SUBMARINE CABLES.

All that has been said applies by implication to the protection of cables, as much as to any other sort of covered wire out of which it is desired to keep violent rushes of potential, but about cables there are a few special things to be said which we will proceed to say now. Not only is a cable a tremendously valuable piece of property in which a slight fault costs a large sum to repair, and hence the utmost precaution ought to be taken in their case (even the instruments employed in signalling being so expensive as to deserve a thorough protection if it can be given), but the fact that cables are always coated with a stout metallic sheathing is a peculiar circumstance not found in the lines of land telegraphs, whether overhead or underground, and it is a circumstance which I wish to point out renders their complete protection from lightning peculiarly definite and easy.

First, it is clear that risk is run wherever a cable is connected to a land line. I do not suppose this is ever done with the long ocean cables, but for short lengths, across gulfs, etc., I suppose transmission is usually immediate. Even with ocean cables I understand that the land line to the station is often led to the same switchboard as the cable instruments are connected to, and whenever there is any sort of proximity of this kind a flash received by some distant part of the land line must be liable to spit across some of the terminals and flick off a bit of itself into the cable and its instruments.

Two lightning switches at least ought to be employed in every such station, one, a coarse one, at the place where the land line enters the building, to eliminate the grosser violence, and another, a fine one, at the mouth of the cable, to filter out the last traces of dangerous disturbance.

A proper mode of connecting one of my protectors to a cable is shown in Fig. 14. Here the outside sheath of the cable is used as sole earth, as is, I believe, customary. Another proper mode is to have a subsidiary or local earth, connection being made as in Fig. 15.

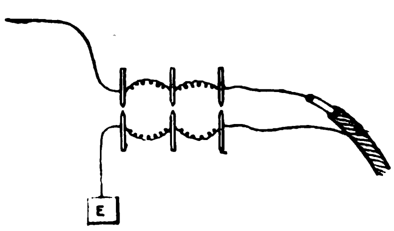


FIG. 15.

I am not prepared to support one of these in strong preference to the other. The second plan, however, is not to be adopted without the local earth. If there be no local earth, the first is the only proper plan, for it permits disturbances coming down the line to get to the outer sheath of the cable as directly as possible, the interior being protected by impedance ; it also permits disturbances surging up the cable sheath, as they may when the shallow shore water is struck by a flash, to get to the line capacity directly, and not to easily enter the cable core.

But now suppose a case where no land line or connection is permitted to come within many yards of the cable station, though I suppose such a plan would be extremely inconvenient ; let the cable be connected to nothing but its own instruments—where is the need of a lightning-switch then ?

The only danger that can occur now is when these instruments are struck direct, either from the roof or walls, or from gaspipes, or from the earth upon which they stand. A filter must therefore be arranged to protect the cable, even in this case. No fragment of cable core exposed outside its sheath can be considered safe. It would only be quite safe if it could be wholly put inside its metallic sheath and kept there.

(*To be continued.*)

## PROF. ELIHU THOMSON'S ELECTROMAGNETIC INDUCTION EXPERIMENTS.*

BY J. A. FLEMING, M.A., D.SC., M.I.E.E.

I. In the Paris Exhibition of 1889, and in the United States Court, many present will, perhaps, recollect to have seen a collection of electrical apparatus, contributed by Prof. Elihu Thomson as his private exhibit. These pieces of experimental apparatus constituted the appliances for illustrating some highly remarkable and interesting facts in electromagnetic induction. It is more than probable that very many persons interested in electrical discovery either did not find, or did not happen to see in action, these instruments, or perhaps had not the opportunity to see them at all. By the kindness of Prof. Elihu Thomson, to whom I am indebted for the loan of the apparatus, it is in my power to repeat some of these experiments before you to-night ; and my obligations are likewise especially due to Mr. Ernst Thurnauer, the engineer of the European Thomson-Houston Electric Light Company, for affording me his valuable aid in bringing them before you, and to Mr. Garfield, of the Thomson Electric Welding Company, for assistance in preparing the experiments. A few introductory remarks will be essential in order that I may carry the whole of my audience with me in subsequent explanations ; and these remarks will refer to that which is so very familiar a subject to every electrician—viz., the mutual induction of electric circuits. Before me lies a very large bobbin, or spool, wound over with two insulated copper wires. These wires were wound on the spool together, and for convenience sake we will distinguish them by calling them A and B (Fig. 1). Bear in mind that the wires or circuits are insulated from each other throughout their entire length, but lie closely adjacent on the bobbin. I can at pleasure insert a large bundle of soft iron wires tied up together into the hollow split brass tube which forms the body of the spool. The ends of one wire, say A, are connected to the terminals of a glow lamp, and I can pass or interrupt an electric current which traverses the other circuit, B, and a second glow lamp in series with it. You will note at once what happens when I start or stop the electric current in the circuit B. The lamp connected to circuit A flashes up momentarily at the instant when the current begins to flow in circuit B, and also when it ceases to flow ; but whilst the current flows steadily in the circuit B and illuminates the lamp in series with it, the lamp in series with circuit A is not illuminated at all. We have

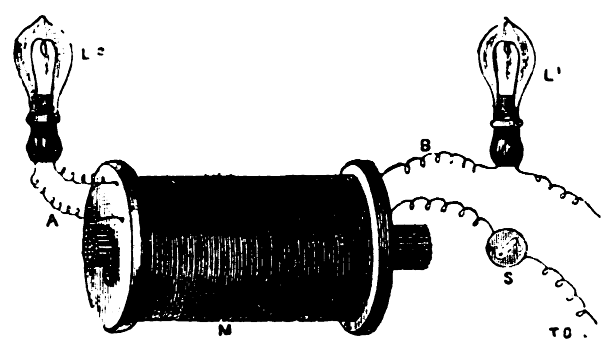


FIG. 1.

here a lecture experiment illustrating the familiar classical discovery of Faraday of the mutual induction of two electric circuits—viz., that the starting or stopping of an electric current in one circuit induces at the instant of commencement or cessation a brief secondary current in another closed adjacent circuit. I shall not take up time by dwelling on the historical details of this fundamental fact. You know them well. If instead of starting and stopping a continuously flowing electric current through the circuit B, and observing at each "make" or "break" a brief secondary current in circuit A, we supply the circuit B with an alternating electric current, one of which the direction is rapidly reversed many times in a second, and connect as before a glow lamp in series with circuit A, we find that this lamp glows continuously whilst the alternating current flows in circuit B. This also is familiar to us all. If in our first experiment we had employed, as a current detector in the secondary circuit, not an incandescent lamp, but some kind of galvanometer capable of indicating the direction of the induced electric current, we could easily have established for ourselves the fact that at the instant when the continuous electric current begins to flow in the circuit B it generates an oppositely directed induced secondary current in the circuit A, which is merely a transient current. At the instant when the continuous current is interrupted in circuit B, it gives rise to a similarly directed transient induced electric current in the circuit A. The momentary currents in A are called the inverse and direct secondary currents, induced by the commencement or cessation of the continuous primary current in circuit B. If the primary current is rapidly reversed, as in the case of an alternating current, then the secondary current consists likewise of a rapid succession of currents alternating in direction. In most of our experiments this evening we shall employ an alternating current, having a "frequency" of 90 per second, that is to say, changed in direction in the circuit 180 times in a second, and provided for us by the kindness of the London Electric Supply Company. If such an alternating current traverses a primary circuit, it induces a secondary alternating current of the same frequency in an adjacent secondary circuit, and this secondary periodic current may be made to induce in another circuit a tertiary current of like frequency, and this, again, a quaternary current, and so on, these successive orders of induced currents being, as it were, the children,

* Paper read before the Society of Arts, May 14, 1890.

grandchildren, and great-grandchildren of the primary parent current to which they owe their birth. (Fig. 2.)

The same large spool of insulated wire will provide us with the means of illustrating another important fact. I join up the two wires, A and B, into one length, so as to form one continuous bobbin of wire, and connect this great spiral of wire with a couple of glow lamps, one being in series with the wire spiral, and the other being in parallel with it (Fig. 3). On sending a steady current through the system, it divides

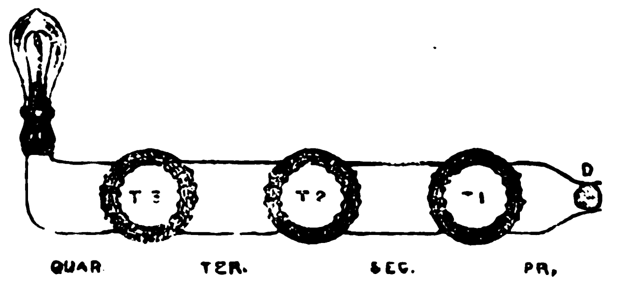


FIG. 2.

between the wire spiral, S, and the lamp, $L_1$, and I adjust the strength of this current so that the lamp, $L_1$, is barely visibly red hot. On interrupting suddenly this electric current, the lamp, $L_1$, flashes up for a moment. We recognise that we have here to consider an inertia effect familiar to us as the effect of the "self-induction" in the long coil of wire. Audiences in this room have been so carefully informed on many past occasions by brilliant and capable teachers, that I may spare you a reiteration of elementary facts concerning the self-induction

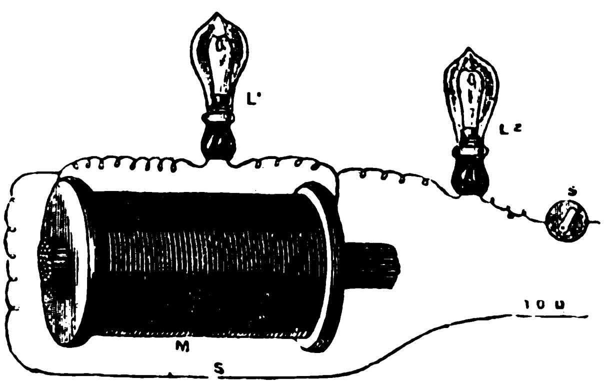


FIG. 3.

or inductance of conducting circuits, and take it for granted that everyone here is intimately acquainted with them, and that you will recall to your recollection that when an E.M.F. acts upon any closed electric circuit generating in it an electric current, this self-induction exhibits itself by delaying or retarding the rise of the current strength to its full or its maximum value; and that, similarly, when the E.M.F. is withdrawn, it operates to give the current a persistence, or to retard the rate of reduction of the current strength. The convenient term "time-constant" of a circuit is employed to denote

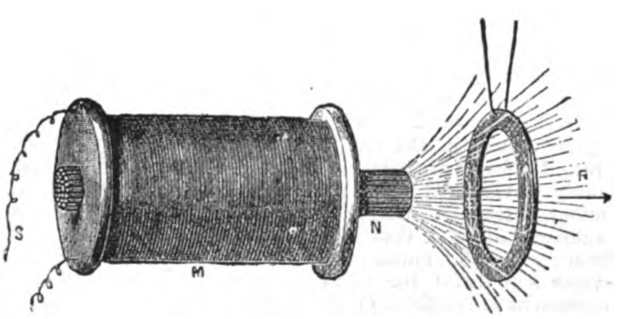


FIG. 4.

that time, expressed in fractions of a second or any other unit, which must elapse before a current rises to a certain definite fraction of its full value, when a steady E.M.F. acts upon that circuit. I will next beg you to turn a moment's attention to the electro-dynamic actions or forces which are brought into play when a circuit of any kind is subjected to electromagnetic induction in a magnetic field. Consider, for instance, a ring of copper hanging in front of the pole of an electromagnet (Fig. 4), having the plane of the ring perpendicular to the lines of magnetic force proceeding out from the pole. Let the magnet be an electromagnet, and let the pole be suddenly made a north or marked pole. Lines of magnetic force are thrust into the aperture of the ring. This magnetic flux, in accordance with a well-known law, generates an inductive E.M.F., which causes a transient current to flow round the ring in a counter clockwise direction, as looked at from the north magnetic pole. The ring becomes virtually a magnetic shell, having a north pole facing the north pole of the exciting magnet. By the fundamental laws of action between currents and magnets established by Ampère, the ring experiences a slight repulsive force, due to the electro-dynamic action between the current in the ring and the magnetic pole. The generation of the momentary induced current in the ring is accompanied by an electro-dynamic impulse tending to thrust it away from the pole. Suppose, next, that the electromagnet is demagnetised. The ring has generated in it a reverse induced current flowing in the same direction as the hands of a clock move when looked at from the magnetic pole. This is also accompanied by an electro-dynamic attraction of the ring towards the pole, but which is much more feeble than the previous repulsion. These attractions and repulsions are well seen when small discs of copper or aluminium are suspended in front of the poles of a powerful electromagnet, which is alternately "made" and "broken." They have been particularly investigated by Mr. C. V. Boys.*

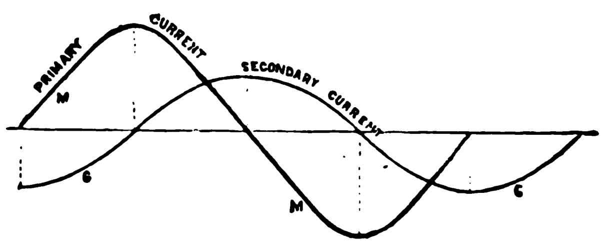


FIG. 5.

