The Telegraph

An article which is believed to be from the
August, 1873 issue of Harper's Weekly

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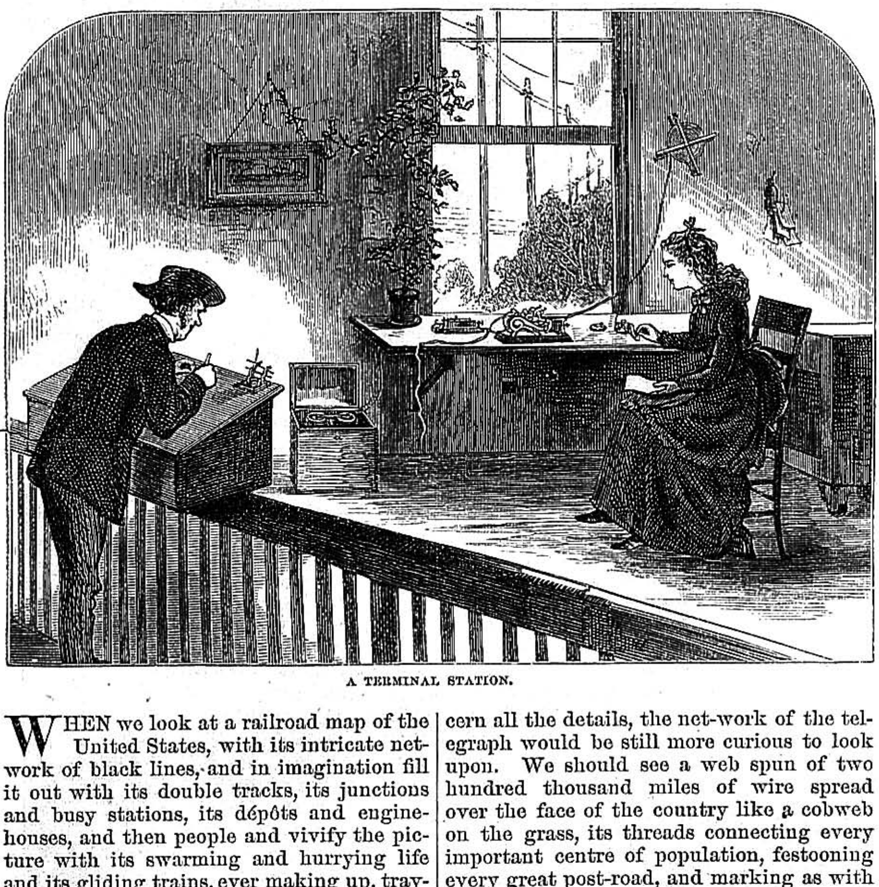
Under the proposed law a new official has to be appointed by the Governor, to be called the "Inspector of Factory Children." Such an officer, acting under so wise and humane a law, can not but accomplish immense good throughout the State.

It is a matter deeply to be regretted that certain manufacturers in the State Legislature in Albany have not imitated their more enlightened and humane contemporaries in Massachusetts, and given their hearty support to so beneficent a measure. Instead of this, we are sorry to be informed that they are offering a factious opposition which may entirely defeat this act, and put New York in a very unfavorable position, as compared with the New England States, in her legislation to protect factory children.

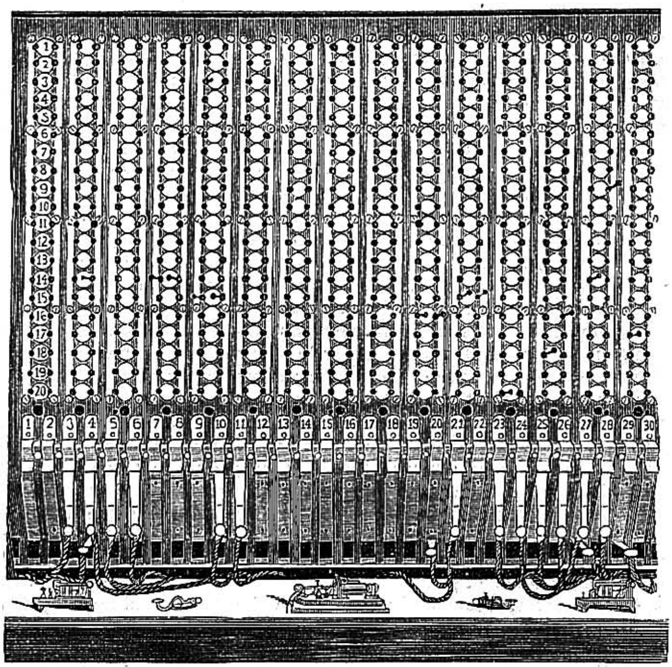
THE TELEGRAPH.



A TERMINAL STATION.

WHEN we look at a railroad map of the United States, with its intricate net-work of black lines, and in imagination fill it out with its double tracks, its junctions and busy stations, its dépôts and engine-houses, and then people and vivify the picture with its swarming and hurrying life and its gliding trains, ever making up, traversing the field, breaking and forming new combinations, incessantly succeeding, passing, and crossing each other; and when we add the bands of pioneers, surveyors, engineers, laborers, and construction trains which form the fringe of this net-work, constantly extending its meshes in every direction, and adding new intricacies to its most crowded parts—the mind is almost bewildered with the thought of such an immense labyrinth, such complex organization.

If we could rise above the surface of the earth, and take in the whole country at a bird's-eye view, with visual power to discern all the details, the net-work of the telegraph would be still more curious to look upon. We should see a web spun of two hundred thousand miles of wire spread over the face of the country like a cobweb on the grass, its threads connecting every important centre of population, festooning every great post-road, and marking as with a silver lining the black track of every railroad. We should observe men, like spiders, busily spinning out these lines in every direction, at the rate of five miles an hour for every working hour in the year. If we should trace these threads back from the circumference, we should find them converging from every direction to certain central knots, like Chicago, St. Louis, Cincinnati, Buffalo, Washington, and many others of equal importance, and thence running in great strands, doubling and multiplying in number as they approach the centre, but so arranged as to bind every city and town to all its neighbors, near and far. If the eye, seeking to analyze this labyrinth, should pursue the converging lines, it would at last follow a great band of more than two hundred and fifty wires, from every point of the compass, running into one great centre in the city of New York, in the main office of the Western Union Telegraph Company. Other minor centres would appear, but this one would immediately be recognized as the great core or heart of the system.



ONE-QUARTER OF SWITCH-BOARD, WESTERN UNION OFFICE, NEW YORK CITY.

If, now, such an observer could be gifted with a magic power of vision, which man has not yet dreamed of attaining, so as to be enabled to see that unseen and silent force we call electricity, and discern its instantaneous actions and reactions from point to point over this bewildering maze, the net-work of the telegraph would present a spectacle far more amazing than that of the railroad system.

As the morning sun sends the hour of nine across the continent, the offices are filled with operators, an army of nearly ten thousand persons, engaged in the various functions involved in the service. The batteries, which we may imagine to have been mostly slumbering during the night, all awake to their work, and the quiverings and scintillations of electric action along the wires would show the whole net-work to be now alive. On the great trunk lines the last of the night work is finished, the morning orders are circulated, and around the circuit flash the humorous salutations which the operators exchange with their unseen fellows, who seem to be concealed at their elbow, but who are in reality hundreds or thousands of miles away. Ten o'clock finds the offices full of business. Outward-bound messages pour in to be dispatched, and messages received are ticked off by the talking armature, to be written out and sent off for delivery. By eleven o'clock the press news begins to crowd upon the operators, and then for two or three hours the excitement is at its height. Every one must be at his post, every faculty alert, and attention incessant. The zinc in the batteries burns fiercely under the corroding acid, the mysterious "current," which becomes more wonderful the more conscious we become of human ignorance respecting it, leaps to its work. Every available circuit on the great lines is pressed to its utmost. The operator's keys dance their tattoos, to which the distant receiving instruments instantly respond, reproducing the slightest, most transient motion. The whole net-work of wires, and the submarine cables which connect it with other equally active systems on the other side of the globe, are all quivering from end to end with signals of human intelligence.

After two o'clock signs of relaxation appear. The press messages diminish; messages that have been waiting to take their turn are cleared off. At four the heavy business of the day in many offices is about over. The great lines are still crowded, and their work runs on into the evening. At last the business of night work begins, and the press messages from Washington, and the business and social messages that are taken at half price, in consideration of their being allowed to be sent at leisure, to be delivered next morning, are transmitted between the great cities, north, south, east, and west.

Every phase of the mental activity of the country is more or less represented in this great system. The fluctuations in the markets; the price of stocks; the premium on gold; the starting of railroad trains; the sailing of ships; the arrival of passengers; orders for merchandise and manufactures of every kind; bargains offered and bargains closed; sermons, lectures, and political speeches; fires, sickness, and death; weather reports; the approach of the grasshopper and the weevil; the transmission of money; the congratulations of friends—every thing, from the announcement of a new planet down to an inquiry for a lost carpet-bag, has its turn in passing the wires. Amidst all this private business perhaps some political incident of prime importance transpires at Washington, or some terrible casualty shocks Boston or Chicago. Almost instantly the knowledge of it reaches the nearest ganglion of our great artificial nervous system, and it spreads simultaneously in every direction throughout the land. Along every wire the same pulsations run, speaking their message upon all the instruments in a circuit at once. Thus, to borrow the striking figure of Scripture, quick "as the lightning that lighteneth out of the one part under heaven shineth unto the other part under heaven," an electric flash of intelligence spreads over the country, carrying a thrill of gratification or of grief.

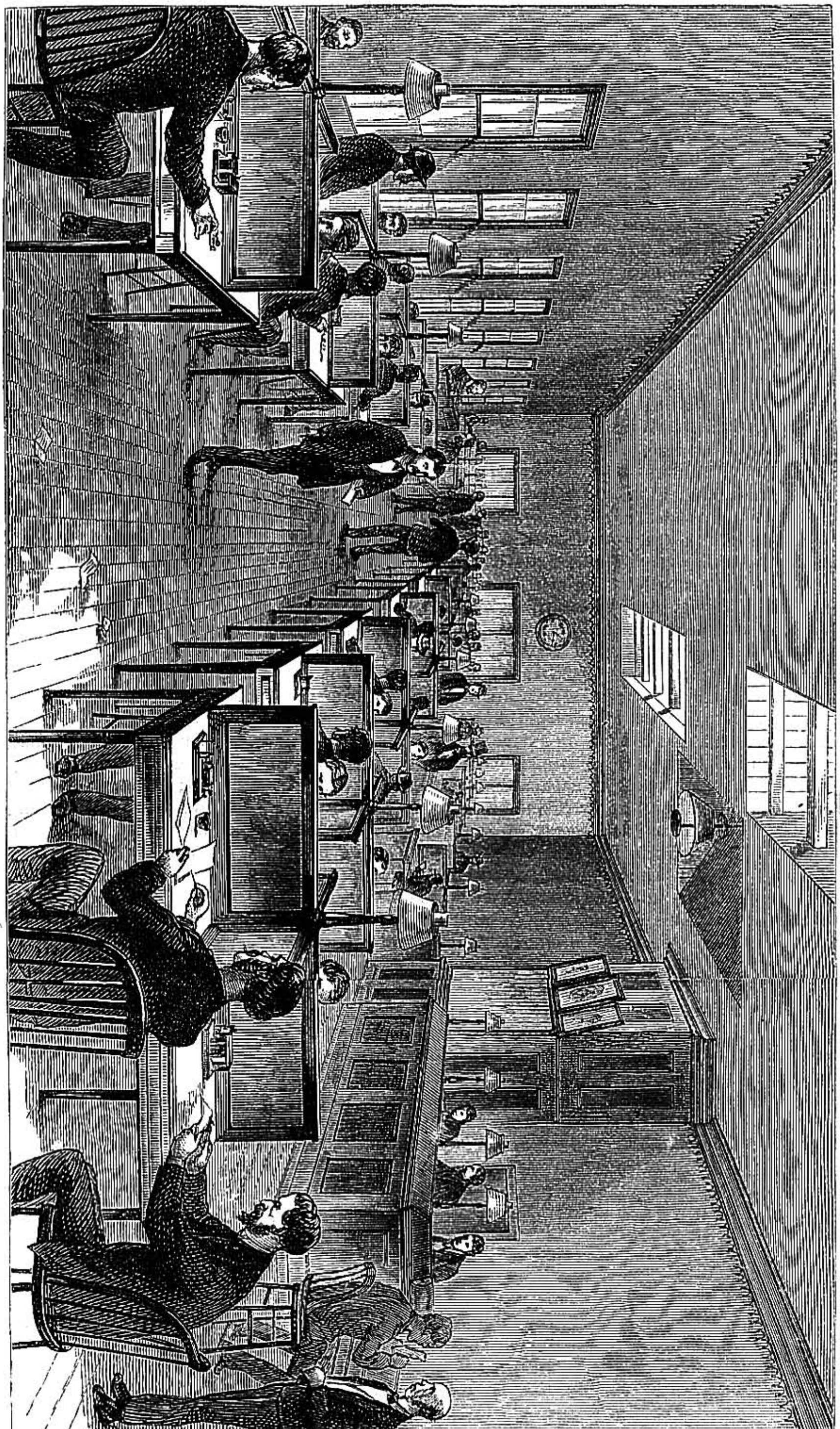
Our observer, if he could not only see the oscillations of electric condition, but also discern the meaning of the pulsations, and read the messages as they circulate, would thus have a panorama of the business and social affairs of the country passing under his eye. But the telegraph has now become so true a representative of our life that it would hardly be necessary to read the messages in order to find an indication of the state of the country. The mere degree of activity in the business uses of the telegraph in any given direction affords an index of the prosperity of the section of country served thereby. Mr. Orton, the president of the Western Union Company, gave a striking statement of this fact in his argument before a committee of Congress in 1870. He said: "The fact is, the telegraph lives upon commerce. It is the nervous system of the commercial system. If you will sit down with me at my office for twenty minutes, I will show you what the condition of business is at any given time in any locality in the United States. After three years of careful study of the matter, I am ready to appeal to the telegraph receipts as a criterion under all circumstances. This last year the grain business in the West has been very dull; as a consequence, the receipts from telegrams from that section have fallen off twenty-five per cent. Business in the South has been gaining a little, month by month, for the last year or so; and now the telegraphic receipts from that quarter give stronger indications of returning prosperity than at any previous time since the war."

