and the spring × pulls up the lever, M N, so striking the arc. The shunt circuit (fine wire) through S is still at work, and continues to operate the feeding, increasing as the resistance of the arc lengthens.

The present attempt to furnish a classification of the various mechanisms, electrical and mechanical, of the arc lamp is probably extremely imperfect, but it may at least claim to supersede the old and ludicrous division of lamps into "monophotal" and "polyphotal." In conclusion, it may be pointed out that there exists a curious sort of family likeness between the several members of the three species of lamps most in use. The rack train lamps, which may be considered as the prevailing Continental type, are for the most part, in their design and construction, essentially clockmakers' lamps; they have a horological aspect. The clutch lamps so universal in America have a sort of sewing machine look, the working parts being only finished where necessary for actual work, all else being left rough or merely painted over. The clutch wheel lamps favored by British inventors have, in contrast to these, a look as though they had been designed and constructed by a trained engineer; they are essentially engineers' lamps.

APPENDIX—SAMPLE OF FILLING UP OF SCHEDULE.

SCHEDULE OF ARC LAMP MECHANISM.

NAME OF LAMP.—Thomson-Houston. Single arc.
NATURE OF SUPPLY.—Constant current; *amperes* 9·8.
RESISTANCES.—*Main circuit coil*, 0·09; *shunt*, 279; *cut-out*, 0·85 *ohm.*

A	*Driving power*	Gravity on upper carbon rod.
B	*Striking*	Main circuit electromagnet attracts lower end of seesaw, lifts clutch.
b	*do. adjustment* ..	(1.) Special resistance coil shunting main circuit coil. (2.) Spring on tail of clutch.
C	*Feeding*	Shunt electromagnet attracts upper end of seesaw, lowering clutch.
c	*do. adjustment* ..	Same as *b*.
D	*Moderating*	Air dash pot on horizontal tail of seesaw.
E	*Replacement*	None required.
F	*Focusing*	None.
f	*do. adjustment* ..	None.
G	*Change-over.*	None.
H	*Cut-out*	Insulated contact on lower end of seesaw, pulled over by shunt coil, and puts cut-out resistance as shunt from + to — terminal.

A NEW GALVANOMETER FOR PROJECTION.*

By Prof. J. W. MOORE.

THE galvanometer about to be described has been used for many years and has given great satisfaction.

It is small, compact, cheap, and sensitive, and can be used apart from the lantern. Experiments which ordinarily require large and expensive apparatus may be well shown in connection with the ordinary lecture table instruments of the shops.

It is the well known two-coiled galvanometer adapted to the American form of vertical lantern. It was found that this lantern would project an object upon the screen if an aperture of only one inch and a half was allowed at a height above the stand of three and one half inches. Advantage was taken of this fact to adapt the galvanometer for projection. Fig. 1 represents the instrument apart from the vertical lantern.

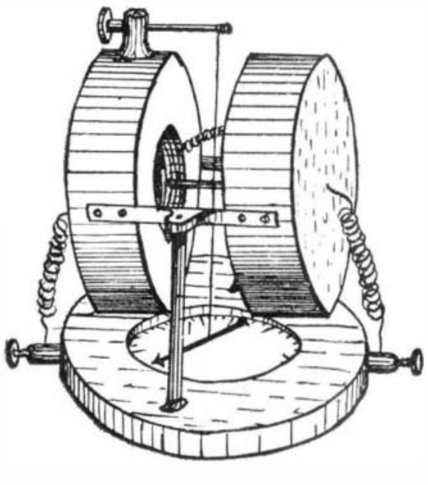

Fig. 1.

It may be very much diminished in size if brass is used instead of wood in its construction. Wire of different sizes can also be employed.

A wooden base five and a half inches in diameter was turned upon the lathe and made to fit the lantern stand; in the center a hole two and a quarter inches in diameter was cut; a shoulder was turned upon the circumference of this hole, wide enough to support a circular glass plate of suitable diameter, upon which a scale of 360° was photographed. The diameter of the scale is two inches.

About two hundred feet of No. 14 (0·064 B. and S.) insulated copper wire were wound into two coils whose external diameters were three and a half inches, and thickness one and a half inches. The diameter of the opening in each coil was about one inch. Two wooden boxes were provided in which the coils were placed, each spiral of the coil having been further insulated with paraffine and the whole box filled with the same substance. The resistance of the completed system is about 0·5 ohm.

Two metal pillars, three and one half inches high, are fixed in the wooden base, and the coiled wire is supported on these by metal cross bars screwed to the coil boxes. The boxes are separated a distance of one inch and a half.

On the top of one of the boxes a small standard is placed which holds a horizontal adjusting rod. This rod has a motion of translation, also of rotation. The magnetic part of the apparatus consists of a piece of steel knitting needle, one inch and a half in length, strongly magnetized. This needle is attached to a fiber of unspun silk, the upper end of which is fastened to the extremity of the adjusting bar. Since the needle is out of focus with the photographed scale, a light, stiff wire, at the lower end of which is attached an arrow made of thin writing paper, is fastened to the center of the needle and so adjusted that the paper arrow and the scale are projected upon the screen at the same time. The combined length of the needle suspension is about six inches. The length of the needle is in a horizontal plane passing through the centers of the two coils. The ends of the coil wires are permanently attached to two binding posts, screwed into the wooden base, for convenience in the attachment of wires. Fig. 2 represents the galvanometer placed upon the lantern stand.

