ELECTRICITY BY MAGNETIC INDUCTION.

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The peculiar species of energy residing in magnetic bodies is capable of a wide range of practical application aside from its extensive use in telegraphy and telephony; and since the permanent magnet, provided with proper accessories, furnishes an ever-available means of converting mechanical force into electrical energy, it may for very many uses be substituted for the battery without the loss of materials inseparable from this use of batteries.

To Faraday we owe the inversion of the process of magnetization—that is, the generation of electrical impulses in a coil by means of a permanent magnet. Upon this fundamental discovery are based all induction machines and instruments. The mode of producing the current varies in the different applications of the magnet, but the same general principle is necessarily involved.

It is not the design of this article to treat on all means and methods of producing induced electrical currents, but to describe a few electrical appliances and machines in which ordinary permanent magnets are the means for converting mechanical force into electric energy.

A common method of magnetizing steel is to place it in a coil and then connect the coil with the poles of a battery or some other form of current producer. Faraday's experiment (Fig. 1) was the reverse of this process, and consisted in suddenly inserting a permanent magnet into the coil, A, the latter being connected with a galvanometer, B, to indicate any action that might occur.

In this experiment when the magnet is inserted in the helix the galvanometer needle is instantly deflected, and the magnet being allowed to remain the needle immediately falls back to 0° of the scale. If the magnet be now suddenly withdrawn the needle is momentarily deflected in the opposite direction. To insure success in this experiment it is necessary to move the magnet very quickly, for if the magnet be slowly introduced or slowly withdrawn from the coil no perceptible effect will be produced.

Although coils of rather coarse wire are preferred for the magnetization of steel, and coils of very fine wire are better adapted for induction experiments, the reciprocal action of the electric current and magnet may be strikingly illustrated by employing a magnetizing coil of wire of medium size in connection with suitable battery power to magnetize the steel bar, and then by substituting a delicate galvanometer for the battery, and by introducing the magnet into the coil, a current is induced in the coil, as indicated by the galvanometer, showing that the battery current has imparted to the steel a quality which is capable of inducing a current in the wires of the coil.

It makes no material difference in the result, whether a magnetized steel bar is introduced into the coil, as in Fig. 1, or whether the coil is provided with a soft iron core capable of being magnetized by induction, by contact with, or proximity to, a permanent magnet. Fig. 2 illustrates an experiment of this kind, in which the coil, A', of very fine wire, is provided with a permanent soft iron core, and is connected with the galvanometer, B'. By placing the poles of a permanent horseshoe magnet in contact with the projecting ends of the soft iron core of the coil, the core instantly becomes a magnet by induction, and a current is set up in the coil in the same manner as in the former experiment. When the magnet is removed the magnetism of the core departs, which is equivalent to the removal of the magnet from the coil in the first experiment, and the result is a momentary current in a direction opposite to that of the first.

The inductive effect of the magnet is much the same if the bobbin of fine wire be placed around a permanent magnet and the magnetic tension be disturbed by the application and removal of an armature. The Bell telephone (the essential parts of which are shown in Fig. 3) is a familiar example of this species of generator of induced currents. When the diaphragm, acting as an armature, approaches the magnet, a momentary current is set up in the bobbin, A'', in one direction, as indicated by the galvanometer, B'', and when the diaphragm recedes from the magnet the current set up in the bobbin is in the opposite direction. In the telephone these currents have sufficient power to operate a second instrument of the same sort; but owing to the fact that the armature is very light, and never touches the magnet nor recedes very far from it, and the further disadvantage arising from the use of a bar magnet, the apparatus cannot rank high as a generator of electric currents, however well it may serve the purpose of a telephone.

Another form of apparatus (Fig. 4), operating on the same principle, generates currents sufficiently powerful to work a polarized bell or annunciator over a line several miles long. This magneto key is made by clamping two 6-inch horseshoe magnets upon opposite sides of two soft iron pole extension pieces, *a*, one-half inch in diameter, one and a half inches long, and projecting one inch beyond the poles of the magnets. Each extension piece is provided with a bobbin, D, one inch long and one and a quarter inches in diameter, filled with No. 36 silk-covered wire. These bobbins are wound and connected like the spools of an electro-magnet, and have a combined resistance of 200 ohms.

In front of the poles of the magnet an armature, E, one-quarter inch thick, a little longer than the width of the extremities of the magnet, and about one inch wide, is pivoted at its lower edge, and provided with a key lever by which it may be drawn from the poles of the magnet. A spring under the key lever throws the armature back into contact with the magnet. This is a simplified form of Breguet's exploder used in firing mines, and although much smaller than the apparatus referred to, it is capable of ringing a polarized bell over fifteen or twenty miles of wire, and will give a powerful shock. It is a convenient and inexpensive apparatus for signaling, and is particularly adapted to the telephone when used in connection with the polarized annunciator or polarized bell, presently to be described. In this apparatus like poles of the magnets must oppose each other, and the clamping pieces and screws should be of non-magnetic material. If two magnets do not produce a current of sufficient strength two more may be added.