I will now ask you to consider what would happen if the coils of the electromagnet were traversed by an alternating current? Furthermore, we shall first suppose that the copper ring has a zero time-constant, that is to say, the induced currents in the ring rise up and sink down in strength in exact synchronism with the changes in the inductive E.M.F. acting on the ring. If the current flowing in the coils of the electromagnet is represented as to changes in strength by a simple periodic curve, we may suppose that the magnetism of the core and the magnetic induction through the ring follow a similar law. It is very easy, then, to show that the induced E.M.F. acting in the ring circuit, and hence the current in the ring, follows a similar law of fluctuation, but that the instant of

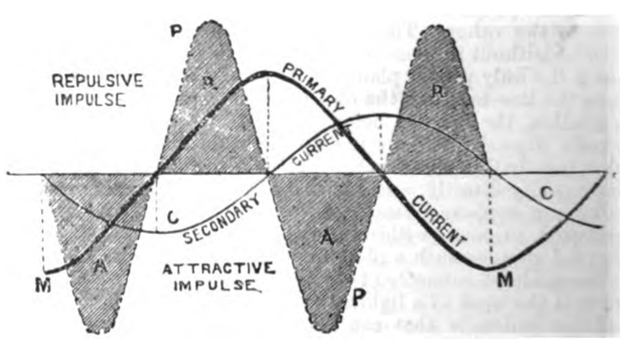


FIG. 6.

maximum current in the ring coincides with the instant of reversal of magnetism in the electromagnet. Under these circumstances we can represent the changing strength of the magnetic field in which the ring is immersed by a simple periodic curve, *m*, and the changes of current strength in the ring circuit by another simple periodic curve, *c*, shifted backwards relatively to the first by a quarter of a wave length (Fig. 5).

By Ampère's law the force acting on the ring at any instant is proportional to the product of the instantaneous value of the surrounding field and this current strength. If we multiply together the ordinates of these two curves, *m* and *c*, and form a third curve, *p*, whose ordinates at every point is proportional to the product of the ordinates of the other curves (Fig. 6) at those points, we obtain a curve which represents the fluctuation of force at every instant acting upon the ring. This curve, *p*, is also a wave-like curve, lying symmetrically above and below the horizontal line. The positive and negative areas of this curve included between the curve and the horizontal line represent the impulses or time integrals of the forces which act upon the ring. These impulses are alternately positive and negative.

* "On a Magneto-electric Phenomenon." By C. V. Boys, F.R.S., *Proceedings* Phys. Soc., London, vol. vi., p. 218.

This is equivalent to saying that under the circumstances assumed the ring gets a series of small pushes and pulls, or repulsions and attraction, which succeed each other at the same rate as the changes of magnetic polarity of the magnet. The series of rapidly alternating and equal impulses would result in leaving the ring apparently unmoved. No real conducting ring can, however, behave in this fashion, because every ring has a sensible "time-constant." Let us next see how the above statements will be modified if the ring has such a sensible self-induction that the current induced in the ring lags behind the inducting E.M.F. in phase. Repeating the above construction for a force curve, on the assumption that the instant of maximum of the current in the ring occurs later than the instant of reversal of magnetism in the magnet, it is easy to see that the force curve consists now of two very unequal parts. It is not symmetrically situated with respect to the horizontal lines (*see* Fig. 7). The area of the hummocks (shaded portions) which lie above the datum line, and which represent the repulsive impulses on the ring, are much larger than the area of the hummocks below the datum line, and which represent the attractive impulses acting on the ring. This means to say, that the ring when possessing self-induction experiences on the whole a repulsive force, or a series of repulsive impulses, when immersed in such an alternating magnetic field radiated from a magnetic pole, and this repulsive force will be within certain limits more pronounced, other things being equal, the greater the time-constant of the circuit. You see clearly, therefore, that a ring or disc of copper in which the induced currents lag behind the inducing E.M.F. in phase must experience a repulsive force when this inducing E.M.F. is caused by a rapid flux backwards and forwards of lines of magnetic forces perforating through the ring or disc. The realisation of this inference in a striking

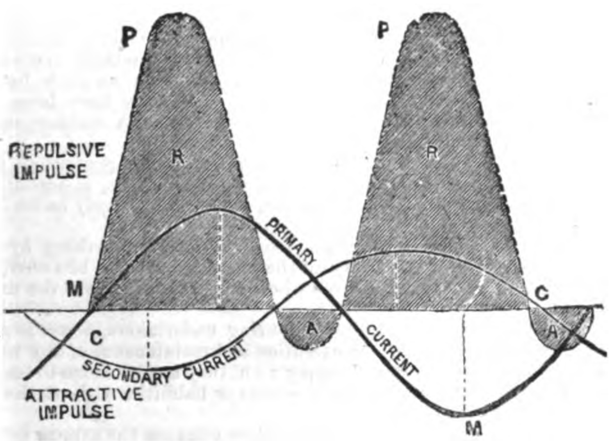


FIG. 7.

manner is the first of a series of remarkable experiments on this subject due to Prof. Elihu Thomson. We have on the table an electromagnet suitable for these experiments, which consists of a core of divided iron, surrounded by a coil, in which I can cause to circulate a powerful alternating current of 40 to 50 amperes. Let us, however, begin with an experiment in which we employ a continuous current to energise the core. I give you, in Prof. Elihu Thomson's own words,* an account of this preliminary experiment:

"In 1884, while preparing for the International Electrical Exhibition at Philadelphia, we had occasion to construct a large electromagnet, the cores of which were about 6in. in diameter and about 20in. long. They were made of bundles of iron rod about 5-16ths of an inch in diameter. When complete the magnet was energised by a current from a continuous-current dynamo, and it exhibited the usual powerful magnetic effects. It was found also that a disc of sheet copper of about 1-16th of an inch in thickness, and 10in. in diameter, if dropped flat against a pole of the magnet, would settle down softly upon it, being retarded by the development of currents in the disc, due to its movement in a strong magnetic field, and which currents were of opposite direction to those in the coils of the magnet. In fact, it was impossible to strike the magnet pole a sharp blow with the disc, even when the attempt was made by holding one edge of the disc in the hand and bringing it down forcibly towards the magnet. In attempting to raise the disc quickly off the pole a similar but opposite action of resistance to movement took place, showing the development of currents in the same direction as those in the coils of the magnet, and which currents, of course, would cause attraction as a result. The experiment could be tried in another way. Holding the sheet of copper by one edge, just over the magnet pole (Fig. 8), the current in the magnet-coils was cut off by shunting them. There was felt an attraction of the disc, or a dip towards the pole. The current was then put on by opening the shunting-switch, and a repulsive action or lift of the disc was felt. The actions just described are what would be expected in such a case, for when attraction took place currents had been induced in the disc in the same direction as those in the magnet-coils beneath it, and when repulsion took place the induced current in the disc was

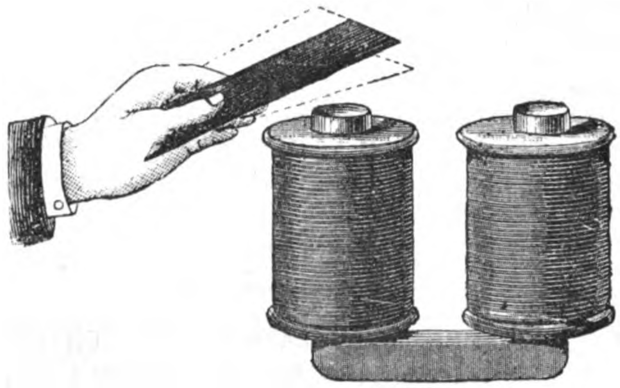

FIG. 8.

of opposite character or direction to that in the coils. Now, let us imagine the current in the magnet-coils to be not only cut off, but reversed back and forth. For the reasons just given, we find that the disc is attracted and repelled alternately; for whenever the currents induced in it are of the same direction

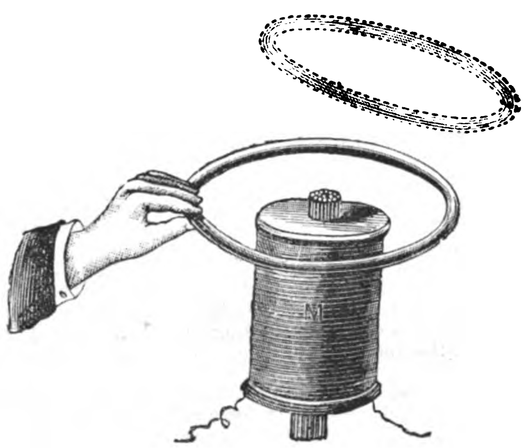


FIG. 9.

with those in the inducing or magnet-coil, attraction will ensue, and when they are opposite in direction repulsion will be produced. Moreover, the repulsion will be produced when the current in the magnet-coil is rising to a maximum in either direction, and attraction will be the result when the current of either direction is falling to zero, since in the former

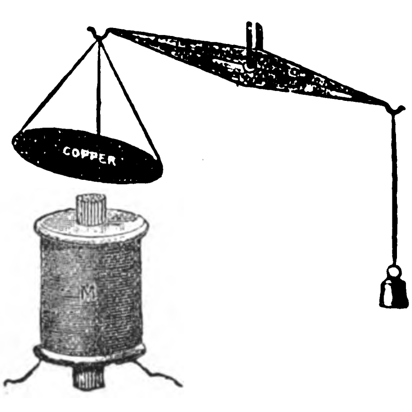


FIG. 10.

case opposite currents are induced in the disc, in accordance with well-known laws, and in the latter case currents of the same direction will exist in the disc and the magnet coil. The disc might, of course, be replaced by a ring of copper or other good conductor, or by a closed coil of bare or insulated wire, or by a series of discs, rings, or coils superposed, and the results would be the same."

We have already seen that in an alternating field the electro-

* See the *Electrical World*, May, 1887, p. 258, or the *Electrical Engineer* (American), June 18, 1887, p. 211:—"Novel Phenomena of Alternating Currents," by Elihu Thomson.

dynamic impulses so experienced by the disc or ring are alternately attractive and impulsive, and that when the circuit possesses a sensible self-induction the repulsive impulses overpower the attractive ones, and their repetition constitutes a repulsive force. Before adding a few more words of explanation, permit me to show you some of these electro-dynamic repulsions produced by an alternating electromagnet. Here is a copper ring, and I lay it upon the top of this electromagnet, having a divided iron core, and excited by a powerful alternating current. On energising the magnet the ring jumps up in the air (Fig. 9). If a copper plate is hung like a scale pan from a balanced beam, and placed over the magnetic pole, it gives evidence of being strongly repelled the moment we pass the current through the coils of the magnet (Fig. 10). Instead of employing copper rings or copper plates, we can use closed coils of thick wire, either insulated or not. If, however, our plates or rings have a radial slit made in them, or if our coils of wire are not closed-circuit coils, all the effects vanish.

