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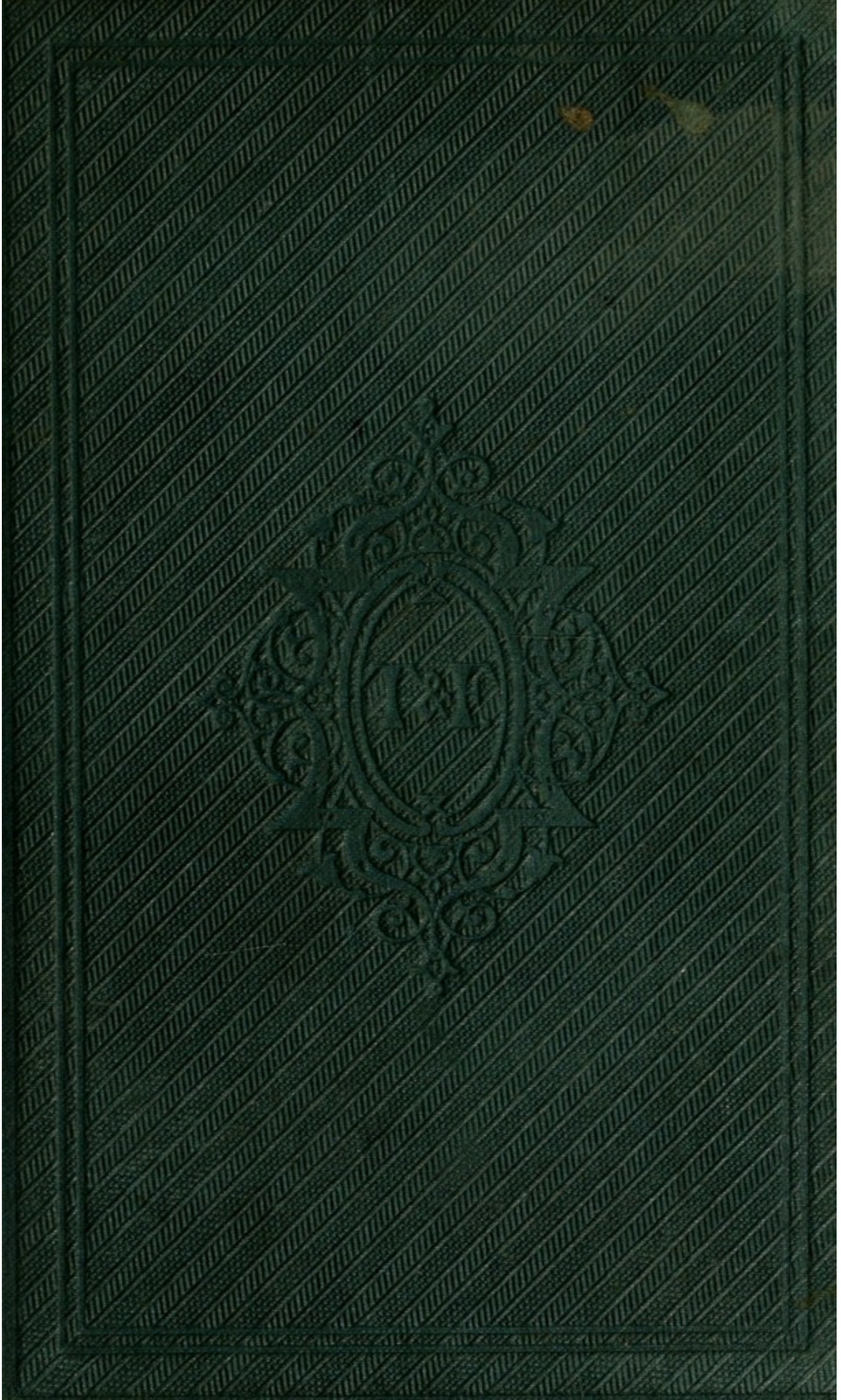

