does its work so noiselessly that a person standing near cannot tell without the closest observation whether it is running or not.

The ease with which these blowers can be set up and connected to the dynamos, without requiring any shafting, belting, or other contrivance except the small wire, has already brought them to the attention of ship builders. For exhaust ventilation electric blowers cannot be surpassed.

The following table gives necessary information relating to this combination :

Type number.	Speed per minute.	Cubic feet of air per minute.	Height in inches.	Diameter inlet in inches.	Diameter outlet in inches.
0	2,000	450	18	5¾	4¾
1	1,900	635	20	6½	5¾
2	1,700	900	24	7½	7½
3	1,300	1,150	27	9	9
4	1,150	1,425	33	10½	10½
5	1,040	2,340	40	12	12
6	975	3,375	45	14	14
7	875	4,840	50	16	16

SHIP LIGHTING.

The following circular has been addressed by the Secretary of Lloyd's to those interested in the electric lighting of vessels :

"Sir,—The attention of the committee of this society has been drawn to the circumstance that in vessels lighted with electricity fires have occurred through defects in fittings, or in the insulation of the wires.

"As such accidents are of great importance to all concerned in the safety of vessels, the committee are very desirous of obtaining the fullest and best information possible respecting the use of the electric light for lighting vessels.

"I am directed, therefore, to address you on the subject, and to intimate that the committee will feel much obliged to you for any remarks and suggestions with which you may kindly favour them with regard both to methods of installation, and also to the most satisfactory means of maintaining the insulation of wires and fittings unimpaired, so as to eliminate as far as practicable the risk of fire which at present appears to attend the use of the electric light.

"I am, Sir,
"Your obedient servant,
"B. WAYMOUTH, Secretary."

We give below a specimen of the replies sent to the above circular :

"Dear Sir,— The Electric Lighting of Ships.— The subject of the circular has great interest for us, as also for probably most other London electric lighting companies.

"In our opinion, the chief cause of the fires you refer to is the exceedingly bad work that is, as a rule, put into ships' installations, and the bad quality of the wires used for conveying the current over the vessels. For a long time past the London firms interested in this class of work have almost ceased to tender for ship work, owing to the absurdly low prices paid for it, and which would not, were the work of a proper character, in many cases pay for the value of the materials used, without any consideration of the amount to be spent in the work of installing; these firms being used, owing to the strict regulations insisted on by the various insurance companies, to executing work of a very high character alone, and knowing as they do from experience that safety with electric lighting can only be obtained when the work is thus excellent, they do not care to associate themselves with work of a character that will lead to accidents and thus injure their reputation. The wisdom of the regulations of these fire insurance companies is amply proved by the absolute immunity from accidents that has been enjoyed by those using electric light on land when their installations have been carried out under the supervision of these companies. It must not be forgotten in this connection that the currents used for the distribution of electricity from central stations on land are of a much more dangerous character than those used for ship lighting, and that therefore the accidents on land should be greater in number than on the sea, the other conditions being equal.

"Unhappily, the builders and owners of ships are quite ignorant, as a rule, of the classes of electrical work, and almost invariably accept the lowest tender, with the result mentioned in your circular. As an example of this, the writer, when on a voyage to the States on the "Umbria," one of the finest Atlantic liners afloat, witnessed a small fire caused by the electric lighting. We can safely say that work of the kind on this steamer would not be carried out by a third-rate firm in London ; it was as bad as could be.

"Another source of accidents on board ship is the use of the hull of the ship as a return wire. This at once halves the security of the installation, as if one branch of the other wire comes into contact with the hull of the ship an accident at once occurs, whereas had two wires been used the first contact would make no difference. The most stringent rule enforced in land installations is that the earth should form no part of the circuit, and it is difficult to know why this rule, if it is important on land, should not be thought so on ships, where, owing to the continual presence of damp, the chances of a short circuit are so much increased.

"In our opinion, the proper course to pursue to place sea installations on the same footing as land installations, and thus making them as safe, is :

"1. To insist on the work and the material being of the best possible character. To ensure this a system of inspection, like that of the fire insurance companies, should be instituted under a properly-qualified head, and vessels should be required to be certificated before acceptance as safe.

"2. The 'single-wire' system of installing the electric light should be absolutely abolished, and a double-wire system without any 'earth connection' be insisted on in all cases.

"If we can give you any further information on the subject we shall be happy so to do."

PHENOMENA OF ALTERNATING CURRENT INDUCTION.*

BY PROF. ELIHU THOMSON.

About three years ago I had the pleasure of bringing to the attention of the American Institute of Electrical Engineers at its annual meeting, certain phenomena of the repulsive action between conductors such as coils of wire traversed by alternating electric currents. It was then noted that if such a current be sent through a circuit wound as a coil, and either provided with an iron core, or not so provided, and permitted to induce in another coil or circuit a current under conditions which allowed a lag or displacement of phase of the latter from its theoretical position, a repulsive effort would be exerted, tending to remove one coil from proximity with the other, or to deflect one of them to a position such that the plane of the coils would be at right angles one to the other.