The observer, whom we have supposed capable of seeing electricity, would find that the whole surface of the earth, the atmosphere, and probably the fathomless spaces beyond, were teeming with manifestations of the electric force. Every chemical process, every change of temperature, all friction, and every blow, in nature or in art, evolves it. The great process of vegetation, and the reciprocal process of animal life, all over the globe, are accompanied by it. As incessantly as the sun's rays pass around the earth, warming every part, in alternation with the cooling influence of night, great currents or fluctuations of magnetic tension, which never cease their play, circulate about the globe, and other, apparently irregular, currents come and go, according to laws not yet understood, while the aurora borealis, flaming in the sky, indicates the measureless extent of this wonderful power, the existence of which the world has but begun to discover. Our observer would see that these great earth currents infinitely transcend the little artificial currents which men produce in their insulated wires, and that they constantly interfere with the latter, attracting or driving them from their work, and making them play truant, greatly to the vexation of the operators, and sometimes to the entire confusion of business. If a thunder-storm passed across the country, he would see all the wires sparkling with unusual excitement. When the rain fell, and water, which is a conductor, trickled along the wires, and stood in drops upon the insulators, he would see the electricity of the line deserting its path, and stealing off slyly, in greater or less quantities, over the wet surface of the insulators, or by the wet straws or kite strings that sometimes hang across the line. Now and then he might see the free electricity of the storm overleap the barriers, and take possession for the moment of some unguarded circuit, frightening operators from their posts.

Such an observer would realize, what it is difficult adequately to conceive, that electricity is, as has been said, the great hidden force in nature, and still remains, so far as man is concerned, almost dormant. A high scientific authority has remarked, in speaking of metals, that the abundance of any object in nature bears a proportion to its adaptation to the service of man. If this be true in general, we may expect that electricity will become one day a most familiar thing.

With the exception of those general readers whose taste or course of reading has led them somewhat into scientific paths, there are not many persons who find it easy to form a definite idea of the precise mode of action by which a telegraphic wire conveys its messages—so multitudinous and varied in their character, and transmitted with such inconceivable rapidity.

We are, it is true, most of us somewhat farther advanced in our ideas on the sub-



OPERATING-ROOM OF THE WESTERN UNION COMPANY, NEW YORK.

ject than the good old lady was who, when a telegram was brought to her purporting to come from her son, and asking her to send him some money, said they could not swindle her in that way, for she knew her son's handwriting perfectly well, and she was sure that dispatch never came from him; or than the child who, hearing that dispatches of various kinds were sent by telegraph, watched a long time in hopes of seeing some of them darting along the wires. Still, to the mass even of intelligent and well-informed readers, the precise mode in which the communications are made is a mystery more or less inscrutable.

The difficulty of forming a clear conception of the subject is increased by the fact that while we have to deal with novel and strange facts, we have also to use old words in novel and inconsistent senses. Scientific men have, of course, found it necessary, in describing the phenomena of electricity, to use words which mankind have heretofore used to designate other things of somewhat analogous nature, and which call up in the mind conceptions quite inadequate to the new fact. Thus, when it is said that a current of electricity *flows* along the wire, that the wire or the current *carries* a message, the speaker takes language universally understood, relating to a fluid moving from one place to another, and a parcel or letter transported from place to place. He does not, however, mean that there is any stream flowing, or any thing whatever transported, but he is speaking only of the action and reaction of an imponderable force, and the making of intelligible signals by its means at a distance. Such language the world must, perhaps for a long time to come, continue to employ; and it is not strange that those to whom the subject described by it is entirely new should be sometimes laughably misled by it.

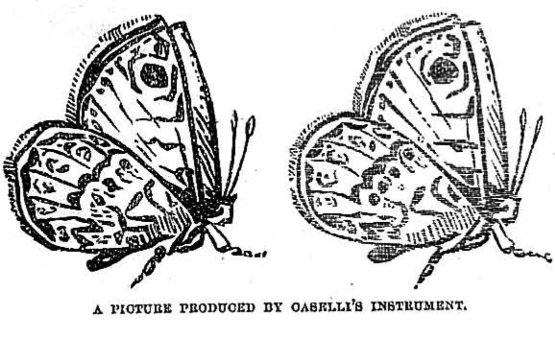
Not long since a countryman came into a telegraph office in Bangor, Maine, with a message, and asked that it be sent immediately. The operator took the message as usual, put his instrument in communication with its destination, ticked off the signals upon the key, and then, according to the rule of the office, hung the message paper on the hook with others that had been previously sent, that at night they might all be filed for preservation. The man lounged around some time, evidently unsatisfied. "At last," says the narrator of the incident, "his patience was exhausted, and he belched out, 'Ain't you going to send that dispatch?' The operator politely informed him that he had sent it. 'No, yer ain't,' replied the indignant man; 'there it is now on the hook.'"

So far as the exact use of language was concerned, the man was right. Still more ludicrous mistakes sometimes occur. Thus the German papers reported that at Carlsruhe, toward the close of the late war, an aged mother came to the telegraph office carrying a dish full of sauerkraut, which she desired to have telegraphed to Rastadt. Her son must receive the kraut by Sunday. The operator could not convince her that the telegraph was not capable of such a performance. "How could so many soldiers have been sent to France by telegraph?" she asked, and finally departed grumbling.

Almost every operator meets with equally amusing instances. One recently related the following incident: "A gentleman came to my office to send a message, and after writing it, waited, as people often do at small offices, to see it sent. I called 'Office,' and the operator at the other end of the line came to the key and said, 'Busy—wait a minute.' So I leaned back in my chair to wait, when the gentleman said, 'Have you sent it?' I said, 'No; they say they are busy—to wait a minute;' whereupon he said, looking surprised, 'Why, I didn't hear them;' and then added, brightening up, as if he had thought of the reason, 'but I'm *a little deaf in one ear!*' I think I managed to keep a straight face till he left, but it was hard work."

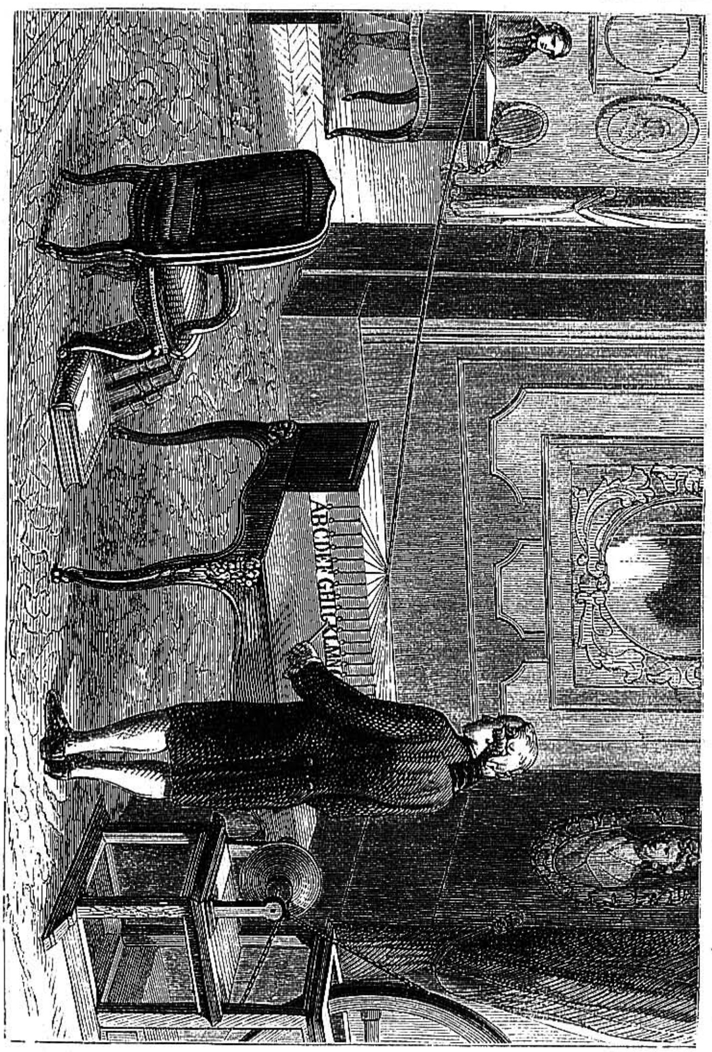
It may make this distinction more clear if we advert to the transmission or production of designs, drawings, etc., by telegraph.

There is an instrument, which we shall hereafter briefly describe, by which this can be done. We should not, however, say, in the case, for instance, of the butterfly in the illustration, that a butterfly was sent by telegraph, nor even that a picture was sent. The operator, being furnished with one picture, created another like it, hundreds of miles away, by means of the telegraph.



A PICTURE PRODUCED BY CASELLI'S INSTRUMENT.

The first step in endeavoring to understand the operation of the telegraph is to learn to make allowance for the new sense in which many terms are employed, and to form a new conception for each, more appropriate to the new fact. Thus, though we



LESAGE'S TELEGRAPH.

continue to speak of the current, it must always be understood as not designating a flowing fluid, and we are not to conceive of the electricity as carrying the message that we write, but rather as enabling the operator at the other end of the line to write a similar one.

Nearly two hundred and fifty years ago, when men were still dreaming of alchemy and the philosopher's stone, they conceived of two sympathetic needles which, instead of always pointing toward the north pole, should be so powerful in relation to each other that in whichever direction one was turned, the other would imitate its motion.

Strada, an ingenious and learned Jesuit of Rome, is quoted as having said, in describing this project, "If you wish your distant friend, to whom no letter can come, to learn something, take a disk, or dial, and write round the edge of it the letters of the alphabet in the order in which children learn them, and in the centre place horizontally a rod, which has touched a magnet, so that it may move and indicate whatever letter you wish. Then, a similar dial being in the possession of your friend, if you desire privately to speak to the friend whom some share of the earth holds far from you, lay your hand on the globe, and turn the movable iron as you see disposed along the margin of all the letters which are required for the words. Hither and thither turn the style and touch the letters, now this one, and now that......Wonderful to relate, the far-distant friend sees the voluble iron tremble without the touch of any person, and run now hither, now thither: conscious, he bends over it, and marks the teaching of the rod. When he sees the rod stand still, he, in his turn, if he thinks there is any thing to be answered, in like manner, by touching the various letters, writes it back to his friend."

This conceit, which Addison, in No. 241 of the *Spectator*, delicately ridicules as a chimerical notion, has proved to be a very graphic description of Wheatstone's needle telegraph, so well known in England. If we add that the needles are kept in this sympathy with each other by a wire stretched from the stand of one to the other, so that whatever electrical disturbances affect the wire affect both needles alike, the reader will have a more accurate conception of the elementary principle of the telegraph than by any notion he can form of a current sent from one place to another along a conducting wire.

About a hundred and fifty years after Strada wrote—namely, in 1774—a successful attempt was made by Lesage, a philosopher of Geneva, to establish a real and physical connection between two distant places by means of frictional electricity, the only form in which electricity was at that time known.

The engraving shows the construction of his apparatus, and the manner in which it operated, though, of course, on a small scale, as the distance is only from one room to another. The rope which forms the medium of communication between the two stations is formed of wire. It consists of twenty-four strands, one for each letter of the alphabet. These strands are insulated from each other in the rope, by being each covered with some non-conducting substance, and the ends are separated at each station, and made to diverge over a table of glass or other non-conductor; and finally, the extremity of each strand terminates at each station in a pith-ball electrometer, which hangs over the letter that that strand represents.

On the right, in the foreground, is seen an electric machine for producing frictional electricity.

The arrangement of the separated ends of the wires at the farther station, and their connection with the pith balls and the letters, are the same as at the station in the foreground.

The operator at the hither end of the line has now only to make a connection by means of a discharging rod between the conductor of the electric machine and any one of the wires. The wire, being insulated, becomes electrified through its whole length, and indicates its condition by means of the pith ball at the farther end, and so points out to the observer there the letter that is intended. In this way, of course, by designating different letters in succession, any desired communication could be made.

This method was founded on correct principles, and for certain very short distances it was practically successful. It could, however, never be any thing more than a philosophical toy, on account of the difficulty of transmitting the electrical influence, *in that form*, to any considerable distance. Those characteristics of frictional electricity which are ascribed to what is termed a condition of *great intensity*—whatever that may mean—make it very difficult to insulate a conductor of any great length or extent of surface, employed to contain or transmit it. Lesage's apparatus could not be made to operate except for very short distances—too short altogether to make it of any practical use. It was not until after the discovery of a form of electricity of extremely *low* intensity—so low as to allow of the easy insulation of thousands of miles of wire—and the discovery of the relations of electricity and magnetism, by which two magnets thousands of miles apart can be put into communication with each other, and made to act synchronously, that the invention of the electric telegraph, as now constructed, became possible. The invention of Lesage, however, taken in connection with the fantastic idea of Strada, may be considered as in some sense the embryo and prototype of the modern marvel.

The histories of the inventors of the telegraph are more or less familiar to many readers, and without pausing to recount them here, let us pass to some account of the features of the system now in use.

If one should cut the wire as it hangs between two telegraph poles, and take one end in each hand, he would feel a slight succession of shocks, as the impulses of electric force by means of which the signals are made would course through his arms from one hand to the other. What this subtle force *is*, no one knows. Some of its properties are now understood, but the thing itself eludes our cognizance. The only difference between those least acquainted with the subject and the professional electricians who devote their lives to the study of it is that with the latter the mystery, without being less, lies deeper. In respect to the operations of electricity, as is true, in fact, in respect to all the operations of nature, though scientific men may succeed in tracing the steps of the process a little way, they are sure to come to the region of inscrutable mystery at last. As one has well said, the further the radius of investigation is extended, the greater appears the circumference of the unknown beyond.

There are certain general principles, however, on which the phenomena of the electric telegraph depend, which are also exemplified in a great many of the most important processes going on around us in nature and in art, which it affords great pleasure to all who love knowledge for its own sake to understand, though it must be confessed that the understanding of them is not of any practical importance in enabling us to transact our business at a telegraph office.

One of the most important and most fundamental of these principles is this, namely, that whatever force is expended in separating from each other two substances that are found naturally united, is given out again when the substances once more come together. Thus, if a weight is raised for a certain distance above the earth, a certain force being expended in the raising of it, precisely that amount of force, neither more nor less, will be exerted by the fall of the weight back to its original position.