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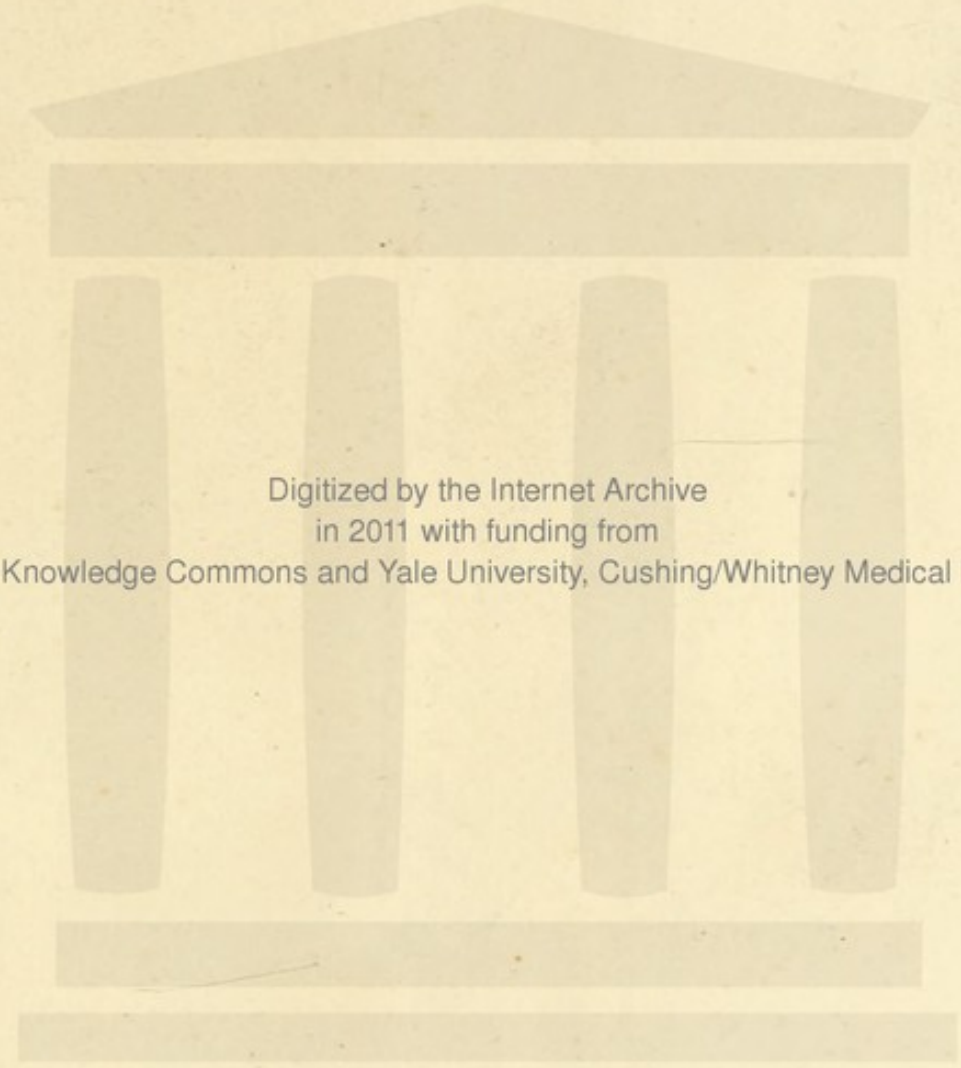

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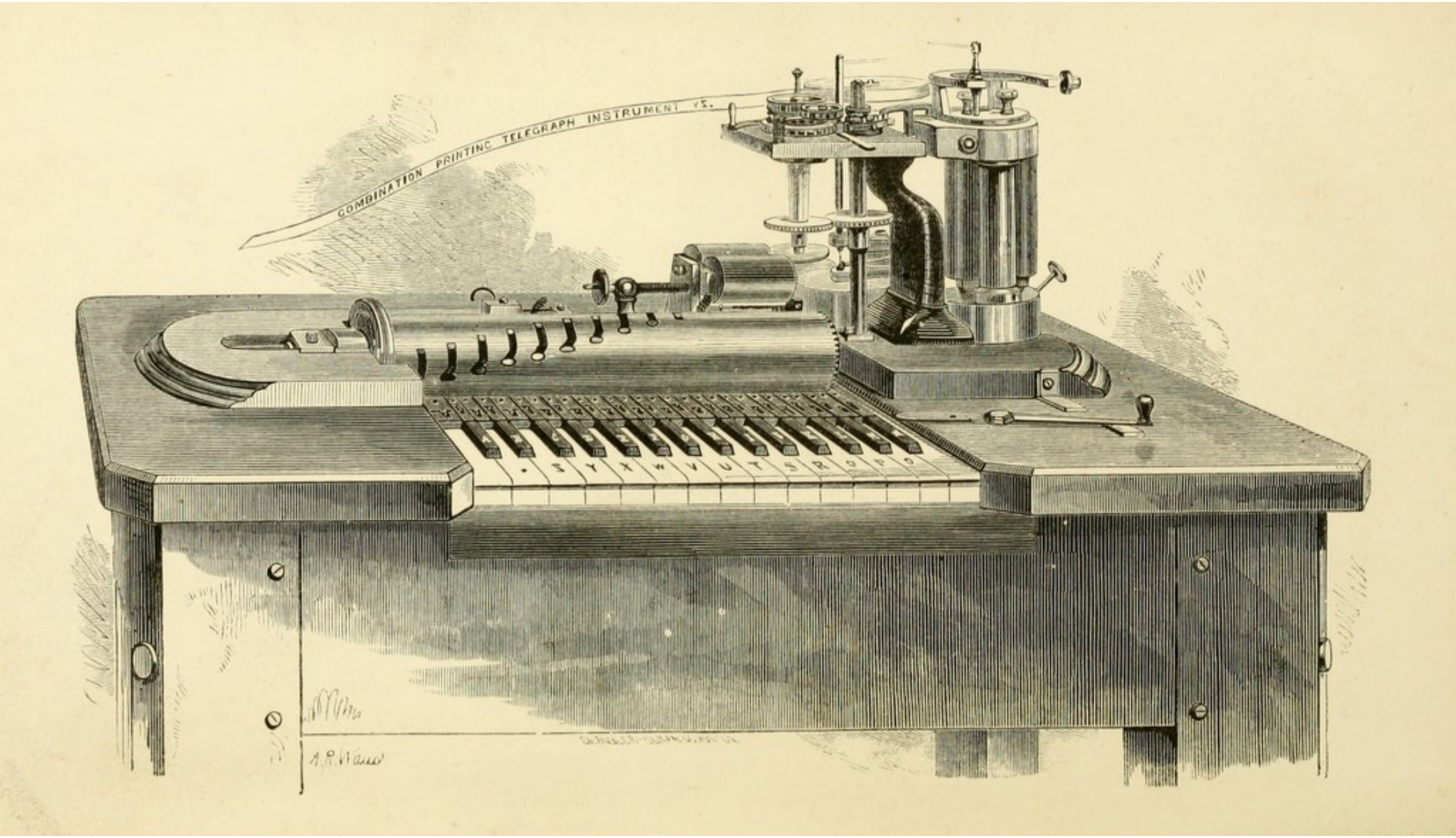
COMBINATION PRINTING TELEGRAPH INSTRUMENTS.
A.R.Ward