*(To be continued.)*

## THE TREATMENT, REGULATION, AND CONTROL OF ELECTRIC SUPPLY BY THE LEGISLATURE AND THE BOARD OF TRADE.*

BY MAJOR P. CARDEW, R.E., MEMBER.

Before starting with the undertaking which in a moment of weakness I have laid upon myself, I have to ask a favour and convey a warning. The favour is that you will bear in mind that nothing I may say to-night possesses any official sanction, or can be taken as in any way expressing the views of the Board of Trade.

Before preparing the paper I obtained permission from the Department under which I serve to do so; but some rather delicate ground is traversed in the paper, and I am sure I may rely upon your forbearance to-night, in any discussion which may arise, to avoid any questions of policy. The warning is that I am painfully conscious that the paper is very dry and portentously long.

The subject which I have the honour to submit to your notice to-night is "The Treatment, Regulation, and Control of Electric Supply by the Legislature and the Board of Trade." I am afraid the scientific interest of the paper is very small; but as many of you are practically concerned in the matters dealt with, I hope it will not be considered to be out of place.

The first attempt to deal with the question of electric supply on the part of the Legislature was the Act of 1882. As notice had been given of many private Bills to be brought in to acquire the necessary powers for a general supply, proceeding on very varying lines, it was thought that the time had come for a general Act dealing with the subject.

The two principal objects of this Act were—(1) To empower electric supply companies, or persons, or local authorities desirous of undertaking this supply for their own districts, to lay their mains in the public streets, and conduct the business of supply generally in a manner recognised by law; (2) to recover charges for supply made to consumers. At the same time proper regulations and conditions were imposed upon the undertakers to secure the safety of the public and the adequacy of the supply; while the fear of creating a new perpetual monopoly was evidently present in the minds of the framers of the Act.

This Act is so familiar that a short sketch of its provisions will be sufficient. It sets out by detailing the various ways in which statutory powers can be obtained. These are—(1) By license; (2) by provisional order; (3) by special Act.

The issue of licenses is left entirely in the hands of the Board of Trade, but the consent of every local authority affected must first be obtained. The original period for which a license is granted must not exceed seven years, but it may be renewed with the like consents. A license may be for "public purposes" or "private purposes." "Public purposes" only allows supply for electric lighting of streets, public places, buildings, theatres, etc.; while "private purposes" allows general supply, not only for lighting, but for any other purpose, except the transmission of any telegram. The Board of Trade is empowered to make such regulations and conditions in a license as it may think expedient.

Provisional orders in this Act may be granted without requiring the previous consent of the local authorities affected, but have no force unless and until confirmed by Act of Parliament. The period of an order may be limited, or it may be unlimited in duration. There appears to be very generally diffused a mistaken idea on this point. Many people appear to think that a provisional order only lasts for 42 years, or 21 years under the old Act. This was stated in the *Times* the other day as a fact. It is, however, quite a mistake. The orders granted by the Board of Trade, and confirmed by Parliament, have hitherto been, without exception, I think, unlimited in duration. There are various provisions for sale or transfer of the undertaking, including, in the case of a company, compulsory sale to the local authority; but these provisions may never be acted upon, and even if they are put into force do not extinguish the powers granted.

Section 6, with respect to regulations, is so important that it will be better to read the exact words—

6. The undertakers shall be subject to such regulations and conditions as may be inserted in any license, order, or special Act affecting their undertaking with regard to the following matters:

(*a.*) The limits within which and the conditions under which a supply of electricity is to be compulsory or permissive;

(*b.*) The securing a regular and efficient supply of electricity;

(*c.*) The securing the safety of the public from personal injury, or from fire or otherwise;

(*d.*) The limitation of the prices to be charged in respect of the supply of electricity;

(*e.*) The authorising inspection and enquiry from time to time by the Board of Trade and the local authority;

(*f.*) The enforcement of the due performance of the duties of the undertakers in relation to the supply of electricity by the imposition of penalties or otherwise, and the revocation of the license, order, or special Act where the undertakers have, in the opinion of the Board of Trade, practically failed to carry the powers granted to them into effect within a reasonable time, or discontinued the exercise of such powers; and

(*g.*) Generally with regard to other matters in connection with the undertakings.

Provided always that the Board of Trade may from time to time make such regulations as they may think expedient for securing the safety of the public from personal injury or from fire or otherwise, and may from time to time amend or repeal any regulations which may be contained in any such license, order, or special Act in relation thereto; and any regulations so made or amended by the Board of Trade shall, from and after the date thereof, have the like effect in every respect as though they had been originally inserted in the license, order, or special Act authorising the undertaking; and every regulation so repealed shall, from and after the date thereof, be repealed accordingly, but such repeal shall not affect any liability or penalty incurred in respect thereof prior to the date of such repeal, or any proceeding or remedy which might have been had in relation thereto.

Any local authority within any part of whose district electricity is authorised to be supplied under any license, order, or special Act may, in addition to any regulations which may be made under the preceding provisions of this section for securing the safety of the public, from time to time make, rescind, alter, or repeal by-laws for further securing such safety; and there may be annexed to any breach of such by-laws such penalties, to be recovered in a summary manner, as they may think necessary: Provided always that no such by-laws shall have any force or effect unless and until they have been confirmed by the Board of Trade and published in such manner as the Board of Trade may direct.

The proviso enabling the Board of Trade to make regulations from time to time, and to amend or repeal any regulations, is certainly a wise provision, and, as you are aware, it has been largely carried into effect.

The power conferred upon the local authority of making by-laws for further securing the safety of the public should also be noted, and that this may be exercised even where they are themselves the undertakers.

In the case of local authorities being undertakers, power is given for them to contract for the execution and maintenance of any works, or for the whole business of supply; but they are forbidden to transfer or divest themselves of any legal powers or liabilities without the consent of the Board of Trade.

As regards overhead wires, undertakers must get the express consent of the local authority for their erection along, over, or across any street, and the local authority may remove any electric line placed above ground without such consent, and, even where such consent has been given, a court of summary jurisdiction may order the removal of any electric line, on the ground of public safety.

It must be noticed, however, that nothing in this Act empowers any interference on the part of the Board of Trade or any other authority with electric lines erected by persons who are not undertakers. The undertakers are not allowed to prescribe any special form of lamp, or to interfere with the use made by any consumer of the supply given to him; but no consumer is to deal with his supply in such a manner as to unduly or improperly interfere with the supply to other consumers; and any dispute as to this is to be determined by arbitration.

There are provisions against undue preference on the part of the undertakers in their supply and charges. I take the meaning of these sections (19 and 20) to be this—that the undertakers may make any agreement as regards price, hours of supply, etc., provided that the price is not in excess of the maximum rates laid down; but that, where they have made any such agreement with any private consumer, any other private consumer may demand a similar agreement, where the conditions are similar; and so in the case of street lighting authorities; but not that a private consumer could demand to be supplied at the same rate as is agreed upon for the street lighting or for lighting a large theatre.

Supply may be cut off for neglect of payment of charges due, but only until these charges and any expenses incurred in cutting off the supply are fully paid.

Any unlawful and malicious injury of electric lines and works is made a felony, and any person who maliciously or fraudulently abstracts, causes to be wasted or diverted, consumes or uses, electric energy is declared to be guilty of simple larceny—in fact, to have stolen it.

The purposes for which the officers of the undertakers may enter premises of consumers are strictly defined, and they have no legal right of entry for any other purpose—*e.g.*, to inspect the electric lines and fittings of the consumer.

The Board of Trade has, however, so framed the orders and safety regulations as to make it unlikely that any consumer would refuse entry to a properly authorised agent of the undertakers, if required by them to make an inspection of these electric lines and fittings.

In the section of the Act providing for the protection of the Post-

* Paper read before the Institution of Electrical Engineers.

attery should be at least four times as large, because there ill be days when there will be no power available for harging the cells. In this case, however, 200 ampere-hour ells would be sufficient. With such a storage battery lant and an efficient dynamo the lighting of a small manion could be effected with great success. It is manifest hat the use of such switch as that described would be ecidedly advantageous in such an installation.—*Western lectrician.*

## INSTALLATIONS IN FRANCE AND ALGERIA.

The following list of towns in France and Algeria possessing installations of electric light is published in the *Bulletin nternationale de l'Electricité*, and has been brought as far s possible up to the present date. The first name given s that of the county.

Ain.—*Nantua*: Partial distribution of electricity Guitton, engineer).—*Pont de Vaux*: Electric lighting of he town.

Allier.—*Montluçon*: "Société Anonyme d'Eclairage Elecrique de Montluçon" (Mora, manager).

Ariège.—*Aix-les-Bains*: Municipal central station, 100 amps, and private lighting, since October, 1888. Waterower (M. Brillouin, engineer).

Basses-Alpes.—*Manosque*: Local Electric Light Company 40 h.p., 95 lamps, 16 c.p. for the streets, and 216 lamps 16 to 20 c.p. for private houses).

Ardèche.—*Bourg-Saint-Andéol*: Electric light company Lauzan, director).

Ardennes.—*Rethel*: "Société Electrique Rethelaise" at ault-le-Rethel (Gauson, manager).

Aveyron.—*Espalion*: Electric lighting of the town Lamy et Cie.).

Marseille.—Station at the Rue de Pavilion (250 h.p.) of he "Compagnie du Gaz de Marseille." Station at the Rue uriol No. 23 (200 h.p.) (M. Gillibert, director).

Charente.—*Angoulême*: Central station, 300 lamps, team engines, since January, 1888 (M. Brillouin, ngineer); made over to the gas company in February, 890. Installation of 1,000 lamps now being erected Brillouin).

Charente-Inférieure.—*Marennes*: Electric light station Guitton, engineer).

Cher.—*Vierzon-Ville*: Electric light station (Guitton, enineer).

Côte-d'Or.—*Dijon*: Electric light station (De Brancion, ngineer).

Creuse.—*Bourganeuf*: Electric lighting, station at Nisme Marcel Deprez, engineer).

Dordogne.—*Périgueux*: Electric station (Guitton, engieer. *Montpont*: Electric lighting (Guitton, engineer).

Drôme.—*Dieulefit* and *Valréas*: Supplied by the central tation at *Bécone* (Lombard-Gérin, manager).

Finistère.—*Châteaulin*: Electric light station (Lamy et ie.).

Gard.—*Lassalles*: Municipal electric lighting. *Valleanges*: Public lighting of the town (Lamy et Cie.).

Gironde.—*Bordeaux*: Partial electric lighting station, 24, ue Saint-Colombe (Société Edison).

Haute-Garonne.—*Toulouse*: "Société Toulousaine d'Elecricité," 10, Quai Saint-Pierre.

Indre-et-Loire.—*Tours*: Electric light station (Compagnie nternationale d'Eclairage Electrique).

Isère.—*Grenoble*: Electric lighting of the town, 900 mps. *Rives*: Electric light works.

Jura.—*Nantua*: Electric light station.

Loire-et-Cher.—*Saint-Aignan*: Central electric lighting ation.

Loire.—*Saint-Etienne*: Central electric supply (200 h.p.) ociété Edison).

Lozère.—*Mende*: Central electric light station (Lamy et e.).

Manche.—*Saint-Hilaire-du-Harcouët*: Water power electric ation (Lamy et Cie.).

Meuse.—*Verdun*: Central station since 1888 (Couten et hamel).

Meurthe-et-Moselle. — *Nancy*: "Compagnie Nancéenne Eclairage Electrique."

Marne.—*Reims*: Electric light works.

Morbihan.—*Hennebont*: Electric lighting of the town (Bonfante, manager).

Nord.—*Cambrai*: Central electric light works.

Oise.—*Compiègne*: Electric light station, Rue Pierre-Sauvage.

Orne.—*Domfront*: Electric lighting of the town.

Basses-Pyrénées.—*Pau*: Central electric light station, town and private lighting, since January, 1888 (Brillouin). Steam power, 1,500 lamps, made over to Société Electrique des Pyrenées in May, 1889. Extension by waterpower now being erected.—*Nay*: Central station, 1,500 lamps being erected, waterpower (Brillouin).—*Oloron*: Electric lighting of the town d'Eaux Bonnes, 32, Rue Chanzy.