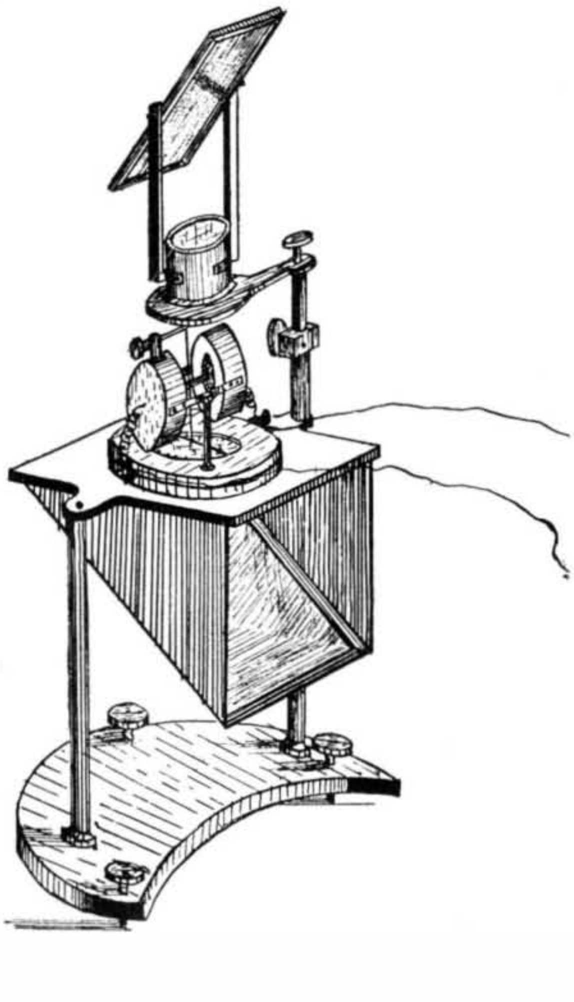

Fig. 2.

The image upon the screen is well defined and large enough, when the lantern is placed at a moderate distance from it, to be visible to a large audience.

This instrument has been principally employed in showing the fundamental experiments of electro-magnetic induction.

In 1831 Faraday's magnificent discoveries were made, which may be embraced in the following statement:

If a magnetic (including electro-magnetic *) field be cut across by a moving conductor or the field of a conductor by a magnet (including an electro-magnet) an electromotive force will be set up in the conductor when the number of positive lines of force embraced by the conductor is increased or diminished by the cutting.

A.—UNIFORM FIELD.

1. *Straight Conductor.*—The field of force surrounding a magnet may be uniform or variable. The lines of magnetic force surrounding the earth, in a limited space, are straight, parallel, and equidistant. The field, therefore, is uniform. Their direction is determined by that of the dip needle, which places itself tangent to them. The earth, therefore, may be used to prove the truth of Faraday's statement.

An insulated copper wire was stretched from one side of the lecture room to the other, a distance of thirty-five feet, and connections made to the galvanometer as represented in Fig. 3. The wire hung loosely

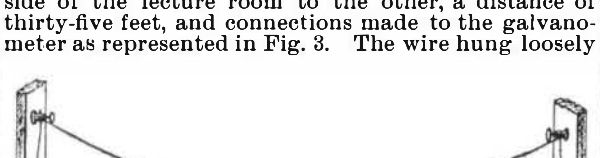

Fig. 3.

like a jumping rope. Upon swinging it in one direction across the earth's field, a deflection of the needle took place. When the needle was allowed to come to rest and the wire was swung backward, there was a deviation of the needle, but opposite in direction.

From the middle of the wire a weight was suspended so as to convert the wire into a pendulum of the same period as the needle. As the pendulum oscillated to and fro, impulses properly timed were given to the needle, and the deflection increased greatly in amplitude. The original number of lines of force embraced in the circuit was diminished by swinging the wire toward the galvanometer, and increased when swung from; therefore, momentary currents were induced.

It is evident that if the wire were moved so as to cut the earth's lines at right angles, the number of lines cut, and therefore the electromotive force set up, would depend:

1st. Upon the number of lines in the field, that is, the strength of the field, which may be called *m*.

2d. On the length of the cutting wire, which *l* may represent.

3d. On the distance the wire is moved parallel to itself, which may be denoted by S.

4th. On the time, T, during which the cutting takes place, all of which facts may be expressed in the equation

$$E\,M\,F = m\frac{S}{T}l, \text{ or representing } \frac{S}{T} \text{ (which is a velocity)}$$

by V, $E\,M\,F = m\,V\,l$, all of which truths were proved by Faraday.