HISTORY, THEORY, AND PRACTICE

OF THE

ELECTRIC TELEGRAPH.

BY

GEORGE B. PRESCOTT,
SUPERINTENDENT OF ELECTRIC TELEGRAPH LINES.

THIRD EDITION, REVISED AND ENLARGED.

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PREFACE.

THERE is no subject upon which the American public should be better informed, and none, perhaps, in which it should feel greater pride, than in that of the foremost invention of the age, the Electric Telegraph; for aside from the fact that three of the best systems in use are American inventions, and that to our countrymen is due the credit of producing the first successful recording electric telegraph, it is more generally used in this country than in any other, and probably more than in all others combined, for the common convenience of mankind.

In Europe, with the exception of Great Britain, the use of the telegraph is almost wholly under the control of the governments, and its use restricted by the high rates of tolls to the wealthier classes, while in this country it is alike open to all, and telegraphic despatches are "household words" among the poorer as well as the wealthier citizens.

The wires extend, not only through every State in the Union, from Maine to Texas, and from Massachusetts to Kansas, but already they are creeping over the Rocky

Mountains, and erelong we shall have momentary advices from the Pacific States.

We have endeavored in this volume to explain the principles and operations of the various systems of electric telegraph in such a manner as to be readily comprehended by every reader. In order to accomplish this, we have in the first three chapters given a brief treatise upon electricity in theory and practice.

As there has been much controversy between rival claimants to the discovery of the principles of the electric telegraph, we have devoted much time to the full consideration of the claims of each, and present the facts so obtained to the impartial judgment of the reader.

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INTRODUCTION.

THE Electric Telegraph constitutes a true science, even for the subordinate *employés* charged with putting it in practice. The operator, besides being able to transmit and receive despatches, ought to possess a knowledge of the technical part of his service, to foresee natural phenomena which can influence transmission, and understand the derangements which take place so frequently upon posts, wires, and other apparatus of the line, determine their causes, repair accidents, in the majority of cases, and furnish, when there is need, a fund of general knowledge upon the subject, to meet all emergencies.

It is, then, indispensable that he be initiated into the laws and properties of electricity, that he may render himself entirely competent to comprehend all the laws respecting the transmission of electric currents, and that he know perfectly all the details of construction of the batteries, instruments, &c.

He ought besides to consider his post a place of observation, from which he can survey daily all the different effects of atmospheric electricity. He ought to be in the state of an observer, an analyzer, and a register; in short, as far as his means will allow, to advance the theory of the branch of knowledge so little known, and which is the means of furnishing such important results. He is often called to make meteorological observations, and to transmit their results by the telegraph. In short, he takes hold in the midst of practical difficulties, often obtaining results from which he is enabled to discover useful improvements, and contribute to the adoption of most happy modifications.

Beside these requirements the operator should possess a general knowledge of business, be a correct reader of manuscript, and a careful transmitter and receiver of all despatches intrusted to him. He should look upon his occupation as one of the most honorable and responsible character; for the most important and weighty matters are confided to his care, and not only so, but they are intrusted to him without exacting from him any guaranty that they shall be faithfully performed; thus reposing in him more confidence than the patrons of banks and other similar institutions exercise towards their officers; for they require checks and bonds as a guaranty against error or mismanagement.

This being the case, how careful ought the managers of telegraph lines to be in the selection of their *employés;* and upon their part, how exact should the *employés* be in their business and deportment to merit the confidence thus reposed in them.

In France, the chief electrician of the telegraph lines publishes at regular intervals a record of telegraphic observations which are transmitted to him by the operators from the several stations, and thus presents, in a few years, the most valuable data upon this interesting subject.

It is greatly to be hoped that the American companies will yet see the propriety of constituting a similar department,— appointing to the place a thorough electrician, whose observations upon lines of so great an extent could not fail to prove of the highest importance.

Many works have appeared upon the Electric Telegraph, but in general they have borne descriptions of the apparatus too meagre and insufficient to give a satisfactory solution of the different questions which present themselves. They have been written, too, from an outside point of view. None of the writers have had an opportunity of witnessing the practical operations of the instruments which they attempt to describe, and it is for this reason that no operator can derive any satisfaction from reading them; and the public is not really enlightened upon any essential points. What the student requires is facts, presented in a lucid manner, and from a source entitled to credit.