Many modifications of the arrangements of the coils were described and apparatus based upon the principle of inductive repulsion, as I called it, were touched upon. I need not now enlarge upon these matters. It may suffice to say that current indicators and potential indicators or voltmeters have been constructed embodying the principle as applied to the quantitative measurement of alternating currents. Arc lamps have been made in which the regulation of the carbons has been effected by the repulsive action of a coil traversed by the current fed to the lamp, or by a derived current around the arc, acting on a closed band or circuit movable with the regulating and feeding frame of the lamp. Various forms of alternating-current motors have been made in which the revolving portion is composed of coils arranged to be closed upon themselves, and inductively acted upon by the currents in what may be called the field or inducing coils connected with the alternating current source. The principle has been applied in other apparatus,

* Abstract of a lecture delivered before the American Institute of Electrical Engineers at Columbia College, April 2, 1890.

such as regulating mechanism for alternating currents and in electric meters.

It is my purpose this evening to bring before the institute some experimental apparatus showing the action of inductive repulsion in some of its phases, following this by a brief account of a number of other effects somewhat allied to it, with experimental demonstrations of the same. Some of these experiments were to be seen at the Paris Exposition of last year in connection with my exhibit there, and others of them are more recent still, while still others have never been shown at all in public. The field is a fruitful one, and there is not time to touch upon other than the more striking and perhaps interesting phases of the actions exhibited, which are susceptible of modification to a great extent by changes in proportion and arrangement of apparatus.

I may here revert to one experiment, which is almost a repetition of one I made about five years ago. If a copper disc or closed coil be balanced in front of another coil and parallel thereto, it will be noticed that on passing a current into the second coil the disc or closed coil will be repelled slightly, and if the current be afterwards shunted or cut off there will be a slight attraction. By opening and closing the shunt so as to put the current successively on and off the coil, there will be alternate repulsions and attractions exhibited. Let the current, however, be so put on and off very quickly, and the attractive effect will become less than the repulsive effect, and the disc or closed coil will be driven away or bodily repelled. Replace, now, the intermittent current by an alternating current, which reverses many times per second, and the repulsive effect alone is noticed, provided that the disc or closed coil is of sufficient mass and conductivity to allow currents of high self-induction to be set up in it, whereby such disc or coil or current in it may, as it were, exert a controlling influence upon the magnetic field in immediate proximity to it.

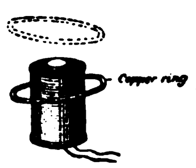


FIG. 1.

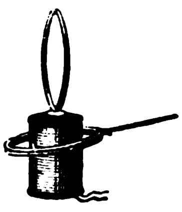


FIG. 2.

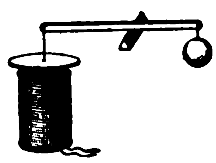


FIG. 3.

The amount of this repulsive effect may, under favourable circumstances, become so great as to give with moderate-current densities a very considerable pressure or force.

I have selected some particular instances of this action for our experiments, as it will be understood that time is too short to show many variations of the effect as found in numerous experimental trials.

Placing a copper ring over a coil which has been wound upon an iron core, and passing an alternating current through the coil, gives so much repulsive effect that the ring is thrown forcibly away and up into the air (Fig. 1). Or, again, the ring may be supported for a moment in free air, though its condition is one of unstable equilibrium. Further, we may arrange a string or thread to so guide the ring that it cannot move laterally though free to fall towards the alternating-current coil (Fig. 2). It is in this case supported in the magnetic field of the coil and away from it. It takes a position of balance between the repulsive effect and its own weight, which are opposed forces. As a curious variation, another copper ring (Fig. 2) may be added under the former, to which it seems to be attracted as though magnetised, after which both rings are supported as one. The explanation is very simple. The currents induced in both rings are in the same direction at any instant and produce attraction. The bearing of this will be seen in later experiments where rotary actions are produced.

Copper plates are but imperfect discs and act as closed coils. Aluminium rings, having much less weight than copper, might at first be expected to be more readily supported, but it must be remembered that the conductivity of aluminium is much less than that of copper, and hence that since the effect depends on current induced and retardation of phase or lag of such current, copper is the better on account of its high conductivity.

By attaching the closed ring or coil to a balance beam (Fig. 3), we are able to measure the amount of force exerted with different currents, and the different materials or constructions.

Such measurements show very decidedly that the repulsive effort depends on the strength of the current in the inducing coil, and in the ring or closed coil, and on the relation of the position of the waves of induced current in the closed coil or ring with those of the inducing coil. The effects are, properly considered, magnetic repulsive effects of the opposing fields of the induced and inducing currents relatively.