In this form of magneto-induction apparatus the action of the magnet and coil is identical with that of the Bell telephone. The rational explanation of this action may be found in the action of two permanent horseshoe magnets having their unlike poles in opposition. In this case the opposing poles neutralize each other to such an extent as to almost destroy all magnetic effects. It amounts to the temporary demagnetization of the steel. On separating the poles of the two magnets they regain their normal magnetism. The case is precisely the same with the magnetic key. The armature, E, when applied to the pole extensions, becomes a magnet by induction, and by its reaction upon the magnet neutralizes the power of the magnet and produces nearly the same result as withdrawing the magnet from the bobbin. When the armature is withdrawn suddenly from the magnet the effect upon the wires of the bobbins is the same as would be produced by introducing into them the poles of the magnet.

To render the electrical pulsations of this class of machines continuous the armature may be rotated, as shown in Fig. 5, which represents a modification of an old and well known magneto-induction machine, in which the bobbins, D', are placed on pole extensions of the magnets, C', and the variations in magnetic force are produced by the wheel armature, E.

Another method of generating currents by a rotary movement of the armature is to make the armature in the form of an electro-magnet, and mount it upon a rotating spindle so that it may revolve in close proximity to the poles of a strong permanent horseshoe magnet. This form of machine, which is the invention of Clarke, is shown in Fig. 6. It has long been used for medical purposes, and before the invention of the more recent machines was employed for electro-metallurgy and for other purposes.

The electro-magnetic armature, G, is mounted on a shaft, so that it may revolve very near but not in contact with the poles of the compound magnet, F. One of the terminals of the bobbins is in electrical connection with the shaft, the other is connected with an insulated ferrule on the shaft. The alternating current is taken off by two springs, one touching the insulated ferrule, the other bearing against the shaft. When the current is required to flow in one direction the insulated ferrule is split longitudinally into two equal separate halves, each of which is connected with one terminal of the armature wire. This split ferrule, together with springs, H, which press upon its diametrically opposite sides, forms a commutator which sends the momentary currents of like name all in one direction.

The slots of the ferrule are arranged relative to the springs, H, and armature, so when the polar faces of the armature cross a line joining the poles of the permanent magnet the springs will leave one-half of the ferrule and touch the other half.

Fig. 7 shows a modification of Clarke's machine, in which the permanent magnet, F', is provided with pole extensions of soft iron surrounded by fine wire bobbins, D''. These bobbins are connected like an electro-magnet, and when the armature, G', is turned so as to send a current through the springs, H', an alternating current may be taken from the bobbins, D''.

Fig. 8 shows a kind of commutator designed for short circuiting the machine through a part of the revolution, so that when the short circuit is broken a direct extra current capable of giving powerful shocks will pass over the conductors leading from the machine. Each half, *d*, of the commutator ferrule is provided with an arm, *e*, terminating in a curved piece, *g*, attached to opposite sides of the insulating cylinder, *c*. The curved pieces, *g*, are pressed by springs which are electrically connected with the commutator springs on their respective sides of the cylinder, so that when the piece, *g*, is touched by its spring and the ferrule, *d*, is touched by its spring—the two springs being in electrical communication with each other—the machine is for the moment short-circuited, but when contact with *g* is broken the extra current passes by the usual channels from the machine.

A magneto-electric machine, equal in power to about six Bunsen elements, is shown in Figs. 9, 10, and 11. The compound field magnet is composed of twelve six-inch horseshoe permanent magnets, K, arranged in two groups of six, with their like extremities clamped between curved soft iron bars, J, as shown in the vertical longitudinal section, Fig. 11. These bars consist of sections cut from common wrought iron washers, 3 inches external diameter, ¼ inch thick, and having a 1⅝ inch hole through them. The washers are all drilled to receive the bolts, *h h*, before they are cut in two. The washers, J, and magnets, K, are placed in alternation and clamped between brass angled plates, L, by which the middle portion of the field magnet is fastened to its base. The magnets are further secured to the base by standards, *j*, which clamp the sides of each group of magnets, the magnets being kept the proper distance apart by interposed strips, *i*.