We have sought, in this work, to supply this want, by presenting

with an eye to practical application all the laws of electricity,— its effects upon different bodies,— the different systems of telegraphic apparatus which have been devised,— and also to solve all questions as to priority of invention.

It is due to the reader, as well as to ourselves, to say, that we have been engaged over thirteen years in practical telegraphing. During this period, which dates back to the very commencement of telegraphic operations in this country, we have served as a practical operator upon the three great systems of the art, viz. the Morse, the House, and the Bain. We have, during this long period, lost no opportunity of informing ourselves upon all points relating to this favorite science which the discoveries in this country and Europe have presented. We have also been a close observer of the phenomena of magnetic storms and other atmospheric disturbances, which we have from time to time made public through the daily journals, but which are now for the first time brought together in a connected and permanent manner. We allude, in this connection, to the chapters upon Electrical Disturbances and the Aurora Borealis, which, we believe, will prove highly interesting to the man of science as well as the general reader.

Although the main part of this work is devoted to our own observations, and to the history and description of the several systems of telegraphy which are, or have been, operated in this country, still we have endeavored to present an accurate description of the systems in use in Europe, and to present the latest and most approved theories of the *savans* of Europe, as well as of our own country, upon the various phenomena connected with dynamic and static electricity.

In order to avoid the necessity of placing notes at the bottom of the pages, in giving our authorities, we have preferred to place a list of the authorities consulted in the preparation of this work at the end of each chapter.

In the first three chapters of this work we detail the elementary facts of the science of electricity, without which it is impossible to comprehend the electric telegraph.

In the fourth chapter we investigate the electric telegraph from

its most general point of view, without making any general hypothesis, under the form of apparatus.

The succeeding half-dozen chapters are devoted to a description of the instruments and other apparatus that are most generally employed in this country and in Europe. These will embrace the history and description of the Morse, House, Bain, Hughes, and Combination systems, at present used in the United States; the Needle system of Messrs. Cooke and Wheatstone, of Great Britain; the Dial systems of MM. Froment and Bréguet of France, and M. Siemans of Germany; and a brief description of the systems of Messrs. Rogers, Horne, Zooke and Barnes, Farmer and Batchelder, and others which have been devised, but are not at present operated in this country.

These are succeeded by an examination into the foreign influences which disturb the transmission of electric impulses, giving general rules to be followed for the discovery of the causes of these derangements.

We next consider the proper modes of constructing telegraph lines; the quality and size of the wire most desirable for the purpose; the species of wood best adapted for posts; the proper length of the posts; and a full description of all modes of insulating lines, with the results of each. We also give the cost of constructing lines in the United States, England, France, and Germany, together with the value of the several kinds of apparatus.

We also give a description of all the submarine and subterranean lines which have ever been laid down; their cost per mile, and the length of time during which they have been in use, together with a full revision of all the experiments made in Europe and this country in regard to static induction from electric currents passing through long insulated conductors, and of other interesting phenomena which have been developed by submarine and subterranean telegraphy.

We also give a history and description of the laying and working of the Atlantic Cable, with several poetical contributions upon the subject from Dr. Holmes, John G. Saxe, Esq., and others.

The progress of the electric telegraph in all quarters of the world is given, with a brief description of the mode of conducting

the business in each country, together with a description of the apparatus used in working through the Atlantic Cable.

The different applications of the electric telegraph are detailed, with a description of the Fire Alarm Telegraphs of Boston, St. Louis, and New Orleans, and the use of the telegraph for strictly scientific observations.

One chapter is devoted to miscellaneous matters, — mistakes of the telegraph, humorous anecdotes, reading by sound, reading by shocks, reading by sight, reading by taste, reading by smell, music by telegraph, and a meeting of telegraph operators, with a chairman at Boston and secretaries in Portland and New York, while speeches are made all over the country, and listened to with the gravest interest.

We have presented in chronological order, in one chapter of this work, the discoveries in electro-dynamics previous to Morse's invention, commencing with the experiment of Le Mounier in the garden of the Tuileries in the middle of the eighteenth century, down to the latest improvements by Ampère, Henry, Gauss and Weber, Steinheil, Daniell, Wheatstone, and other philosophers, to whom the world is indebted for the knowledge which enables us to send communications, by means of the mysterious fluid, with the quickness of thought, and to annihilate time as well as space.

These facts were elicited during the suit for an injunction brought by the Morse patentees against the House Telegraph Company, in 1850, before Judge Woodbury of the United States Supreme Court, and present a reliable and interesting *résumé* of the whole subject. They were printed for the convenience of the Court, but have never before been published.

The concluding chapter is devoted to a full consideration and *résumé* of the important subject of Galvanism, — the value of each kind of battery in use, together with its electro-motive force and adaptedness to electric telegraphy. This will be found of very great importance in estimating the amount of battery power required of any particular kind for any length of circuit.