When the closed coil or disc is mounted so that it can only turn on an axis in its plane then the repulsion resolves itself into a deflection of its plane to a position at right angles to the plane of the inducing coil, or, more strictly, to parallelism with the direction of the magnetic lines set up by such inducing coil. The effect of the control exhibited by such a closed circuit of good conducting power over the magnetic field of the inducing coil, is seen by interposing such closed circuits between the inducing coil and another coil acting as a secondary and feeding an incandescent lamp (Fig. 4). The light of the lamp is cut down and extinguished thereby, as the alternating field is now almost completely shielded from the secondary. The coil feeding the lamp undergoes a slight repulsion. This is easily exhibited by placing in a glass jar with water a lamp and coil, the lamp wires being connected with the coil terminals, and so loading it that it just sinks to the bottom of the jar. Placing this above the inducing coil so as to bring it into the alternating magnetic field is attended not only with the lighting

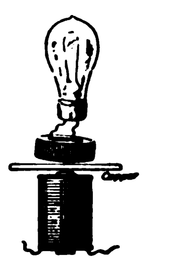


FIG. 4.

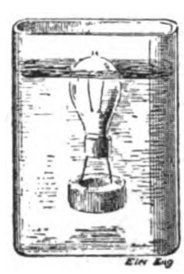


FIG. 5.

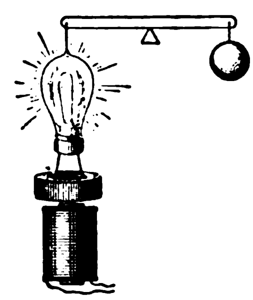


FIG. 5a.

of the lamp under water, but there is noticed a repulsion or floating of the lamp to a certain point (Fig. 5), at which its tendency to sink just balances the repulsion exerted. So long as the lamp remains so suspended in the water its brilliancy is constant, notwithstanding that the strength of the inducing current be raised or lowered considerably. It is, of course, unnecessary to use water to balance the lamp coil; a beam and counterpoise weight will suffice (Fig. 5a).

In utilising the repulsive action for obtaining movement from alternating currents, the closed coil or circuit may be mounted in various ways.

A convenient form is one in which a bent core of iron wire or plates which may be a ring is wound over with insulated wire at a portion only of its surface. A closed band or secondary is pivotally mounted, so as to pass over the curved core, and also over the wire-covered portion if moved around the pivot by a suitable carrier (Fig. 6). A spring or weight may tend to cause the closed band to pass over the wire-covered portion of the core. Currents sent in the wire coil produce repulsion and movement of the closed band about the pivots to a position on the core removed from the coil.

This apparatus, and some of its modifications, is a valuable reactive coil, which gives a smooth variation, and hence is called a "smoothly-acting reactive coil," for it enables us by changing the relation of the closed band or secondary circuit to affect the inductive resistance, as it may be termed, or the impedance of the coil wound on the core, the changes being made by swinging the closed band on its pivotal support by a suitable operating handle. It so varies the effects in an alternating circuit as to represent those of variable resistance in a continuous-current circuit, but it does this without much loss of energy, and not by steps, but through the finest gradations. The power is greatly increased by the provision of a movable iron armature for the core, centrally placed and pivoted, carrying the closed secondary coil upon it.

It is easy to see that by placing on a laminated armature core a series of coils which can be suitably short-circuited by a commutator, and placing such armatures between poles of alternating magnetic polarity, or, better, surrounding such armature by coils for producing directly in it an alternation of magnetic states, while the magnetic circuit is completed by an outside magnetic circuit of laminated iron, we have obtained a rotary motor for alternating currents which may be termed a transformer-motor, since the armature currents are induced and not obtained from the outside.

But by properly constructing such a machine, it is not necessary to have a commutator if we are content to start the motor initially by some means, for we may close the armature coils on themselves, pass alternating current through the field coils so as to establish an alternating field in which the armature exists, and it will be found that the machine will turn in the direction in which it has been started and run up to a speed depending on the construction. I have constructed a number of such machines, some of which are self-starting without a commutator. They are made self-starting by special features of construction. Whether they can be made of high or fair efficiency remains to be seen. Using only one alternating current they can, of course, be used on existing lines.

There are a number of curious effects to be described which depend on a shifting or propagation of magnetic lines of force.

Many of these effects were worked out conjointly by Mr. M. J. Wightman and myself, and some of the ways of exhibiting them are due to the skill of my workmen carrying on the construction of apparatus.

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 it in part, as it were, while a part of the pivoted disc is placed under it, or over it, in front of the alternating field pole (Fig. 7). The disc then revolves from the unshaded portion of the pole towards the shaded portion where the closed ring or plate is placed.

The actions are due to lines of magnetic force at each alternation of current in the magnetising coil below meeting a retarding influence or opposition to their development over that part of the pole shaded by the copper ring or plate owing to currents induced therein. The copper disc is the seat of similar currents, but chiefly about those portions not shaded by the ring or plate. Owing to self-induction, these currents in ring and plate tend to persist into the period of reversal of the field. This gives rise to a movement of those portions of the disc where current is flowing into a position directly adjacent to the ring or the currents flowing in it, an action which is repeated at every alternation and results in a revolution of the disc. While this explanation is probably the simplest it must be borne in mind that it is but an expression of a set of magnetic actions or changes in the magnetic field; such magnetic field being the resultant of the changing force of the original alternating inducing field and of the magnetic effects of the currents set up in a ring or plate and the disc, both of which latter have a retarding action due to self-induction of the currents in them.