And in the same manner, whatever force has been expended in separating the particles of two substances which are united by a strong chemical affinity is precisely restored when they are allowed to come together again. The most common case of such separation and reunion consists in the abstraction of oxygen—which is the great substance in nature that has the strongest affinity for almost all other substances—and the return of the oxygen to its original combinations again. In this return it gives out, of course, the force which was expended in the separating of it. This force usually reappears in the form of *heat*, and in cases in which the action is very intense—that is, in which the force is made to reappear in a very rapid manner—heat and light combined, thus producing the phenomenon which we call combustion.

Under some conditions, however, the restored force appears in the form of *electricity*. Of the inner and intrinsic nature of this form of energy we know very little. Still a great deal, comparatively, is known of the effects which it is capable of producing, and the cause producing them was formerly supposed to be a distinct and specific substance. When, however, it was at length found that the development of the electric action was always accompanied by the expenditure of some form of force, and that the force in which it thus originated disappeared just in proportion as the electric agency was developed, and, moreover, as the electric agency could be made to produce again the forms of force in which it originated, disappearing itself as the others reappeared, the conclusion was apparently inevitable that the effects are produced not by the *transfer of a substance*, but by the agency of some one of the numerous forms which the mysterious principle of force is continually assuming.

That which passes along the wires, therefore, is simply *an impulse of force.*

This force must not, however, be conceived of as a single force: it exists in two forms or phases, having a very remarkable relation to each other. Many years ago, when electricity was generally supposed to be a separate substance, permeating all ordinary objects, there were supposed to be two kinds, which were described as two fluids. Any object electrically excited was said to be charged with an excess of the one fluid or the other, sometimes the "vitreous fluid," sometimes the "resinous fluid." And a discharge or current of electricity was understood to be the disturbance caused by these two fluids in coming together again and neutralizing each other. The ordinary condition of objects not electrically excited was explained by regarding them as charged with both fluids in equal degree. Franklin sought to explain the same phenomena by the simple theory that there was only one fluid, that vitreous electricity was an excess of this one fluid over the natural amount, and that a deficiency was resinous electricity. He accordingly called the one "positive" and the other "negative;" and he described a current or discharge as the act of the excess contained in an overcharged object passing to an object which was undercharged, thus restoring the natural or ordinary equilibrium in both.

The invention of the galvanic battery was developed during periods when these theories were in vogue, and the terms "current," "positive electricity," and "negative electricity" were accordingly adopted in the language used to describe the action of the battery, and still continue in use to some extent, and although literally inappropriate, we shall have constant need to employ them in the following pages.

In a recent article in the *Journal of the Telegraph*, Mr. Prescott, the electrician, describing the propagation of electricity, compares it to heat, in the following language: "Toward the end of the year 1859, M. Gaugain, an able electrician, who had for some time occupied himself in verifying the laws of Ohm in regard to the transmission of electricity over bad conductors, sought to solve the causes of this disaccord [alluding to disaccord of scientists who had not accepted Ohm's laws], and at last found the key to the enigma. He became convinced that electricity, instead of being propagated as a wave, or in a manner analogous to that of sound or light, was, on the contrary, transmitted, as stated by Ohm, in the manner of heat in a metallic bar, which is hot at one end and cold at the other. In this case the heat and the cold communicate from place to place gradually from the two extremities of the bar, and in proportion as this double movement of heat and cold is propagated toward the middle of the bar the parts first heated and cooled acquire and lose a quantity of heat, until, the two calorific movements having met each other, the different points of the bar lose on one side as much heat as they gain on the other. Then the calorific equilibrium is established, and the distribution of heat upon all parts of the bar remains the same. This is what is called the permanent calorific state. But before a metallic bar arrives at this state it requires more or less time, according to its calorific conductivity, and this time, during which every point of the heated body unceasingly changes in temperature, constitutes a variable period, which, if the assimilation of the propagation of heat with that of electricity is true, ought to exist in the first moments of the transmission of a current; for, in this hypothesis, an electric current is only the result of the equilibrium which tends to establish itself from one extremity of the circuit to the other, between two different electric states constituted by the action of the battery, and representing, consequently, the two different temperatures of the heated bar."

This comparison will afford better elements for forming a conception of the electric force than the notion of fluids and currents.

The battery is the source of power for the telegraph, and in this respect it may be compared to the boiler in the steam-engine.

It is now believed that all chemical action, however slight, gives rise to a development of electricity; and a battery is an arrangement of metals and acids combined in such a form as to cause a powerful chemical action. The electric result is greatest when two metals are used one of which is strongly and the other slightly acted on. If two such pieces of metal are connected by a conducting wire, positive electricity moves or acts from the former metal through the acid to the latter metal, leaving the negative force in preponderance in the former metal. The positive electricity does not, however, remain quiescent in the second metal; it passes out by the conducting wire, and returns to the place of its origin in the first metal, where it is neutralized as fast as it arrives by the negative electricity there accumulated.

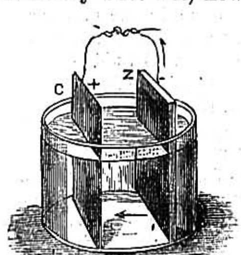


FIG. 1.—THE VOLTAIC PAIR.

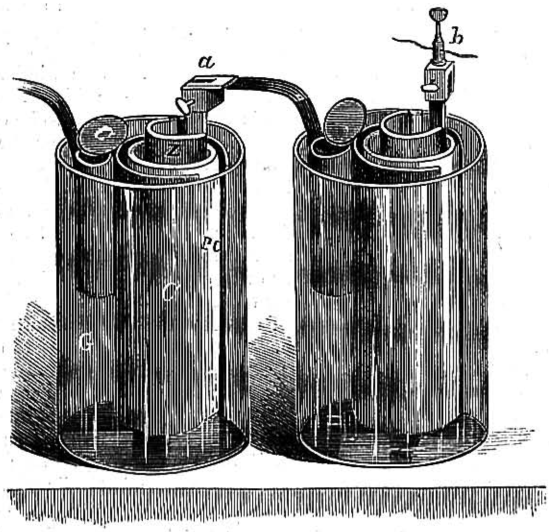


FIG. 2.—THE DANIELL BATTERY.

G is the glass or earthen jar, which is nearly filled with a saturated solution of the crystals of blue vitriol (sulphate of copper). If a bit of white paper is dipped beneath the surface of the liquid, the color of the liquid is very apparent, for it makes the paper look blue. C is a plate of copper, bent into a cylindrical form so as to fit loosely within the outer vessel. It has a pocket or chamber of copper, fastened to the upper part, with a perforated bottom, into which fresh crystals of vitriol are thrown from time to time to renew the strength of the solution. These crystals might as well be thrown to the bottom of the jar, were it not that by being dissolved near the surface they keep the solution of nearly equal strength throughout, instead of making it much the strongest at the bottom. P C is the porous cup, about two inches in diameter, which stands within the copper cylinder. It is nearly filled with soft water, or salt-water, or sometimes with a solution of sulphate of zinc. Z is the plate or block of zinc. This is made in various forms—a hollow cylinder being more powerful, on account of its greater surface, but more difficult to clean, than a plain strip. A binding screw (*b*) at the top of the zinc plate receives the negative pole wire. A strip of copper fastened to the copper cylinder, and provided with a binding screw (*a*), receives the positive pole wire, or serves to make connection between the copper of one "element" (as each jar or each pair of metals is called) and the zinc of another, when it is desired to unite several jars, or elements, to gain additional force.

This arrangement is shown in Fig. 1.

Here, in a glass vessel, are inserted, on the right hand a plate of zinc, and on the left a plate of copper (lettered respectively Z and C). The conducting wires, or pole wires, are brought around, and touch each other above. If, now, the vessel is filled with diluted sulphuric acid, the liquid begins to corrode the zinc—it burns it, so to speak—and gradually dissolves away the surface. This chemical action consists largely of the oxygen of the water leaving the particles of hydrogen with which it was united, and combining with the zinc. The force that is evolved in this change, as above explained, is in the form of positive and negative electricity. These, separating from each other, pass out of the battery, one going through the fluid to the copper and thence to its wire, and the other in the opposite direction, and they meet and seek to recover their union and equilibrium in those parts of the circuit where no chemical change is taking place.

Meanwhile the process of evolving more positive electricity upon the copper and more negative upon the zinc goes on, so that a continuous current is said to flow from the battery. The point of contact where the positive electricity leaves the battery for the conductor is termed the positive pole, the other the negative. The course of the currents is indicated in the figure by arrows.

FIG. 3.—REPLENISHING THE BATTERY.

The force generated by a battery of so simple construction as this soon becomes weak from the decomposition of the liquid and other causes. To remedy this defect several batteries have been devised which are constant in their force. These are usually designated by the names of their inventors. Daniell's and Grove's are the two forms perhaps most generally used in this country.

The Daniell battery is the one commonly used in small offices for the local purposes which will afterward be explained.

In Grove's battery, which has long been in use at the great central offices for the principal supply of the main lines, the outer vessel is filled with diluted sulphuric acid, and in this the zinc plate is immersed. The porous vessel placed within the zinc plate is then filled with strong nitric acid, and in this a plate of platinum is immersed. The platinum here takes the place of the copper used in the other form of battery.

The object of the porous cup in both these batteries is simply to separate the two liquids without intercepting either the chemical action between their constituent elements or the electric current. A very beau-

FIG. 4.—A CELL, OR PAIR, IN GROVE'S BATTERY.

A, glass vessel partially filled with dilute sulphuric acid; Z, cylinder of zinc; V, vessel of porous pipe-clay, containing nitric acid; P, plate of platinum, bent in the form of an S, and fixed to a cover, *c*, which rests on the porous vessel; *a*, binding screw.

FIG. 5.—THE CALLAUD BATTERY.

C, the copper plate, with crystals of sulphate of copper lying on it; B, solution of sulphate of copper; D, solution of sulphate of zinc; Z, zinc suspended in the latter solution; *a*, positive pole wire, connected with copper plate; *b*, negative pole wire, connected with zinc.

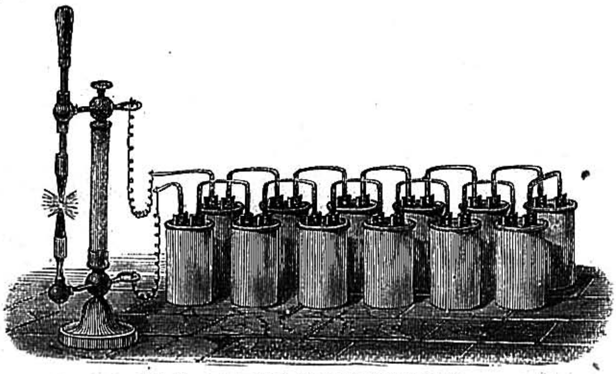


FIG. 6.—A BATTERY OF TWELVE ELEMENTS.

tiful improvement is presented in the Calland battery, in which the chemical solutions are placed in a single jar. One solution being saturated, and heavier than the other, sinks to the bottom, where the copper plate lies. The lighter solution, diluted, fills the upper part of the glass, and in this the zinc is suspended.

To gain the intensity of force necessary for main lines, a number of these cups or cells with their respective pairs of metals are united by connecting one pole of each to a pole of its next neighbor. Each cell or pair is termed an "element." For instance, a battery of fifty elements means one composed of so many jars thus united.*

Many persons have noticed that a humming sound—a low musical note—sometimes proceeds from the telegraph wires as they hang stretched upon the poles, which is caused by the wind playing upon them as upon the strings of an Æolian harp. Even when the wind is light, the sound can often be heard by applying the ear closely against the pole. Some persons have erroneously attributed this sound to the electric current. That it really proceeds from a vibration of the wires, strung as they are, may be proved, when there is no wind, by punching the pole with the end of a cane or umbrella so as to jar it slightly, and the same sound may then be heard given forth by the trembling wires.

A very strong wind sometimes, by tightening the wire, stops its vibration. The power of the wires to carry their own resonant sound to a distance enables an operator at an office sometimes to hear men working upon the wire miles distant. It is related that at the time of the completion of the telegraphic line to the Catskill Mountain House strong winds prevailed for a few days, causing a peculiarly loud humming noise of the wires. At length the wind died away, and the telegraphic Æolian harp was mute. Several days thereafter the proprietor of the Mountain House, on his way to Catskill, reined up in front of the Half-way House to water his horses, when he was accosted by the Kiskatom landlord: "How's things on the mountain?" "Lively," was the response. "Ain't doin' much telegraphin', are you?" "Oh yes; the line is quite well patronized." "Well, I didn't think so; *I ain't heerd a dispatch go up in three or four days.*"

In truth, the mysterious form of force which we call a current of electricity passes along the wires of the telegraph both silent and unseen. The clicking that is heard in the operation of the telegraph instruments is not the voice of electricity. Just as the force of gravitation pulls in perfect silence upon the weights and pendulum of a clock, and it is only by the resistance which the escapement incessantly interposes to the revolution of the toothed wheels that the tick of the clock is produced, so the electric current, though it sets in motion the tapping armature, is itself silent.

This noiseless and invisible force acts with inconceivable rapidity. The celerity of its passage varies somewhat with the appropriateness of the conductor which forms its path; but the movement is so

* Those who wish to pursue this subject will note a distinction here, which only professed electricians fully understand, and, indeed, on which the best authorities seem not to be fully agreed—the distinction between intensity or degree of tension of electricity, and the quantity of electricity. The nature of the distinction may be illustrated thus: If there were a ball of iron as large as this earth, and a common cannon-ball, both heated red-hot, the *degree* of heat in both would be the same, but the *quantity* of heat in the great globe would be vastly larger than that in the cannon-ball. The thermometer measures intensity or degrees of heat, though it does not measure the quantity or amount. There is a somewhat similar distinction in respect to electricity. The earth is charged with electricity to a certain degree or tension. If a cannon-ball lies on the ground in contact with the earth, it will be charged with electricity in the same intensity. But the quantity contained in the earth is vastly greater than that in the cannon-ball.

Increasing the size of a cell or pair, or—what produces the same effect—connecting all the zincs of several elements together, and all the coppers together, increases the quantity of electricity evolved without increasing its tension. Increasing the tension is accomplished by connecting the zinc of each element with the copper of its next neighbor.

