips of hard rolled metal, and continued under the lever *g*, which must be kept down on *f* while signalling with the bells, but be in contact with *i* when speaking. This is done by hanging the ear-tube on the lever hook, or the Bell receiver, should that be used instead of the electro-magnetic one. In coupling the instrument, the *l* of one is connected with the *e* of the other. The transmitter swings on 2 small brackets inside the front, and contact is made at *j* and *k* when the front is closed. The carbon-cups are made out of ½-in. carbon, and are best done with a rose countersink, large enough to take half the ball without touching the head of the screw which secures the cup in its place, or the cup may be glued in its place, contact being made by twisting a wire round the outside; the discs are made from slices of carbon-pencil with a groove round them to have wire twisted, and when the balls are screwed up in the case they should be quite free to rattle. The cups should be arranged 1 in. apart. An old saw and a file will do all the cutting and shaping, and if you have no lathe, a brace will answer the purpose. In the receiver, a bundle of iron wires takes the place of the permanent magnet, which was devised to meet the case of "Bell's" disclaimer, in which he disclaims a magnet excited by a battery in the line circuit. The adjustment of the diaphragm has to be made before finally screwing up, and will give no trouble if you observe to file the faces of the body of receiver and the core a dead level. Then cut a ring of stout writing-paper, with the hole about 2 in.; glue one on each side, and when the ferrotype plates are laid on, they will be the right distance from magnet, and may be screwed up. Instruments switched in this manner are as loud as any made; but they can only be used in pairs, unless a separate switch is used with each instrument to reverse the poles of the battery. But in order to remove that obstacle, if the receiver is formed of a small induction-coil instead of the simple one, then an alternating induced current is produced, without using an induction-coil in the instrument. The result of this will be that any resistance in long lines may be overcome by simply increasing the battery power to increase the power of the magnet, the induced current being proportionately strengthened.

(*f*) Communication.—Fig. 126 represents the 2 boards, one at each end of line, fitted with bell *a*, bell-push *d*, telephone, telephone-hook *f*, and terminals for transmitter *b*; also 4 terminals on the top of each for carbon of battery *c*, zinc of ditto *z*, earth *e*, and for line. Note the difference in battery wires in No. I. and No. II. stations. The push *d* is a 3-line push, line and bell being in contact; when pressed, bell is cut out, and line and battery are in contact. The hook is balanced on pivot *f*. When telephone is on it, the other end is in connection with bell stud; when removed, it falls to the other stud, and puts bell out and telephones in circuit. The currents pass as follows:—No. I. to ring up No. II.; *c* to push *d* and line, enters No. II. by line to push, hook, bell, earth, to *e* No. I. to *z*; No. II. to ring back; *c* to *e*, to *e* No. I., to bell, hook, push, line, enters line No. II. to push, *z* and *c*. To speak No. I. to II., unhang telephones each end; *c* to transmitter, telephone, hook, push, line; enter line No. II. push, hook, telephone, transmitter, *z* through battery to *c*, *c* to *e* No. I. and *z*. To reply No. II. to No. I. *c* to *e*, to *e* No. I., *z*, *c*, transmitter, telephone, hook, push, line. Enters No. II. line, push, hook, telephone, transmitter, and *z*.

FIG. 126.



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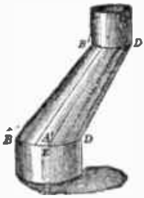

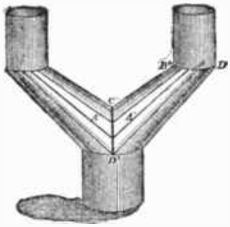

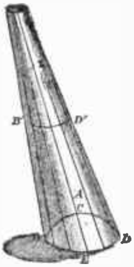

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