formula? E, then, is electromotive force. But what is electromotive force? A force tending to set electricity in motion; or, to use a better phrase, to set up that motion which we call electricity. Here it will be seen we have at once two considerations presented to us: an effect, the motion produced; a cause, the force producing the motion. Of these the first, the motion, is of necessity an actual thing, though we may hold different ideas as to what the thing itself really is. But does the force exist, that is to say, as a special force? There are actual forces having real existence, such as the various attractions, of which we may take gravitation as the type; these are, so to speak, self-existent—we know not their causes. But there are other agencies which we call forces, yet which have only a temporary existence; they are, in fact, simply transfers of energy.

Any agency may be called a force which is capable of setting up motion, or altering the conditions of motion, in a mass of matter. Thus, if we take a ball of lead and let it fall, motion is imparted to it by gravitation; we may push the same ball of lead along a table, or by muscular energy hurl it to a distance; we may strike it as a cricket-ball is put in motion, by a percussive blow; or we may, by aid of a gun, set it in motion by means of compressed air or by the explosion of gunpowder. In all these cases motion is produced, and we may call the agent in each case a force. We may even embody all these agencies in one expression and attribute the motion generated to the action of a "Mechanico-motive Force," the intensity of which we can measure by the amount of motion produced. Such an expression might be correct enough mathematically, but physically it would be a delusion, for only in one instance, that of gravitation, is there an actually existing agency, properly called a force, at work. But any mechanico-motive force can be compared to gravity, because all can be expressed in terms of the velocity which has been set up, or which can be imparted to a unit mass of matter in a unit space of time; the force of gravitation on this earth being such as to generate a velocity of 32 feet per second in round numbers, or an actual motion of 16 feet per second.

But gravitation, and all similar natural forces of the nature of attraction, are constantly acting (and such attractive forces as electricity and magnetism increase during their action, because the distance diminishes), and, in consequence, its effects are cumulative, and result in a regularly accelerating motion, while the other forms of force noticed are simple impulses, and set up a fixed velocity at the origin of the motion. We may, however, for some purposes of reasoning, ignore this property of gravitation, and consider only its unit action, as I shall do presently, in order to make some comparisons with electromotive force.

Now, then, what is electromotive force? When we dissolve zinc in a battery, this force makes its appearance. It is said by some to be due to the contact of the two dissimilar metals; that at the point of contact there is a sort of attraction or repulsion which decomposes the supposed natural or normal electricity, and sends the two halves to seek reunion through any roundabout or difficult path. But one thing is certain—this force can do no work unless it is maintained by an equivalent supply of energy, and as a matter of fact easily proved, the degree of electromotive force produced is measurable in terms of the chemical actions which occur; and, speaking roughly, it is proportional to the difference of the tendencies of the two metals to combine with the radicals of the acids acting; that is to say, to the heat generated by these metals in the act of combination.

But if we expose the junctions of two different metals to heat, we find electromotive force set up in degrees depending (1) upon some inherent property of the metals (which has an appearance at all events of supporting the contact theory of its origin); and (2) upon the different temperature produced, which means in fact the quantity of energy which can be thrown into the circuit.

Again, if we move a conducting body in the neighborhood of a magnet in certain directions, we find electromotive force in action: here no contact of different metals exists to account for the fact; but an amount of energy is absorbed proportionate to the forces.

On examining the various modes of developing electromotive force, we find, in fact, that it always involves an absorption and distribution of energy, and that the same principles are involved as in the case of what I have called mechanico-motive force; but we find in no case (except apparently in the attractive force of static electricity) any force analogous to gravitation, or to any of the natural attractive forces. Electromotive force is constantly acting upon the circuit, but it has no accelerating action. We are therefore forced to the conclusion that it has no actual existence, but that, like mechanico-motive force, it is simply an application of energy.

E, then, in Ohm's formula is simply an expression, valuable in use for calculation, but symbolizing not a thing, but a value, a quantity of energy applied in a specific mode, to produce a definite molecular disturbance in a conductor and a propagation of electrical action. This will be seen more completely by-and-by.—*English Mechanic.*

ON SIMPLE FORMS OF MICROPHONE RECEIVERS.