The first electric telegraph appears to have been made about the year 1786; though long before that time the vague idea of a magical magnetic telegraph was entertained. Strada, a Jesuit

priest, in a curious book, published in 1649, describes a fabled contrivance of two magnetic needles, attached to dials, bearing a a circle of letters, and which possessed the property of always indicating the same letter; so that when one needle was made to point to any particular letter, the other needle, however distant at the time, placed itself so as to point to the same letter.

In 1774, George Louis Lesage, a philosopher of French origin at Geneva, constructed an apparatus composed of twenty-four wires, corresponding to the twenty-four letters of the alphabet, and separated from each other by insulators. To the extremity of each one of these wires a pith-ball was suspended by a silk thread. By touching the wires with an electrical machine, the other extremity of the conductors — the pith-ball — would be repulsed, and thus make known the letter indicated.

In 1793, Claude Chappé, after much labor and research, established between Paris and Lille the first line of aerial telegraph; and this happy result established the success of the system.

Before this epoch, several philosophers proposed to employ electricity in the transmission of despatches, upon their knowledge of the phenomena of static electricity, and from their having observed its prodigious rapidity.

The Electric Telegraph, like all great inventions, was not the work of a single mind. It has followed science in different developments, and could not have passed the domain of science into application, except the laws and principles of electricity were known, — which inspired new efforts that were to be crowned by a complete success.

From 1780 to 1800, Reiser of Germany, and Salva and Bethancourt of Spain, tried some similar systems. Static electricity is, however, a production so volatile, and its insulation so difficult, that the problem of the electric telegraph could be considered only as a scientific conception without the discovery of dynamic electricity.

In 1800, the curious discoveries of Galvani conducted Volta to the discovery of electric currents, and their chemical and physiological properties. A new era opened for the science, and permitted a substitute of permanent supply of electricity in place of the electrical machine and the Leyden jar.

Dr. Coxe, an American, about the same time, proposed a telegraph, the principle of which consisted in the decomposition of chemicals by the electric current.

Mr. Francis Ronalds, in 1816, constructed a telegraph, by which he was able to send signals with considerable facility and rapidity through a distance of eight miles. His plan was very simple. At either end of the wire was a clock carrying a light paper disc, on which were marked the letters of the alphabet, and certain words and numbers. By means of a perforated cover (Fig. 1), only one letter was seen at a time. As the clocks run together, of course the same letter would be visible at the same time; and if an electric discharge were sent from one station to another when a particular letter was exhibited on the dial, the observer at the other end would readily know the signal intended.

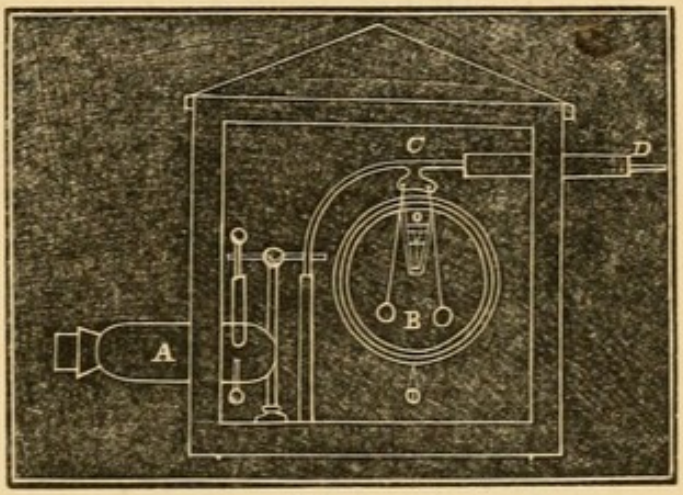


Fig. 1.

Harrison Gray Dyar, an American, constructed a telegraph, in 1828, at the race-course on Long Island, and supported his wires by glass insulators, fixed on trees and poles. By means of common electricity acting on litmus-paper, he produced a red mark, and then passed the current through the ground as a return circuit. The difference of time between the sparks indicated different letters arranged in an arbitrary alphabet, and the paper was moved by the hand. Owing to the use of frictional electricity, which is too easily dissipated, and difficult of being confined to conductors, this telegraph could not have been of any practical use; although, had Mr. Dyar not been prevented, through fear of prosecution on a charge of conspiracy to send secret communications in advance of the mail, from prosecuting his discovery, he would undoubtedly have achieved great success, as his system possessed many of the principles and features

of the Morse invention. This matter will be fully discussed hereafter.

The discovery of the magnetization of soft iron under the influence of currents of induction, is due to Arago and Faraday; but the development of the motor function of electricity, or of the means by which electro-magnetic power can be exerted at a distance, is due to the early experiments of the Secretary of the Smithsonian Institution, Professor Henry, whose discoveries in electro-magnetism, and especially of the quantity and intensity of the magnet, in 1830, laid the foundation for all subsequent forms of electro-magnetic telegraphs, and made succeeding steps comparatively easy. In the publication of these experiments, the induction of the electric telegraph as thenceforth possible was distinctly made by him; and at a period not much later weights were released and bells rung by him at a distance, by electric influence transmitted through long conductors.

The determination of laws upon the intensity of currents is due to Ohm and Pouillet, and the invention of the batteries which generate the currents belongs to Becquerel, Daniell, Bunsen, and Grove.