2. *A Circular Coil.*—To intensify the effect a circular coil of insulated wire, Fig. 4, two feet in diameter, was

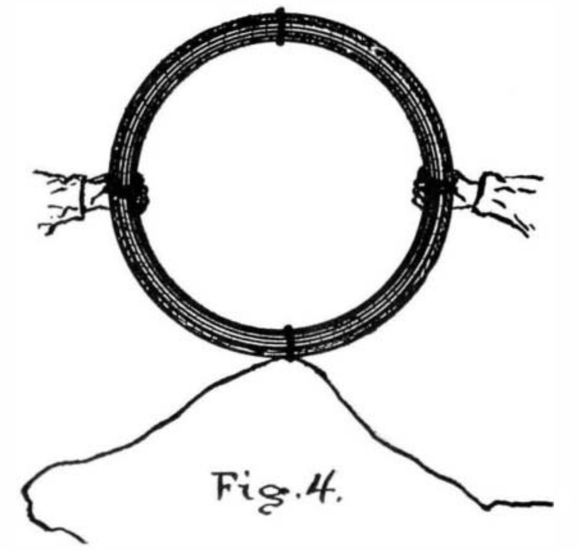

Fig. 4.

used, the extremities of which were joined to the galvanometer. When the coil was placed with its plane perpendicular to the dip needle and then moved parallel to itself, the number of lines embraced remained unchanged and the galvanometer needle failed to respond. When the coil was held in the same position and rotated upon its axis, there was no deflection, for the same reason. If the coil was given a motion of translation, there was no current, since the same number of lines was cut positively as negatively; but when it was rotated on an axis in its plane, the needle was deflected; if rotated backward, the needle was deflected oppositely.

The electromotive force for a single loop can be easily calculated, for let *m* equal the strength of the earth's field, then $m\pi r^2$ represents the number of lines embraced when the plane of the loop is perpendicular to the lines of force—*r* representing the radius of the loop.

If the loop is rotated through 180°, each half cuts through $m\,\pi\,r^2$, therefore the whole number cut through is $2\,m\,\pi\,r^2$.

If a number of loops, *n*, is used as in the experiment just described, the average electromotive force is equal to $n\,(2\,m\,\pi\,r^2)$. This apparatus is the same in principle as Delezenne's ring.

In order to determine the direction of the induced currents, we may use the ordinary *memoria technica* represented in Fig. 5.

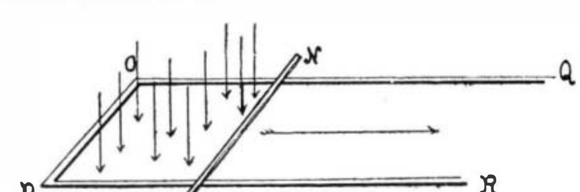

Fig. 5

Let O Q and P R represent two conducting rails in electric communication by means of P O. Imagine M N to be a moving axle. The arrows represent the lines of force of the earth. Now, if the observer looks downward in the direction of the lines of force and M N is moved to the right, the number of lines embraced by the circuit will be *increased*—an inverse current will be induced—that is, in the direction M N O P, or contrary to the direction of the hands of a watch. If M N is moved toward the left, the number of included lines will be diminished, a direct current will be induced in the direction N M O P, or clockwise.

Ampere's method may be modified to apply to all cases, as follows: Look in the positive direction of the lines of force, imagine yourself identified with the conductor; if you and the conductor are moved to the right, the number of lines of force embraced by the circuit will be increased, hence the current will flow from the feet to the head; if the motion is toward the left, the induced current will flow from head to feet.

B.—VARIABLE FIELD.

1. *Straight Conductor.*—When two insulated wires, Fig. 6, about fifteen feet in length, were stretched near each other, but not touching, and a current passed through one from the battery * used in experiments upon "lines of force," a distinct deflection of the needle of the galvanometer, connected with the other, became evident; when the current was broken, an opposite deflection occurred.

If the makes and breaks were timed to the oscillations of the needle, it was caused to swing through many degrees. When the circuit is closed, a field of circular lines grows around A B.†

On account of the nearness of C D, the galvanome-

* An expansion of a paper presented to the A. A. A. S., at the Cleveland meeting.

* SCIENTIFIC AMERICAN SUPPLEMENT, Nos. 642, 643, 644.

* SCIENTIFIC AMERICAN SUPPLEMENT, No. 642, p. 10256.

† SCIENTIFIC AMERICAN SUPPLEMENT, No. 642, p. 10256, Figs. 3 and 3a.

ter circuit embraces some of these, and a current is induced. When the battery circuit is broken, the field surrounding A B dies out, and hence the lines embraced by C D have no existence, that is, a less number is embraced. This illustrates the difficulties met with

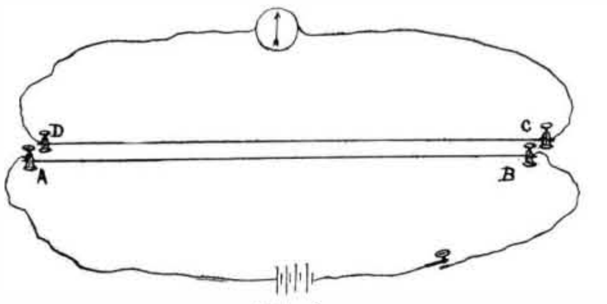

Fig. 6

from induction on telephone lines in connection with the Morse system, and the alternating currents of light machines.