Frictional electricity, or the free electricity of the thunder-storm, is found to be the same as magnetic electricity, except that it is of a very high degree of tension, and can not be produced in sufficient quantities, nor can the lines be sufficiently insulated, to make it available for telegraphs, as Lesage attempted to do. Its tension being very high, the degree of resistance which effectually insulates galvanic electricity is not a barrier for it, and it escapes from the wires.

nearly instantaneous that practically the only delay, even on the longest lines, is in the intervals of time occupied by the operator at one end in setting the successive pulses of the current in motion, and by the operator at the other in observing almost at the same instant their passage.

The force which passes from a battery over the wires, though it moves with such marvelous rapidity, and though, so far as we can picture it to our imagination, it consists simply of some vibratory or quivering motion among the particles of the wire, is really much greater in amount than one would be inclined to suppose. The particles of oxygen and hydrogen, for example, as united in water, are held together by an immensely powerful attraction, and a very great force is necessary to separate them. This force, or *energy*, as it is technically called, is all given back when the separating particles come together again in the process of combustion, by which the water is re-formed. It is the same with the particles of oxygen and those of zinc. A great force, though it is a force acting through very minute distances, is expended in separating the oxygen from the zinc in the ore, to form the metallic zinc used in the batteries. All this force is given back when the oxygen is restored, and under the conditions in which the restoration takes place in these batteries the restored force reappears in the form of electricity. It is said that the annual cost of the maintenance of the batteries used by the Western Union Telegraph Company—that is, for the supplying the force which is expended in the electrical pulsations which pass over their wires—is over $125,000.

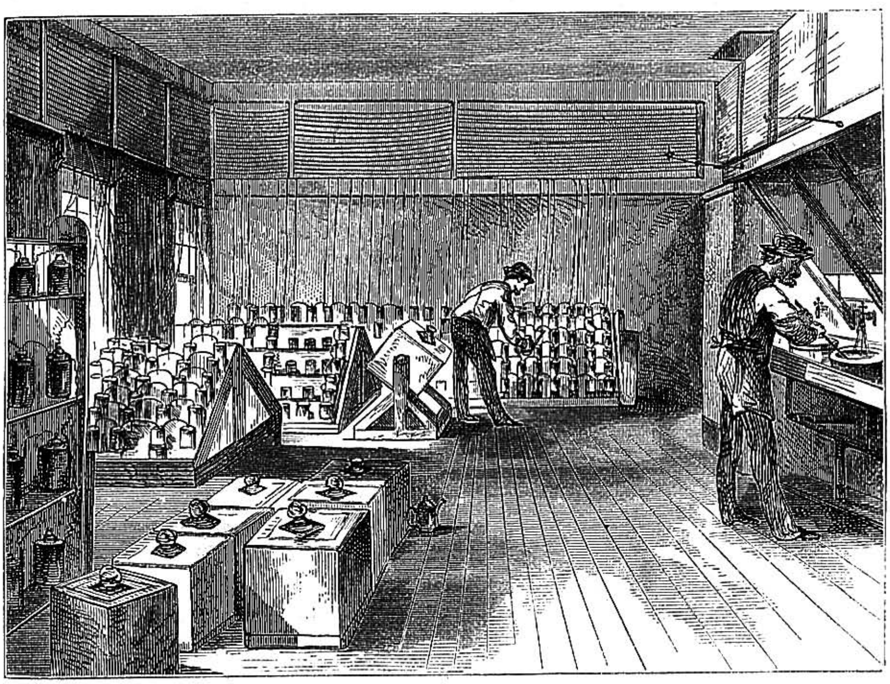
When this current and the means of producing it became known to the world, many minds busied themselves with the thought of sending messages to a distance by means of extending the wire circuit, and a great variety of devices were tried for this purpose.

One inventor arranged a key-board with ten keys, one for each finger, and with ten wires, one communicating with each key. The operator who was to receive the message sat with fingers and thumbs upon the keys, and received a little shock in one after another of his digits, each of which he interpreted to mean a certain letter, according to a prearranged table.

Another proposed to resort to the light and heat which are developed when the electric current is made to pass from point to point of two pencils of charcoal, in connection with the opposite poles of the battery.

To form an intelligent idea of the principle of the telegraphs now in use it is necessary to advert to a very peculiar property of electricity, which constitutes, in fact, one of the most curious and singular facts in nature.

If a current of electricity is passed along a wire near to a compass or magnetic nee-



VIEW OF THE BATTERY OF THE WESTERN UNION TELEGRAPH OFFICE IN NEW YORK.

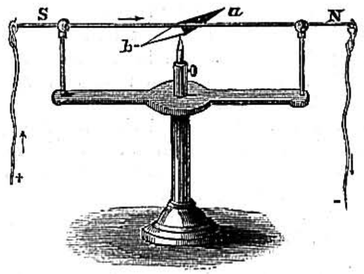


FIG. 7.—THE DEFLECTION OF THE NEEDLE.

dle, without however touching it, it will cause the needle to turn and take a position at right angles to the wire, or to tend toward such a position in a degree proportioned to the strength of the current. If the current is passed in a similar manner across a bar of soft iron, without touching it, it causes the iron to be a magnet; that is to say, the proximity of the current will make iron that is not a magnet become one, and will make iron that is a magnet turn at right angles to the current. When the current ceases the needle returns to its ordinary position, the bar ceases to be a magnet. Singularly enough, if the wire is suspended so as freely to turn, and a magnet is laid beneath it, the wire will turn so as to cross the direction of the magnet.

This power of the current to make a temporary magnet of every piece of soft iron within its influence, and to turn magnetic needles at right angles to itself, is the property resorted to, under one form or the other, in nearly all the telegraphs now in use. It is a mysterious sympathy, which has afforded to scientific observers a great many curious and beautiful experiments.

If a double current is carried past the needle or bar of iron, double the effect is produced. To enhance the power of the current, therefore, a coil of wire passing around the bar or needle is commonly employed. Thus Fig. 9 represents a rod of soft iron inserted within a spiral coil of a conducting wire. The effect of the coil is to make the path of the wire lie across the rod for a long distance, and the magnetism of the bar is very perceptible. If the spiral is right-handed—that is, if it runs like the thread of an ordinary screw—the north pole of the bar will be at the end at which the positive current emerges, the south pole at the end at which it enters. Whenever the current ceases the bar loses its magnetism. If both spirals were wound on the same bar, and equal currents sent through them, the influence of one upon the bar would be counteracted by that of the other, and it would not become a magnet.

The attractive power of both poles can be used at once, if the rod and coil be bent into the form of a horseshoe, and can be shown by its lifting iron pins from a tray, or holding even a heavy weight.

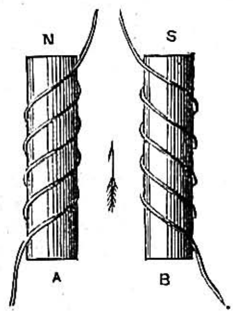


FIG. 9.—THE SPIRALS.

A, a right-handed spiral; B, a left-handed spiral; N, north pole; S, south pole.

But if in the construction of such a magnet the wire is wound in the wrong direction on half the bar, the two parts neutralize each other. Which end of the iron shall become the north pole depends on whether the wire is wound from right to left or from left to right. If even the same wire is wound both ways, the one influence counteracts the other. It must be made as if wound on a straight shaft, and afterward bent. The effect is not produced if the bare wire is wound on the bar, returning on itself, like thread on a spool; the wire is therefore always covered with silk or some other insulator, so that each turn is separated from the others, and the current is compelled to follow the entire length of the wire.

These two spools, covered and painted black, and in form rudely resembling the barrels of an opera-glass, may be recognized in the instruments in any telegraph office.

If the line is not too long, and the battery is

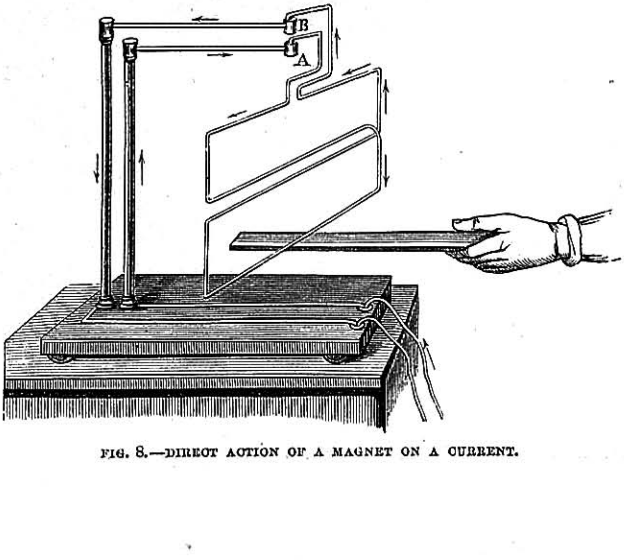


FIG. 8.—DIRECT ACTION OF A MAGNET ON A CURRENT.

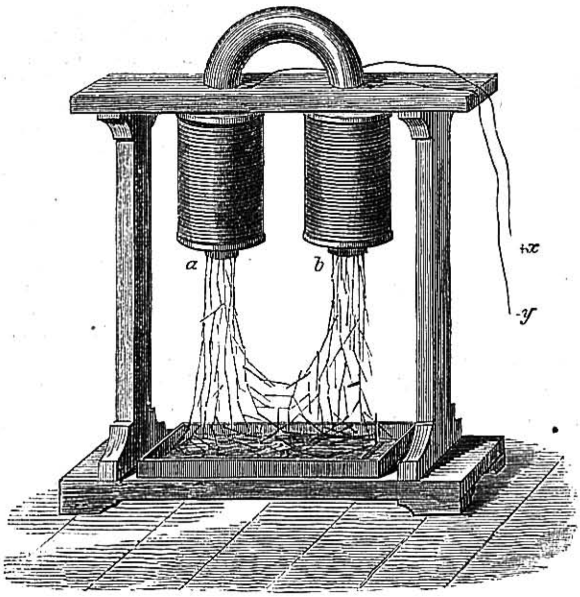


FIG. 10.—THE ELECTRO-MAGNET.

sufficiently powerful, the magnet may be made to attract an armature, or bar of iron suspended near it, and the armature in moving may sound a bell. Fig. 12 represents an alarm-bell of this kind, which has been much used in Europe. The wire may be traced entering the apparatus at A. Being fastened there with a thumb-screw, it is in contact with the wire coiled around the magnet at B. The other end of the wire coil is connected with a metallic rod in the bottom of the case, to which the spring that supports the armature is affixed. The other wire of the line enters from the other side, and is fastened to a thumb-screw from which rises a slender tongue of metal against the armature. When the current is established through wire, coil, armature, spring, and wire again, the magnet attracts the armature, and the hammer, G, strikes the bell, H. But the armature, by the act of leaving the spring, F, breaks the circuit, for the current can no longer pass from the armature to the line wire. The horseshoe bar therefore ceases to act as a magnet, and the armature falls back to its place. The instant it touches the spring, F, the current is again established, the magnet acts, the bell strikes, and so again, thus ringing like an alarm-clock. As seen in Fig. 15, the armature, instead of ringing a bell, may be made to move a pencil or a pointed stylus, and make a mark upon a moving strip of paper.

In the dial telegraph the armature moves a lever which drives a rachet-wheel, and this carries an index, or pointer, by which words are spelled out on the dial. If we imagine the circumference of the wheel to bear type, so that each letter could in turn be printed, we have a clew to the principle of the little stock telegraph instrument which may be seen at work any day printing off quotations in any broker's office or great hotel in New York.

It has been said above that the current does not actively manifest itself unless the two poles of the battery are connected by a conductor. When this connection is broken, the current ceases to flow, not only at the point where the break is made, but in every other part of the wire at almost the same instant.

Those who have attended an experimental lecture upon electricity may have witnessed, or perhaps participated in, the formation of a ring by those members of the audience who were willing to try a shock. The person at one extreme takes hold of the chain connected with the con-

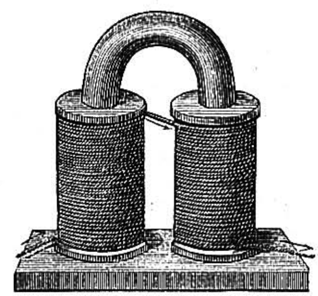


FIG. 11.—THE BOBBINS.

ductor, but no sensation is felt until the one at the other extreme touches the opposite pole of the machine. So far as manifestations in the sensation of the circle show, the

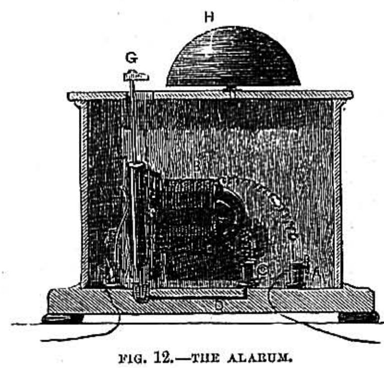


FIG. 12.—THE ALARUM.

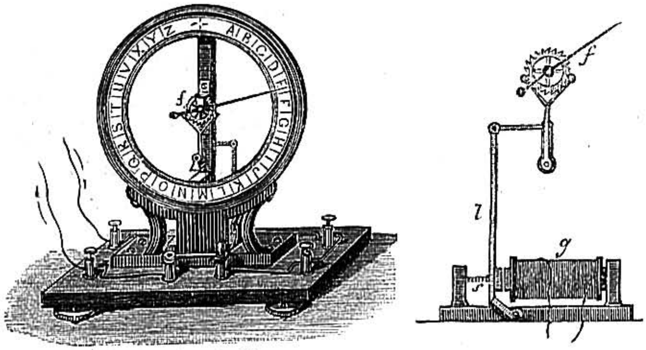


FIG. 13.—THE DIAL TELEGRAPH.
g, The bobbins; *s*, spring to draw back armature; *l*, lever; *f*, index.

electricity seems not to start at all until it can go entirely around. The instant the connection is formed the electricity, so to speak, discovers that the course is clear, and flashes through the whole circuit of outstretched arms and hands.