If, now, two discs be used instead of one (Fig. 8), it will be found that they may each shade a portion of the pole, and that the discs, if made to overlap, will both revolve in opposite directions relatively.

An iron disc may be substituted for one of the discs above and used with the fixed plate or ring below it, and

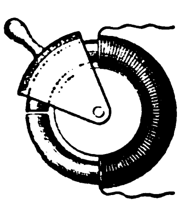


Fig. 6.

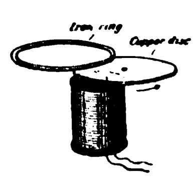


Fig. 7.

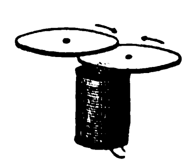


Fig. 8.

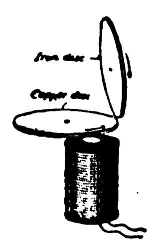


Fig. 9.

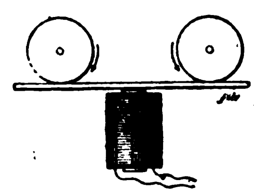


Fig. 10.

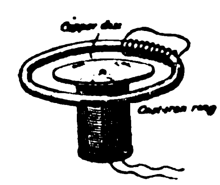


Fig. 11.

The principles 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 magnetic 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 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.

The experimental demonstration of these principles can be carried out with very simple apparatus. The explanations of the actions which occur in accordance with known principles are in many cases very evident, and in others are arrived at with a little study. Nevertheless, the experiments illustrate, in a marked manner, properties of matter and peculiarities of magnetic action which will probably never be fully understood unless the nature of the ether and its relations to what we call matter are discovered.

We will return to the case of the ring attracting another ring to it. Here we have the case of like currents in parallel direction producing attraction. Such an action can be made continuous. We have only to place a ring or plate over the alternating-current coil or pole of its core

so be caused to revolve, and its position can be changed so that it is in a plane vertical to the plane of the plate or ring (Fig. 9). Also, it may be similarly used in relation to the revolving copper disc. In fact, the positions of two copper discs pivoted so as to be revolvable, or of a copper and iron disc, may be greatly varied and effects of rotation obtained.

If we vary the experiment by placing a closed coil around a part of an iron core upon which is also wound a coil which can be put into an alternating-current circuit the effects obtainable are similar to those described above—that is, the structure becomes capable of revolving copper or iron discs held near it. The direction of revolution is such as to indicate a propagation of magnetism or magnetic polarity at a retarded rate through that portion of the iron core covered by the closed coil. In this respect a bar of iron unlaminated, or not divided, is the same as a core surrounded by a closed coil, for it is also capable of causing the rotation of the discs, when such a bar is abutted to a laminated core alternatively magnetised, or when such a bar is surrounded at part of its length only by the magnetising coil. A bar of steel substituted for the iron, even if well laminated, is able to cause brisk rotations of the copper or iron discs.

With hardened steel the action is the more marked, a file serving for the experiment. Here the "hysteresis," or coercive force, or magnetic friction retards the propagation of the magnetic wave. By laying a large file flatwise against the alternating magnet pole at about the middle of the file (Fig. 10) two discs of copper or iron may be kept revolving, or one each of copper and iron held over those portions of the file projecting from the pole of the magnet over which it is laid will revolve. The iron disc may be held vertically, and the copper horizontally or flatwise to the file.

Cast iron behaves like steel, though more feebly. A ring of cast iron, having a closed coil wound on one part (Fig. 11), can be laid on the pole of the alternating magnet coil, and it will rotate an iron disc concentric with it if the placing of the closed coil portion of the ring is not made so as to bring it either over the pole or diametrically opposite that point, the best effect being obtained when it is alongside of the pole.

(To be continued.)

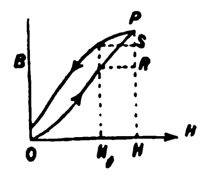
PHYSICAL SOCIETY.—April 18.

Prof. W. E. Ayrton, F.R.S., President, in the chair.

Mr. W. B. Croft was elected a member of the society.

