termed a dry area. Damp against the face of the walls may be partly combated by a careful selection of a non-absorbent brick with a hard face and by struck joints. But it is most effectually kept at bay by the expedient of building the wall hollow; that is to say, making the external wall of the house to consist of two perfectly distinct walls, standing about 2 in. apart, and held together by ties of earthenware or iron. The result is that the moisture blowing through the outer skin does not pass the cavity, but trickles down on the inner face of the outer wall, while the inner wall remains dry. The ties are constructed of shapes to prevent their conducting water themselves from without to the inner wall. In addition to this, a series of slates forming an intermediate protection is sometimes introduced, and forms an additional and most valuable screen against weather. Sometimes, the two skins of the wall are closer together—say $\frac{1}{2}$ in.—and the space is filled with a bituminous material.

A substance of a bituminous nature, called hygeian rock, has been of late years introduced, and is being extensively used for this purpose; it is melted and poured into the open space hot, and quickly hardens. The use of such a material is open to the objection that no air can pass through it. The rooms of our houses are receiving air constantly through the walls, and much of the constant current up our chimneys is supplied, to our great advantage, in this very imperceptible manner. The house breathes, so to speak, through the pores of its brickwork. When this is rendered impossible, it seems clear that fiercer draughts will enter through the chinks and crevices, and that there will be a greater demand upon flues not in use, occasioning down draught in the chimneys.

Another mode of keeping out weather is to cement the face of the brickwork. But this hides up the work, and so tends to promote bad work, besides being often very unsightly.

Among other peculiarities of brickwork are the facilities for introducing different colors and different textures of surface which it presents, the ease with which openings and arches can be formed in it, the possibility of executing ornament and even carving, and the ease with which brickwork will combine with other building materials. It cannot be well made use of for columns, though it may readily enough be turned into piers or pilasters. It cannot, generally speaking, with advantage be made use of for any large domes, though the inner dome of St. Paul's and the intermediate cone are of brick, and stand well. But it is an excellent material for vaulting arcades and all purposes involving the turning of arches.

Brickwork must be said to be durable, but it requires care. If not of the best, brickwork within the reach of the constant vibration caused by the traffic on a railway seems to be in danger of being shaken to pieces, judging from one or two instances that have come under my own observation. The mortar, and even in some cases the bricks themselves, will rapidly deteriorate if moisture be allowed to get into the heart of a brick wall, and in exposed situations this is very apt to happen. Care should always be taken to keep the pointing of external brickwork in good order, and to maintain all copings and other projections intended to bar the access of water coming down from above, and to stop the overflowing of gutters and stack pipes, which soon soaks the wall through and through.

Of course, if there is a failure of foundations, brickwork, as was pointed out earlier, becomes affected at once. But if these be good, and the materials used be sound ones, and if the other precautions just recommended be taken, it will last strong and sturdy for an immense length of time. In some cases, as for example in the Roman ruins, it has stood for 1,500 years under every possible exposure and neglect, and still shows something of a sturdy existence after all, though sadly mutilated. If we now return to the question, What can be well done in brickwork? no better answer can be given than to point to what has been and is being done, especially in London and within our own reach and observation.

Great engineering works, such as railway viaducts, the lining of railway tunnels, the piers and even the arches of bridges, sewage works, dock and wharf walls, furnace chimneys, and other works of this sort are chiefly done in brickwork. And notwithstanding that iron is far more used by the engineer for some purposes and concrete for others now than formerly, still there is a great field for brickwork. The late Mr. Brunel, who was fond of pushing size to extremes, tried how wide a span he could arch over with brickwork. And I believe the bridge which carries the G.W.R. over the Thames at Maidenhead has the widest arch he or any other engineer has successfully erected in brick. This arch has, it is stated, a span of 128 ft. It is segmental, the radius being 169 ft., and the rise from springing to crown 24 ft., and the depth of the arch 5 ft. 3 in. Nowadays, of course, no one would dream of anything but an iron girder bridge in such a position. Mr. Brunel's father, when he constructed the Thames Tunnel, lined it with brickwork foot by foot as he went on, and that lining sustained the heavy weight of the bed of the river and the river itself.