Hautes-Pyrénées.—*Argelès*: Central station, municipal and private lighting, steam, erected in July, 1887 (A. Brillouin). Waterpower installation now being erected.

Pyrénées-Orientales.—*Perpignan*: Electric light works, Rue des Abreuvoirs (Lamy et Cie.).

Rhône.—*Lyon*: Central station, 7, Rue de Savoie (the Gas Company), "Compagnie Lyonnaise d'Eclairage Electrique" (600 h.p.).

Sarthe.—*Le Mans*: Electric light works (the Gas Company, Seguin). — Central station, Société Générale d'Electricité du Mans, May, 1887; taken over again by M. Brillouin, June, 1889, 500 lamps.

Savoie.—*Modane*: Electric light works (Fardel, manager).

Haute-Savoie.—*La Roche-sur-Foron*: Electric light works (Garnot).

Seine.—*Paris*: Municipal lighting; Cie. Continentale Edison; Cie. Victor Popp; Société de la Transmission de la Force par l'Electricité; private companies lighting the islands on the Seine.

Seine-Inférieure.—*Rouen*: Electric light works (100 h.p.), 87, Rue Lafayette; Société Normande d'Electricité, 14, Rue du Petit-Salut, October, 1888 (MM. Lelordier et A. Brillouin); steam power, 300 h.p., 2,400 lamps.—*Le Havre*: Electric light works (Mildé et Cie.).

Vaucluse.—*Pertuis*: Electric lighting of the town.

Vendée.—*La Roche-sur-Yon*: Electric light works (50 h.p.).

Haute-Vienne.—*Limoges*: Electric light works, Carrefour Tourny (Lamy et Cie.).

Yonne.—*Saint-Fargeau*: Electric lighting of the town (Luneau et Plagneux).

ALGERIA.—*Milianah*: Electric lighting of the town (Galli et Dalloz).—*Orléansville*: Electric lighting of the town (Galli et Dalloz).

As will be seen, several gas companies supply electric light at the same time as gas.

## PROF. ELIHU THOMSON'S ELECTROMAGNETIC INDUCTION EXPERIMENTS.*

BY J. A. FLEMING, M.A., D.SC., M.I.E.E.

(*Continued from page 414*).

So strong is this repulsion, with proper appliances, that light copper rings tethered by strings may be held suspended in the air against the force of gravity, the upward electromagnetic repulsion overcoming their weight, and holding them, like Mahomet's fabled coffin, floating in the air (Fig. 11). In cases where we are dealing only with impulsive effects, aluminium rings or discs give most marked results, because aluminium has the highest conductivity per unit of mass; but in the cases like those just considered, where what is required is the greatest force effect, copper or silver gives a better result than aluminium, because they have the highest conductivity per unit of volume. In Mr. Boys's experiments, if I remember rightly, he found aluminium the best to employ. In these cases of electro-dynamic repulsion the force effect depends essentially upon the lag of the induced current, or its retardation in phase behind that of the inducing field, and, other things being equal, this is proportional to the conductivity of the circuit. I will pass before your view a series of diagrams intended to represent various cases and modes of production of these repulsive effects, giving you descriptions of them in Prof. Elihu Thomson's own words. He says:

"This preponderating repulsive effect may be utilised, or may show its presence by producing movement or pressure in a given direction by producing angular deflection as of a pivoted

* Paper read before the Society of Arts, May 14, 1890.

body, or by producing continuous rotation in a properly-organised structure.

"In Fig. 12 C is a coil traversed by alternating currents, B is a copper case or tube surrounding it, but not exactly over its centre. The copper tube, B, is fairly massive, and is the seat of heavy induced currents. There is a preponderance of repulsive action tending to force the two conductors apart in an axial line. The part B may be replaced by concentric tubes slid

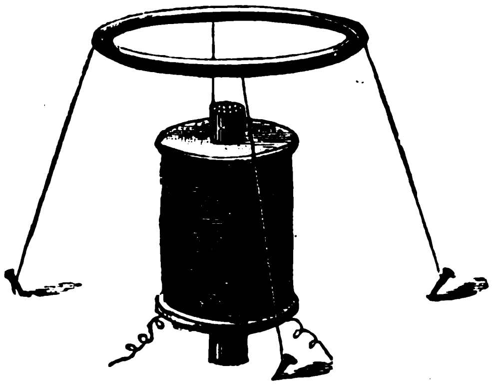

Fig. 11.

one in the other, or by a pile of flat rings, or by a closed coil of coarse or fine wire, insulated or not. If the coil C, or primary coil, is provided with an iron core, such as a bundle of fine iron wires, the effects are greatly increased in intensity, and the repulsion with a strong primary current may become quite vigorous, many pounds of thrust being producible by apparatus of quite moderate size.

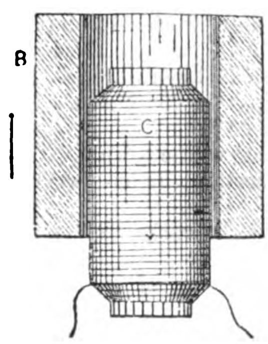


Fig. 12.

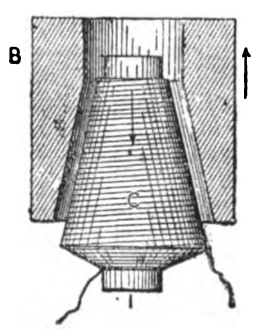


Fig. 13.

"The forms and relations between the two parts, C and B, may be greatly modified, with the general result of a preponderance of repulsive action when the alternating currents circulate.

"Fig. 13 shows the part B of an internally tapered or coned form, and C of an externally coned form, wound on an iron wire bundle, I. The action in Fig. 12 may be said to be analogous to that of a plain solenoid with its core, except that repulsion, and not attraction, is produced; while that of Fig. 13 is more like the action of tapered or conically-wound solenoids and taper cores. Of course, it is unnecessary that both be tapered. The effect of such shaping is simply to modify the range of action and the amount of repulsive effort existing at different parts of the range.

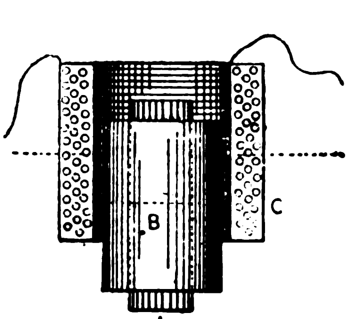


Fig. 14.

"In Fig. 14 the arrangement is modified so that the coil, C, is outside, and the closed band or circuit, B, inside and around the core, I. Electro-inductive repulsion is produced as before.

"It will be evident that the repulsive actions will not be mechanically manifested by axial movement or effort, when the electrical middles of the coils or circuits are coincident. In cylindrical coils, in which the current is uniformly distributed through all the parts of the conductor section, what I here term the electrical middle, or the centre of gravity of the ampere-turns of the coils, will be the plane at right angles to its axis at its middle, that of B and C in Fig. 14 being indicated by a dotted line. To repeat, then, when the centres or centre planes of the conductors, Fig. 14, coincide, no indication of electro-inductive repulsion is given, because it is mutually balanced in all directions; but when the coils are displaced a repulsion is manifested, which reaches a maximum at a position depending on the peculiarities of proportion and distribution of current at any time in the two circuits or conductors.

"In Fig. 15 B represents a copper ring, and C an annular coil placed parallel thereto; and an iron core or wire bundle

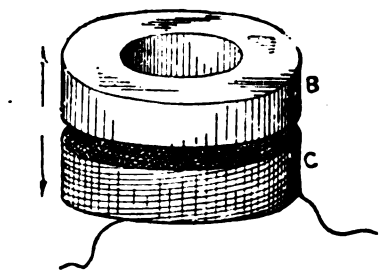


Fig. 15.

placed in the common axis of the two coils, shows the repulsive action when an alternating current is passed through C. B may be simply a disc or plate of any form, without greatly affecting the nature of the action produced. It may also be composed of a pile of copper washers or a coil of wire, as before indicated.

"An arrangement of parts somewhat analogous to that of a horseshoe electromagnet and armature is shown in Fig. 16. The alternating-current coils, C C′, are wound upon an iron wire bent into U-form, and opposite its poles is placed a pair of thick

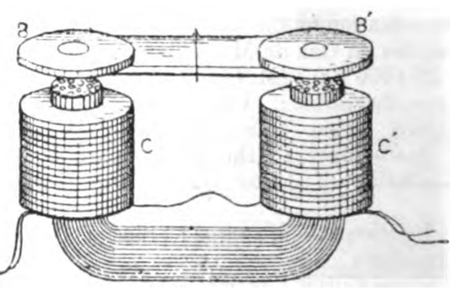


Fig. 16.

copper discs, B B′, which are attracted and repelled, but with an excess of repulsion depending on their form, thickness, etc.

"If the iron core takes the form of that shown by I I, Fig. 17, such as a cut ring with the coil, C, wound thereon, the insertion of a heavy copper plate, B, into the slot or divided portion of the ring will be opposed by a repulsive effort when alternating currents pass into C. This was the first form of device in which I noticed the phenomenon of repulsive prepon-

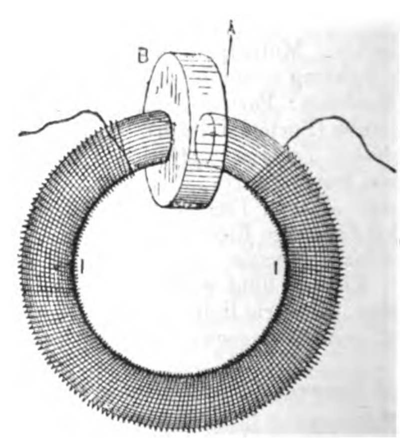


Fig. 17.

derance in question. The tendency is to thrust the plate, B, out of the slot in the ring, excepting only when its centre is coincident with the magnetic axis joining the poles of the ring between which B is placed.

"If the axes of the conductors (Fig. 15) are not coincident, but displaced, as in Fig. 18, then, besides a simple repulsion apart, there is a lateral component or tendency, as indicated by the arrows. Akin to this is the experiment illustrated in Fig. 19. Here the closed conductor, B, is placed with its plane at right angles to that of C, wound on a wire bundle. The part B tends to move toward the centre of the coil C, so that its axis will be in the middle plane of C, transverse to the core, as indicated by the dotted line. This leads us at once to another class of actions—*i.e.*, deflective actions.

"When one of the conductors, as B (Fig. 20), is composed of a disc, or, better, of a pile of thin copper discs, or of a closed coil of wire, is mounted on an axis, X, transverse to the axis of coil C, through which coil the alternating current passes, a deflection of B to the position indicated by dotted lines will

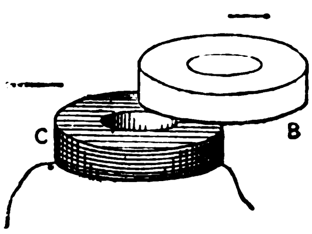


Fig. 18.

take place, unless the plane of B is at the start exactly coincident with that of C. If slightly inclined at the start deflection will be caused as stated. It matters not whether the coil C encloses the part B, or be enclosed by it, or whether the coil C be pivoted, and B fixed, or both be pivoted. In Fig. 21 the coil C surrounds an iron-wire core, and B is pivoted above it, as shown. It is deflected, as before, to the position indicated in dotted lines.*

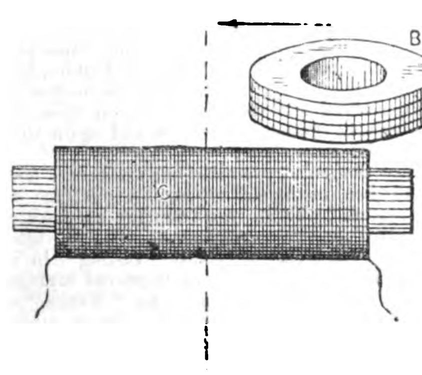


Fig. 19.