This completes the series of necessary investigations for the application of electricity to the telegraph.

Among the philosophers who have occupied themselves with this question, we cite in order, up to the time when the system was perfected, Alexander of Edinburgh, M. le Baron Schilling, M. Vorselmann de Heer, MM. Gauss and Weber, M. Amyot, MM. Bréguet and Masson, Sir Humphrey Davy, Professors Henry and Coxe, and Dr. Jackson.

MM. Gauss and Weber, in 1834, constructed a line of telegraph over the houses and steeples of Göttingen. The circuit contained about 15,000 feet of wire. They used galvanic electricity, and applied the phenomenon of magnetic induction discovered by Professor Faraday. The slow oscillations of magnetic bars caused by the passage of currents, and observed through a glass, furnished the signals for corresponding. The operation was complicated, slow, and inefficient.

M. Steinheil established at Munich, and worked, in 1837, an

electric telegraph between two distant points. Up to this time the electric telegraph had been considered only as a curious theoretical science, without possible application, as, for the most part, the apparatus required separate wires for each letter or signal; but it was not doubted, if the practical realization of the idea could be arrived at, that they could reduce this number to two, or even to one, by means of conventional combinations.

There remained, however, still an important question, which experience alone could solve, — whether it were possible to obtain upon a great length of wire a sufficient insulation without too great expense. The great extension of the lines of railway, in 1838, and the necessity felt for the means of rapid communication, hastened the solution of this question.

The first electric telegraph established in Europe for the actual transmission of despatches between distant points, was between London and Birmingham, in 1838, by Professor Wheatstone. Shortly after, lines were constructed by simply suspending the wires upon porcelain supports, when sufficient intensity was obtained to work the apparatus to a great distance.

The first line in France was constructed, in 1844, between Paris and Rouen, along the line of the railway. The lines between Paris and Orleans, and Paris and Lille, were constructed in the years 1847 and 1848. Shortly after, lines were constructed along the several lines of railway throughout France.

The first line constructed in the United States was put in operation in the month of June, 1844, between Washington and Baltimore. The next year it was continued to New York and Boston, and in 1846 to Buffalo and Harrisburg. The succeeding year a line was constructed between Buffalo and Montreal, and during the same season between Boston and Portland. The next year, 1848, found the entire country excited upon the subject of the telegraph, and lines were projected and constructed in every direction.

CHARLES FEVRET DE SAINT-MEMIN

PART I.

PRELIMINARY NOTIONS.

CHAPTER I.

ELECTRICAL MANIFESTATIONS.

By the friction of two bodies of different natures, they acquire a remarkable quality of attracting light substances, such as small fragments of paper, small balls of elder-pith, feathers, &c., when placed in their vicinity. This attraction occurs at a distance; and the substances upon which it is exercised adhere to the surface of the rubbed body by which they are attracted; or rather are alternately repelled and attracted by this body. In order to explain these singular phenomena, we admit that the friction of two bodies develops upon each a peculiar fluid, which we designate by the name of electricity. This name, *electricity*, is derived from the Greek word ἤλεκτρον, signifying *amber*, the first substance, it is said, upon which electrical properties were observed. These two invisible fluids, imponderable, escape our means of observation. Their presence can only be known by the effects which they produce. The one of the fluids we call positive, or vitreous electricity; the other, negative, or resinous. The particles of the same fluid repel themselves, and attract those of the other fluid. This force of attraction and repulsion augments or increases with the friction of the particles.

A stick of glass, rubbed with a piece of cloth, charges itself with the positive fluid. A stick of resin rubbed in the same manner charges itself with the negative. It is this which gives name to the two electricities, vitreous and resinous.

This idea of two different fluids is purely hypothetical, but it explains sufficiently well the phenomena, and remains in the language as a simple means of exhibiting all the facts which present themselves in the study of electricity.

A metallic conductor in contact with an electrized body charges itself instantly in all its parts with electricity, whilst a stick of glass or of resin placed in the same condition electrizes only the point in contact.

We conclude, then, that electricity propagates itself easily upon certain bodies, which we call conductors, and with difficulty upon others, which we call non-conductors or insulators.

Mercury and metals are very good conductors. Glass, resin, bone, rubber, gutta-percha, dry air, and silk are bad conductors, or insulators. Between these two categories of bodies there are other matters, such as steam, vapor, charcoal, &c., which are medium conductors. We can, then, classify all substances by placing them in order according to their conductibility. The metals would then occupy the first rank, and glass and resin the last.

The metals are almost perfect conductors, but they present differences among themselves relatively to their degree of conductibility; and the same metal conducts better, or worse, according to its dimensions and its temperature. Resinous substances, vitreous substances, silk, oils, bone, rubber, gutta-percha, are substances that insulate very well, but not all to the same degree; thus, a very fine filament of gum-lac insulates better than a filament of silk or glass of the same diameter. Gum-lac and the resins insulate better, as they are drawn into finer filaments; it is the reverse with glass, which, when drawn into fine threads, becomes a tolerably good conductor. Wood, pure water, the human body, a great number of minerals, conduct imperfectly; that is to say, they conduct powerful electricity well, but feeble electricity not so well, and sometimes not at all.