By W. J. MILLAR, C.E.

THE following are notes of experiments made by the author upon various forms of microphone receivers. When studying the action of a galvanometer needle under the action of a current of electricity, it occurred to the author that if the needle were replaced by a bar magnet not free to move, sounds might be produced. This seemed more likely from the author's experiments upon "Transmission of Sound by Wires,"* where the strains induced in the wires by the aerial vibrations were reproduced to the ear again at varying distances from the origin. A small bar magnet, 3 in. long, having a number of turns of covered copper wire passed along it lengthwise, was connected with a battery consisting of a single Leclanche cell, weakly charged; it was then found that, upon breaking contact, scraping sounds were heard in the magnet. On placing a pasteboard box, or better still, a small tin plate upon the flat side of the magnet, these sounds were much intensified (see Fig. 1). A horseshoe magnet (Fig. 2), 6 in. long, was then tried in a similar manner, and it was found that the sounds were much stronger. Afterwards a bar magnet, 4½ in. long, having about 10 yards of No. 30 wire passed lengthwise along it and placed in a small tin box, the magnet being kept in position by a lid of tin fastened down above it, was tried and found to make an excellent receiver. With all these arrangements, when a microphone, of the ordinary vertical type, was placed in the circuit, various sound phenomena could be reproduced, such as speaking, whispering, singing,

musical sounds, etc. On placing the small 3 in. magnet with its covering of wire in a shallow wooden box, it was found that the sounds were as well heard when the ear was placed against the wood as against the tin plate fixed down on the magnet. When any of these receivers were placed on the edge of a tin box, the sounds due to breaking contact were much intensified.

In the above receiver a permanent magnet was used, but some very curious results were obtained without the aid of the permanent magnet. A piece of tin, 2 in. diameter, was taken, and about half-a-dozen yards of covered copper wire passed around it first in one direction, and then at right angles (see Fig. 3); a couple of plates of tin were placed one on each side of this first plate, and the whole placed in a box. With this arrangement, musical sounds, breathing, etc., were transmitted; the word sounds were low and indistinct. About half-a-dozen yards of the same wire were wrapped round the middle part of a ferrotype plate (see Fig. 4); tuning-fork sounds and the ticking of a watch were transmitted when the plate was tightly pressed to the ear. An additional loose ferrotype plate placed on the former did not, in this case, improve the results.

The scraping sounds due to breaking contact are readily obtained by simple combination of wire and iron. Thus a turn or two of wire around a tin plate, a rod of iron, or along a few iron nails rolled up in paper, is sufficient for the emission of sounds when placed against a tin plate and the whole pressed to the ears. When the ferrotype plate and wire mentioned above were placed on the flat side of the horse-shoe magnet, the wire lying parallel to the limbs of the magnet, an excellent receiver was obtained (Fig. 5), the ticking of a watch being well and clearly defined.

Some experiments were made with this latter form, and it was found that when the wire was passed round other substances than tin or ferrotype, such as wood, pasteboard, or zinc, and placed on horse-shoe magnet as above (see Fig. 5), the sounds were still obtained. A single turn of wire, about 6 in., round a piece of pasteboard, was found sufficient for the emission of sounds, when placed on the horse-shoe magnet.

It was also observed that when the wooden plate was placed so that the wrapping of wire formed varying angles with the longer axis of the magnet, various tones were produced; these also varied as the plate was moved towards the center of the magnet.

In all cases the strongest sounds were obtained when the plates were nearer the poles than when at or near the middle. Square pieces of tin plate usually emitted stronger sounds than rounded pieces.

The tin plates were allowed to lie as close to the magnets as the magnetic attraction allowed of, no attempt being made to keep them from touching the surface of the magnet.

When the connecting wires were fastened to the ends of a bar magnet so as to make the latter part of the circuit, the sounds due to breaking contact were heard when a piece of tin was laid on the side of the magnet.

NEW MICROPHONE RECEIVERS.