Prof. Rucker described the results of "**Some Recent Magnetic Work**" undertaken by himself and Prof. Thorpe in connection with their magnetic survey of the United Kingdom. In a paper read before the Royal Society last year they have shown that the United Kingdom can be divided into seven or eight distinct districts, in each of which a source of disturbance seems to exist. The probable cause of these disturbances the authors believe to be the presence of "magnetic rocks." If this be true, an intimate connection should exist between the magnetic elements of a district and its geological structure. If a magnetic mass be supposed to exist below the surface, then one would expect the vertical force to be greatest above that mass, whilst the horizontal disturbances would tend towards the mass, and would differ in direction on its opposite sides. With a view to testing more fully than heretofore the magnetic constitution of the districts above referred to the work (the results of which Prof. Rucker now described, was undertaken. Two test districts were selected in which numerous observations were taken; one of these is situated on the west coast of Scotland, and the other embraces parts of Lincolnshire and Yorkshire. The first of these districts was chosen for two reasons: First, because it is very disturbed, and owing to the vast masses of basalt would be a specially difficult one, and, secondly, because it is near the borders of their survey, and is thus particularly open to suspicion that the calculated values of the elements may be inaccurate. By the aid of magnetic maps Prof. Rücker showed that a centre of disturbance exists to the west of Iona and south of Barra. Both the vertical force and the horizontal disturbances indicate the same position, and hence favour the hypothesis. In the Lincolnshire and Yorkshire district, extending from The Wash to Appleby, there is a region in which the horizontal disturbances along the east side tend towards the west, whilst along the west side they are on the whole directed easterly. This points to a ridge of magnetic material along the middle of the region, and from numerous observations the approximate position of the ridge line has been determined over a length of 150 miles. In Lincolnshire the ridge follows closely the line of Wolds, whilst at the Kettlewell end it is directed towards the Cumberland lake district. Places of maximum vertical force occur near Market Weighton and Harrogate. The observers were directed to Market Weighton by Prof. Judd, as being situated where the liassic strata thins out. Harrogate stands on the summit of an anticlinal. The fact that such places of maximum vertical force exist where, according to hypothesis, they would be expected, tends to confirm the supposition, and thus to demonstrate that a very close connection exists between the magnetic elements and the geological structure of a country. This is further confirmed by the observation that in Lincolnshire the line of disturbance follows closely the line of the Wolds, and that from Market Weighton it passes across the plain of York to the millstone grit and limestone, which are the oldest rocks in the neighbourhood. **Mr. Whipple** said he had listened with very great pleasure to the most interesting details and results given by Prof. Rücker. Never to his knowledge had a magnetic survey been conducted with such minuteness and accuracy. The older surveys related chiefly to declination, whilst the determinations of intensity were made in a very primitive way. He looked forward with great interest for other important results which he felt sure would follow from the admirable survey of Profs. Rücker and Thorpe. A most cordial vote of thanks was accorded to Prof. Rücker for his most interesting and valuable communication.

Mr. T. H. Blakesley, hon. secretary, read a paper on "**A Theory of Permanent Magnetism,**" by M. Osmond. The author stated that iron exists in two distinct physical states—one soft, or "*α iron,*" and the other hard, or "*β iron.*" The *β* variety is non-magnetic, and is formed during heating, hardening, or by electrolysis, whilst the soft or *α* modification is produced by long annealing. In a piece of steel the author considers the *β* molecules to form a rigid framework in which the *α* molecules become interlocked under the influence of magnetising force, and on the degree of interlocking the permanent magnetism depends. By a graphical method it is shown that the permanent magnetism should be a maximum when the two varieties are present in equal quantities. If the proportions of carbon and manganese in the steel are considerable, then nearly all the iron is of the *β* variety, and the steel is nearly non-magnetic. In hardening a piece of ordinary steel, the surface layers being cooled most rapidly contain more *β* molecules than the interior; hence for a certain degree of hardness (when the outer layers have more *α* molecules than *β* ones) a laminated magnet will be a better permanent magnet than a solid one, but for a much greater degree of hardness the reverse may be the case. **Mr. Swinburne** asked if the theory would account for the increase of induction which occurs when the circuit of a permanent magnet is closed. Most theories founded on the orientation of particles by the magnetising force seemed defective in this respect. Some time ago he had suggested that the permeability of iron should be tested by first magnetising it one way, and then at right angles to the first direction; recently he had been informed that no increase of permeability was observed when the experiment was performed. **Prof. Perry** said he had subjected iron to magnetisation in one direction, and found the permeability for small forces in a direction at right angles much smaller than he had anticipated; the first magnetising force was kept constant when the small perpendicular one was applied. **Mr. Swinburne** thought that for such small perpendicular forces the permeability should be nearly infinite. He also said there seemed to be a sort of angular hysteresis in iron, for if a loose running armature was turned slowly round by hand it would come back two or three degrees when left free. The **President** remarked that as far as he could see M. Osmond's theory does not account for the great influence which a small percentage of tungsten has on the magnetic property of steel, and all theories which failed in this particular must necessarily be imperfect. **Mr. Blakesley** pointed out that the ordinary hysteresis curves showed that a small superimposed magnetising force, in a direction different from the primary one, produced only a small change in the induction, and hence would



give a small permeability. For example, the increment, H^1 H, (see Figure) causes an increase, R P, in the induction, whilst an equal decrement, H^1 H, produces only a change, P.

EASTBOURNE.

THE ELECTRIC LIGHT QUESTION.

At the last meeting of the Town Council a matter important to most supply companies was discussed.