The conducting property of bodies appears to depend essentially on their chemical nature; thus we see all the metals are good conductors, while all hydrogenated substances are bad conductors. However, in many cases the physical constitution also

exercises an influence upon conductibility: ice does not conduct, while water does conduct; tallow and wax become conductors only when they are melted, and it is the same with several salts. Glass is a good conductor when heated to redness. Diamond is a perfect insulator, whilst mineral carbon is a good conductor, if it has been strongly heated. Carbon in general conducts better or worse according to the manner in which it has been prepared, and according as it has been more or less baked. Air and gases are less insulating as they are more rarefied, which is the same as saying that vacuum is a good conductor of electricity.

Finally, there is one circumstance, independent of the chemical nature and the physical constitution of bodies, which renders them better or worse conductors; it is their degree of affinity for the humidity of the air. We have already seen that moist air and gases cease to be insulators. Glass, which is of itself a good insulator, easily becomes a conductor as soon as it is exposed to humidity; it attracts to its surface the aqueous vapors of the atmosphere; they form there a thin film of water, by which the electricity passes away. Thus, in order that glass rods shall well insulate the electricity accumulated upon the conductors to which they serve as supports, care is taken to cover them with a thin coat of varnish, made with gum-lac dissolved in alcohol, — a coating which protects the surface of the glass against the deposition of moisture, and which at the same time insulates itself very well.

It is probably to the hygrometric property of glass that we must attribute the conducting faculty which it acquires on being drawn out into thin filaments, because it then presents more surface to the moist air.

The following is an approximative table of the conducting and insulating faculty of different bodies. This table contains in one column the conducting bodies, placed in the order of their conductibility, beginning with the best conductors; and in the second, the insulating bodies, placed in the order of their insulating faculty, beginning with the poorest insulators. Therefore the second column may be regarded as a continuation of the first.

Conducting Bodies.	Insulating Bodies.
Silver.	Dry metallic oxides.
Copper.	Oils: the heaviest are the best.
Gold.	Ashes of vegetable bodies.
Mercury.	Ashes of animal bodies.
Cadmium.	Many dry transparent crystals.
Zinc.	Ice below 13° Fahr.
Tin.	Phosphorus.
Iron.	Lime.
Lead.	Dry chalk.
Platinum.	Native carbonate of baryta.
All other metals.	Lycopodium.
Well-burnt carbon.	Caoutchouc.
Plumbago.	Camphor.
Concentrated acids.	Some siliceous and argillaceous stones.
Dilute acids.	Dry marble.
Saline solutions.	Porcelain.
Metallic ores.	Dry vegetable bodies.
Animal fluids.	Wood that has been strongly heated.
Sea-water.	Dry gases and air.
Spring-water.	Leather.
Rain-water.	Parchment.
Ice above 13° Fahr.	Dry paper.
Snow.	Feathers.
Living vegetables.	Hair, wool.
Living animals.	Dyed silk.
Flame.	Raw silk.
Smoke.	Transparent precious stones.
Vapor.	The diamond.
Salts, soluble in water.	Mica.
Rarefied air.	All vitrefactions.
The vapor of alcohol.	Glass.
The vapor of ether.	Jet.
Earths and moist rocks.	Wax.
Powdered glass.	Sulphur.
Flowers of sulphur.	The resins.
	Amber.
	Gutta-percha.

All bodies, therefore, are capable of becoming electrical by friction; but they differ among themselves with regard to the faculty they possess of transmitting electricity. Some transmit it promptly and freely; others more slowly and with difficulty; while others still seem almost incapable of transmitting it. However, they are all susceptible of taking electricity from an electrized body with which they are touched; only if the touched body is an insulator, it takes electricity on that part of its surface alone which has been touched; whilst, if it is a conductor, it acquires it throughout its whole extent, although it has received it only upon one point. This is a means of electrizing which is termed *to electrize by communion.*

If the electrized body is an insulator, it gives the electricity it possesses to the conducting body that touches it only at the point in which the contact takes place; but if it is a conductor, there occurs a division of its electricity between itself and the touched body, — a division which is subject to a very simple law, namely, that each of the two bodies which we necessarily suppose insulated takes a part of the total electricity proportional to its own surface.

If we bring into contact two conductors of the same size, charged with different kinds of electricities of equal quantities, these two electricities of which the particles are possessed unite, and all trace disappears upon the two conductors. This experiment goes to prove that all bodies in nature possess in equal quantities both kinds of electricity, the union of which produces a fluid without action, or neutral; and that friction does not liberate the two kinds of electricity, but only separates them.

The quantity of neutral fluid which a body contains cannot be determined, but all goes to prove that it is very great.

An electrized body that is put in communication with the earth loses at once all its electricity. The earth is designated, for this reason, the *common reservoir*, in order to indicate that to it is carried the electricity of bodies placed in communication with it. The reason why it is able to absorb the electricity of all bodies brought into contact with it, is to be found in the fact that it is a body of such an enormous conducting surface, that all other con-

ducting bodies must be infinitely small in comparison with it, and therefore retain, after contact, infinitely less electricity, or none at all.