Electricity, like light, heat, and sound, requires time for its passage through space; yet so rapid is its motion that it was formerly supposed that it could not be timed, but recent experiments have succeeded in doing so. The wires between Cambridge, Massachusetts, and San Francisco were connected several years ago, making a circuit of over 7000 miles, with thirteen repeaters. The time required for the flow of the current was seventy-four-hundredths of a second, or, deducting the time required to open and close the repeaters, about three-tenths of a second, or at the rate of 1,400,000 miles a minute. The rapidity of the motion is shown by the following illustrations:

If a magnetic spark is flashed through gunpowder, it may scatter the kernels of powder without igniting them. If a silvered wheel is made to revolve many thousand times a minute, the spark will show it at rest. If a man be struck by lightning, death appears to follow before sensation has time to reach the brain through the nerves.

The signals, whether by means of the needle or the electro-magnet, are made by a succession of shocks or pulses; and to produce these it is necessary to break the circuit and to close it again many times in succession. Cutting the wires of a telegraph, which we used to hear of when there were fewer lines than now, stops communication. When the ends of the wire are fastened together again, communication is re-established. If no instrument for making the signals is at hand, as is sometimes the case, the signals can be made by taking an end of the wire in each hand, and touching them together again and again. Insulation may be preserved by wearing silk gloves, or using a silk handkerchief.

The genius of Morse showed itself in the simplicity of the means he devised; and it is to their simplicity that they owe their pre-eminence and their almost universal adoption.

The Morse key, or transmitter, which is the name given to the instrument he devised for making and breaking the circuit with speed and accuracy, is simplicity itself; but upon this little lever, capable of but a single motion, may be expressed every word the pen can write or the tongue speak. It will be most readily understood, perhaps, by a drawing of a rude form in which it was at first made.

The reader who has followed these somewhat dry details respecting the battery, the instantaneous current, the electro-magnet signals, and the mode of making the circuit and breaking it again, is prepared to understand the "circuit," and to trace the operation of the telegraph upon it.

It has already been said that a complete circuit must be formed in order to induce the current to move. The earlier telegraph lines were formed by a wire running from one terminus to the other, and then returning to the battery at the starting-point, thus making a complete metallic circuit. It was discovered, however, by some investigators, who were endeavoring to make the track of a railway serve instead of a wire, that the earth itself would act as a conductor for the return current, or, as perhaps it may be more properly conceived, that the earth being a vast reservoir of electricity, the current from the battery will willingly leave the battery by the positive pole, and traverse the conducting wire to a great distance, if it be allowed at last to enter the earth, and if, at the same time, the battery, by having its negative pole also connected

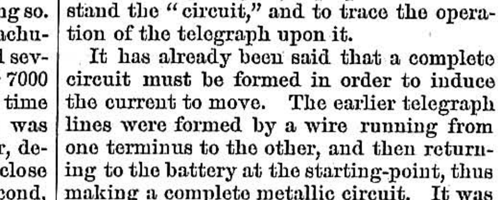


FIG. 14.—THE PRINCIPLE OF THE MORSE KEY.

The wire, *a*, is carried through the table, B, and connects with the little nipple or anvil, A. The table being a non-conductor, the current can not pass through it. When the button, C, at the end of the spring or lever, D, is pressed down so as to touch the anvil, the current instantly passes through, and from the metallic block, E, passes to the wire, *b*.

with the earth, be allowed to draw an equal amount from that natural reservoir, and thus in effect maintain the circuit. Since this discovery a single wire serves for a complete line, provided adequate connection with the moist soil of the earth be maintained at each extremity. In cities and towns where there are gas and water pipes, it is sufficient to carry the extremity of the wire to these pipes. In some offices it is twisted around the gas bracket in the wall of the room. In places where there are no such pipes a sheet of metal is fastened to the end of the wire, and buried in some damp cellar.

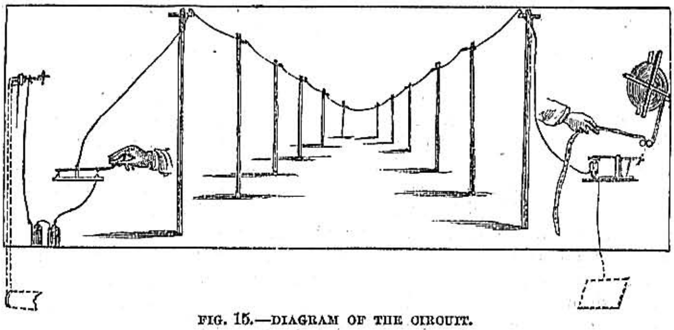


FIG. 15.—DIAGRAM OF THE CIRCUIT.

This is called making a "ground."

In Fig. 15 we have a diagram illustrating a circuit. In the office or terminus on the left are two jars upon the floor, which may represent the battery. From the positive pole the wire is carried beneath the table, there to connect with the anvil of the key. From the axis of the key the main wire or line wire runs, suspended in the air by being tied to glass insulators upon the poles. At the other terminus is an electro-magnet, placed upright, with an armature over it. The armature is fastened to one arm of a lever. The other arm is provided with a pencil or style, above which is a slip or ribbon of paper. The paper may be pulled by hand, as in the diagram, but for greater steadiness and convenience clock-work is employed. The armature hangs above the magnet, and is kept up by a delicate spring. To make a circuit, so as to enable the current to return to the battery, as the saying is, the wire is connected at each end with the earth.

This arrangement constitutes a circuit; but the current will not act in it while it is broken at the key, as represented in the diagram. The electricity is not powerful enough to leap from the anvil to the hammer under the lever of the key. In this position of the key the circuit is said to be open. The instant the hand of the operator presses down the key the circuit is closed, the whole line is excited by the electric force, the bar becomes an active magnet, and draws down the armature, which clicks, as up goes the pencil or style against the moving paper. If the operator at the key holds the key down a short time, a dash is made on the paper. If he releases it as soon as it is down, a dot is made.

Some one may ask, how is the answer sent back upon the same wire? To do this it is only necessary to have a key inserted in the wire at the right-hand office, and a register, or sounder, as the electro-magnet is called, in the other office.

The railroad traveler who looks out of the car window at some rural station often sees that the window of the telegraph office is the principal object of interest. A little group of loungers are gathered about the window-sill looking in. If he should enter the room, he might see the operator at the key, holding a dispatch in her hand, and with the key making the strokes which are necessary for its transmission. The line wire connecting with the key passes up the window-frame, and through the wall, to the telegraph poles beyond. Next to the key, upon the broad shelf which serves as a table, is the switch, or cut-off, that enables the operator at pleasure to connect or disconnect the wires that are concealed beneath the table. The largest instrument in the centre is the register, and a heavy weight hung from it drives the rollers which draw the slip of paper from the reel above to be marked by the styles. Beyond the register may be seen the sounder, or relay, connected beneath the table with a ground wire running through the floor, and with the two wires of the local battery. Upon the wall near the operator are the hooks on which the written message papers are filed after the messages have been sent.

If we imagine the message to be carried by a current flowing from the battery at one end to the magnet at the other end of the line, it might seem that a battery at the other end also would be essential to enable a reply to be sent back. But, as has been explained, we are to conceive of the current rather as an excitement of force taking place throughout the whole line if at all, ceasing every where if the line is broken at any point whatever. Bearing this in mind, it will be seen that half a dozen magnets might be inserted at as many different places, and the key might be put in any where, and signals made upon it would be responded to by all the magnets at the same time.

In fact, to conceive an actual telegraphic circuit, the reader may suppose that a line of wire thirty or forty miles long runs through half a dozen towns, passing through ten or twelve offices. In every office there is a key and an electro-magnet. A very simple and ingenious attachment to the keys prevents the key of each office from interrupting the circuit for the other offices, except when it is in use for making signals.

In every office means are provided for cutting off the magnets from connection with the line, so that messages may go through unobserved, but in ordinary practice messages sent from one point to another on the same circuit are heard at intermediate points. A visitor was recently in the office at Hallowell, Maine, and while conversing with the operator, who was at leisure, the sounds of the instrument went on in this way as usual. Soon the operator began to laugh. "What are you laughing at?" inquired the visitor, who saw no occasion for laughter in their conversation. "Oh!" replied the operator, "Bath is saying such droll things to Augusta."

Sometimes all the operators on a large circuit assemble at their posts and hold a conference, in which whoever speaks is heard simultaneously in all the offices. The press reports are usually delivered in this way. All the principal offices in the State of New York are thus supplied with the reports by one writing.

From various causes, some of which will be hereafter mentioned, the force of the current diminishes as the line is extended and the number of instruments is increased; and hence a current which would be powerful enough to traverse a short private line on which there were no intermediate stations, and to move the register at the terminus, may not be powerful enough to serve a circuit upon long lines employed in the service of the public. To increase the force of the current sufficiently is expensive, and practically inconvenient. Resort is had to an ingenious device called the repeater. The name "relay," which was used for the device first adopted for this purpose, suggests an illustration which will enable the reader to form an idea of it. The Persian and Assyrian monarchs, and some European kings of the Middle Ages, had a system of posts for couriers, which were stationed usually at a day's journey from each other. At each post were a courier and horses at all hours ready to start. The courier bearing a dispatch rode all day, and at night he reached a post, where fresh horses were saddled ready for the next stage of the journey, but he himself was exhausted. His force was nearly spent, but he could awaken the courier who was stationed there and deliver the dispatches to him, and he, with fresh strength, instantly took up the journey. In the same way the reader may conceive of the electric current arriving at a station or office so nearly exhausted that it can not go farther with power to deliver intelligible signals, but it still has strength to wake up another battery and set in motion a fresh current, which shall, so to speak, receive and carry forward the message which the exhausted current has just strength to utter.

The means by which this is effected vary with the circumstances, in some cases involving complex apparatus, which seems incomprehensible to any one but a professional electrician, but the main principle which lies at the foundation may be seen in this diagram. The current arrives on the line, say from the west (W), nearly exhausted

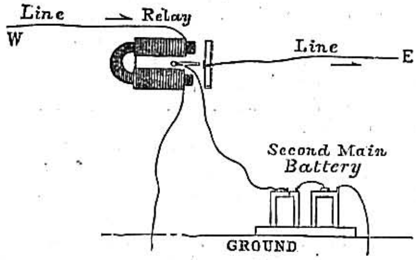


FIG. 16.—PRINCIPLE OF THE REPEATER.

by the resistance or by defects of insulation, etc. It has gone as far as it can carry the power of producing convenient signals. At this point, therefore, the line is cut, and a magnet inserted and connection made with the ground. The magnet is so adjusted that when it draws the armature the latter will touch a metallic point that is fixed between the bobbins. It is then only necessary to connect the further part of the line wire with the armature, and a fresh battery with the metallic point, and whenever the current arriving draws the armature, whether for a dot or a dash, a fresh current of precisely the same length will pass from this battery to the armature, and thence down the line, thus continuing the passage of the message without the intervention of the operator. If there is sufficient power to deflect a magnetic needle in a perceptible degree, this can be made to open and close a circuit by which a fresh powerful current will be set in motion.

It is found that it requires greater force to operate the register by which the message may be recorded on the slip of paper than merely to move the armature and produce a sound which the operator may understand. Hence the same device is used constantly to move the register or sounder.

These, then, are the principal elements of the telegraphic system: an extended insulated wire connected with the earth at both ends, and communicating with a battery which agitates it throughout with electrical excitement; a key by which the continuity on which this excitement depends can be rapidly broken and renewed at pleasure; and a magnet whose armature, by moving under the influence of the alternations of excitement and quiescence, will instantaneously indicate to the observer every opening or closing of the circuit by the key.

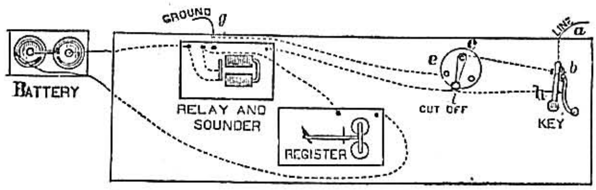


FIG. 17.—DIAGRAM OF THE TABLE OF A TERMINAL STATION.

The main line arrives on the right and enters through the wall at *a*, and reaches the key through its screw from beneath the table at *b*. From the same point a wire is carried beneath the table to the cut-off or switch at *c*. By moving the arm of the cut-off, *d*, so as to bring it in contact with the head of the screw on its left, at *e*, connection is made with the continuation of this wire, *g*, to the ground. To make this connection is called putting on a ground. If the current can go this way, it will not undertake to pass through the instruments. In the position of the cut-off indicated in the diagram the connection is broken, and the current is compelled to pass from the key at *h* to and through the relay before it can reach the ground. The motions of the armature of the relay bring the current of the local battery to operate on the register, if desired, so as to record the message.

When we attempt to extend our conception to a congeries of circuits, ramifying in every direction like the fibres of the nervous system in the human body, and constituting a net-work which embraces within its reach every important point in nearly three millions of square miles, we may form some idea of the vastness and complexity of this delicate, sensitive, and all-pervading organization.

The immense net-work of wires which is embroidered over the surface of the United States contains about seven thousand offices (including branch offices in cities), and probably about an equal number of relays.