A letter was read from the Board of Trade forwarding copy of a letter received from the Eastbourne Electric Light Company's agents in support of the company's application for a provisional order, and pointing out that the maximum charge in the model form of order prepared by the Board of Trade was 8d. per unit. The Board stated they did not propose to allow a higher price unless special circumstances existed to justify it, and they asked for the observations of the Corporation at as early a date as possible.

The letter from the company's agents set forth various reasons why a charge of 10d. per unit should be sanctioned. The company had, it was stated, laid out between £25,000 and £30,000 in engine works, in the laying on of nine miles of mains, and other purposes incidental to the supplying of electricity in Eastbourne. The charge now made was 1s. per unit. At that price no profit had been made. The use of electricity would be confined to shops and the houses of wealthy residents, which were generally detached and therefore involved a large amount of "mainage." In asking for 10d. the company were acting on no speculative theory, but were thoroughly convinced that if a lower charge were insisted on it was impossible to put forth any prospect of obtaining a dividend, so as to induce capitalists to put money into the business. Attention was called to the fact that the Corporation of Eastbourne had assented to the application and to a charge of 10d. being included in the order, and a hope was expressed that the Board of Trade would allow that figure to stand, particularly as the local authority had power of appeal every seven years. The company claimed during the last eight years to have acted as the pioneers of electric lighting in England.

The **Mayor**: What will you do with this communication?

The **Deputy-Mayor** (who is chairman of the Electric Light Company): I may be allowed to say that 8d. is a sum at which the electric light could not be supplied. Therefore, if 8d. is fixed by the Board of Trade the Electric Light Company will be obliged to shut up their works and post up on the door, "No further supply."

Mr. Homewood: What, as a Corporation, have we do with the matter? We have the electric light on the parade, but as a Corporation this question of what the general charge should be does not seem to belong to us at all. It is for the public to say whether they will pay 8d., 10d., or 1s. when the charge is made.

The **Mayor**: There is a form to go through with regard to these provisional orders, and the Board of Trade have pointed out the condition on which they will sanction a higher price than appears in the model order.

Mr. Wallis: I would suggest that inasmuch as the Corporation have no experience as to the manufacture of electricity the answer should be given by the Electric Light Company. It seems to me an extraordinary piece of legislation on the part of the Board of Trade to issue an order of that character. I apprehend a number of provisional orders have been granted at much higher rates; and is it the intention of the Board of Trade to withdraw their sanction and require these companies to supply at an unremunerative price? We have heard from Mr. Boulton that the light cannot be manufactured at 8d. If the Corporation decide to give an answer, we should first obtain information of a practical character, based on experience, and that cannot be got better than by consulting the directors of the Electric Light Company.

copper or insulation. The space lost in passing from the external to the internal circumference is thus gained by the conductibility of the metal.

The connections of the opposite strips of the armature are made at the ends by plates of copper, and the contacts at the junctions are simply obtained by a strong pressure of the extremities, which have been cleaned with care.

With such an arrangement an output of 40 watts per kilogramme (18·2 watts per lb.) of machine can be obtained.

The circumferential velocity for normal speed is 10 metres per second, which is the minimum of the speed ordinarily chosen.

The following table gives the specific output of the different types of ordinary machines of which we have been able to obtain particulars:

Edison dynamo (1885)	6·7 to 11·6
Edison dynamo (1889)	9·5 to 12·2
Thury (1886)	11·8 to 15·2
Dulait	8·3 to 13
Ganz	6·1 to 11
Rechniewski	19·0 to 26·4
Breguet (1886)	10·2 to 24

It is to be noticed that, of all these machines, those which have the largest activity are those which at the same

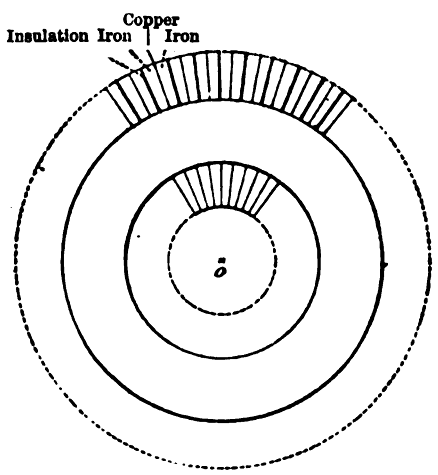


Diagram of the Reignier-Bary Armature.

time have the greatest linear velocity. Even under these conditions we have already a very great superiority from the point of view of weight; but to make the comparison perfect we ought to raise the velocity to 16 metres per second, which would give an output of 64 watts per kilogramme of machine.

Why, it may be asked, have we remained at so small a velocity when the employment of metallic strips instead of copper wire would guarantee a resistance to centrifugal force considerably greater than what would be admissible in others? In this we have simply followed a question of routine. It is not the custom to exceed a certain speed. We have, in this instance, kept to the usual figures, content to mark the machine for a smaller power than that which it can produce.