2. *A Loop and a Coil.*—The usual lecture table apparatus employed for illustrating electro-magnetic induction is represented in Fig. 7, and called a "dissected coil." The electro-magnet fastened to the base is the

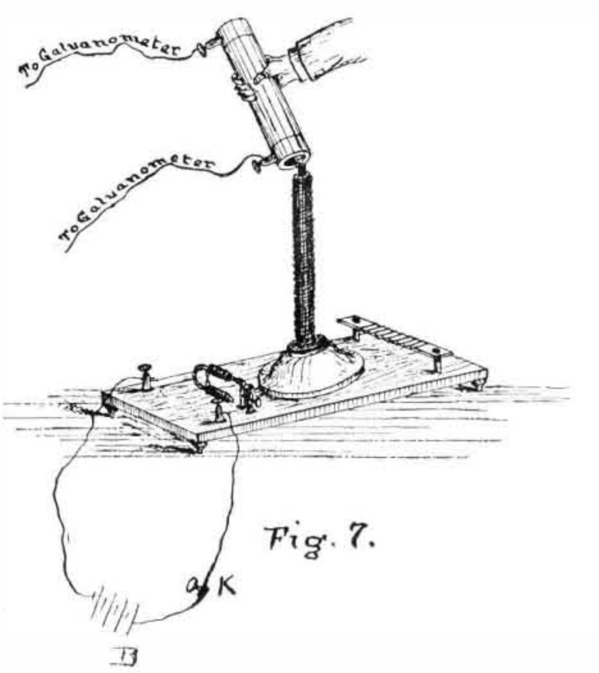

Fig. 7.

primary coil; the coil held in the hand is called the secondary. The former consists of a few turns of thick insulated wire, the latter of many turns of insulated thin wire.

Let the secondary coil be entirely removed, and then pass the current of the battery, B, through the electro-magnet. A reference to Figs. 23 and 29, SCIENTIFIC AMERICAN SUPPLEMENT, No. 644, shows that lines of force spring up from the upper extremity like the branches of a tree, which turn down and meet the lines striking out from below like its roots. Pass the current so that the upper end is a N pole—the plus direction of the lines will then be from the N, upward, outward, and downward, toward the S pole.

If now the simple loop, connected with flexible wires (Fig. 8) to the galvometer, be brought down over the top of the electro-magnet, a sudden slight deflection of

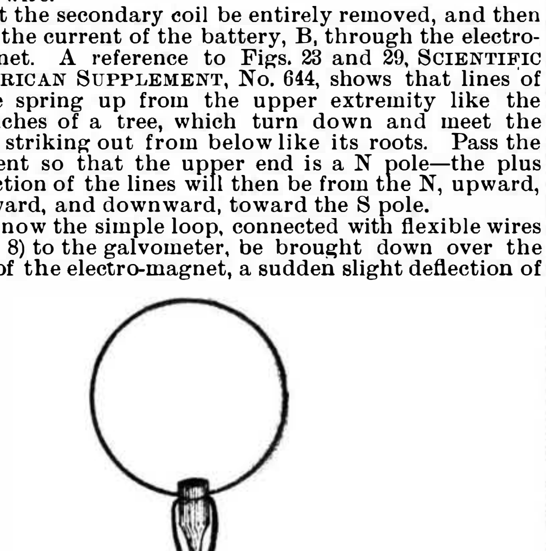

Fig. 8.

the needle will be observed; if the loop be stopped at the middle, the needle will come to rest. If now the loop be suddenly removed, the needle will be deflected in the opposite direction, and will again come to rest.

If the approach and recession of the loop are timed to the swing of the needle, a very large displacement may be observed.

It is obvious that when the loop approaches the electro-magnet a greater number of lines of force is embraced in its circuit, and, upon its withdrawal, a less number; hence the experiment proves—

1st. That a current is induced upon both the approach to and withdrawal from a constant current of a conductor.

2d. That these currents are instantaneous.

3d. That they are opposite in direction to each other.

The effects may be greatly intensified by disconnecting the loop (Fig. 8) and connecting the secondary coil (Fig. 7) to the galvanometer. On approaching the electro-magnet—slipping it over the electro-magnet—a violent push is given to the needle in one direction, and, upon suddenly withdrawing it, a violent deflection in the opposite direction. The needle may be caused to violently rotate.

It is desirable to know the direction of the induced current in the loop.

In order to determine this it is necessary to imagine one's self fixed in a certain position, relatively to the electro-magnet and loop. As good a convention as any is to look in the positive direction of the lines of force (*i. e.*, the direction a free N magnet pole would be urged; upward in Fig. 3). Now, holding the loop in a horizontal plane and looking upward from the electro-magnet, if the loop approaches, the number of positive lines embraced will be *increased.* A current from right over to left, anti-clockwise, will be induced, that is, an *inverse* current.

If the loop is withdrawn, the number of plus lines will be *diminished* and a *direct* or clockwise current will be induced.

This is practically the same as the method already given above.

3. *Primary and Secondary Coils Fixed Relatively to Each Other.*—When both the electro-magnet and conductor are at rest relatively to each other, so that no motion is possible to either, the number of lines of force embraced by the conductor may be increased or diminished by increasing or diminishing the magnetism of the electro-magnet.

Fig. 9 is sufficiently clear. It represents the ordinary "dissected coil" coupled up with two batteries, B_1, B_2,

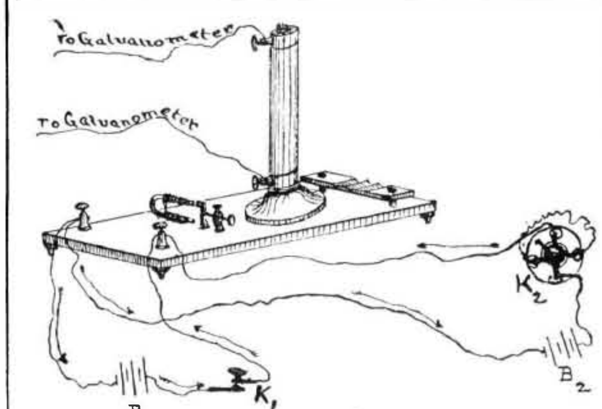

Fig. 9.

and a key in each circuit. The secondary coil is placed over the primary, and connected with the galvanometer. It is obvious that when no current passes there is no field. Allow K_2 to be opened. Immediately the circuit is closed by the key, K_1—the lines of force grow up around the electro-magnet, and the secondary coil embraces its maximum number; hence *closing* the circuit here is equivalent to *approaching* the electro-magnet with a movable coil.