If you leave London by either of the southern lines, all of which are at a high level, you go for miles on viaducts consisting of brick arches carried on brick walls. If you leave by the northern lines, you plunge into tunnel after tunnel lined with brickwork, and kept secure by such lining. Mile after mile of London streets, and those in the suburbs, present to the eye little but brick buildings; dwelling houses, shops, warehouses, succeed one another, all in brickwork, and even when the eye seems to catch a change, it is more apparent than real.

The white mansions of Tyburnia, Belgravia, South Kensington, and the neat villas of the suburbs are only brickwork, with a thin coat of stucco, which serves the purpose of concealing the real structure—often only too much in need of concealment—with a material supposed to be a little more sightly, and certainly capable of keeping the weather out rather more effectually than common brickwork would.

More than this, such fine structures, apparently built entirely of stone, as are being put up for commercial purposes in the streets of the city, and for public purposes throughout London, are all of them nothing more than brick fabrics with a facing of masonry. Examine one of them in progress, and you will find the foundations and vaults of brickwork, and not only the interior walls, but the main part of the front wall,

executed in brickwork, and the stone only skin deep. There are, however, two or three ways of making use of brickwork without covering it up, and of gaining good architectural effects thereby, and to these I beg now to direct your attention.

The architect who desires to make an effective brick building, which shall honestly proclaim to all the world that it is of brick, may do this, and, if he will, may do it successfully, by employing brickwork and no other material, but making the best use of the opportunities which it affords, or he may erect his building of brickwork and stone combined, or of brickwork and terra cotta. Mr. Robson, till lately the architect to the School Board for London, has the merit of having put down in every part of the metropolis a series of well contrived and well designed buildings, the exterior of which almost without exception consists of brickwork only.

If you examine one of his school-houses, you will see that the walls are of ordinary stock brickwork, but usually brightened up by a little red brick at each angle, and surmounted by well contrasted gables and with lofty, well designed chimneys, rising from the tiled roof. The window openings and doorways are marked by brickwork, usually also red, and sometimes moulded, and though I personally must differ from the taste which selected some of the forms employed (they are those in use in this country in the 17th and the last centuries), I cordially recognize that with very simple and inexpensive means exceedingly good, appropriate, and effective buildings have been designed.

Among examples of architecture wholly, or almost wholly, executed in red brick, I cannot pass over a building built many years ago, little known on account of its obscure situation, but a gem in its way. I allude to the schools designed by Mr. Wilde, and built in Castle street, Endell street.

Of buildings where a small amount of stone is introduced into brickwork we have a good many fine specimens in London. One of the best—probably the best—is the library in Lincoln's Inn Fields. This is a large and picturesque pile, built under Mr. Hardwick, as architect, in red brick, with patterns in the blank parts of the walls done in black brick. It has splendid moulded brick chimneys, and the mullions of the windows, the copings, the entrances, and some other architectural features done in stone. The building is a good reproduction of the style of building in Tudor times, when, as has been already mentioned, brickwork was taken into favor.

Another building of the same class, but not so good, is the older part of the Consumption Hospital, at Brompton. Brickwork, with a little stone, has been very successfully employed as the material for churches, and in many such cases the interior is of unplastered brickwork. Such churches often attain, when designed by skillful hands, great dignity and breadth of effect. St. Albans, Holborn; the great church designed by Mr. Butterfield, in Margaret street; Mr. Street's church near Vincent square, Westminster; and several churches of Mr. Brooks', such as he was kind enough to enable me to illustrate to-night, may be mentioned as examples of the sort. Mr. Waterhouse has built an elaborate Congregational church at Hampstead, which shows the use with which such effects of color may be obtained in interiors, and has kindly lent some drawings. Mr. Pearson's church at Kilburn may also be referred to as a fine example of brick vaulting. Brick and terra cotta seem to have a natural affinity for one another. Terra cotta is no more than a refined brick, made of the same sort of material, only in every respect more carefully, and kiln baked. Its similarity to brick is such that there is no sense of incongruity if moulded or carved brickwork and terra cotta are both employed in the same building, and this can hardly be said to be the case if the attempt is made to combine ornamental brickwork and stone ornaments.