"It is important to remark here that in cases where deflection are to be obtained, as in Figs. 20 and 21, B had best be made of a pile of thin washers or a closed coil of insulated wire, instead of a solid ring. This avoids the lessening of effect which would come from the induction of currents in the ring, B, in other directions than parallel to its circumference."

Returning for a moment to the theory of these repulsive and deflective actions, it will repay us to consider it in the form placed before us by Prof. Thomson, in his first paper on the subject, read before the American Institute of Electrical Engineers, May 18, 1887. He says: "It may be stated as certainly true that, were the induced currents in the closed conductor unaffected by any self-induction, the only phenomena exhibited would be alternate equal attractions and repulsions,

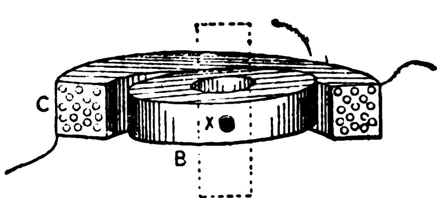


Fig. 20.

because currents would be induced in opposite directions to that of the primary current when the latter current was changing from zero to maximum positive or negative current, so producing repulsion; and would be induced in the same direction when changing from maximum positive or negative value to zero, so producing attraction.

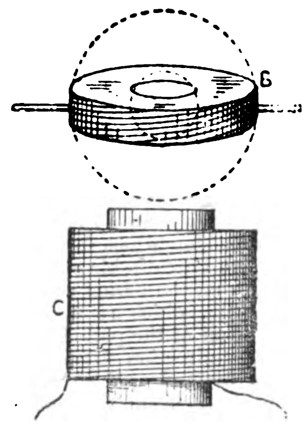


Fig. 21.

"This condition can be illustrated by a diagram, Fig. 22. Here the lines of zero current are the horizontal straight lines. The wavy lines represent the variations of current strength in each conductor, the current in one direction being indicated by that portion of the curve above the zero line, and in the other direction by that portion below it. The vertical dotted lines

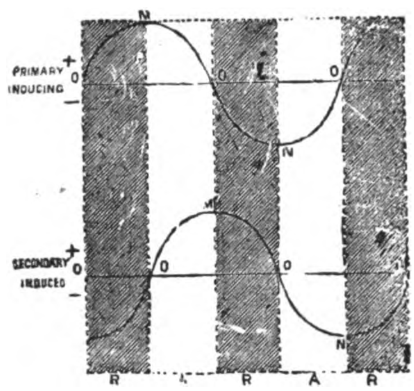


Fig. 22.

simply mark off corresponding portions of phase or succession of times.

"Here it will be seen that in the positive primary current descending from *m*, its maximum, to the zero line, the secondary

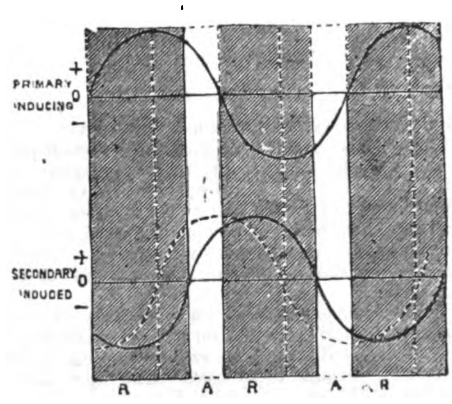


Fig. 23.

current has risen from its zero to $m^1$, its maximnm. Attraction will therefore ensue, for the currents are in the same direction in the two conductors. When the primary current increases from zero to its negative maximum, *n*, the positive current in the secondary closed circuit will be decreasing from $m^1$, its positive maximum, to zero; but as the currents are in opposite directions, repulsion will occur. These actions of attraction and repulsion will be reproduced continually, there being a repulsion, then an attraction, then a repulsion, and again an attraction, during one complete wave of the primary current. The letters *r*, *a*, at the foot of the diagram, Fig. 22, indicate this

* This deflection by an alternating current of a copper disc suspended within a coil with its plane inclined to the plane of the coils, I myself noticed independently in March, 1887, and subsequently described a copper-disc galvanoscope for alternating currents, based on this fact (see *The Electrician*, May 6, 1887). I did not at the time know how thoroughly Prof. Thomson had explored the phenomena, but the substantial explanation of it had already occurred to me,

succession. (The shaded portions in the diagrams represent the time during which the force between the primary and secondary circuits is a repulsive force.)

"In reality, however, the effects of self-induction in causing a lag, shift, or retardation of phase in the secondary current will considerably modify the results, and especially so when the secondary conductor is constructed so as to give such self-induction a larger value. In other words, the maxima of the primary or inducing current will no longer be found coincident with the zero points of the secondary currents. The effect will be the same as if the line representing the wave of the secondary current in Fig. 22 had been shifted forward to a greater or less extent. This is indicated in diagram, Fig. 23. It gives, doubtless, an exaggerated view of the action, though from the effects of repulsion which I have produced I should say it is by no means an unrealisable condition.

"It will be noticed that the period during which the currents are opposite, and during which repulsion can take place, is lengthened at the expense of the period during which the currents are in the right direction for attractive action. These differing periods are marked *r*, *a*, etc., or the period during which repulsion exists is from the zero of the primary or inducing current to the succeeding zero of the secondary or induced current, and the period during which attraction exists is from the zero of the induced current to the zero of inducing current. (It will be seen that the shaded portions in Diagram 23 have been widened out at the expense of the unshaded parts.)

"But far more important, still, in giving prominence to the repulsive effect than this difference of effective period is the fact that during the period of repulsion both the inducing and induced currents have their greatest values, while during the period of attraction the currents are of small amounts comparatively. This condition may be otherwise expressed by saying that the period during which repulsion occurs includes all the maxima of current, while the period of attraction includes no maxima. There is, then, a repulsion due to the summative effects of strong opposite currents for a lengthened period against an attraction due to the summative effects of weak currents of the same direction during a shortened period, the resultant effect being a greatly preponderating repulsion.

"It is now not difficult to understand all the actions before described, as obtained with the varied relations of coils, magnetic fields, and closed circuits. It will be easily understood, also, that an alternating magnetic field is in all respects the same as an alternating-current coil in producing repulsion on the closed conductor, because the repulsions between the two conductors are the result of magnetic repulsions arising from opposing fields produced by the coils when the currents are of opposite directions in them."

(*To be continued.*)

## THE TREATMENT, REGULATION, AND CONTROL OF ELECTRIC SUPPLY BY THE LEGISLATURE AND THE BOARD OF TRADE.*

BY MAJOR P. CARDEW, R.E., MEMBER.

(*Continued from page 415.*)

### NATURE AND MODE OF SUPPLY.

In the old orders two systems were mentioned—viz., the "parallel system" and the "series system," meaning constant-pressure and constant-current systems respectively. Now no system is specified, except that it must be one approved by the Board of Trade. A new sub-section was added to this last year at the instance of the telephone companies, by agreement with the promoters, for the protection of the telephone circuits against interference by induction or otherwise, they being naturally rather alarmed at the proposed general use of alternating currents.

In the "Works" clauses, I need only mention that in the new model it is proposed to give powers for the construction of "street" boxes in place of "distributing" boxes. The special power taken is necessary, I believe, because these boxes come up to, and may come above, the surface of the ground. Also, that the prohibition of overhead wires, introduced last year, is inserted in the new model for companies, with the alteration that the time allowed for removal of existing overhead wires is reduced to one year. But they may be erected or continued in use with the consent of the local authority. This prohibitory section is based upon, and really does not go beyond, section 14 of the Act of 1882.

The "Compulsory Works" clauses provide generally that the undertakers shall do something substantial towards carrying out their undertaking within a specified time, under penalties of fine or revocation of the orders. The Board of Trade, however, must, in the case of a company, be moved to exercise its power of revocation by the local authority, except in the last model, where this has been altered; while in the case of a local authority being the undertakers, the Board of Trade has not hitherto, so far as I am aware, thought fit to exercise its power of revocation for non-performance of works within the required time, probably considering the plea that the practical knowledge and experience of electrical distribution was not sufficient to justify any expenditure of public funds, a valid one. This plea, however, is obviously daily diminishing in force. In nearly all orders the specified time within which mains have to be laid in certain streets is two years. It is three years in the Birmingham Order of last year, but all streets within the area are included. The Liverpool Order is also an exception.

In the old orders two years was also the period that had to elapse before any supply could be requisitioned in other streets, and six months more is allowed to comply with the requisition. In last year's London orders and the new forms, however, supply can be requisitioned after 18 months, with six months for compliance; so that persons in streets not scheduled can get a supply at the same time as those in scheduled streets. Also, in the recent orders, as already mentioned, supply can be requisitioned for any part of the area included in the order; whereas in the old orders it could only be requisitioned for the A district.

There is a slight variation, too, in wording, which may be important, viz., whereas in the old orders mains were to be laid *in* every street, now it is *throughout* every street.

The requisition to lay distributing mains in any street has to be signed by a number of persons, which number is a very variable quantity in different orders.

Thus in the old orders of 1883 it was two or more owners or occupiers in the case of an order given to a company or person, and the owners or occupiers of not less than one-fourth of the premises in the street in the case of a local authority. In the Chelsea Order of 1886 it was six or more owners or occupiers.

Last year the Board of Trade reverted to the former practice both in the case of companies and local authorities, except in the Birmingham and Liverpool Orders, where no power of requisitioning is given to owners. These two orders are very exceptional in respect of these clauses.

This year, in the model forms, which are not intended to apply to London, it is proposed to follow the precedent of the Chelsea Order, and to require six signatures to a requisition, the number being the same both for local authority and company orders.

After the requisition clause follows a long clause intended to provide that the undertakers shall, if they so require, be guaranteed by the persons making the requisition a return for their outlay in laying the requisite mains of 20 per cent. per annum for three years in the old orders, two years in the London Orders, and again three years in the new model orders.

After these "Compulsory Works" clauses come a few clauses headed "Maps," and then, in the old orders, "Regulations as to supply on the parallel system." These regulations are not inserted in any of the recent orders, but are issued separately with the safety regulations. Then we come to some clauses headed "Testing" in all orders up to this year; but in the new models an improved arrangement has been followed, and "Supply" comes next to "Works," which certainly seems a more logical sequence; also, the clauses applying to the appointment and duties of electric inspectors are now put under a separate heading.

Taking these clauses first, the appointment of electric inspectors is vested, in the case of all orders to companies, except the London Orders, in the local authority; in the London Orders it is vested in the County Council; and in all existing local authority orders in a court of summary jurisdiction, moved either by a consumer or by the undertakers themselves. In the new model this appointment is vested in the Board of Trade. In case of the local authority not appointing an inspector, or imperfectly attending to inspectional duties, there is a provision in all company orders for appointment, in some cases by a magistrate, in others by the Board of Trade.

In the new model orders a clause has been added specially stating that the Board of Trade may appoint an inspector for the purposes of any enquiry on an accident or as to safety. I think it is obvious that the Board of Trade has in any case, whether expressed in the order or not, the right to make enquiry as regards safety.

All local inspectors are to be paid by the local authority, or County Council for London; but fees may be charged by means of which part, at any rate, of the cost of inspection will be recouped.

Inspectors may be appointed from time to time for particular services, or the appointment may be continuous. It is rather difficult to see how this matter will work in small towns where there may be no resident electrician unconnected with the undertakers, or, at any rate, none who would care to undertake the job for such remuneration as could be offered without unduly increasing the cost of the supply, since the expenses of inspection must in one way or another be borne by the consumers.

Probably one electrician will secure the appointment for several towns not very far apart, and reside in a convenient locality for his district. It will be something like the birth of a new species; and some follower of Darwin will in the next century write an exhaustive monograph on the genesis of the electric inspector, showing how he came to differentiate from ordinary mortals, how he gradually acquired an extra sense warning him against high pressure, etc.

The duties of electric inspectors are clearly defined in the new model orders, as follows:

The duties of an electric inspector under this order shall be as follows:

(*a*) The inspection and testing, periodically and in special cases, of the undertakers' electric lines and works, and the supply of energy given by them.