From his experiments the author concludes that the sounds originate in the magnet, and that the iron plate being closely connected with the magnet re-enforces these sounds. This it may do either as simply an extension of the vibrating surface, or as an extension of the magnetized body; any change in the magnetic field due to the passage of the current will be spread over a larger area. When a large tin plate, such as the lid of a box, was placed on the magnet, the vibrations could be felt by hand as a tremor through the metal. So far as the author has observed, clearness of articulation has depended on the condition of the microphone carbon transmitter and the volume of sound affecting it, rather than upon any nicety of arrangement of the receiver. With the arrangements tried, speaking about one foot back from microphone gave best results. Violin music was always beautifully and readily transmitted; singing and breathing were also transmitted without difficulty.

FULLER'S ELECTRIC LIGHT.

An improved induction apparatus for lighting by electricity, invented by the late J. B. Fuller, is shown in perspective by Fig. 2, and in section by Fig. 1. The inventor's aim in the construction of this apparatus is to operate along

FIG. 1.

spective by Fig. 2, and in section by Fig. 1. The inventor's aim in the construction of this apparatus is to operate along

the main electric circuit a large number of small lights, each being placed in a local circuit, whose currents are induced by the currents of the main circuit. Two magnet cores are arranged parallel with each other, and connected magnetically at the ends, as shown in Fig. 1. Around the

FIG. 2.

center of each of these cores is a soft iron head, and at a short distance from each side of this is a head of insulating material. The outer ends of the cores are coiled with insulated copper wire, and so connected together and to the electric generator as to produce, when in action, two consequent opposite magnetic poles, at N and S. A, B, C, D, and E,

represent the connections of these coils. Between the iron heads and these coils are wound smaller coils of insulated wire, the fineness of which depends upon the tension of the current required.

There is an iron arm hinged to one of the iron heads, so as to swing over upon the seat connecting magnetically the poles, N and S, as shown in Fig. 1. Now, if electric currents be sent through the main circuit, flowing around the large coils, and rapidly changing, in alternately opposite directions, the magnet cores will as rapidly change polarity, and these changes will induce in the small coils electric currents of greater or less tension, according to the fineness of the wire composing the small coils.

In the circuit of each of the small coils may be placed a lamp, F, of minimum illuminating capacity. Two small coils may be connected together, parallel or in series, for producing a light of medium capacity; or four small coils may be connected, for producing one light of maximum capacity, as shown in Fig. 1.

These connections for producing any changes in the circuits are made by means of ordinary switches, plugs, or keys. The arm which extends across the face of the coil in Fig. 2, acts as a governor of the light, by strengthening or weakening the magnetic poles, and thereby varying the strength of the current.

Any number of such apparatus which the electromotive force of the generator will supply may be arranged along the line of a conductor, the large coils being included in the circuit, and, by means of a switch in the local circuits, each or any lamp may be lighted or extinguished independently from the others.

M. ADER'S TELEPHONE WITHOUT A DIAPHRAGM.

By M. LE COMTE DU MONCEL.

THE actual form of the telephone of M. Ader is shown on the next page, which represents a longitudinal section of the instrument. The difficulty which was presented in the first instance was that of acoustically insulating the two extremities of the iron wire which is terminated at each end by metallic masses. In order to solve this problem, it was found necessary to envelop one of the two masses in India-rubber, so that this mass could be placed in a metallic case fitted to the other mass, so that no confusion of vibrations resulted.

When simple voltaic currents are employed to make the instrument work, a well-annealed iron wire must be employed; but, if induction currents are used, as in the Edison system, which allows the apparatus to work to a long distance, the iron wire should be replaced by a strongly magnetized needle. The induced currents cannot work telephones constructed with a simple iron wire.

* Communicated to Physical Society, 1878.

The telephone is extremely portable and efficient, and, moreover, is, in outward appearance, similar to the ordinary Bell telephone.

In the figure, the following are the several parts:

- A. Ear-piece of wood.
- B. Outer case.
- C. Mass of lead.
- D. Copper disk soldered on the lead.
- E. Copper mass.

F. India-rubber mass.

H. Flexible envelope of India-rubber for insulating the vibrations of the mass, C.

M. Bar of iron one millimeter in diameter, well annealed, and soldered to the mass, E, and to the disk, D.

N. Olive-shaped bobbin wound with fine insulated wire, and placed in the middle of the iron bar.

O O. Holes through the lead mass through which the conducting wires pass.