At South Kensington, a whole group of examples of brickwork with terra cotta meet us. The Natural History Museum, the finest of them all, is hardly fit for our present purpose, as it is as completely encased in terra cotta as the fronts of the buildings in this avenue are in stone. But here are the Albert Hall, a fine specimen of mass and effect; the City and Guilds Institute; the College of Music, and some private houses and blocks of flats, all in red brick with terra cotta, and all showing the happy manner in which the two materials can be blended. In most of them there is a contrast of color; but Mr. Waterhouse, in the Technical Institute, has employed red terra cotta with red bricks, as he also has done in his fine St. Paul's School at Hammersmith, and Mr. Norman Shaw has, in his fine pile of buildings in St. James' street. This combination—namely, brick and terra cotta—I look upon as the best for withstanding the London climate, and for making full use of the capabilities of brickwork that can be employed, and I have no doubt that in the future it will be frequently resorted to. Some of those examples also show the introduction of cast ornaments, and others the employment of carving as means of enriching the surface of brick walls with excellent effect. Here we must leave the subject; but in closing, I cannot forbear pointing to the art of the bricklayer as a fine example of what may be accomplished by steady perseverance. Every brick in the miles of viaducts or tunnels, houses, or public buildings, to which we have made allusion, was laid separately, and it is only steady perseverance, brick after brick, on the part of the bricklayer, which could have raised these great masses of work. Let me add that no one brick out of the many laid is of no importance. Some time ago a great fire occurred in a public asylum, and about £2,000 of damage was done, and the lives of many of the inmates endangered. When the origin of this fire came to be traced out, it was found that it was due to one brick being left out in a flue. A penny would be a high estimate of the cost of that brick and of the expense of laying it, yet through the neglect of that pennyworth, £2,000 damage was done, and risk of human life was run. I think there is a moral in this story which each of us can make out if he will.

A FIREPROOF whitewash can be readily made by adding one part silicate of soda (or potash) to every five parts of whitewash. The addition of a solution of alum to whitewash is recommended as a means to prevent the rubbing off of the wash. A coating of a good glue size made by dissolving half a pound of glue in a gallon of water is employed when the wall is to be papered.

PHENOMENA OF ALTERNATING CURRENTS.*

By Prof. ELIHU THOMSON.

THE actions produced and producible by the agency of alternating currents of considerable energy are assuming greater importance in the electric arts. I mean, of course, by the term alternating currents, currents of electricity reversed at frequent intervals, so that a positive flow is succeeded by a negative flow, and that again by a positive flow, such reversals occurring many times in a second, so that the curve of current of electromotive force will, if plotted, be a wave line, the amplitude of which is the arithmetical sum of

FIG. 1.

the positive and negative maxima of current or electromotive force, as the case may be, while a horizontal middle line joins the zero points of current or electromotive force.

It is well known that such a current passing in a coil or conductor laid parallel with or in inductive relation to a second coil or conductor, will induce in the second conductor, if on open circuit, alternating electromotive forces, and that if its terminals be closed or joined, alternating currents of the same rhythm, period, or pitch, will circulate in the second conductor. This is the action occurring in any induction coil whose primary wire is traversed by alternating currents, and whose secondary wire is closed either upon itself directly or through a resistance. What I desire to draw attention to in the present paper are the mechanical actions of attraction and repulsion which will be exhibited between the two conductors, and the novel results which may

FIG. 2.

be obtained by modifications in the relative dispositions of the two conductors.

In 1884, while preparing for the International Electrical Exhibition at Philadelphia, we had occasion to construct a large electro-magnet, the cores of which were about six inches in diameter and about twenty inches long. They were made of bundles of iron rod of about $\frac{1}{4}$ inch diameter. When complete, the magnet was energized by the current of a dynamo giving continuous currents, and it exhibited the usual powerful magnetic effects. It was found also that a disk of sheet copper, of about $\frac{1}{8}$ inch thickness and 10 inches

FIG. 3.

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 disk 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 disk, even when the attempt was made by holding one edge of the disk in the hand and bringing it down forcibly toward the magnet. In attempting to raise the disk quickly off the pole, a similar but opposite action of resistance to

FIG. 4.

movement took place, showing the development of currents in the same direction to those in the coils of the magnet, and which currents, of course, would cause attraction as a result.

* From a paper read before the recent meeting of the American Institute of Electrical Engineers, New York, and reported in the *Electrical World*.