If the circuit is broken by K, the branches and roots of the magnetic tree wither and disappear, and the number of lines embraced now is *nil;* the needle is deflected in the opposite direction. *Breaking* the circuit is therefore equivalent to *withdrawing* the conductor from a fixed field; *hence, as the books put it, a current is induced when tne primary current is made or broken.*

The direction of the current is obviously determined as before. This is the principle of the inductorium.

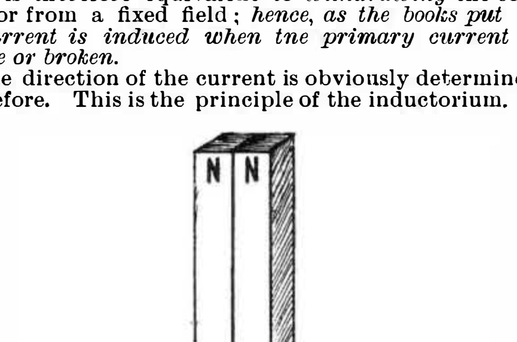

Fig. 10.

If K is kept closed and the commutator, K_2, manipulated, it is obvious that the current in the primary coil will be increased and diminished in strength according as the current of the battery, B_2, is sent in the same or opposite directions to the current of B_1. If the primary current is strengthened, additional lines of force will grow up and be embraced by the secondary coil; if weakened, a less number will be included. In each case a momentary induced current will be made evident by the galvanometer.

The ordinary text-book statement is that currents may be induced by increasing or diminishing the strength of the primary current.

4. *The Field of a Permanent Magnet.*—Since a permanent magnet, as regards its external effects, is the equivalent of an electro-magnet,* two ordinary steel magnets, each nine inches long by one half an inch square, Fig. 10, were substituted for the electro-magnet in Fig. 7.

When the magnets were placed with their north poles up so as to have a field like that of the electro-magnet, exactly similar effects were produced with the loop, Fig. 8. On approaching, the needle was deflected in one direction, on withdrawal in the opposite direction; the currents were momentary, and their directions in the wire could be determined by the usual convention.

When the secondary wire of the "dissected coil" was connected with the galvanometer, Fig. 11, and used in

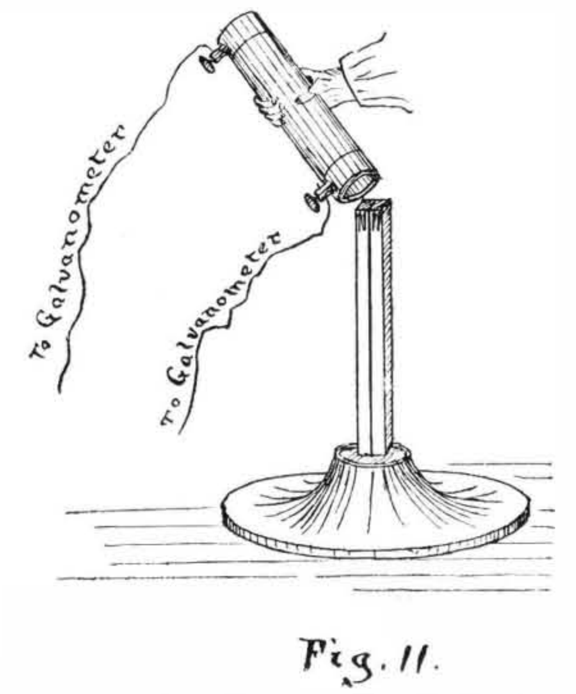

Fig. 11.

the same manner as the loop, more striking results were exhibited.

The method of expressing these facts in the text-books is that a current is induced in a conductor when it is brought up to or withdrawn from a magnet.

This experiment illustrates the principle of construction of the magneto-electric machine.

Fig. 12 illustrates an interesting form of experiment. Remove the secondary wire from the dissected coil,

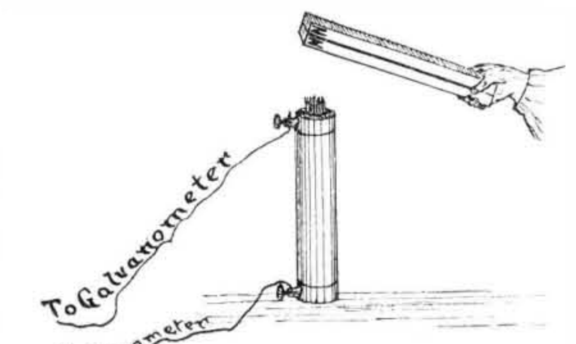

Fig. 12.

connect it with the galvanometer, and introduce into it a bundle of soft iron wire. It is obvious that if in any way the wire can be magnetized, a field will grow up around it, and the surrounding conductor will embrace an increased number of lines of force—if demagnetized, the lines will disappear.