(*b*) The certifying and examination of meters; and

(*c*) Such other duties in relation to the undertaking as may be required of him under the provisions of this order, or of any regulations under this order.

* Paper read before the Institution of Electrical Engineers.

poration. Those who are conversant with the early history of electric lighting will know that until recently the principles of incandescent electric lighting were not generally understood, and though Mr. Lane Fox himself well knew the value of his patents, they were not properly appreciated by the companies who held them, and were mixed up and entangled with the claims of other patents held by the same companies for other and competent objects.

6. In illustration of the general contemporary ignorance of the principles now stated to be obvious, it may be mentioned that when first enunciated by Mr. Lane Fox they were received with ridicule and decried as impracticable, and that such staunch supporters of the system as Messrs. R. E. B. Crompton and W. H. Preece were at first opposed to them; even so great an authority as Sir William Thomson had for a time his doubts as to their theoretical soundness.

7. This opportunity may be taken to correct an impression which, to our great surprise, appears to prevail—namely, that Mr. Lane Fox confined himself, some 12 years ago, to shadowing forth the bare outlines of a scheme the essential details of which were laboriously worked out by others. This is not true. Not only were the principles of incandescent electric lighting distinctly enunciated by Mr. Lane Fox as stated above, but all details necessary to their efficient application were worked out by him independently, or through his agency, during the years 1878 to 1883. Thus in his hands the system became a thoroughly working system; installations were put up at home and abroad, and when Mr. Lane Fox temporarily abandoned electric work at the end of 1883 his system, which was ridiculed as late as 1881, was accepted and largely used.

8. After many abortive attempts to regain possession of the patents, attempts giving rise to "agreement" after "agreement" (each, as it was subsequently found, adding to rather than removing the confusion), an agreement was finally come to upon the conclusion of the recent litigation between the Anglo-American Brush Electric Light Corporation and the Edison-Swan United Company, Limited. By this agreement, dated 3rd December, 1889, each of the two litigating companies obtained a license to use the patents in the future, and an indemnity in respect of the past, but subject thereto and to certain licenses affecting the foreign patents, all the patents were assigned absolutely to Mr. Lane Fox.

9. In February of this year the Lane Fox Electric Company, Limited, was formed to carry out the long-postponed designs of Mr. Lane Fox, and to vindicate his position as the inventor of the true principles of incandescent electric lighting. The company, however, do not propose to charge vindictive royalties, or in any way to attempt to impede the progress already made, even by the unauthorised use of the Lane Fox patents.

10. Many times in the course of his prolonged negotiations with the Anglo-American Brush Electric Light Corporation Mr. Lane Fox was invited by competent financiers to join in the formation of a "ring" to control to their own exclusive advantage the electrical industry. Mr. Lane Fox declined. He wished to liberate and not to strangle the industry. Such still is his wish; and the wish of the Lane Fox Electrical Company is the same; but as true liberty consists in justice, and not in injustice, the company will vindicate the patents, and insist upon the payment of royalties in respect of them.

11. In pursuance of this purpose the company have formulated proposals, the terms of which will in due course be advertised; the pith of these proposals being that if those now using the patents will accept the proposed terms, or such modification of them as may be agreed upon by the middle of June next, no royalties will be claimed for the use of the patents prior to December 31, 1889.

12. It is confidently hoped that the companies and the electrical industry generally will see the fairness and reasonableness of the terms proposed, and will co-operate in giving Mr. Lane Fox the position he can fairly claim in the electrical world.—Yours, etc.,

C. A. STEPHENSON,
Managing Director Lane Fox Electrical Company, Limited.
May 31, 1890.

## TO HAUL OUR READERS!

Whatever be the creeds of men,
  Their race, or clique, or faction,
We're quite indifferent to them
  And fairly gone on Traction.

The wind may blow, the rain may pour,
  And down the people's backs run,
We only go and shut the door,
  And hurry on with Traction.

Electric lights we patronise,
  That is, we don't attack some;
On ev'ry subject we are wise,
  But ain't we nuts on Traction!

On engines we're Willan to oblige,
  Though fonder still of Paxman,
And wouldn't Robey of a prize
  For he is great "at-traction."

Though Ransome is as Ransome does
  He never fails in action,
But then we never make a fuss
  When things go wrong in Traction.

If Weatherby fine then Rust-on adds
  To summer shows distraction,
And Marshalls all his latest fads
  With other cranks on Traction.

And so our readers may be sure
  We shan't the beaten track shun,
But well or ill, or rich or poor,
  Continue haul for Traction.

## PROF. ELIHU THOMSON'S ELECTROMAGNETIC INDUCTION EXPERIMENTS.*

BY J. A. FLEMING, M.A., D.SC., M.I.E.E.

(*Continued from page 434*).

One of the most beautiful of Prof. Thomson's experiments illustrating this repulsion can, I think, be shown to you now.

An incandescent lamp is attached to the terminals of a coil of wire, and the coil and lamp floated in water or hung from a scale beam (Fig. 24) over the pole of an alternating magnet.

FIG. 24.

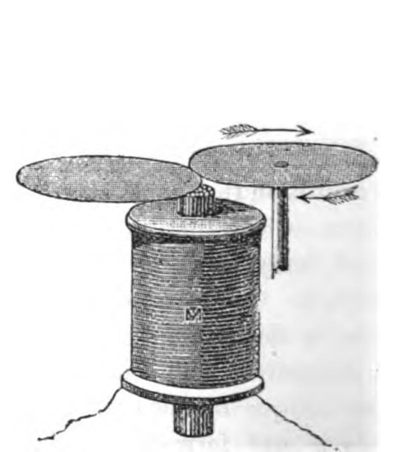

FIG. 25.

The coil and lamp form, as it were, a balloon and car floating in space, and placed in a magnetic field. When that magnetic field is rapidly alternated by exciting the magnet, the induced currents created in the coil make themselves evident by illuminating the lamp, and the repulsive electro-dynamic action shows itself by lifting the lamp and coil upwards through the water or the air.

The same experiment renders it possible to show the effect of

* Paper read before the Society of Arts, May 14, 1890.

magnetic screening very prettily. If I introduce a plate of copper between the magnet pole and the induction coil attached to the lamp, the copper "screens" the coil from the inductive action of the pole, and the light of the lamp disappears. I must next direct your attention to some curious effects which are found to exist when two conducting circuits are exposed to the magnetic flux from an alternating magnetic pole, and which depend upon the interaction of the currents induced in each respectively. Prof. Thomson embodies these facts now to be considered in four laws, which may be briefly stated as follows:

1. If two or more closed circuits are similarly affected inductively by an alternating magnetic field they will attract one another, and tend to move into parallelism.

2. Iron or steel masses placed in an alternating field give rise to shifting magnetism or lines of force moving laterally, and may, therefore, act to move closed circuits in the path of such shifting lines.

3. Closed circuits in alternating magnetic fields or fields of varying intensity give rise to shifting magnetism, or lines of force moving laterally to their own direction, and may, therefore, act to move other closed circuits in the path of such lines.

4. Iron or steel masses may, when placed in an alternating magnetic field, interact with other such masses, or with closed electric circuits, so as to produce movement of such masses or circuits relatively, or give rise to tendencies to so move, the effects depending on continual adaptations of shifting magnetism and retained magnetism relatively.

It is a simple matter to illustrate these principles; and the experiments which are designed so to do bring before us some striking peculiarities of the action of magnetic force upon closed circuits, and upon masses of conducting and magnetisable matter.

Returning, first, to the simple experiment of a copper ring repelled by an alternating pole, we find that if we add a second ring under the first, they both attract one another, and the two rings are supported and repelled as if they were one ring. It is obvious that at any instant the induced currents in both rings are in the same direction, and hence they attract one another.

Such an attractive action can be made to produce continuous rotation. We have only to place a copper ring or plate over the alternating-current coil or pole, and then bring a copper disc, free to revolve on pivots, into proper position relatively thereto. This can best be done by placing the ring or plate so as to be somewhat to one side of the pole, so as to "shade" part of it, as it were, while a part of the pivoted disc is placed under or over it, in front of the alternating pole. The disc then begins to revolve rapidly on its pivot (Fig. 25). A little consideration shows that in this case the fixed copper plate shields a portion of the pivoted plate. The currents induced in the fixed plate attract the non-symmetrically placed induced currents in the other disc, and exert a tangential action or couple upon it, tending to pull it round. The continual repetition of this action as each portion of the place becomes in turn the seat of maximum inductive action, results in a continual revolution of the plate. Two pivoted discs may be used instead of one, and it will be found that they may each "shade" a portion of the pole, and if made to overlap they will pull each other round and revolve in opposite directions when the alternating pole acts upon them.

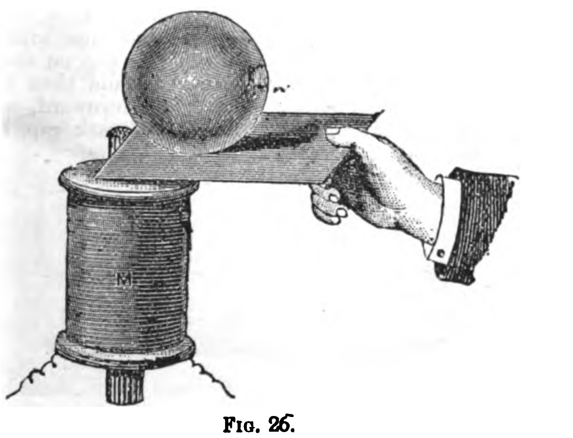


FIG. 26.

This principle of "shading" a portion of the magnetic pole, and hence causing an unsymmetrical distribution of induced currents in a conducting body capable of revolution on a pivot, has been developed by Prof. Thomson in many extraordinary ways.

Floating, for instance, a hollow sphere of copper on the surface of water in a glass vessel, he places this over an alternating magnetic pole. If the pole is placed directly under the sphere the electromagnet action would, as before explained, result in a repulsive force acting upon the disc. If, however, a sheet of copper is placed half over the pole so as to "shade" a portion of the copper sphere, the currents induced in it are unsymmetrically situated with respect to its centre, and react upon the current induced in the plate. Hence, the electromagnet action resolves itself into a torque or couple, causing the ball to spin rapidly upon its centre and take up a rapid rotation. So considerable is the rotational force brought to bear that the ball will rotate when merely laid on a sheet of copper, even overcoming the friction of such rotation on its equatorial line, provided that the ball and supporting plate are so held over an alternating pole that the plate shields a portion of the sphere (Fig. 26). Given this principle that by properly "shading" a pole from a portion of a solid body capable of revolution round a line or axis, it is easy to see that countless forms of electromotor can be designed.

A sort of anemometer, with copper discs for cups, resembling the cross of a Crookes' radiometer, can be set in rapid rotation by an alternating pole if a copper screen is placed so as to shade one side of it.

This unsymmetrical development of the induced currents can be produced by a suitable disposition of the magnetic pole alone. Thus we may place a cone or wedge of iron on the alternating pole, and hold near it a copper ring mounted so as to be able to revolve (Fig. 27). The copper cylinder or wheel revolves

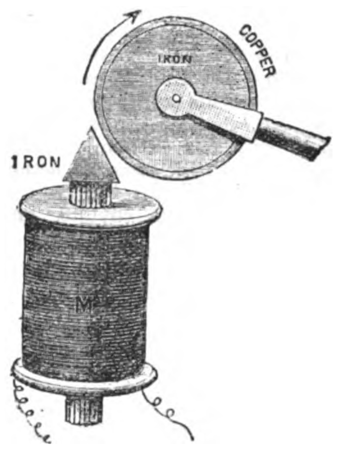


FIG. 27.