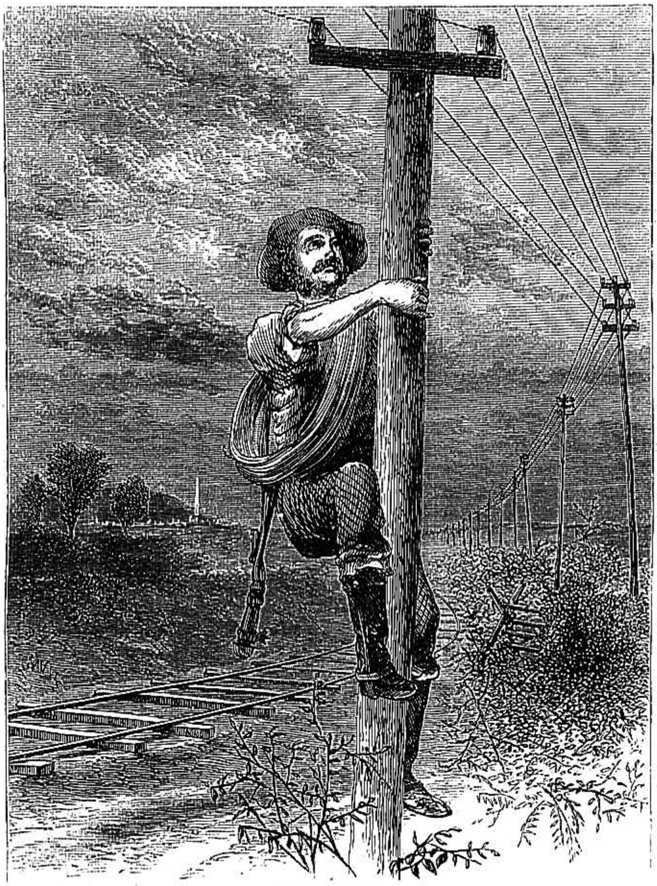
The first time a visitor enters the operators' room in a great central office the scene is a labyrinth of perplexity and confusion to him. A hundred keys and sounders are clicking all at once, making a noise like a diminutive cotton-mill. The floor is filled with ranges of tables, at which the operators are seated, separated from each other by glass screens. Against one wall is the switch-board, the most conspicuous object in the room. Without any actual resemblance, it recalls to the imagination of many visitors the thought of a great organ, its ranges of slender wires behind the screen suggesting the trackers and pipes, and the innumerable switches representing the keys and stops. Boys are passing to and fro with papers, and messages are sending and receiving from almost every table in the room. But though this may be to the visitor a scene of intricate entanglement, to the mind of the manager, who stands at his side, every instrument and every wire in this maze is clear in itself and in its connections. The expressive description given by a railroad superintendent of his own business is not inappropriate. "When we first take a man on," said he, "every thing is confusion to him, except the one thing he has to do as fireman or brakeman. But when he has served a good time every thing comes out clear to him, and he sees it all different. In fact, *his mind is all made over;* so that, in all the dépôt grounds, with the scores of switches and sidings and signals, and cars and engines moving, his eye sees every thing in its connection, and takes in the whole situation at a glance."

The switch-board, to which allusion has been made, is the central ganglion of the whole system. Every current passes through this apparatus. The manager, standing here, can, by inserting a brass wedge in the course of any current, hear what message is passing. He has thus the means of inspecting and listening to all that is going on over all the wires connected with the office.

To form an adequate conception of the intimacy and delicacy of the apparatus upon which this system depends would require a great degree of technical knowledge. In fact, the recent progress both in scientific investigation and in the art of manipulation has opened almost a new world of facts and principles, which are of engrossing interest to those who have the special training to master them, and which to the rest of us eclipse in marvelousness and mystery the fables of fairy-land and the dreams of magicians. To one to whom measuring the quarter of a second with a stop-watch has seemed to be the height of accuracy, the idea of dividing a second into a million parts, and measuring the duration of electric sparks, and finding that they vary from four-millionths to eighty-six-millionths of a second, appears not merely incredible, but inconceivable. Yet this is done.

Some of the curiosities of the telegraph will, however, be intelligible and interesting. Every substance has a certain specific resistance to the passage of electricity, peculiar to itself, just as some substances are good conductors of light, as glass; others poor, as painted or ground glass; others still are opaque or non-conductors, as wood.

A good conductor of electricity is a substance that presents a low degree of resistance to the passage of the current; a good insulator is one that presents a high degree of resistance. At one time many electricians were engaged in endeavors to devise some arrangement by which lightning might be



THE REPAIRER.

ly all that can be learned about electricity depends on the definiteness of the laws of resistance and the accuracy of the means of measuring it; and if all substances were alike in respect to their resistance (if this be conceivable), we should probably know nothing about electricity.

Metals present less resistance than other substances, and it is fortunate that it is so. If glass were the only good conductor, the construction of a telegraph line would be a delicate undertaking. Different metals differ in their conductivity. Silver offers the least resistance, copper is almost equal to it, and it is six times better as a conductor than iron. The wonderful difference between substances in this respect will be seen when it is said that iron presents six times the resistance presented by copper, and that pure water presents 6754 million times as much resistance as copper; and yet water presents far less than some other substances. Telegraph wires can not be carried through water without carefully insulating them with an impervious covering, while the dry air of the atmosphere presents such enormous resistance that the wires can be strung along through it without any protection from it.

The resistance of a solid conductor, such as a wire, is in direct proportion to its length, if it be of the same size throughout, and is in inverse proportion to its size. Four wires an eighth of an inch thick are equal in size to one wire a quarter of an inch thick. Hence four miles of the latter will present no more resistance than one mile of the former. Upon the same principle a very small copper wire is as good a conductor as a large iron one. If one examines the instruments in a telegraph office he will see that the copper wire used in the connections of the apparatus is very small in comparison with the iron wire used for the main line.

prevented from taking possession of the wires, or safely diverted from them when it had done so. Ingenious inventors had produced a variety of elaborate devices for this purpose, when some practical operator hit upon the expedient of winding the main wire once around the gas-pipe over his table before its connection with the instrument. He interposed a slip of paper between the wire and the pipe to keep them from touching each other. The paper presented a sufficient degree of resistance to prevent the escape of the small current used in telegraphing; but if the lightning took to the wires, the current, being very powerful, overcame the resistance of the paper, passed through, and escaped by the gas-pipes, leaving the instruments unharmed. This practical expedient, which in this country has substantially superseded other inventions, is a curious illustration of the simplicity of the most valuable inventions.

The whole system of the telegraph depends on this principle of resistance, and the different degrees which different bodies present. It is, perhaps, not too much to say that near-

The electric current, in passing through a circuit, expends or loses a part of its force in overcoming this resistance. The purer the metal, and the more perfect the joints are, the less is the resistance; but it is always something; and the more the line is extended the greater is the aggregate resistance, and hence the more force lost, until, if the line be too long, and without repeaters, not enough reaches the terminus to make intelligible signals.

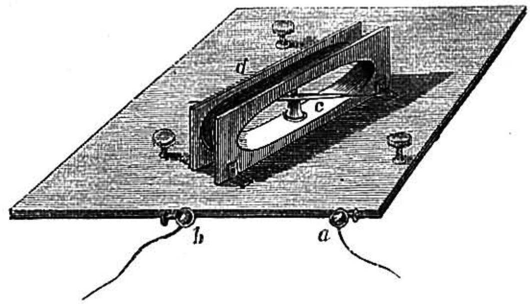


FIG. 19.—GALVANOMETER NEEDLE.

a and *b*, Wires from the battery connecting with the two ends of the coil, *d*; *c*, the needle. The three screws serve to adjust the tablet to a level.

Allusion has already been made to the power of an electric current to deflect a magnetic needle placed near it. This, of course, enables the electrician to detect the existence of a current.

When we ask in what direction the needle will turn, one is amused at the answer. It depends on the direction of the current; and the relation of the two motions is commonly described by a grotesque illustration. If we imagine, say the electricians, that an observer—an imaginary miniature man—is placed in the conducting wire in such a position that the current entering by his feet issues by his head (in other words, that he should swim *with* the current), and then the needle is brought near the wire in front of him—that is, so that his face is toward the needle—it will be found that the north pole of the needle will always turn toward the left hand of the imaginary man.

This singular property of the current affords the electrician the means of ascertaining not only the existence of a current, but also its direction, or its negative or positive quality. And since the degree of the deflection is proportioned to the intensity of the current, the magnetic needle affords a very delicate and sensitive instrument for reading the electric condition of a wire.

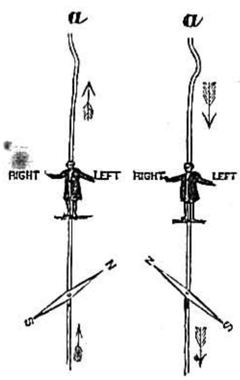


FIG. 18.—DIRECTION OF THE DEFLECTION.

If the wire, instead of being passed in a single strand near the needle, is wound in a coil, and the needle hung within it, the effect is multiplied.

In one form of galvanometer the needle is weighted at one end and hung perpendicularly in the coil. When the current flows around it, it tips to the right or left as the case may be. In diagrams used in books on electricity a ring with a needle hanging perpendicularly within it is used to signify that the diagram represents a circuit with no current in action, while a ring with the needle hanging aslant indicates that the current is in action, and the degree of the inclination of the needle indicates the relative force of the current.

A very curious property of the current must be adverted to here, which is, that if two paths are open to it the current will split or divide into two portions, each taking one of the paths; and if the paths differ in the degree of resistance they offer, the division will be accordingly, and the larger part of the current will take the easier path. This proportion is exact. For instance, if a wire after running a certain distance should be split into two unequal strands, one of which was twice the size of the other, the current would divide in the same proportion precisely, because the resistance of the small strand would be double that of the other. If, however, the smaller strand were cut off to be half the length of the larger, then the division of the current would change, and one-half would take each strand, because by reducing the length of the smaller strand to one-half, its resistance would be reduced to the same amount as that of the larger but longer strand.

This property of the current, together with that to which allusion has been made, of its power to deflect a magnetic needle to a greater or less degree, enables the electrician to ascertain whether a current is flowing in a wire, and if so, in which direction, and also how great its force, and the length of the wire in which it is flowing. To determine the latter, all he has to do is to connect with the wire a coil of a given length, and see how much of the current is diverted by it. Suppose the electrician, for instance, is brought to the wire as it hangs between the poles in the fields between two stations, and is asked if the line is in operation, and which way the message is passing, and how far it is going. It will easily be

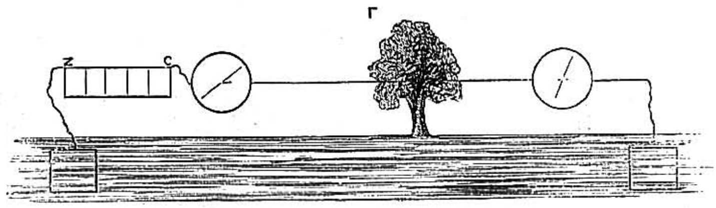


FIG. 20.—PARTIAL EARTH.

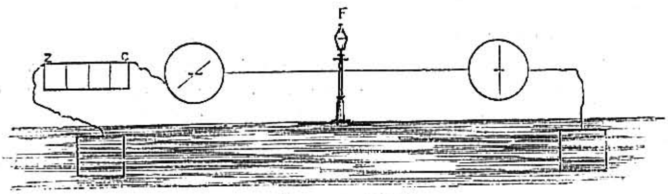


FIG. 21.—DEAD EARTH.

imagined that by cutting the wire and making it pass through the apparatus which contains his magnetic needle and his resistance coils he can tell, by the direction of the deflection of the needle, the course of the current, and by the degree of its deflection the force of it, and by the proportion in which it divides when he invites part of it to pass through his coils—or rather by the length of wire in the coils which he must add in order to divide it equally—how many miles of line wire it has to traverse.

Perhaps a rude illustration will assist some of our readers here. If a house were supplied with water by a long tube and a force-pump at a distance, we shall readily see that the force required to be applied to the pump handle to drive the column of water through the pipe the given distance would be a fixed, definite quantity. Suppose some morning, on applying our hand at the pump, we found that much less force was required, we should infer at once that something had happened to the pipe; probably a break had occurred, by which the water escaped nearer, and therefore more easily. If we had a coil of hose of the same size as the pipe, and which therefore we may suppose would offer the same resistance, and found that the force required to work the pump when connected with the aqueduct was just the same as that required to force water through thirty feet of hose, we might conjecture that the pipe had broken under-ground about thirty feet from the pump, and might begin to dig accordingly.

The measurements made with the apparatus of the electrician are so delicate and exact that an operator, interrupted by a fault in the line, can, without leaving the office, detect within half a mile the place of a leak or defect of insulation a hundred miles away, and at ordinary distances can determine it within a few hundred feet. If a defect occurs any where within the city of New York, for instance, the electrician in the central office can ascertain its location within half a block.

Many curious stories are told by electricians of the incidents that occur in testing for faults. In one case a California miner seeing a broken wire on the line near where he was at work, and knowing nothing of the nature of a conductor, benevolently mended the gap with a piece of blasting fuse of about the same size and color as the wire. Of course this interposed a complete resistance to the current. Repairers were sent out, who reported the line intact at the place indicated; and only a careful examination from pole to pole along the line detected the cause of the difficulty.

In another case an earth current made its appearance on the line between Boston and Salem every night. The electricians dispatched the repairers, who reported that every inch of the line was in good order, and so it proved during the daytime. But at night there was always trouble. Some of the operators began to suspect the intervention of spirits. It was at last found that where the line passed by a switch at a railway station the tall iron switch-rod was pushed against it every night at seven o'clock by the switchman who moved the switch for the evening train.

If a large leak should be made in a gas-main under the street, midway between the company's reservoir and the house where the gas was to be consumed, the effects of this unseen leak would be perceived at each end of the pipe, but in different ways. At the gas-works it would be found that the pipe took an unusually strong current; the resistance to the flow of gas in the pipe would be diminished—in other words, the leak would facilitate the escape of the gas—and hence the degree of pressure which was previously necessary to force the gas through the pipe in a sufficient quantity for the consumer would now drive a much larger quantity. At the other end of the pipe, however, the consumer would find his supply diminished, and if the leak were considerable he might no longer receive enough to give a flame.

These homely illustrations may suggest to the reader the basis of a rude conception of the means by which electricians test for faults. But in the case of electricity the subject dealt with is so delicate in its nature, and the conditions under which it is treated are prepared with such minute exactness and precision, that the computations of distance are expressed in algebraic formulas, and the results attained are often marvelous in their accuracy.

Watching an electrician measuring the resistance of a wire or the force of a current, one might imagine him a chemist weighing some invisible atoms in the most delicate of balances. Before him under a glass case is the slender needle of the galvanometer, and concealed around its base are the two wires through which the divided current is to flow, its parts taking opposite directions around the needle, so that if the current is precisely equally divided between the two wires, the influence of one upon the needle will exactly counteract that of the other, while the slightest excess of one over the other will be instantly shown by a deviation of the needle to the one side or the other, according to the position of the stronger current.

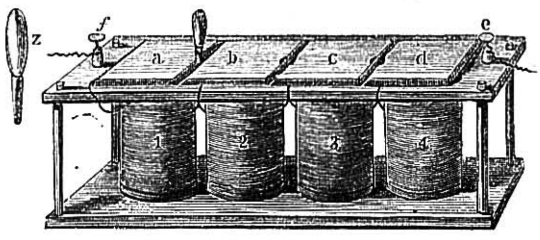


FIG. 22.—RESISTANCE COILS.