To effect this result, bring up near to the bundle the

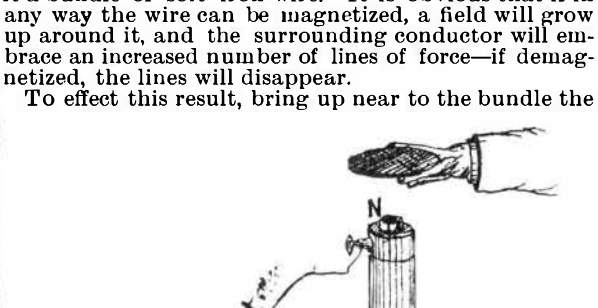

Fig 13

two magnets of Fig. 10. Instantly the needle is deflected; withdraw the magnet, the needle flies in the opposite direction; hence, as the books put it, a current may be induced by the production or destruction of magnetism.

Fig. 13 represents another form of the experiment. It is evident that if the production and destruction

* SCIENTIFIC AMERICAN SUPPLEMENT, No. 644.

of magnetism can induce a current, an increase or diminution of magnetism already existing will produce the same effect.

In Fig. 13 the bundle of soft wire is removed and the two magnets are put in their place.

If a piece of soft iron, as in the figure, or a bundle of soft iron wire be brought near and withdrawn from N, the magnetism of N will be altered and the needle will exhibit the effect by moving to the right or left.

This is the fundamental experiment in the telephone receiver of Bell.

SELF-INDUCTION.

The phenomena of self-induction can easily be exhibited by this galvanometer. Fig. 14 represents, in

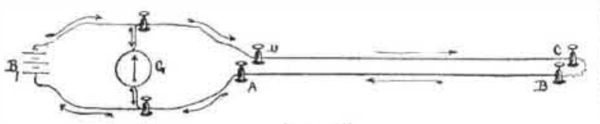

Fig. 14.

diagram, the connections. The two wires of Fig. 6 are joined at their extremities, B C, with a short piece of wire, so that A B C D is now continuous. A very weak battery, B, is coupled up with the galvanometer, G, and the wire, A B C D; when the circuit is closed, the current divides at the binding posts as represented in the figure. The needle is deflected through a number of degrees.

Now, while the current is passing, turn the needle back to its original position, then suddenly *break* the circuit; the needle will be deflected in a direction opposite to that due to the original current. But, when the battery circuit is broken, where does the current come from which deflects the needle oppositely?

While the current is passing, the circular lines of force of A B and C D mutually embrace each other. When the circuit is broken, each part embraces a less number; therefore a current is induced. It is the same direction as the original current.

When the circuit is made, an induced current is set up opposite to the battery current. These were formerly called extra currents.

It is obvious, therefore, that the part of A B C D adjacent to D C may be treated as if it were a separate circuit.

The effect may be greatly magnified by replacing A B C D with the coil so much used in that system of electric gas lighting in which the extra current on breaking the circuit is employed.

Lafayette College, Easton, Pa.

THE ELECTRICAL TREATMENT OF SEWAGE.

MR. WILLIAM WEBSTER recently gave a practical demonstration of his electrical method for the purification of sewage, at the main drainage outfall at Crossness. Permission was obtained from the Metropolitan Board to erect temporary experimental works on a piece of vacant ground at Crossness, the expense being defrayed by the inventor, who had his sewage for nothing, except that he bore the cost of pumping. On the present occasion Mr. Webster showed how he could deal with a flow of sewage equal to 12,000 gallons per hour. The works were avowedly not the best that could be devised for the purpose, the ground being limited in extent, and experience being wanting at the outset. By the time the works were finished, it was easy to propose some better mode of setting them up. The dynamo was not in the best place. The two portable engines, used alternately, were made a quarter of a century ago, and the provisional nature of the works showed itself in various ways. The experimental works have a capacity for dealing with half a million gallons of sewage per day.

Mr. Webster describes his invention as consisting of an improved mode of electrolysis for oxidizing and precipitating organic matter and decomposing inorganic salts, such as chloride of sodium, potassium, magnesium, etc., and all salts contained in sewage. For this purpose, in treating sewage and similar impure liquids, he subjects the liquid, while flowing through channels or reservoirs, to the electrolytic action of positive and negative electrodes made of iron and having very extended surfaces. Ammonia and other alkalies are evolved at the negative electrode, and assist the precipitation of the iron salts formed at the positive pole, where at the same time nascent oxygen and chlorine are evolved, partly acting on the iron and producing an acid reaction whereby the organic impurities in suspension are precipitated, while those in solution are oxidized and converted into innocuous compounds. Of course the nascent chlorine will have much greater efficiency than the chlorine present in chloride of lime, and the nascent oxygen will have much more effect on the organic matter in the form of albumenoids than the oxygen of the atmosphere.