The whole mass, C, D, does not fit tightly in the case, B, but has about a millimeter of space around it.

CHANGES OF SPECTRA.

If a small quantity of mercury is placed in a hydrogen Geissler tube, E. Wiedeman finds that an induction current gives the hydrogen spectrum at ordinary temperature. But if the tube is warmed in an air-bath, as the temperature rises the mercury lines appear, while the hydrogen lines grow fainter and finally disappear. If a tube of hydrogen and nitrogen is warmed at any point, so as to free sodium or other metals from the glass, the hydrogen and nitrogen lines vanish almost entirely while the lines of the metal appear. Does the hydrogen disappear, or is it transmuted into some other substance?—*Comptes Rendus*.

J. B. FULLER.

ONE of the early friends and associates of Edison* was a young man named J. B. Fuller, a Connecticut Yankee, in whom the inventive faculty was active from boyhood. Fuller made a great deal of telegraph machinery and invented many industrial processes, such as modes of utilizing wood pulp in paper making, etc. Ten or fifteen years ago, Fuller separated from Edison, because it would no longer do to have them work in company. The inventions of the one might easily have been said to be due to the suggestions of the other, and so the two men parted, never to see each other again. They were men of very different qualities, Edison being quick to seize upon a new thought in natural science and apply it to practical use long before any one else could see its practical value, while Fuller loved deep problems and research, and was much more gifted in the work of discovering new principles than in applying them. He was an eager student and a desperate worker, and succeeded in mastering so many of the mathematical and other problems connected with electrical science that he became the greatest authority thereon, particularly on magnetic induction, in this country. Fuller took up the subject of the electric light in 1874, and has been studying it, in an obscure laboratory in Brooklyn, until the present year. He found at the outset, like so many other men, that there was need of a good magneto-electric machine. He invented his own, based on the principle of Gramme's, and produced so powerful a one that three years ago he succeeded in having it adopted by the Gold and Stock Telegraph Company of this city for practical telegraphy. The company named has over a thousand machines in different parts of the city, upon which are printed every few minutes the quotations of stocks in Wall Street through the business hours of the day. The Fuller magneto-electric machine was adopted to operate the wire connecting with these gold and stock indicators. Fuller has studied ever since to improve his generator; but when he had once obtained a generator of reasonable power, he returned to experiments with a lamp. He shunned publicity, and in the obscurity of his little shop toiled for years over his lamp. He was the man best fitted in the United States to attempt a solution of the problem. This inventor evolved a whole system of lighting—the generator, a lamp, and a meter. He proposed to use two large street mains, one of them insulated, disconnected at the outward ends. The positive main was to throw off a branch wire into each building to be lighted, the wire entering the meter, performing a certain service there, and then returning to the street to the negative main. The main current was not to do the lighting, but it was to generate another current in a series of induction coils, and each lamp was to be lighted by the current, from one of these coils. An alternating current was to be used. The induction coils were thus made: Two magnet cores, arranged parallel to each other, were connected magnetically at the ends. Around the centers of each of these cores was a soft iron head, and at a proper distance from this a head of insulating material. The outward ends of the cores were coiled with insulated copper wire, and so connected together and to the main wire (or generator) as to produce two opposite magnetic poles. Between the soft iron heads and the coils were wound smaller coils of insulated wire, the fineness of which would depend on the tension required. To one of the iron heads was hinged an iron arm, so made as to swing over upon the other, connecting magnetically the poles N and S. In a coil so made, if a current be sent through the main wire rapidly changing in opposite directions, the magnetic cores will change polarity, and the change will induce a current of great tension in the smaller coils, and this second current, if conducted by proper wires to a lamp, will maintain platinum or carbon in a high state of incandescence. Two induction coils, or four, can be coupled together for lights of stronger power. A

graduated switch is used in this lamp, so as to permit its brightness to be varied at will. A great many experiments were made with this style of lamp with platinum burners, and they operated admirably. A number of capitalists of Brooklyn, hearing about these experiments, organized a company, with 1,000,000 dollars capital, last December, to adopt Fuller's inventions and introduce his light throughout Brooklyn. A new shop was fitted up for the inventor on Broadway, near 36th street, in New York City, near his

residence, and in this shop Fuller toiled for six months almost literally day and night. His whole system was in a most promising shape, when last February an incident occurred which put a stop to the progress of experiments in household lighting.