The experiment was, however, varied, as in Fig. 1. The disk, D, was held over the magnet pole, as shown, and the current in the magnet coils cut off by shunting them. There was felt an attraction of the disk or a dip toward the pole. The current was then put on by opening the shunting switch, and a repulsive action or lift of the disk 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 disk, D, in the same direction as those in the magnet coils beneath it, and when repulsion took place the induced current in the disk was 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.

FIG 5

For the reasons just given, we will find that the disk, D, is attracted and repelled alternately; for, whenever the currents induced in it are of the same direction 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 case opposite currents are induced in the disk, D, in accordance with well known laws, and in the latter case currents of the same direction will exist in the disk, D, and the magnet coil. The disk 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 disks, rings or coils superposed, and the results would be the same. Thus far, indeed, we have nothing of a particularly novel character, and, doubtless, other

FIG 6.

experimenters have made very similar experiments and noted similar results to those described.

The account just given of the effects produced by alternating currents, while true, is not the whole truth, and just here we may supplement it by the following statements:

An alternating current circuit or coil repels and attracts a closed circuit or coil placed in direct or magnetic inductive relation therewith; but the repulsive effect is in excess of the attractive effect.

When the closed circuit or coil is so placed, and is of such low resistance metal that a comparatively large current can circulate as an induced current, so as to be subject to a large self-induction, the repulsive far exceeds the attractive effort.

For want of a better name, I shall call this excess of repulsive effect the "electro-inductive repulsion" of the coils or circuits.

This preponderating repulsive effect may be utilized or may show its presence by producing movement or pressure in a given direction, by producing angular

FIG. 7.

deflection as of a pivoted body, or by producing continuous rotation with a properly organized structure. Some of the simple devices realizing the conditions I will now describe.

In Fig. 2, C is a coil traversed by alternating currents, B is a copper case or tube surrounding it, but not exactly over its center. 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 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.

The forms and relations of 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. 3 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. 2 may be said to be analogous to that of a plain solenoid

FIG. 8.

with its core, except that repulsion, and not attraction, is produced, while that of Fig. 3 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.

In Fig. 4 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

FIG. 9.

parts of the conductor section, what I here term the electrical middle, or the center 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. 4, being indicated by a dotted line. To repeat, then, when the centers or center planes of the conductors, Fig. 4, 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.

It is not my purpose now to discuss the ways of determining the distribution of currents and mechanical effects, as that would extend the present paper much beyond its intended limit. The forms and relative arrangement of the two conductors may be greatly varied. In Fig. 5 the parts are of equal diameter, one,

FIG 10.

B, being a closed ring, and the other, C, being an annular coil placed parallel thereto; and an iron core or wire bundle placed in the common axis of the two coils increases the repulsive action. B may be simply a disk 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 electro magnet and armature is shown in Fig. 6. The alternating current coils, C C', are wound upon an iron wire bundle bent into U form, and opposite its poles is placed a pair of thick copper disks, B B', which are attracted and repelled, but with

FIG. 11.

an excess of repulsion depending on their form, thickness, etc.

If the iron core takes the form of that shown by I I, Fig. 7, 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 in C.

This was the first form of device in which I noticed the phenomenon of repulsive preponderance in question. The tendency is to thrust the plate, B, out of the slot in the ring excepting only when its center is coincident with the magnetic axis joining the poles of the ring between which B is placed.

If the axes of the conductors, Fig. 5, are not coincident, but displaced, as in Fig. 8, 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. 9. Here the closed con-

FIG. 12.

ductor, 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 center 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. 10, composed of a disk, or, better, of a pile of thin copper disks, 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 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, incloses the part, B, or be inclosed by it, or whether the coil, C, be pivoted and B fixed, or both be

FIG. 13.

pivoted. In Fig. 11 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.

It is important to remark here that in cases where deflection is to be obtained, as in Figs. 10 and 11, 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.

We will now turn our attention to the explanation of the actions exhibited, and afterward refer to their

FIG. 15.

possible applications. 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, 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.

This condition can be illustrated by a diagram, Fig. 12. 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 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 current has risen from its zero to m' , its maximum. 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' , 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. 12, indicate this succession.