The mode in which this process is made to operate will be seen by the accompanying engravings. The ground plan, Fig. 1, representing an area of about 250 ft. by 60 ft., shows the position of the two engines and the dynamo. At a little distance to the rear of the latter is the pump for raising the sewage; the shed containing the engines and dynamo appears on the right in the perspective engraving, Fig. 2. Facing the shed in this engraving and in the ground plan are a range of precipitating tanks. These tanks were used for taking experimental measurements, so as to discover the best mode of arranging the electrodes. Practically they form no part of the present working arrangements, and they would not be repeated in any future works. The sewage raised by the pump passes on through the shoot which runs along one side of the ground plan, and is finally received into one or the other of the settling tanks. A portion of the shoot appears on the right hand side in Fig. 3 opposite the implement shed. Between the shoot and this shed appear the tanks, as on the plan. In Fig. 2 another portion of the shoot is seen opposite the engine shed, with the precipitating tanks intervening. The shoot is an electrolytic channel in which are the iron electrodes arranged as shown in the small sectional drawing, Fig. 4 The shoot is made of wood, but in any permanent work would be constructed of some stronger material. Owing to the restricted space, the shoot at Crossness is fitted with wrought iron plates, but in practice it is intended to make use of cast iron, run direct from blast furnaces. As the sewage travels along the shoot, every particle of the liquid comes into contact with the plates, and is thereby subjected to the electrolytic action. A separation of the solid particles from the actual liquid speedily shows itself, and increases in its intensity as the sewage approaches the settling tank, into which it ultimately descends, and where the separation reaches its final stage.

Each of the portable engines is of 20 horse power. Only one engine is used at a time, both for pumping the sewage and for driving the dynamo. The dynamo is an Edison-Hopkinson, capable of developing an energy of 43 horse power. From the dynamo the leads run through resistance frames, by means of which the amount of current passing on to the electrodes can be regulated without varying the speed of the engine. From the statements made by Mr. Webster it appears that with 27 horse power it is possible to treat one million gallons of sewage in twenty-four hours, presuming the sewage to be of the same strength as average London sewage. In estimating the cost of the engine power, reference is made to the fact that the newest type of engine for driving dynamos may be taken to consume 2 lb. of coal per horse power hour. The price of coal regulates the result. As for the iron consumed in the process, the experiments tend to prove that the consumption in continuous working should not exceed two grains per gallon of sewage. Plates 1 in. thick, if used in sufficient numbers, would last for many years when once fixed. By way of illustration it is stated that the consumption of iron in the case of a town with a population of 333,000, having a volume of sewage equal to ten million gallons per day, or thirty gallons per head, should not exceed 464 tons per annum. The amount of mechanical power required per head of the population is shown to be $\frac{1}{1225}$ horse power, or 8 horse power per 10,000 of the population. A very small electro-motive force, only a little over 2 volts, is used, and about 11 square feet of iron electrode surface per ampere. There seems to be no polarization of the electrodes in the channels.

Running from the shoot, and allowing one hour for settlement in the open tanks, the average of twenty analyses shows that under this treatment raw sewage of a very turbid and opalescent character yields a clear and odorless effluent. Estimated in parts per 100,000, the suspended matter is reduced from 33·35 to 1·56. Nitrogen as free ammonia is reduced from 4·34 to 3·22, and albumenoid matter from 0·5 to 0·2. Chlorine as chlorides becomes 18·62 instead of 21·64, and the oxygen required to oxidize the organic matter becomes 0·52 instead of 1·24. A sample of raw sewage, very turbid and opalescent, and with a bad odor, yielded a clear effluent without odor. The sewage contained 14·52 parts of suspended matter, 5·95 being mineral and 8·57 organic. In the effluent these quantities became respectively 1·48, 1·05, and 0·43. The free ammonia declined from 3·57 to 2·9, the albumenoid matter from 0·6 to 0·28, and the chlorine as chlorides from 14·61 to 13·39. The oxygen required to oxidize the organic matter was 4·03 in respect to the sewage, compared with 1·34 for the effluent.

The disposal of the sludge is a final consideration in this as in other processes where precipitation takes place. But the sludge from the electrolytic action is not swollen by the admixture of any foreign ingredients beyond one or two grains of iron per gallon, which as oxide becomes somewhat more.

In the course of the day's proceedings Mr. Webster stated that he estimated the working cost of his process at 13s. per million gallons of sewage treated. This was irrespective of interest on capital and the allowance to be made for depreciation, except that it included the waste of iron. On 150 million gallons per day, representing the whole of the London sewage, north and south, at the present time, the cost at the

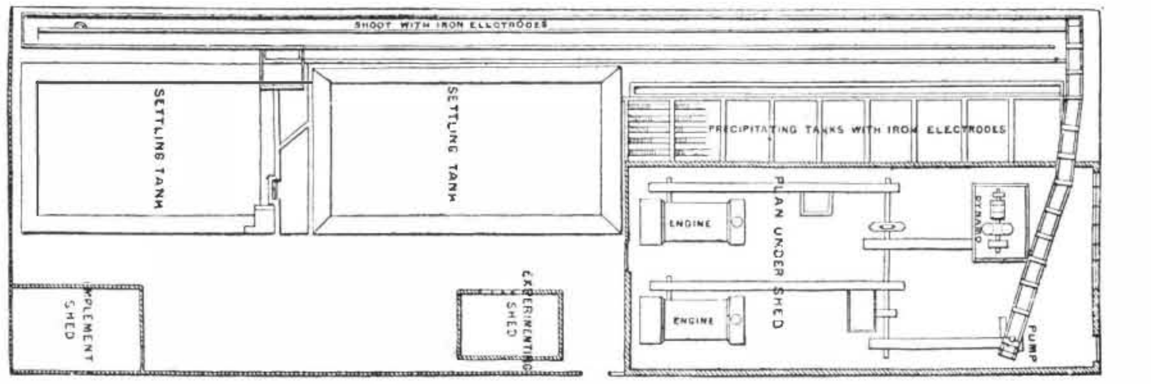

FIG. 1.—GROUND PLAN OF EXPERIMENTAL TANKS.