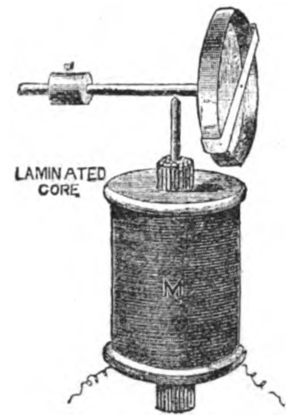


FIG. 28.

rapidly under the action of the periodic field, and its direction of motion is such that it seems to be blown around by a blast from the end of the magnetic cone. Prof. Thomson has constructed a curious electrical gyroscope as follows: A vertical pivot projects from the centre of an alternating pole (Fig. 28), upon which is pivoted a horizontal rod bearing a counterpoise, and a copper wheel, preferably with an iron core attached to it, gyroscope fashion, by means of a copper frame. The copper frame is placed in an inclined position with respect to the horizontal. Under these circumstances a vigorous rotation is communicated to the gyroscope wheel when the alternating field acts upon it. The copper frame shields one side of the wheel more than the other, and as a result the induced currents in the copper wheel are unsymmetrically placed with respect to its axes of rotation, and it experiences a violent torque.

These experiments can, by a little ingenuity, be endlessly multiplied when once the fundamental principle is grasped. Bodies can be made to rotate and move, taking their movements from the magnetised space in which they are placed, and without being supplied with current from an external source.

Prof. Thomson has, however, studied some curious cases of magnetic motion, in which rotations are obtained when iron or copper pivoted discs are placed near to iron or steel bars, in which the propagation of magnetism is throttled by closed cir-

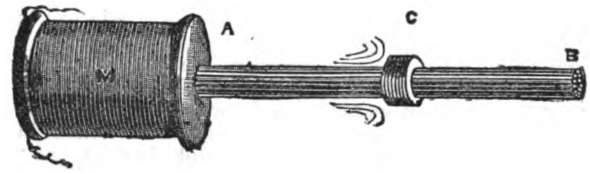


FIG. 29.

cuits. If a longitudinally laminated iron bar has a closed copper band or coil placed round it at one point, and if such a bar is made magnetic by a periodic current traversing a magnetising coil embracing another part, this structure becomes capable of rotating iron or copper discs held near it. The explanation of this effect is probably to be found in the fact that the closed embracing coil tends to throw off the magnetic lines of force laterally at that point. Consider a bar (Fig. 29), A B, in which lines of magnetic force are being established in the direction from A to B. That is to say, let magnetic induction be increasing in the bar in a direction from A to B, at C let there be a closed coil embracing the bar, the magnetic induction during its period of increase is setting up in this circuit an E.M.F. which establishes in the circuit a current whose lines of force are opposed to the primary induction inside the coil, and, therefore, in the iron included in the coil, but in the same direction outside the coil, and, therefore, outside the iron. The result is as if the lines of primary magnetic induction in the iron were shed off laterally and escaped round the coil. When the magnetic induction in the iron, due to the magnetising coil, is made periodic, this action will create a kind of lateral pulsation of the magnetic lines of force in the neighbourhood of the closed coil. If, then, a movable conductor is held near such a magnetically-throttled bar, it will be subjected to a displacement of lines of magnetic force through it laterally, and will hence have eddy electric currents generated up in it. These currents, persisting into the period of reversal of the field in virtue of self-induction in the conductor, will cause the portion of the conductor in which they are set up to be continuously repelled, and hence to take up a motion of rotation. A ring of cast iron, having a closed coil wound on it at one point, is held so that another point on its circumference, 90deg. removed from the closed coil, is on the pole of an alternating magnet. An iron disc, centrally pivoted and held concentric with the ring, is rotated when the magnet is energised by an alternating current. It is not even necessary to have a closed coil on one part of the active magnetic bar, provided that this bar is not laminated, or, better still, is made of hard steel. In these cases there is a lag in magnetisation, due to either eddy currents set up in the bar or to hysteresis, and the result is a lateral escape of lines of force out of the bar. When it is held with one extremity on an alternating magnetic pole, there is in these cases an action which is a true "magnetic self-induction." In the case of electric circuits, if we join in parallel two circuits, one

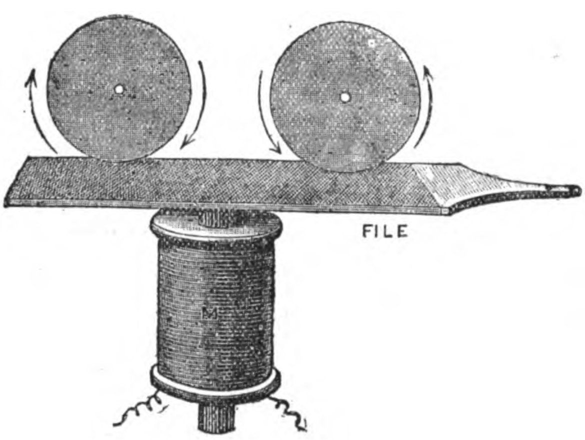


Fig. 30.

having very small ohmic resistance and very high self-induction, and the other very large ohmic resistance and small self-induction, a sudden flow of current chiefly selects the path of least self-induction for its flow during the variable period, although during its steady period it will chiefly flow by the path of smallest ohmic resistance; so in the case of a magnetic and conductive circuit of low magnetic and electric resistance (iron), shunted by a path of high magnetic and electric resistance (air), rapid variations of magnetic induction bring about a state of things in which the magnetic induction seems to chiefly select the path not of least but of greatest magnetic resistance during the variable period. Time will not permit me to develop at greater length the analogies of the magnetic and electric circuits under the conditions of rapidly periodic magnetic induction and electric current; but there are many suggestive ideas which arise when we place before our minds the notion of a magnetic self-induction which is the consequence of a time-element coming into action in the setting up of induction in a magnetic and conductive circuit, and due to the production of electric eddy currents, just as the electromagnetic or ordinary self-induction is the consequence of the time-element coming into action in the setting up of an electric current, and due to the production of a surrounding magnetic field. Just as the rise of current strength under an impressed E.M.F., acting in a conducting circuit, is retarded by linking that conductive circuit with a magnetic circuit, so the rise of magnetic induction under an impressed magnetising force acting on a magnetic circuit is retarded by linking that magnetic circuit with an electric conducting circuit. I am under the impression that Mr. Oliver Heaviside has developed these notions in a mathematical form, but am unable at the moment to place my hands upon the results. The effect, however, of a bar of unlaminated iron when surrounded by a magnetising coil at one end, and traversed by a periodic current, is to cause rotation in copper or iron pivoted discs held near it, or when such a bar of non-laminated iron is abutted on the pole of an alternating magnet. A bar of steel, even if not laminated, is able to cause brisk rotations in copper or iron discs under the same circumstances. With hardened steel the action is more marked. Here the hysteresis retards the propagation of the magnetic wave. By laying a large file flatwise against the alternating magnetic pole at about the middle of the file, discs of copper or iron may be kept revolving if held over those portions of the file which project from the pole of the magnet, Fig. 30. In this case the magnetic retardation in the bar is brought about by its own physical structure, and not by embracing it with a closed conducting circuit. The result is, however, the same in kind. There is a sluggishness in the establishment of the magnetic induction on the steel or iron under the action of magnetising force, which partly depends on the eddy currents in the mass of metal, and partly on hysteresis. As a consequence, we have a periodic lateral displacement of the field. The question of a magnetic leakage dependent on a retardation of induction deserves special attention in the case of commercial alternate-current transformers. Time will not permit me to enlarge on it here to any great extent, but I may observe that in the design of closed-iron circuit transformers this magnetic leakage should not be neglected.

*(To be concluded.)*

## LIGHTNING-GUARDS FOR TELEGRAPHIC PURPOSES.*

BY DR. OLIVER LODGE, F.R.S., MEMBER.

*(Concluded from page 427.)*

To suppose that the axial part of a conductor (whether solid all through or hollow, with a wire along its centre, makes no difference in principle) takes no part in conveying a momentary transfer of electricity, is to make the same error as is published so uniquely and interestingly by Sir William Thomson in the March, 1890, *Phil. Mag.*, wherein he corrects his original idea that the ordinary resistance of a ballistic galvanometer wire would not be the right resistance to introduce into its formula, because the outer layer of the wire conducts most of the current, and shows that, examining the matter still more completely, every part of the wire is ultimately effective, and equally effective as regards integral flow. All the rush does go by the outside at first, and all the *violence* is there expended anyhow, but every part of the section does its full share of conduction ultimately.

It is worth entering thus fully into the matter, because these are things about which it is easy to get bothered if one does not happen to get hold of them right way up. And this matter of protection by cages is one on which there has long been some uncertainty or hesitation.

Now that I see clearly how they act, their behaviour seems natural enough, and what one ought to have expected—what I think Maxwell (doubtless others also) would have expected; certainly it all comes out clearly enough on his principles. But a little time ago the matter was by no means so clear in my mind, and I rather gather that several others felt a similar sort of temporary uncertainty.

One more way of putting the result may be permitted. It is not given as an experiment, because I have not tried it. Take a sheet of metal or gauze, tap it along a certain line with a galvanometer on one side and with a spark gap on the other, arrange to send flashes along the same line, and then fold the sheet into a cylinder either upward or downward, so as to enclose at pleasure the galvanometer or the spark gap, but not both (*see* Fig. 24).

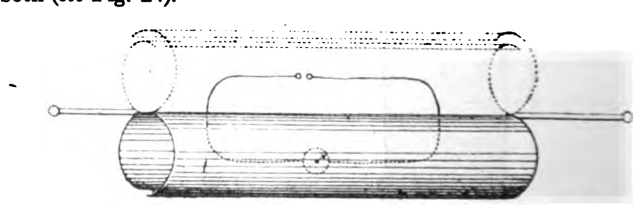

Fig. 24.

The indications of the galvanometer will be wholly unaffected by the way the sheet is folded, or whether it be left flat, provided always the insulation of its wire is and remains perfect. But to the air gap the folding of the sheet makes all the difference; when enclosed it will be quiescent, when exposed it may sparkle.

Discussion.—(*Authorised Abstract*).

**Mr. Saunders** said he got the idea of his lightning-guard in 1854 from noticing that cables were generally connected to land lines

* "On Lightning-Guards for Telegraphic Purposes, and on the Protection of Cables from Lightning, with Observations on the Effect of Conducting Enclosures." Paper read before the Institution of Electrical Engineers, April 24th, 1890.

consumed at the rate of 3·2lb. per electric horse-power hour in the dynamo. A very slight error is made in taking the rate of consumption as constant while changing the capacity of the engines.

Cost of steam plant is taken to vary from 50dols. per horse-power in a small plant to 20dols. in a plant of 1,500 h.p. This latter figure may seem too low to some, but I have recently seen the figures for an 800 h.p. plant in a neighbouring Massachusetts city which cost in place at the rate of 22dols. per horse-power.

(*To be continued.*)

## PROF. ELIHU THOMSON'S ELECTROMAGNETIC INDUCTION EXPERIMENTS.*

BY J. A. FLEMING, M.A., D.SC., M.I.E.E.

(*Concluded from page 452*).

In a closed iron circuit embraced at one part by a magnetising coil, and subjected to rapidly-reversed magnetic force, the magnetic induction does not confine itself wholly to the path of least magnetic resistance—viz., the iron path—but takes a short circuit in part across the interior air space. This waste field may in badly-designed transformers be something considerable. I believe that an important point to hold in view in transformer construction is to subject the iron circuit uniformly to the magnetising force by embracing all portions of the iron circuit with primary windings, and not locating the windings simply at one part. There is, then, a tendency to check the production of waste field by the lateral budging-out of the magnetic lines of force from the iron. In Fig. 31 is a diagram illustrating the

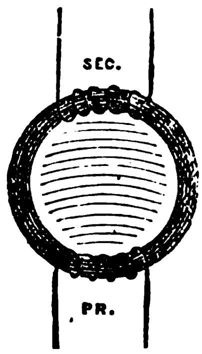


FIG. 31.

arrangement of primary and secondary coils most favourable for the production of waste field, and in Fig. 32 the arrangement least favourable for the same.

The foregoing experiments are of such a nature as obviously to force on us the thought that useful and perhaps important applications can be made in electromagnetic machinery. Prof. Elihu Thomson has, as you can imagine, not been slow to do this; for in him is united both a keen scientific sagacity and that clear mental vision which enables him to pursue to its logical issue in practice the consequences of scientific discovery.