The company had determined to manufacture point-to-point lamps and magneto-electric machines first for factory use. About twenty factories in New England and the Eastern States have this winter introduced the large electric lamps of from 700 to 2,000 candle power into their workrooms, and the demand for the means of lighting had become very active. The Fuller Company resolved, therefore, to solicit orders from factories, and it had 75 machines constructed, which are being finished up this week for factory use. During the first week of February, Mr. Fuller was engaged in perfecting a new point-to-point lamp, and began to be troubled with insomnia. Against the advice of his friends, he worked on his new lamp until it was finished. In the act of tightening up the last screw he faintly and fell to the floor of his shop entirely exhausted, completely worn out with intense mental application and lack of sleep. He was carried to his residence. A week afterward he had recovered so as to be active again. His busy mind had, in the meantime, discovered a new idea in induction. He sent over to the shop for his man George, the foreman of the works, to explain to him the new idea. The two men sat down together, and Mr. Fuller described his idea with much minuteness—the shape of the magnets, the size of the wire, the manner in which the wire was to be coiled on, and so on, motioning with his hands to illustrate his meaning. When Mr. Fuller had finished, he said: "George, do you understand that?" The foreman replied that he did. "Now," said Mr. Fuller, "I want you to understand that, George, for it is very important;" and then he went over the matter again, explaining the whole idea, with the mathematical principles involved in it. When he had completed the explanation the second time he said: "Now, George,

increase the value of any sort of fuel. The only duty of artificial appliances of that nature is to provide for the admission of the necessary amount of air to effect the oxidation of so much carbon or hydrogen, or both, as may be required within a certain period of time. The more carbon a combustible contains, the less ready is it to combine with oxygen, and therefore it is found that with almost pure carbon in bulk—as hard coke for locomotives, etc.—the strongest blast is necessary to cause its complete conversion to carbonic acid.

There are only two means by which the quick and complete combustion of fuel may be effected. The first and most usual is to urge a large quantity of air over and through the great masses of incandescent material; and the other method is that of reducing the fuel itself to a state of fine division, whereby its active service is so much increased, that, when intimately mixed with the proper quantity of air, and brought under suitable conditions, the process of oxidation of each particle is effected *per saltum*.

The theoretical reasons for the latter mode of treatment are perfectly sound, but the efficacy and handiness of the apparatus which has been employed to carry them out has left much to be desired; and the practical advantages which have been actually realized are not such as to cause the general adoption of any of the methods which have been introduced for this purpose. It is, however, on record that powdered coal has been perfectly consumed by the admixture with it, in the furnace, of the exact weight of air theoretically necessary; so that it is evident that this desirable object can be attained in the use of fuel in a more suitable form than in solid lumps borne on fire-bars in the usual way. Of course, fuel in this shape can only be used for steam-boilers, iron furnaces, and similar trade purposes.

The step from fuel in powder to fuel in liquid form is not difficult. If we agree with the arguments in favor of the former, it must be admitted that they apply with great force to the latter. If continuous firing is of any value—and no one would deny that it is so—a fluid can be caused to flow to any desired point with the greatest regularity, and can also be made to take any desired quantity of air with it. An oil is always ready for lighting, and, from the time when it is first set on fire to the last drop, it can be consumed to its fullest power, and without residue of cumbersome and useless matter. As a source of heat under perfect control, and capable of being used in small quantities and without a furnace, oil has only one rival—in gas; and, in point of portability, it is undoubtedly superior to any other combustible. As long as the oils in common use for illuminating purposes were derived from animal or vegetable sources, their cost was such as to preclude their general use as fuel, for which, indeed, they were not eminently qualified; but the cheapness of mineral oils, not less than their calorific power, has led to their common employment as fuel for certain purposes.