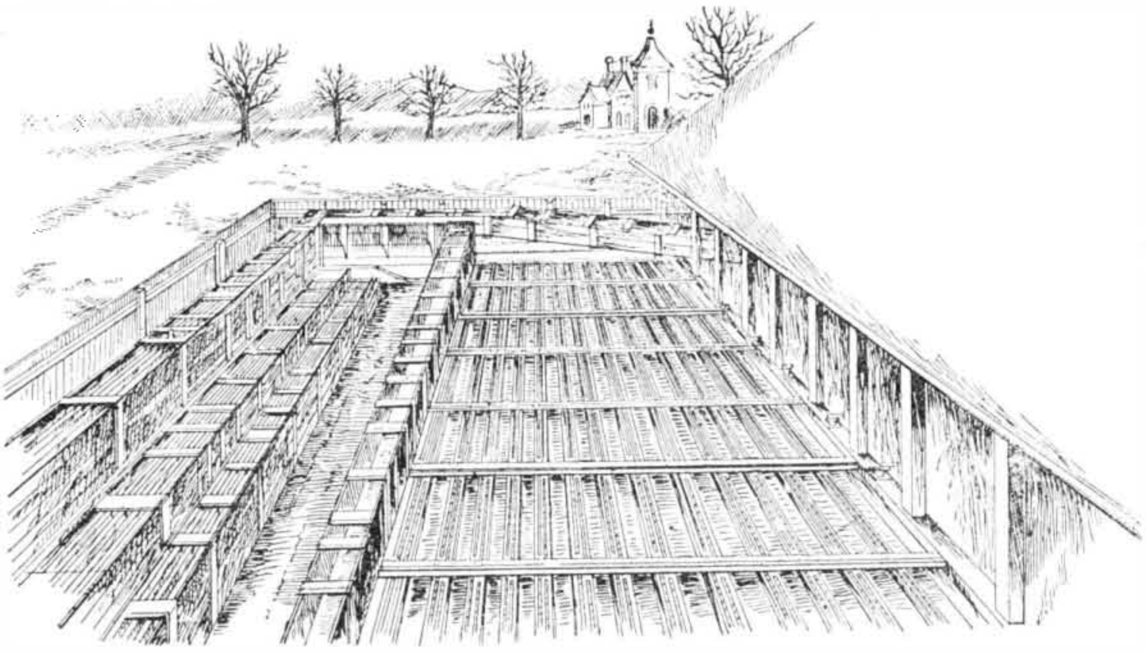

FIG. 2.—UPPER PORTION OF SEWAGE CHANNELS.

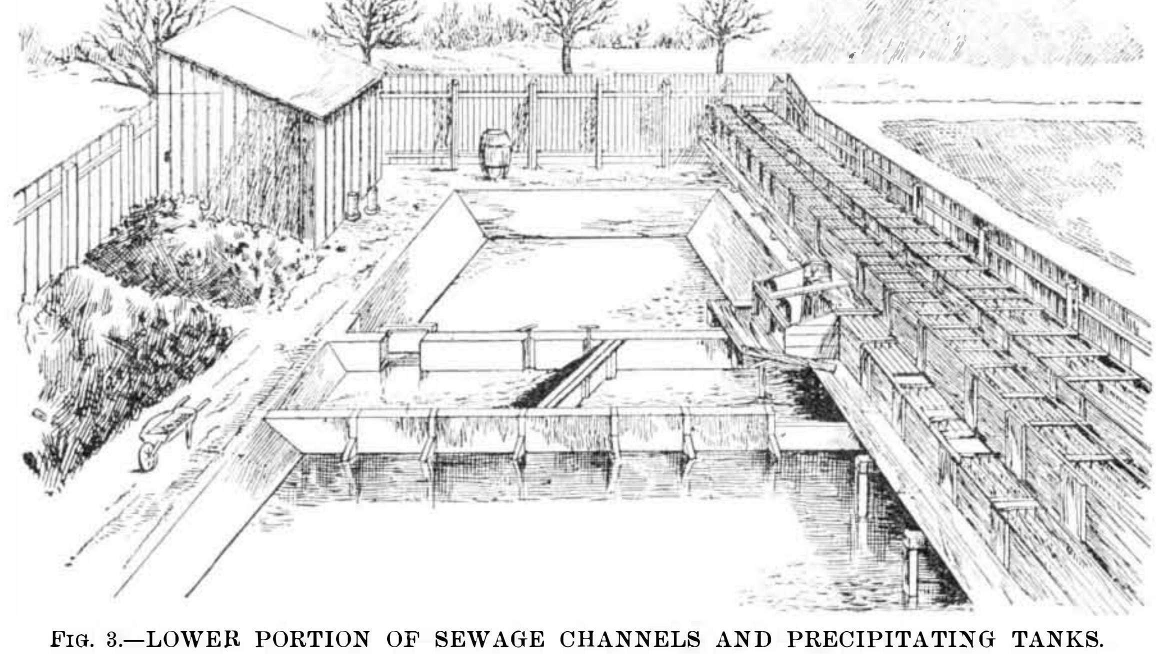

FIG. 3.—LOWER PORTION OF SEWAGE CHANNELS AND PRECIPITATING TANKS.