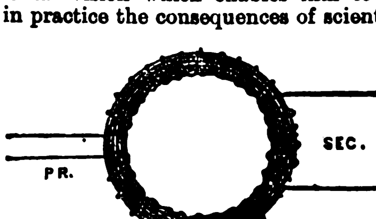


FIG. 32.

He has already applied these principles to the construction of alternating-current indicators, alternating-current arc lamps, regulating devices for alternating currents, and to rotary motors for such currents. For current indicators, a pivoted or suspended copper band or ring, composed of thin washers piled together and insulated from one another, and made to carry a pointer or index, has been placed in the axis of a coil conveying alternating currents whose amount or potential is to be indicated. Gravity or a spring is used to bring the index to the zero of a divided scale, at which time the plane of the copper ring or band makes an angle of, say, 15deg. to 20deg. with the plane of the coil. This angle is increased by deflection, more or less great, according to the current traversing the coil. The instrument can be calibrated for set conditions of use. Time would not permit of a full description of these arrangements as made up to the present.

* Paper read before the Society of Arts, May 14, 1890.

In arc lamps the magnet for forming the arc can be composed of a closed conductor, a coil for the passage of current, and an iron wire core. The repulsive action upon the closed conductor lifts and regulates the carbons in much the same way that electromagnets do when continuous currents are used. The electro-inductive repulsive action has also been applied to regulating devices for alternating currents, with the details of which I cannot now deal.

For the construction of an alternating-current motor, which can be started from a state of rest, the principle has also been applied, and it may here be remarked that a number of designs of such motors is practicable.

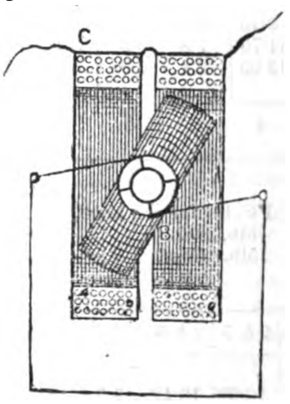


FIG. 33.

One of the simplest is as follows: The coils, C, Fig. 33, are traversed by an alternating current, and are placed over a coil, B, mounted upon a horizontal axis transverse to the axis of the coil C. The terminals of the coil B, which is wound with insulated wire, are carried to a commutator, the brushes being connected by a wire, as indicated. The commutator is so constructed as to keep the coil B on short circuit from the position of coincidence with the plane of C, to the position where the plane of B is at right angles to that of C; and to keep the coil B open-circuited from the right-angled position or thereabouts to the position of parallel or coincident planes. The deflective repulsion exhibited by B will, when its circuit is completed by the commutator and brushes, as described, act to place its plane at right angles to that of C, but being then open-circuited, its momentum carries it to the position just past parallelism, at which moment it is again short-circuited, and so on. It is capable of very rapid rotation, but its energy is small. He has extended the principle to the construction of more complete apparatus. One form has its revolving portion or armature composed of a number of sheet-iron discs, wound as usual with three coils crossing near the shaft. The commutator is arranged to short-circuit each of these coils in succession, and twice in a revolution, and for a period of 90deg. of rotation each. The field coils surround the armature, and there is a laminated iron field structure completing the magnetic circuit."

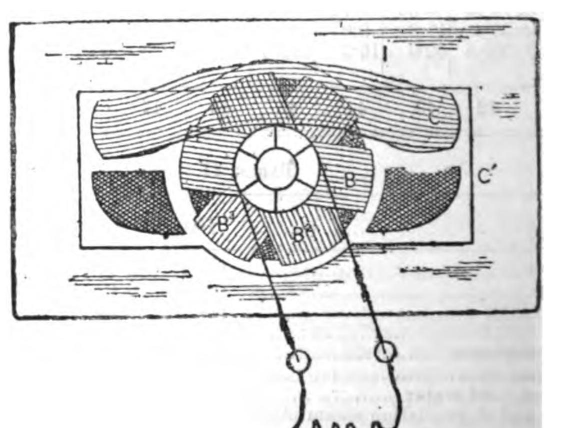


FIG. 34.

In Figs. 34 and 35, we have diagrams which will give an idea of the construction of the motor referred to. C C′ are the field-coils or inducing coils, which alone are put into the actuating alternating circuit. I I is a mass of laminated iron, in the interior of which the armature revolves with its three coils, B, $B^2$, $B^3$, wound on a core of sheet-iron discs. The commutator short-circuits the armature-coils in succession in the proper positions to utilise the repulsive effect set up by the currents which are induced in them by the alternations in the field-coils. The motor has no dead point, and will start from a state of rest and give out considerable power, but with what efficiency is not yet known. A curious property of the machine is that at a certain speed, depending on the rapidity of the alternations in the coil C, a continuous current passes from one commutator brush to the other, and it thus performs the function of converting some electric energy from an alternating to a continuous form.

A small motor of a curious type has been made, utilising the principle of "shading" the pole by closed circuits. A laminated ring (Fig. 36) is wound over with wire, but has a slot cut through it, dividing the ring, and causing it to present two pole-faces opposite to each other at the cut part. Each pole is arranged by a set of closed copper bands to be "shaded." A

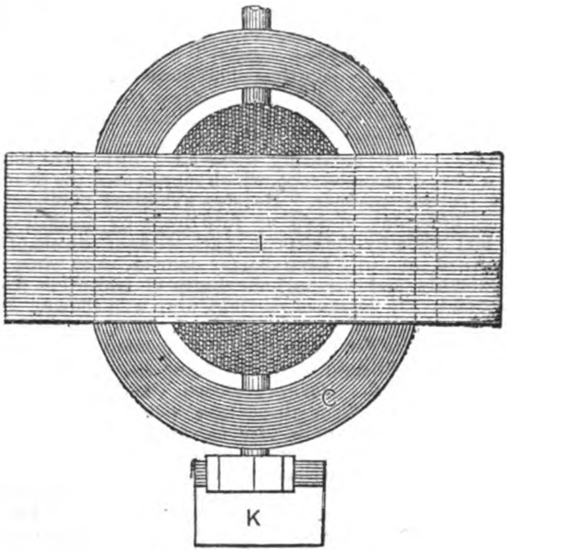


FIG. 35.

copper disc, free to turn on a shaft, is introduced by one edge into the air gap in the magnet, and turns rapidly when the magnet is excited. A silver coin held just at the edge of the air gap in such an alternating magnet with shaded poles, is drawn into the interpolar space and propelled with some force through the same ; but a lead disc or coin of base metal is not acted upon nearly by the same force owing to its inferior conductivity. I have left myself but little time to speak of numerous applications of these principles in alternating-current meters. The well-known meter of Mr. Schallenberger was described to you here quite recently by Prof. Forbes. There is, however, a new form of meter, designed by Messrs. Wright and Ferranti, which exhibits in a most beautiful manner a practical application of some of these principles which have briefly occupied our attention. In Fig. 37 we have a diagram of this meter. It consists in its latest form of a pair of vertical electromagnets —magnets having divided iron cores. To the poles of these magnets are attached curved horns of divided iron, which lie in a horizontal plane. These curved horns are magnetically throttled at intervals along their length with copper bands.

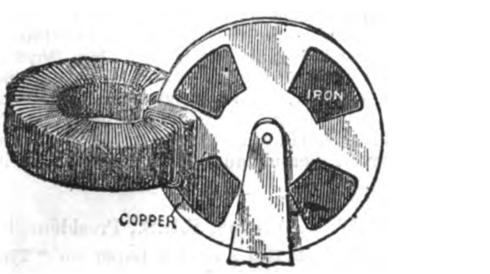


FIG. 36.

The curved horns embrace a circular space, in which can revolve a light copper or iron shallow cylinder of thin metal. This cylindrical band forms the periphery of a light wheel capable of rotation on a vertical axis. Geared to this axis is a counting mechanism. The axis also carries a vane, having mica blades. The electromagnetic principle may be briefly described thus : The throttling of the curved iron horns causes the rapidly reversed magnetism to take the form of a lateral diffusion of lines of force from the sides of the horns. In effect a series of oppositely-named magnetic poles travels along the horn from the base, where it is in contact with the top of the electromagnet to the tip. These poles are represented by a series of bunches of lines of force setting out laterally from the sides of the horn, and travelling up it. The lateral passage of these lines of force through the metal band which forms the rim of the movable wheel generates in it eddy currents. These are continually repelled by the moving field producing them, and hence a motion of rotation is given to the wheel by the alternating magnetism of the magnetic poles. The speed of rotation, being retarded suitably by the vanes, can be made to be proportional to the current strength of the current exciting the magnets, and hence the total turns of the wheel in a given time to the total electric quantity flowing through the meter. A beautiful adaptation has here been made of the principles we have been briefly studying, and much more might be said in explanation, or rather, in elucidation of the action of this meter did opportunity permit.

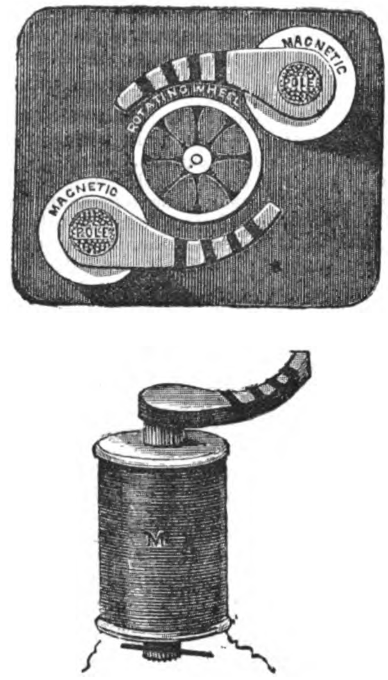


FIG. 37.

It would take me beyond the limits of the time during which I am permitted to trespass upon your attention, if I were to attempt to exhaust the list of electromotor applications that have been made of these electromagnetic repulsions. That is a subject important enough to deserve a separate treatment. In Berlin not long ago I saw a most ingenious form of self-starting alternating-current motor, the invention of Herr von Dolivo Dobrowolsky, in which the rotating portion was merely a solid iron cylinder, constituting a commutatorless armature, revolving in an alternating field, and which acted in a perfectly marvellous manner. The region of practical invention here opened is a very wide one, and I have therefore ventured to direct your thoughts to it to-night, confident that its character in this respect deserves all the attention it can obtain, and that a firm foundation for such work is laid in these interesting researches of Prof. Elihu Thomson.

## LEGAL INTELLIGENCE.

### CROMPTON AND CO. v. ELIESON ELECTRIC COMPANY, LIMITED.

In this action, which began on Wednesday last before Mr. Baron Huddleston and a special jury, the plaintiffs claimed to recover from the defendants a sum of £450 odd for certain goods supplied and work done for the defendants at their request. It was agreed during the trial that £384 was the amount to be paid the plaintiffs by the defendants. The defendants counter-claimed for damages, urging that in May, 1888, it was agreed between them and the plaintiffs—who at that time knew all about certain arrangements by the defendants with the North Metropolitan Tramways Company—that the plaintiffs should, for reward, undertake and be responsible to the defendants for the superintendence and erection of certain works and buildings, and the running arrangements in connection therewith, and should have the sole control and management of the same, and should exercise all due and reasonable care and skill in such management, and that the plaintiffs undertook to put the whole of the said works, buildings, and plant into proper working order and to do all things necessary to insure the proper working and running of the defendants' traction engines and of the traffic on the North Metropolitan Tramway, so far as it depended upon the said engines, and that the plaintiffs thereupon, in pursuance of the said arrangement, entered upon such management and supervision of the said works, etc., and took possession thereof and assumed their whole control. The defendants alleged that in breach of this arrangement the plaintiffs were guilty of negligence in carrying out the same, and had so caused the defendants serious loss and damage, inasmuch as owing to such negligence the North Metropolitan Tramways Company discontinued the use of the defendants' electrical engines, and refused to continue the arrangements then subsisting between them and the defendants