The resistance coils (which correspond to the hose in our illustration of the pump) are like the weights of the apothecary. They are arranged under a series of short metallic blocks (*a*, *b*, *c*, *d*, in Fig. 22). If metallic pegs, which are provided for the purpose, are inserted in the holes between these blocks, the current passes directly from *e* to *f* through the connection formed by the blocks and pegs, which constitute so complete a conductor that the resistance is practically nothing. If the peg between two of the blocks be pulled out, the current can not leap the distance between them, and is obliged to pass from the first block through the coil below it to reach the second block. In measuring a resistance, plug after plug is pulled out until the needle is found to rest at zero. The resistances of the various coils that have been brought into the circuit by pulling out plugs are then added together, and they show the total resistance of the line which has been thus balanced against them. It may truly be said, then, that this intangible, invisible, inaudible force is weighed in the scales, and, marvelous as it may seem, it is measured with far greater exactitude than are those tangible and visible substances which men have so long and so familiarly dealt with.

The extreme minuteness of accuracy to which these measurements are carried is seen in the construction of an instrument called the rheostat, which is often used with the resistance coils. An ordinary resistance coil is of unchangeable length. The rheostat is a changeable or adjustable coil. Imagine two spools, side by side—one full, the other empty—with the end of the thread from the full spool attached to the empty one. It is plain that every turn we should give to the empty spool would wind upon it part of the thread, and reduce by so much the number of turns on the full spool. In the rheostat, wire takes the place of the thread, and on the full spool, which is of wood, it lies in a groove, like that on a screw, which isolates each turn from those next it, so that the current can only pass by following the wire from end to end. But the empty spool is a metallic cylinder, and whatever wire is wound upon it becomes, as a conductor, merged in it, so to speak, by the contact, as the current on reaching this cylinder is free at once to pass to the end of the wire, "across lots," with no perceptible resistance. Practically, therefore, the resistance of all the wire that is wound off upon the second spool is nullified. The length of the wire remaining is indicated on a scale with great precision, even to a fraction of a turn of the cylinder.

The amount of resistance is expressed in "ohms," as they are called. An ohm is the unit of measurement of resistance, just as a foot is a measure of length. All telegraph wire is tested for its resistance, as well as for its strength, before it is put up; and all the lines and magnet coils and batteries in use are constantly tested to detect defects.

The more words that can be transmitted in a given time over a line of telegraph, the greater its value, provided the expense of transmission is not disproportionately increased. We have described the sounder which is commonly used in this country. Its use is practically limited by the number

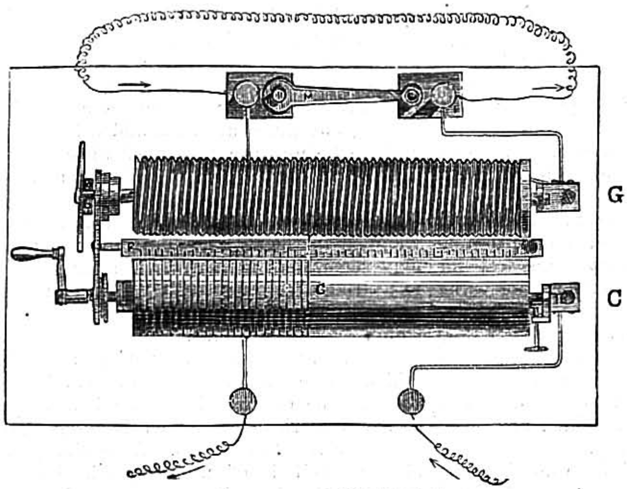


FIG. 23.—WHEATSTONE'S RHEOSTAT.

G, Wooden cylinder, with grooved surface; C, metallic cylinder; F, scale for reading length of wire on the non-conducting cylinder.

of words a man can write in an hour. A good copyist will not usually write over 800 or 1000 words an hour, but a good operator can receive and write 1500 to 1800 words per hour, and on special occasions 2500 to 2600 have been received. Operators on the continent of Europe do not transmit more than half as many in the same time. The number of words transmitted is increased by the use of the printing instrument to between 2500 and 3000 an hour, which are printed in Roman characters as received, and are ready for delivery, therefore, without the delay of writing out. The operator, by the same movement, can print the message at his own desk and at that of the receiver, and at once detect any error. These instruments are very complicated, easily disarranged, require very skillful operators, a second man or some mechanical power to run them, and a well-insulated line, as the movements at each end must keep perfect time. They are much more expensive than the key and sounder, and are only used on circuits where there is a large and steady business. Their construction is too complicated for description. Printers, as they are called, have never been extensively used in Great Britain, although in use on the main lines of the continent of Europe, where, however, they are not worked as rapidly as with us.

In the "automatic telegraph" a little machine is substituted for the operator, and the message is prepared for it on a strip of perforated paper.

Many different plans have been devised for automatic telegraphing, but only two have thus far proved successful—the Wheatstone, or English system, and the automatic, or American system. The former is extensively used in Great Britain, and a line has been recently constructed between New York and Washington for the working of the latter.

The instruments employed by these two systems are entirely different. In each, holes representing the words of the message are first punched in a narrow strip of paper, which are the equivalents of the dot and dash of the Morse alphabet, and are translated into dots and dashes after transmission. The English puncher has three keys; the first punches two vertical holes, :, representing the dot; the third two holes vertical, but not opposite, ·., representing the dash; the centre key simply moves the paper along. The American puncher has a key for each letter, which punches holes representing the dots and dashes of the letter. It is more complicated than the other, but requires less than one-third as many movements of the keys to each letter. The dot is represented by a small hole above the line, ·; the dash by two small holes above and one large one below, ⁘. It is less liable to mistakes, as the operator is not obliged to translate each letter into dots and dashes before punching. The number of words punched by each is said to be about thirty a minute, or eighteen hundred an hour, the maximum amount an ordinary operator can transmit by the Morse key. No strength is required to work the Morse key, but the punchers require considerable. After the punched slip is prepared the machine transmits the message with great rapidity.

The American transmitting and recording instrument, it is claimed, has greatly the advantage over the English both for its simplicity and rapidity of execution. The English instrument, which is too complicated for description here, can transmit from sixty to 120 words a minute, the number diminishing with the distance. Usually about eighty a minute are sent. It is said that from 1000 to 1500 words a minute can be transmitted by the American instrument between Washington and New York; but if only 500 can be sent, and of this, it is claimed, there can be no reasonable doubt, it may prove a very great improvement over other systems for some purposes.

In the American system, after the paper is punched it goes to the transmitter, is received between pressure rollers, and carried by the friction on to a small platform of some non-conducting material. A solid cylinder of copper connected with the line wire is inserted in the centre of the platform. Over this cylinder, and resting upon it, is a needle which has two small wheels at one end, and is connected at the other with the wire leading to the battery. The paper passes between the cylinder and needle, and is carried off by another set of pressure rollers. The circuit is broken by the paper, and closed when the holes in the paper pass under the wheels and the wheels come in contact with the copper cylinder. Where there is a cluster of three holes both wheels form a contact and a dash is transmitted, in other cases a dot.

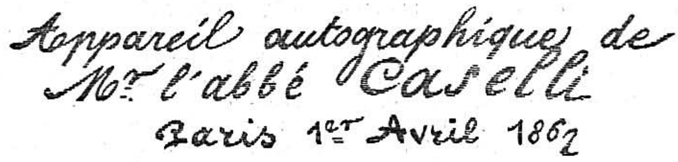


FIG. 25.—AUTOGRAPH TRANSMITTED BY CASELLI'S APPARATUS.

The same instrument answers for a receiver. The message is recorded on chemically prepared paper, rendered sensitive to the slightest current. Occasional errors arise, caused by the dot running into the dash and the dash into a straight line, and can not be detected until the message is translated, so great is the rapidity of transmission; and when they do occur the whole message must be repeated.

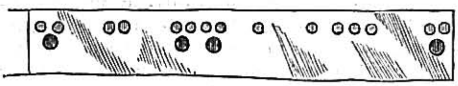


FIG. 24.—MESSAGE PREPARED FOR AUTOMATIC TELEGRAPH.

Punching instruments can be readily constructed and furnished to those who have frequent occasion to use the telegraph, and a clerk can easily punch the telegraphic letters, and thus greatly lessen the expense of sending a long message. On the other hand, it is to be considered that the aggregate of time employed is a considerable offset. In England the automatic system is regarded as indispensable for press messages, for which purpose messages are punched in triplicate, and the same ribbon is used again and again in distributing the message by different instruments in all directions. It is said to be doubtful, however, to what extent great rapidity can be maintained on lines which have more than one wire, for whenever a current is flowing over one wire it induces another current in the other wire at each opening and breaking of the circuit; hence if messages are passing on both wires there is a liability of both being received on each line, and rendered unintelligible. This instrument is not as complicated as the printer, but requires more operators, and is therefore more expensive.

Another very curious and complicated transmitter, used in France, is an autographic instrument by which the *fac-simile* of the handwriting can be produced at any other office where a similar instrument is used. It is especially useful for messages relating to transfers of money, as it affords the receiver an opportunity to test the authenticity of the dispatch by the *fac-simile* of the sender's signature. It is said that on an average nearly thirty messages an hour can be transmitted by it. The message is written on chemically prepared paper, and the price varies with the size of the paper.

This instrument can transmit stenographic writing, and then its rapidity is said to be truly prodigious. Portraits and drawings can also be transmitted by it.

This seems almost incredible. But the reader who has followed the explanations before given can form a general idea of the process by imagining that two great pendulums are made to swing simultaneously, one at either end of the line. Each moves a metallic point back and forth over the surface of chemically prepared paper, and after every movement the position of the pencil is changed a hair's-breadth down the page. If, then, at the instant that the metallic point at one terminus is in contact with a line of the manuscript or copy, a telegraphic current is transmitted to the point at the other terminus, and passes thence through the paper, it will produce a discoloration, which will be a dot or a line according to the duration of the current. If the autograph be closely inspected, it will be seen that it is made up of very fine parallel lines. The same thing will be more clearly seen in the butterfly, shown on a previous page.

The most recent marvel of the telegraph is what is called the duplex telegraph. This invention is a simple and beautiful device by which one wire serves to carry two messages in contrary directions at the same instant without interference. At first thought this may seem an impossibility; but when we consider how sounds, which we know to be vibrations in the air, may be propagated together in almost any number, and pass and cross each other in opposite directions without losing their individuality, we see how it is possible, even if we conceive of two currents as flowing in contrary directions, that currents of electricity, or rather, we should say, the vibratory action and reaction which we term currents, should coexist and interlace without interference. In the ordinary arrangement of a telegraphic circuit, if the operator at New York should commence to send a message to Philadelphia at the same time that the Philadelphia operator was sending to New York by the same wire, confusion would result. On the theory of two currents even, perhaps this confusion would not, under proper conditions, be an interference of the currents in the wire; but if they remained distinct, there would be confusion in the double and broken utterance of the receiving instruments. The distinct currents would both pull upon the armature of the sounder, and the result would be a confusion in the signals. The instruments at each end would utter an unintelligible jargon. To obviate this difficulty some device is necessary which shall cause the current from the battery at either end to flow through the magnet at the same end without affecting it, but yet have its effect on the magnet at the other end. After the current from the transmitting office passes through the key by which the signals are made, the wire is divided into two, one of them leading to the magnet and thence to the main line, while the other leads also to the magnet and thence back to the negative pole of the battery. To prevent too much of the current from following the latter course, which, being very short, presents but little resistance, resistance coils such as have been described are inserted in this short line, and when, by means of these, the resistance is made equal to that of the main line, the current divides equally, one-half passing forward to the main line to carry the message to the other terminus, the other half returning to the battery through the equally difficult path of the resistance coils. The magnet in question has both these wires wound around it in opposite directions, the consequence of which is that the half of the current which is returning to the battery counteracts the influence on the magnet which would otherwise be exerted by the other portion which is going forward on the line, and the outgoing message therefore produces no effect on the magnet. When the part of the current which carries the message, so to speak, arrives at the similar arrangement at the other end of the line, it passes around the magnet there without any such counteracting influence, and therefore makes its signals freely. In other words, the duplex telegraph is a contrivance for dividing the current, and using one-half of it to send the message, and the other half to keep the sounder from being disturbed by the message, thus leaving the sounder free to utter another message which is coming at the same time from the other end of the route.

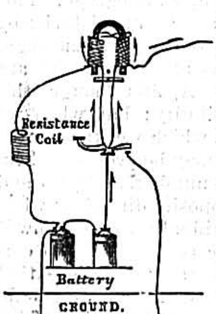


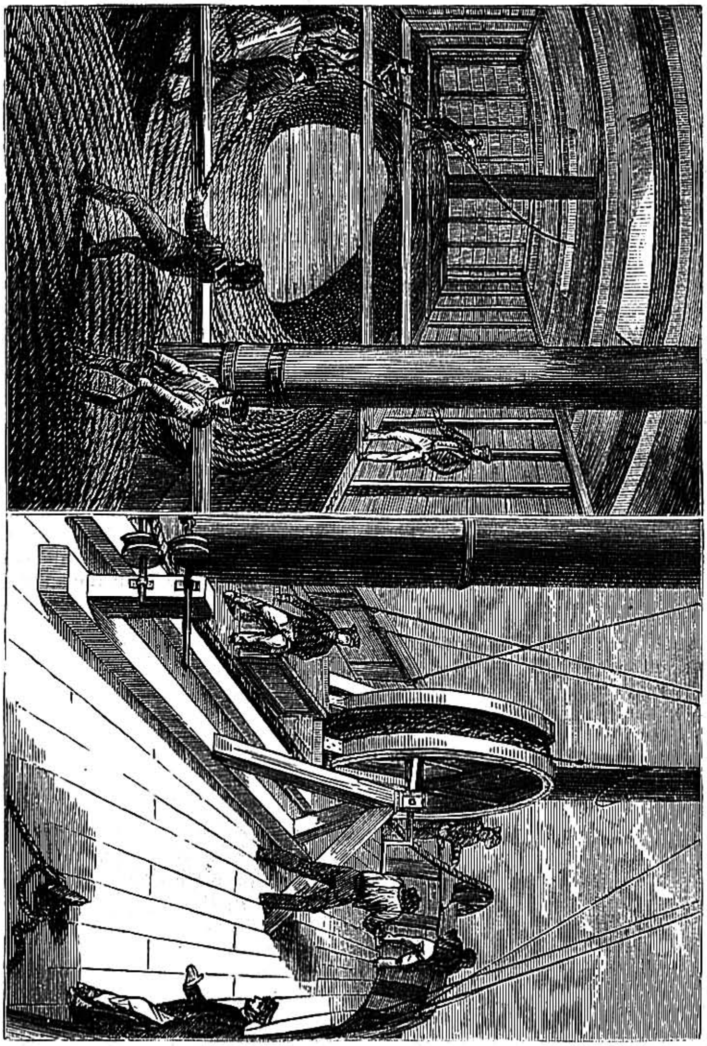
FIG. 26.—PRINCIPLE OF THE DOUBLE TRANSMITTER.