Alcohol has always been in demand as a handy source of heat for small requirements, for which its highly inflammable nature—consuming without depositing soot—renders it very convenient; and although its real heating power is not large, it is readily available. Its costliness, however, even in the form of methylated spirit, is its great drawback.

Bearing these preliminary observations in mind, together with other considerations respecting the comparative suitability of different fuels for ordinary purposes which must occur to every one, the following tabular statement, compiled from various authorities, of the composition and value of various combustibles in common use, will be found useful:—

TABLE OF THE AVERAGE COMPOSITION OF FUELS.

FUEL.	Components per cent. by Weight.							Estimated Value in Units per Pound
	Carbon.	Hydrogen.	Oxygen.	Nitrogen.	Sulphur.	Ash.	Water.	
Hydrogen.....	—	100	—	—	—	—	—	62,500
Carbon.....	100	—	—	—	—	—	—	14,500
Coal—								
Welsh.....	83.78	4.79	4.15	0.98	1.43	4.91	—	14,817
Newcastle.....	82.12	5.31	5.69	1.35	1.24	3.77	—	14,776
Lancashire.....	77.90	5.32	9.53	1.30	1.44	4.88	—	13,776
Derbyshire.....	79.68	4.94	10.28	1.41	1.01	2.65	—	13,841
Scotch.....	78.53	5.61	9.69	1.00	1.11	4.03	—	14,136
Averages.....	80.40	5.19	7.87	1.21	1.25	4.05	—	14,289
Coke—								
Dry and fresh.....	92.00	—	—	—	0.50	7.50	—	13,340
Average state.....	84.75	—	—	—	0.75	7.50	7.00	12,288
Wood—								
Perfectly dry.....	50.00	5.30	41.70	1.00	—	2.00	—	7,312
Ordinary state.....	40.05	4.20	33.40	.75	—	1.60	20.00	5,826
Lignite, dry.....	69.00	5.00	18.80	1.20	—	6.00	—	10,661
Peat.....	45.30	4.60	23.00	1.00	—	1.80	24.20	7,649
Wood charcoal.....	92.00	—	—	—	—	8.00	—	13,340
Petroleum.....	85.00	13.00	2.00	—	—	—	—	20,293
Petroleum oils.....	72.60	27.40	—	—	—	—	—	27,652
Olive oil.....	77.21	13.36	9.43	—	—	—	—	18,808
Alcohol.....	51.98	13.70	34.32	—	—	—	—	13,403
Tallow.....	79.00	11.70	9.30	—	—	—	—	18,042
Beeswax.....	81.60	13.90	4.50	—	—	—	—	21,169

do you think you understand that?" The foreman said he did perfectly. Mr. Fuller looked pleased, lay back in his chair, and died soon afterward. This was on the 15th of February. The inventor's life had flickered out, quietly, but unexpectedly to both men, and Mr. Fuller, as every one who is acquainted with his plans believes, has departed just at the moment when he was about to become famous and rich. His foreman was of a too practical turn of mind to see the poetic aspect of such an incident, and it is only within a day or two that the facts have been privately obtained by the writer.—*New York Correspondent of the London Times*.

GAS AS FUEL.

By "ISCA"—(*Journal of Gas Lighting*).

It must be remembered that a given weight of any fuel will always yield the same amount of heat, so that the heat developed, say from coal in a common grate, is equal to that which would be given by the same quantity of coal in the largest blast furnace. Similarly, the heat of an ordinary lucifer match, or the flame of a tallow candle, is not one whit less than that yielded by an equal weight of wood or tallow burning in the heart of a great conflagration.

No kind of furnace or arrangement of draught can in-

crease the value of any sort of fuel. The only duty of artificial appliances of that nature is to provide for the admission of the necessary amount of air to effect the oxidation of so much carbon or hydrogen, or both, as may be required within a certain period of time. The more carbon a combustible contains, the less ready is it to combine with oxygen, and therefore it is found that with almost pure carbon in bulk—as hard coke for locomotives, etc.—the strongest blast is necessary to cause its complete conversion to carbonic acid.

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* Edison says this story is all fiction. He was never associated with Mr. Fuller.—*I. R.*