The bars, J, are cut away on the inner edges, forming an approximately elliptical opening for receiving the armature, I, which is a very little less than 1⅝ inch in diameter, and is 3½ inches long. It is of the earlier Siemens type, and is wound with four parallel silk-covered No. 32 wires, which terminate in eight insulated metallic blocks on the switch, M, one block to each end of each wire. The switch is shown in detail in Fig. 12—1, 2, 3, 4, 5, 6, 7, 8, being the terminals of the wires of the bobbin. The blocks 1 and 5 represent the ends of the first wire, 2 and 6 representing the ends of the second wire, 3 and 7 the third, and 4 and 8 the fourth; 15 and 16 are curved brass pieces capable of being plugged into connection with the blocks just mentioned, by means of screw plugs, shown in place in the engraving. The pieces, 15 and 16, are connected respectively with the two halves, O P, of the commutator cylinder.

At the ends of the curved pieces 15, 16, there are metallic blocks, 17, 18—the block 17 being connected by a wire with the metallic boss of the rubber wheel upon which the switch is mounted; the block 18 being connected by a wire with a brass ring, Q, on the rubber support of the commutator.

Inside the blocks 1 to 8, there are six metallic blocks, 9, 10, 11, 12, 13, 14, connected together by wires as shown. The opposite sides of the commutator cylinder are pressed by springs or brushes, R, which are sustained by an insulating support and are provided with binding posts for receiving the wires for conducting away the direct current. A spring, T, touches the end of the armature shaft, and has a binding post for receiving a wire conductor, and a spring, U, sustained by an insulator attached to the angle plate, L, has a binding post for receiving a conductor.

The armature is of very soft cast iron of the usual form,* and its shaft is provided with a pulley for receiving power.

This machine will yield currents of three different intensities, and will deliver them either direct or alternating, and it answers admirably as a motor.

To obtain a quantity current the screw plugs are inserted as shown in Fig. 12, so as to connect 1, 2, 3, 4, with 15, and 5, 6, 7, 8, with 16. In this condition it may be used as a motor. The success of the machine as a motor depends in a great measure on the adjustment of the commutator. Its slit should be opposite the center of the open space or groove in the armature.

To secure a current of higher tension connect 5 and 6 with 16, connect 1 to 2 and 2 to 11, connect 12 to 7 and 7 to 8, and finally connect 3 and 4 with 15. To get the highest tension connect 5 to 16, 1 to 9, 10 to 6, 2 to 11, 12 to 7, 3 to 13, 14 to 8, and 4 to 15. Direct currents are taken from the springs, R, alternating currents are taken from the springs, T, U, after connecting 15 to 17 and 16 to 18. The quantity current is obtained from four parallel wires, which are equivalent to one wire having four times the sectional area of the single wire and one-fourth the length. When the medium current is secured the wire is doubled, so that it is equivalent to a wire having twice the sectional area of the single wire and one half the length. For the high tension current the full length of wire is used single.

Fig. 13 shows a method of building up a field magnet from common bar magnets. They are let into and clamped on a block of wood so as to project lengthwise over the armature. An iron cap placed against the fixed ends of all the magnets completes the arrangement.

A further use for permanent magnets is found in polarized bells, relays, and annunciators. Fig. 14 represents a Siemens polarized bell, in which an iron yoke, *m*, is supported from the elongated ends of the yoke of the magnet, *l*, by two brass studs. The yoke, *m*, supports the pivots of the bell armature, *n*, also the studs upon which the bells are placed, and to it is secured the magnet, *p*, which is bent under the yoke of the magnet, *l*, without touching it.

Fig. 15 shows a similar but simpler device, in which the poles of the magnet, *l'*, are fitted with a brass yoke, *m'*, which supports an iron frame in which is pivoted the armature, *n'*, and to which the bell is attached. This frame has a socket *o'*, for receiving one of the poles of a horseshoe magnet, *p*, the other pole of which touches the yoke of the magnet, *l'*.

The polarized annunciator shown in Fig. 16, has two soft iron cores, *r*, carrying two bobbins of fine wire connected like the spools of an electro magnet. In front of these soft iron cores there is a light delicately pivoted plate, *s*, of iron, which is held in contact with the cores, *r*, by magnetism induced in them by a magnet, *t*, clamped in the middle and capable of being adjusted by a spring and screw at the bottom. The iron annunciator plate, *s*, has sufficient inclination to cause it to drop if released from the cores, *r*. The magnet is placed so near the cores, *r*, as to impart to them just enough attractive force to hold the plate, *s*, and no more.

The polarized bells and annunciator may be worked by either of the instruments shown in Figs. 4, 5, 6, 7, and will be found for many uses preferable to electric bells and annunciators operated by battery currents.

* See description of Simple Dynamo Electric Machine, in SUPPLEMENT, No. 161.

Naval and Submarine Engineering Exhibition.

An international exhibition of naval and submarine engineering appliances is announced to be held in London, in April, 1882. It is intended to cover the wide field occupied in the production of machinery and mechanical contrivances employed in shipping, harbors, etc. Prizes are to be given for the best means of saving life in case of shipwreck, and for the best invention of a humane character connected with sea-faring matters.