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 to such self-induction a large 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. 12 had been shifted forward to a greater or less extent. This is indicated in diagram, Fig. 13. 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 unrealizable 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

FIG. 16.

during which the currents are in the same 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.

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.

Thus far I have applied the repulsive action described in the construction of alternating current indicators, alternating current 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, 15 degrees to 20 degrees 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.

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 manner that electro magnets 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.

One of the simplest is as follows: The coils, C, Fig. 14, 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 defective 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. I have, however, 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 disks 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 90 degrees of rotation each. The field coils surround the armature, and there is a laminated iron field structure completing the magnetic circuit. I may say here that surrounding the armature of a dynamo by the field coils, though very recently put forth as a new departure, was described in various Thomson-Houston patents, and to a certain extent all Thomson-Houston machines embody this feature.

Figs. 15 and 16 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 alternating current circuit. I I is a mass of laminated iron, in the interior of which the armature revolves, with its three coils, B, B', B'', wound on a core of sheet iron disks. The commutator short-circuits the armature coils in succession in the proper positions to utilize 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 economy 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 will energize electro magnets and perform other actions of direct currents. Here we have, then, a means of inducing direct currents from alternating currents. To control the speed and keep it at that required for the purpose, we have only to properly gear the motor to another of the ordinary type for alternating currents, namely, an alternating-current dynamo used as a motor. The charging of storage batteries would not be difficult with such a machine, even from an alternating-current line, though the losses might be considerable.

PHOTOGRAPHIC STUDY OF STELLAR SPECTRA, HARVARD COLLEGE OBSERVATORY.

HENRY DRAPER MEMORIAL.
First Annual Report.

DR. HENRY DRAPER, in 1872, was the first to photograph the lines of a stellar spectrum. His investigation, pursued for many years with great skill and ingenuity, was most unfortunately interrupted in 1882 by his death.

The recent advances in dry-plate photography have vastly increased our powers of dealing with this subject. Early in 1886, accordingly, Mrs. Draper made a liberal provision for carrying on this investigation at the Harvard College Observatory, as a memorial to her husband. The results attained are described below, and show that an opportunity is open for a very important and extensive investigation in this branch of astronomical physics. Mrs. Draper has accordingly decided greatly to extend the original plan of work, and to have it conducted on a scale suited to its importance. The attempt will be made to include all portions of the subject, so that the final results shall form a complete discussion of the constitution and conditions of the stars, as revealed by their spectra, so far as present scientific methods permit. It is hoped that a greater advance will thus be made than if the subject was divided among several institutions, or than if a broader range of astronomical study was attempted.

It is expected that a station to be established in the southern hemisphere will permit the work to be extended so that a similar method of study may be applied to stars in all parts of the sky. The investigations already undertaken, and described below more in detail, include a catalogue of the spectra of all stars north of -24° of the sixth magnitude and brighter, a more extensive catalogue of spectra of stars brighter than the eighth magnitude, and a detailed study of the spectra of the bright stars.

This last will include a classification of the spectra, a determination of the wave lengths of the lines, a comparison with terrestrial spectra, and an application of the results to the measurement of the approach and recession of the stars. A special photographic investigation will also be undertaken of the spectra of the banded stars, and of the ends of the spectra of the bright stars.

The instruments employed are an eight inch Voigtlander photographic lens, reground by Alvan Clark & Sons, and Dr. Draper's 11 inch photographic lens, for which Mrs. Draper has provided a new mounting and observatory. The 15 inch refractor belonging to the

Harvard College Observatory has also been employed in various experiments with a slit spectroscopy, and is again being used as described below. Mrs. Draper has decided to send to Cambridge a 28 inch reflector and its mountings, and a 15 inch mirror, which is one of the most perfect reflectors constructed by Dr. Draper, and with which his photograph of the moon was taken. The first two instruments mentioned above have been kept at work during the first part of every clear night for several months. It is now intended that at least three telescopes shall be used during the whole night, until the work is interrupted by daylight.

The spectra have been produced by placing in front of the telescope a large prism, thus returning to the method originally employed by Fraunhofer in the first study of stellar spectra. Four 15° prisms have been constructed, the three largest having clear apertures of nearly eleven inches, and the fourth being somewhat smaller. The entire weight of these prisms exceeds a hundred pounds, and they fill a brass cubical box a foot on each side. The spectrum of a star formed by this apparatus is extremely narrow when the telescope is driven by clockwork in the usual way. A motion is accordingly given to the telescope slightly differing from that of the earth by means of a secondary clock controlling it electrically. The spectrum is thus spread into a band, having a width proportional to the time of exposure and to the rate of the controlling clock.