The American lines are connected with those of the Old World by cables. The cable is an insulated copper wire, surrounded by iron wire, covered with hemp and a thick coating of cement, as it was feared that the crustacea inhabiting the ocean depths might eat through this coating. These creatures were carefully analyzed, and a compound made so hard that they could not act upon it.

The story of the laying of the cable has been often told, and need not be repeated here. The peculiar conditions of submarine telegraphy required the use of batteries of very small power. The current was then found to be so inconstant in its movement that the needle could not be relied upon to open and close a local circuit, while its tremulous movements were so slight that they could not be followed by the eye. We have said that the time required by a current of electricity for its passage through a conductor is directly proportional to its length, other things being equal; but in the case of cables other causes of retardation are added. The current flowing through the cable induces a temporary current in the reverse direction on the outside of the conductor, and the attraction between the two retards the current, and this retardation increases in a geometric ratio with the length of the cable. The cable becomes, in effect, an enormous Leyden jar, the wire constituting the interior, the water the exterior coating, with the gutta-percha insulator between. When the circuit is closed the jar is charged, and discharged when it is opened. This also causes delay. The current moves as a wave which gradually travels along the wire, appearing in different parts at successive intervals of time; and by adjusted touches of the key successive waves may follow each other through the wire before the first has died away. If the battery be too large, the cable will be destroyed; if too weak, the signal is too fleeting to be seen without prolonging the wave to such an extent as to prevent rapid transmission. To remedy these difficulties a very delicate and beautiful form of the galvanometer was invented. It consists of a mirror of microscopic glass about one-eighth of an inch in diameter, suspended by a silk thread in the centre of a coil of very fine wire. A magnet is attached to the back of the mirror made of thin watch-spring. The whole weighs less than a grain. The magnet is so sensitive that if the ends of the wire connecting the coil are held by the hands, one end being covered with tin-foil, there will be sufficient magnetism excited to deflect the needle. If a current equal in strength to that produced by a knife blade when brought near a magnetic needle is received, it will move the magnet. A shaded light is thrown on the mirror, which is reflected upon an ivory scale, and is brought to a sharp focus by the lens. The instant the circuit is closed the magnet and mirror are deflected, and the light moves to the right or left on the scale, as the current is positive or negative. A very minute displacement of the magnet gives a very large movement of the ray of light. A movement on one side of the zero point represents the dot, on the other the dash, of the Morse alphabet, and the interval between the two the space. Before the first element has been received a second and even a third are following in its wake. Thus the thoughts of the East are read in the West by the flickering of a reflected ray of light.

Very recently a registering instrument has been invented as a substitute for the galvanometer. It consists of a small glass tube, which waves to and fro over a running strip of paper without touching it. The ink is spurted upon the paper by a series of electric sparks in a fine shower, which makes a continuous line upon the paper, giving a faithful record of the motion of the current. This instrument nearly quadruples the speed with which messages can be transmitted over the cable, it being capable of recording 120 words a minute, while the mirror galvanometer receives about thirty.

There is, perhaps, no more wonderful example of organization, subordination, and



LAYING OF A SHORT CABLE ACROSS THE STRAITS OF DOVER.

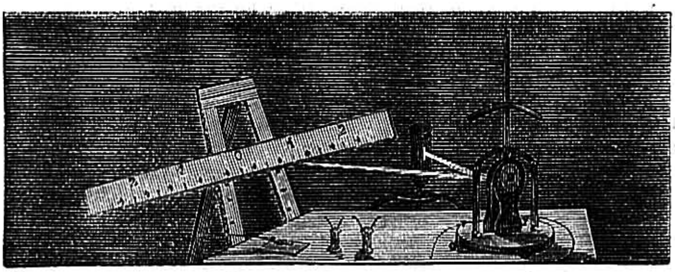


FIG. 27.—THE MIRROR GALVANOMETER.

intense attention and celerity to be found in any department of human affairs than is afforded by the telegraphic service between London and New York. A message sent from New York has to be rewritten four times in its route—that is to say, four times

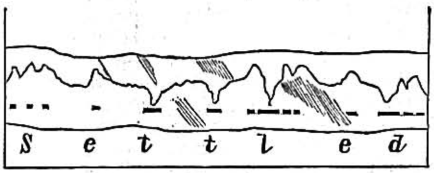


FIG. 28.—A REGISTERED CABLE MESSAGE.

it has to leave the wires and pass in at the eye or ear of an operator, through his mind and by his hand on to paper, or on to the transmitting instrument, or both. These faithful servants of the public, sitting continuously at their posts hundreds and thousands of miles apart, maintain an incessant stream of such communications with such perfect discipline and unbroken attention that the average time for the entire operation, including all kinds of messages, however long, is less than fourteen minutes for each message from New York to London. This, too, is but one short line in a net-work of over seven hundred thousand miles of wire which covers the globe, uniting more than twenty thousand cities and villages in every continent and of every language in one vast organization incessantly in operation.

Almost every season brings forward some new application of the telegraph. A complete net-work of wires now connects the stock exchange with the brokers' offices and the leading hotels, and the business done at the board is printed off in more than a thousand places in New York simultaneously. There is no reason why it should not be employed in a similar way to communicate to the offices of lawyers the progress of proceedings and the call of the calendar in the courts of law. What is called the district telegraph has recently been established in New York. It is a house-to-house telegraph, with a central office in each of a number of convenient districts. Each subscriber pays two dollars and a half a month, for which the company put up a neat little instrument in any part of his house that he desires, by means of which he can at any hour of the day or night summon to his door within the space of three minutes a messenger, a policeman, or a fireman with a fire-extinguisher. For the service of either he is to pay fifteen cents a half hour for the time employed. This system is spreading very rapidly and successfully throughout the city.

Railroad companies are now very generally employing telegraph operators as train dispatchers, and the incessant use of the telegraph is becoming a necessity on every road. Private telegraphs are used by many business houses for communication between the warehouse and the factory, and by gentlemen in their country residences to summon the coachman from the stables and the

THE HOUSE PRINTING MACHINE.

porter from his lodge. There are said to be over four thousand miles of private telegraphs in Great Britain. How many there are in this country we are not informed. In hundreds of public buildings and churches miniature telegraphs are used for lighting

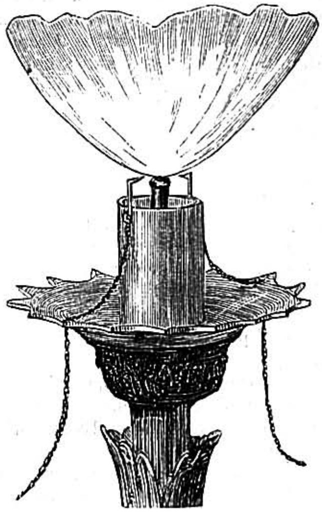


FIG. 29.—LIGHTING GAS BY THE ELECTRIC SPARK.

the gas, and it is estimated that the expense of the apparatus for a large church is repaid in two years by the saving in gas, as compared with the common and wasteful way of turning on the gas and then lighting one burner at a time with a rod and torch.

One of the most curious applications of the telegraph is its use in surgery to discover a bullet in a wound. The probe and forceps are each connected with a delicate battery. When one point of the probe or of the forceps touches the ball no effect is produced, but when both touch it the ball completes the circuit, and the tinkling of a bell

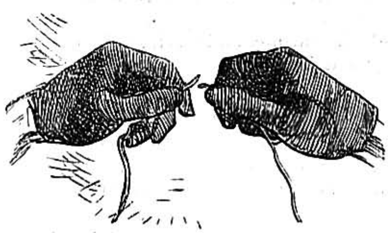


FIG. 30.—THE ELECTRIC PROBE AND FORCEPS.

or the vibration of a spring shows the surgeon that he has seized it.

The immense extension of the general telegraphic system, and its common use for business and social correspondence and the dissemination of public intelligence, are far more important to the community than any of these incidental applications of the system. The telegraph system is extending much more rapidly than the railroad system, and is probably exerting even a greater influence upon the mental development of the people than the railroad is exerting in respect to the material and physical prosperity of the country. It has penetrated almost every mind with a new sense of the vastness of distance and the value of time. It is commonly said that it has annihilated time and space—and this is true in a sense; but in a deeper sense it has magnified both, for it has been the means of expanding vastly the inadequate conceptions which we form of space and distance, and of giving a significance to the idea of time which it never before had to the human mind. It lifts every man who reads its messages above his own little circle, gives him in a vivid flash, as it were, a view of vast distances, and tends by an irresistible influence to make him a citizen of his country and a fellow of the race as well as a member of his local community.

In other respects its influence, though less obvious, will probably prove equally profound. So long as the mysterious force employed in the telegraph was only known in the mariner's compass, or by scientific investigations, or in a few special processes of art, the knowledge of the electric or magnetic force had, so to speak, a very limited soil to grow in. By means of the telegraph many thousands of persons in this country are constantly employed in dealing with it practically—generating it, insulating it, manipulating it. The invention of Morse has engaged some one in every considerable town and village in studying its properties, watching its operation, and using it profitably. Nothing could be better calculated to attract general attention to this new-found power, and to disseminate that knowledge of it from which new applications may be expected to result.

The tendency of scientific pursuits to promote the love of truth and the habit of accuracy is strikingly illustrated in the zeal and fidelity with which the minute and long-continued investigations have been pursued that have led to the development of this new realm of knowledge and this new element in human affairs.

But perhaps the most extended and important influence which the telegraph is destined to exert upon the human mind is that which it will ultimately work out through its influence upon language.

Language is the instrument of thought. It is not merely a means of expression. A word is a tool for thinking, before the thinker uses it as a signal for communicating his thought. There is no good reason why it should not be free to be improved, as other implements are. Language has hitherto been regarded merely in a historical point of view, and even now philology is little more than a record of the differences in language which have separated mankind, and of the steps of development in it which each branch of the human family has pursued. And as a whole it may be said that the science of language in the hands of philologists is used to perpetuate the differences and irregularities of speech which prevail. The telegraph is silently introducing a new element, which, we may confidently predict, will one day present this subject in a different aspect. The invention of Morse has given beyond recall the pre-eminence to the Italian alphabet, and has secured the ultimate adoption throughout the world of that system or some improvement upon it. The community of intelligence, and the necessary convertibility of expression between different languages, which the press through the influence of the telegraph is establishing, have commenced a process of assimilation, the results of which are already striking to those who carefully examine the subject. An important event transpiring in any part of the civilized world is concisely expressed in a dispatch which is immediately reproduced in five or ten or more different languages. A comparison of such dispatches with each other will show that in them the peculiar and local idioms of each language are to a large extent discarded. The process sifts out, as it were, the characteristic peculiarities of each language, and it may be confidently said that nowhere in literature will be found a more remarkable parallelism of structure, and even of word forms, combined with equal purity and strength in each language, than in the telegraphic columns of the leading dailies of the capitals of Europe and America. A traveler in Europe, commencing the study of the language of the country where he may be, finds no reading which he can so easily master as the telegraphic news column. The telegraph is cosmopolitan, and is rapidly giving prominence to those modes of speech in which different languages resemble each other. When we add to this the fact that every step of advance made by science and the arts increases that which different languages have in common by reason of the tendency of men in these pursuits the world over to adopt a common nomenclature, and to think alike or in similar mental processes, we see the elements already at work which will ultimately relegate philology to its proper and useful place among the departments of history, and will free language from those restrictions which now forbid making any intentional improvements in it. With the general use of the telegraphic system other things begin to readjust themselves to its conditions. Short-hand writing is more cultivated now than ever before. The best reporter must understand both systems, and be able to take his notes of a conversation while it passes, and then by stepping into an office transmit it at once without writing out. There is now in practical use in the city of New York a little instrument the size of a sewing-machine, having a key-board like the printing telegraph, by which any one can write in print as legibly as this page, and almost as rapidly as a reporter in short-hand. When we consider the immense number of people that every day by writing a telegram and counting the words are taking a most efficient lesson in concise composition, we see in another way the influence of this invention on the strength of language. If the companies should ever adopt the system of computing all their charges by the number of letters instead of words, as indeed they do now for all cipher or unintelligible messages, the world would very quickly be considering the economic advantages of phonetic or other improved orthography.

These processes are in operation all the world over, and in reference to the use of one and the same alphabet. By the principle which Darwin describes as natural selection short words are gaining the advantage of long words, direct forms of expression are gaining the advantage over indirect, words of precise meaning the advantage of the ambiguous, and local idioms are every where at a disadvantage. The doctrine of the Survival of the Fittest thus tends to the constant improvement and points to the ultimate unification of language.

The idea of a common language of the world, therefore, however far in the future it may be, is no longer a dream of the poet nor a scheme of a conqueror. And it is significant of the spirit of the times that this idea, once so chimerical, should at the time we are writing find expression in the inaugural of our Chief Magistrate, in his declaration of the belief "that our Great Maker is preparing the world in His own good time to become one nation, speaking one language, and when armies and navies will be no longer required."

ON THE BRIDGE OF SIGHS.

By ELIZABETH STUART PHELPS.

It chanceth once to every soul
Whose mystic scrolls illuminate enroll

The hieroglyphics of a peace
Which was the ransom of a pain's release,

Upon life's Bridge of Sighs to stand,
"A palace and a prison on each hand."

O palace of the rose-heart's hue!
How like a flower the sweet light fell from you!

O prison with the hollow eyes!
Your steadfast look reflects no flower's surprise.

O palace of the rose-sweet sin!
O blessed prison that I entered in!