To continue the comparison, we will take different types of machine of the same power.

a. The Rechniewski dynamos produce 800 watts per kilogramme of copper in the armature, and 270 watts per kilogramme of total copper.

b. The Desroziers dynamos give 250 watts per kilogramme of total copper.

c. The Edison dynamos give 500 watts per kilogramme of copper in armature, and 92 per kilogramme of total copper.

d. We have found in our own first trial machine a production of 1,800 watts per kilogramme of copper in armature, and 445 kilogramme of total copper.

These figures are résumed in the following table:

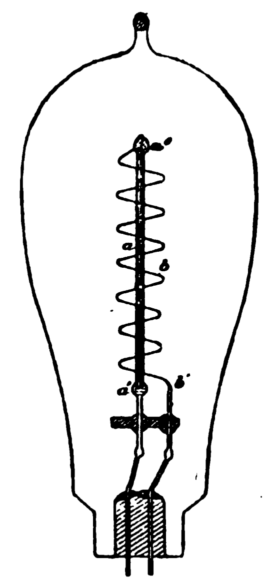
Watts per kilog.	Rechniewski.	Desroziers.	Edison.	Reignier-Bary.
Of dynamo	21·5	21	9	40
Of copper in armature	800	(?)	500	1,800
Of total copper	270	250	92	245

Lastly, the electric efficiency of our dynamo is 94 per cent., and the commercial efficiency reaches 90 per cent. A machine of one-third the weight, which produces the same out-put, is, we think, of sufficient interest to bring before your notice.

LANGHANS INCANDESCENT LAMP.

The Langhans incandescent lamps to which we have already alluded, has been patented and brought out by the Langhans Electrical Company of Berlin. The lamp has the appearance shown in the accompanying illustration. The principal point of novelty is the vertical support *a*, which sustains the spiral filament *b*. This support is connected at a^1 to one of the electrodes and at a^2 to the spiral, which is joined at *b* to the other electrode.

The support consists of a core and a surrounding envelope. The envelope is composed of two metals or alloys of which the coefficient of expansion is different. By reason of the heat produced by the radiation there is a difference of ex-



The Langhans Incandescent Lamp.

pansion between the core and the envelope, and the internal tensions which result prevent all lateral bending.

PHENOMENA OF ALTERNATING CURRENT INDUCTION.*

BY PROF. ELIHU THOMSON.

(Concluded from page 335.)

A small motor of a curious type has been made, utilising the principle of shading the pole by closed circuits. A laminated ring (Fig. 12) 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," as I term it. A copper disc free to turn introduced by one edge into the slot turns rapidly and exerts some power.

Removing the disc it is found that a silver coin can be inserted into the slot and will be drawn into it and propelled with some force through the same, while a lead coin, or coin of base metal, will be scarcely affected. This is due to the vigorous currents which can exist in the silver, owing to its high conductivity, while the very low effect of the lead is due to the opposite cause.

To obtain a rotary effect on a copper disc we can, however, simplify matters very much by using no closed circuit at all, nor even a steel piece. We may place the disc partly over the alternating pole and then hold over the disc a bundle of iron wires or unwound core, taking care to offset its axes to some extent from that of the pole towards which it and the disc are presented. The result is at once a rapid revolution of the disc in the direction of the offsetting.

* Abstract of a lecture delivered before the American Institute of Electrical Engineers at Columbia College, April 2, 1890.

The rotary effects are utilised in the construction of electric motors and meters of more or less merit. They are capable of very great variation by changing the forms and relations of the devices used.

Some curious modifications of the effects are found in the revolution of copper balls or cylinders. A hollow copper ball may be laid on a plate of copper (Fig. 13), or within a ring of the same metal, and set in gyratory movement, its direction of rotation as well as the position of its axis of rotation depending on the relation of the ball and the plate on which it rests or the ring which encloses it in relation to the alternating pole which is used to set it in movement.

It will even rotate on a horizontal axis while resting on a plate of copper; this requires that it rub its equator upon such surface and overcome the friction.

Placing the ball in a vase of water in which it floats and supporting the vase over the pole upon which has been laid a plate of copper partly covering the pole, gives vigorous rotation of the ball in the water. Several balls of various sizes may be placed in the vase, or a copper dish substituted for the plate, or the ball and dish both used together (Fig. 14). The effects of these latter are both amusing and instructive.

We need scarcely stop to consider that these actions are brought about just as the movements of the discs were set up by induced currents and shifting magnetic lines that are retarded by the closed circuit currents set up in the plates, rings, etc., which have been employed to modify the field.

But, as we have shown, it is not necessary for obtaining some of these effects that the field be modified by closed circuit currents. Slight changes in the position or shape of parts may be sufficient to give rise to rotary effects. Thus we may place a cone or wedge of iron on the alternating pole (Fig. 15), and hold near it a copper ring mounted so as to be able to revolve. The ring in this case is best provided with a laminated iron interior, which supports it and enables it to be easily mounted on a shaft. The copper cylinder revolves, and its direction is such that it seems to be blown around by a blast from the edge of the wedge or point of the cone.