This band is generally not uniformly dense. It exhibits lines perpendicular to the refracting edge of the prism, such as are produced in the field of an ordinary spectroscopy by particles of dust upon the slit. In the present case, these lines may be due to variations in the transparency of the air during the time of exposure, or to instrumental causes, such as irregular running of the driving clock, or slight changes in the motion of the telescope, resulting from the manner in which its polar axis is supported.

These instrumental defects may be too small to be detected in ordinary micrometric or photographic observations, and still sufficient to affect the photographs just described.

A method of enlargement has been tried which gives very satisfactory results, and removes the lines above mentioned as defects in the negatives. A cylindrical lens is placed close to the enlarging lens, with its axis parallel to the length of the spectrum. In the apparatus actually employed, the length of the spectrum, and with it the dispersion, is increased five times, while the breadth is made in all cases about four inches. The advantage of this arrangement is that it greatly reduces the difficulty arising from the feeble light of the star. Until very lately, the spectra in the original negatives were made very narrow, since otherwise the intensity of the starlight would have been insufficient to produce the proper decomposition of the silver particles. The enlargement being made by daylight, the vast amount of energy then available is controlled by the original negative, the action of which may be compared to that of a telegraphic relay. The copies therefore represent many hundred times the original energy received from the stars. If care is not taken, the dust and irregularities of the film will give trouble, each foreign particle appearing as a fine spectral line.

Our methods of enlargement have been considered, and some of them tried, with the object of removing the irregularities of the original spectra without introducing new defects. For instance, the sensitive plate may be moved during the enlargement in the direction of the spectral lines; a slit parallel to the lines may be used as the source of light, and the original negative separated by a small interval from the plate used for the copy; or two cylindrical lenses may be used, with their axes perpendicular to each other. In some of these ways the lines due to dust might either be avoided or so much reduced in length as not to resemble the true lines of the spectrum.

The 15 inch refractor is now being used with a modification of the apparatus employed by Dr. Draper in his first experiments—a slit spectroscopy from which the slit has been removed. A concave lens has been substituted for the collimator and slit, and besides other advantages, a great saving in length is secured by this change. It is proposed to apply this method to the 28 inch reflector, thus utilizing its great power of gathering light.

[A description of an accompanying plate here follows, which is omitted, as the plate cannot be easily reproduced for ordinary press printing.]

The results to be derived from the large number of photographs already obtained can only be stated after a long series of measurements and a careful reduction and discussion of them. An inspection of the plates, however, shows some points of interest. A photograph of α Cygni, taken November, 26, 1886, shows that the H line is double, its two components having a difference in wave length of about one ten-millionth of a millimeter. A photograph of α Ceti shows that the lines G and h are bright, as are also four of the ultra-violet lines characteristic of spectra of the first type. The H and K lines in this spectrum are dark, showing that they probably do not belong to that series of lines. The star near χ^1 Orionis, discovered by Gore, in December, 1885, gives a similar spectrum, which affords additional evidence that it is a variable of the same class as α Ceti. Spectra of Sirius show a large number of faint lines besides the well-known broad lines.

The dispersion employed in any normal map of the spectrum may be expressed by its scale, that is, by the ratio of the wave length as represented to the actual wave length. It will be more convenient to divide these ratios by one million, to avoid the large numbers otherwise involved. If one millionth of a millimeter is taken as the unit of wave length, the length of this unit on the map in millimeters will give the same measure of the dispersion as that just described. When the map is not normal, the dispersion of course varies in different parts. It increases rapidly toward the violet end when the spectrum is formed by a prism. Accordingly, in this case the dispersion given will be that of the point whose wave length is 400.

This point lies near the middle of the photographic spectrum when a prism is used, and is not far from the H line. The dispersion may accordingly be found with sufficient accuracy by measuring the interval between the H and K lines, and dividing the result in millimeters by 3.4, since the difference in their wave lengths equals this quantity. The following examples serve to illus-