A curious electrical gyroscope is constructed as follows: A vertical pivot projects from the centre of the alternating pole (Fig. 16), upon which pivot is hung a horizontal rod, bearing on one side of the pivot a copper frame, in which is carried a copper ring or wheel with an iron inner portion, such ring or wheel being delicately pivoted in the frame in the usual way. The rod bears on its other end the counterpoise or balance weight. The copper frame bearing the ring is placed in an inclined direction with reference to the horizontal. Under these circumstances rotation is given by the alternating field in which the instrument is placed, and the properties of the gyroscope are exhibited. It is needless to say that a little ingenuity may modify the instrument in form, or lead to the construction on similar principles of a variety of curious devices, receiving their movements from the actual space, as it were, in which they are placed, and without direct connections of an electrical or mechanical character.

There is a growing tendency among electricians to regard the effects of what is called an electrical current in a conductor to be due, in large part, at least, to a movement of particles, or to a transmitted strain which has its place entirely outside the wire or conductor, and in the space around such conductor. The wire and current in it are regarded simply as the central core of a set of disturbances in the medium surrounding it, by which medium the energy of the current is actually transmitted, if the current itself is not merely an effect of such a set of disturbances in the surrounding medium.

Viewed in this light the phenomena we have been considering are seen to be simply the result of modifying these outside effects by conducting or magnetic masses placed in the medium subject to disturbance. The coil conveying the current sets up a changing set of strains in the ether around it, or rather the coil itself is only the centre of such strains transmitted into the medium surrounding the wire from the source of current used, which may be a dynamo located in a central supply station. The changing set of strains around the coil used in the experiments can set up current in other conductors than the coil subject to their action. Thus are produced the induced currents in the copper rings, balls, plates, etc., used. Such currents react on the medium, and modify the distribution of strains, and so give rise to the movements and other phenomena displayed.

The relation which exists between a primary inducing coil and a secondary coil in an inductive apparatus or transformer is of the same nature. The secondary coil is merely a conductor immersed in the medium which surrounds the primary coil. The latter and the wire leading to it from the source of current is but the core of a set of disturbances or strains in the ether surrounding it, and in which the secondary coil is immersed. Hence, the coils, though insulated from each other, are yet both immersed in the medium whose transmitted strains are the real expression of electrical energy transmitted. The result of this relation is that were it not for the fact that the coils must necessarily be made of imperfect conductors, the amount of energy transmitted to a secondary coil from its primary could be unlimited, it might be thousands of horse-power, and the iron core of the transformer be only of such size as to be easily lifted in the hand.

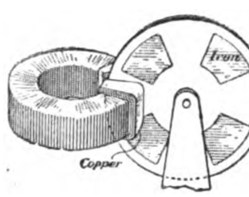


Fig. 12.

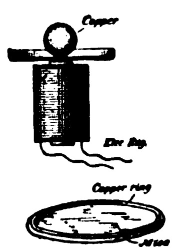


Fig. 13.

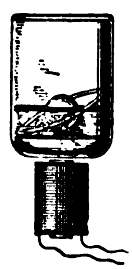


Fig. 14.

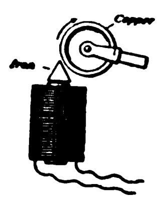


Fig. 15.

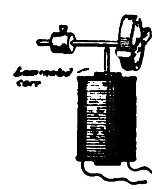


Fig. 16.

Let us imagine the primary and secondary coils of an induction apparatus made of pipe, through which a refrigerant is circulated, or around which a powerful refrigerating action is exerted, such as might be obtained by the evaporation of liquefied gases, and in such case the resistance of the coils would become very small indeed. The coils could carry large currents without loss, and the amount of energy obtained in the secondary would almost keep pace with the energy supplied to the primary. A remarkable example of this wonderful capacity for energy transmission is seen in some transformers for electric welding, in which 20,000 to 30,000 watts, or from 30 to 40 h.p., are transferred to the secondary coil from the primary, apparently, while the iron core or magnetisable core is of quite moderate dimensions. In fact, the iron core has but little to do with the capacity for transmission of energy by induction, though it effects the E.M.F. set up in the turns of wire of the coils.

Could we imagine an open coil without iron, composed of two interwound coils of copper wire or tubes insulated from each other, and kept at the lowest possible temperature, so as to practically abolish the resistance of the copper, we would have an apparatus of the very highest efficiency for the transfer of electrical energy from one circuit to another, and one which could be of very moderate size and yet transfer enormous amounts of such energy, to be used for lighting, metal working or other purposes.

There has only been time in this discussion to touch upon a few salient features of our subject, about which a volume might be written at the present time, the object being to bring to the notice of the institute rather the experimental demonstrations only, stripped of such theoretical considerations as would, if incorporated in this paper, have taken up much more than the space allotted to it, and perhaps have exhausted the interest of the hearers.