The neutralization of the two contrary electricities, a consequence of their attraction, may take place according to different modes. It may operate at a distance, in the case in which neither of the two balls is sufficiently movable to obey the attraction that remains between them.

If we place two metallic balls at the extremity of a glass rod, one electrized vitreously, or positively, the other resinously, or negatively, and then cause them to approach each other, at a distance greater or less according to the electric charge which they possess, an instantaneous spark is seen to shine between them, accompanied by a slight snapping; and immediately after, they may be proved to have lost their electricity, and to be in their natural condition.

This mode of neutralization can only occur when the electrized bodies are placed at an inconsiderable distance apart, — a distance that must vary with the intensity of the electricity with which they are charged, and the condition of the air compressed between them. But whatever the distance, the contrary electricities may be neutralized, on making communication between the two balls, by means of an insulated conductor, such as a metal branch, held by an insulating handle.

Static and Dynamic State of Electricity.

When the neutralization is brought about, either through the air with a spark, or through a conductor, the electricity is said to be in the *dynamic state* for the instant that this neutralization lasts. This denomination of *dynamic* is given to the state of movement in which the two electricities are supposed to be found when they are travelling towards each other to neutralize each other, in opposition to the *static* state, or that of rest, in which these two electricities are found when they are separately accumulated on insulated bodies. The latter state is also named *electric tension ;* the former, *electric discharge.*

The dynamic state may be *instantaneous* or *continuous*. It is instantaneous in the preceding case, in which the two electrized metallic balls are insulated, and consequently acquire no more electricity after that which they possess has once become neutralized. But suppose one of the balls to be in communication with a constant source of positive electricity, and the other with an equally constant source of negative electricity, the two electricities being constantly renewed in proportion as they are neutralized, there will be through this conductor an uninterrupted neutralization, or a continued reunion of the two electricities; this is what is termed *the continuous dynamic state*, or *electric current*. We then say that the conducting body, which serves to establish a communication between the two balls, is traversed by an electric current.

Bodies that serve for the passage of electricity, where it is in either the instantaneous or the continuous dynamic state, undergo, by the effect of this passage, certain modifications, some temporary, others permanent, which are extremely remarkable. If it is a very fine metallic wire, and of no great length, which serves to transmit the dynamic electricity, this wire is heated, becomes incandescent, and may even melt, if the electricities whose reunion it is bringing about have great intensity. If the body through which the transmission occurs is water, this water is in part decomposed; and its two constituent gases, namely, oxygen and hydrogen, are seen to be set free. But this effect is manifested in a more marked degree when the dynamic state is continuous; that of heating occurs equally whether the dynamic state be instantaneous or continuous.

Theories on the Nature of Electricity.

The theory most generally admitted in the present state of our knowledge consists in regarding each of the two electricities, both the vitreous and the resinous, as excessively subtile and imponderable fluids, each composed of particles that mutually repel each other; they arrange themselves on the surface of bodies, where they remain, because they meet the air, which, being an insulating body, does not permit them to go further. In non-conducting

bodies the two fluids are constrained in their movements, which we attribute to their being retained by the particles of these bodies. When the two fluids unite, by virtue of their mutual attraction, they are neutralized, and form *neutral fluid*, or *natural electricity*, the action of which is not sensible, because the effect of the two contrary fluids is counterbalanced. It is admitted that every body contains natural electricity: hence to electrize a body is to decompose this electricity; one of the parts, or one of the *principles*, of which remains in excess on the rubbing body. This is called Symmer's two-fluid theory.

Franklin's theory consists in admitting but one single imponderable electric fluid, very subtile, and all the particles of which mutually repel each other. Each body has a determinate capacity for this fluid. When it contains as much as it ought naturally to have, the body is in the natural electric state. To electrize a body vitreously, is to give it more electricity than it naturally contains; it is then in the *positive* electric state: to electrize a body resinously is to deprive it of a portion of its natural electricity; it is then in the *negative* electric state. We have seen that these denominations of positive and negative electricity, which follow from Franklin's theory, may be justified by considerations altogether independent of every hypothetical view, and based simply on facts.

We shall not here discuss the comparative merit of these two theories; the latter, at least in such sort as Franklin has formularized it, cannot be admitted. The former, although subject to strong objections, is, in the present state of the science, a very convenient and tolerably exact manner of representing to ourselves this agent which we term *electricity;* it is under this point of view that we shall adopt it. However, we may for the present say it is very probable that electricity, instead of consisting of one or of two special fluids *sui generis*, is nothing more than the result of a particular modification in the state of bodies. This modification probably depends on the mutual action exercised on each other by the ponderable particles of matter, and the subtile fluid that surrounds them on every side, — a fluid that is generally designated by the name of ether, and the undulations of which constitute light and heat.

CHAPTER II.

PROPAGATION OF ELECTRICITY.

All bodies may be considered as composed of an infinite number of particles closely united; it results from this, that the electric current upon the conductor does not flow over it in a manner analogous to that of a liquid in a tube, but by a series of successive decompositions and recompositions of the neutral fluid in the different particles.

Many kinds of apparatus have been constructed upon the preceding principles, but we shall limit ourselves to a description of the electric machine.

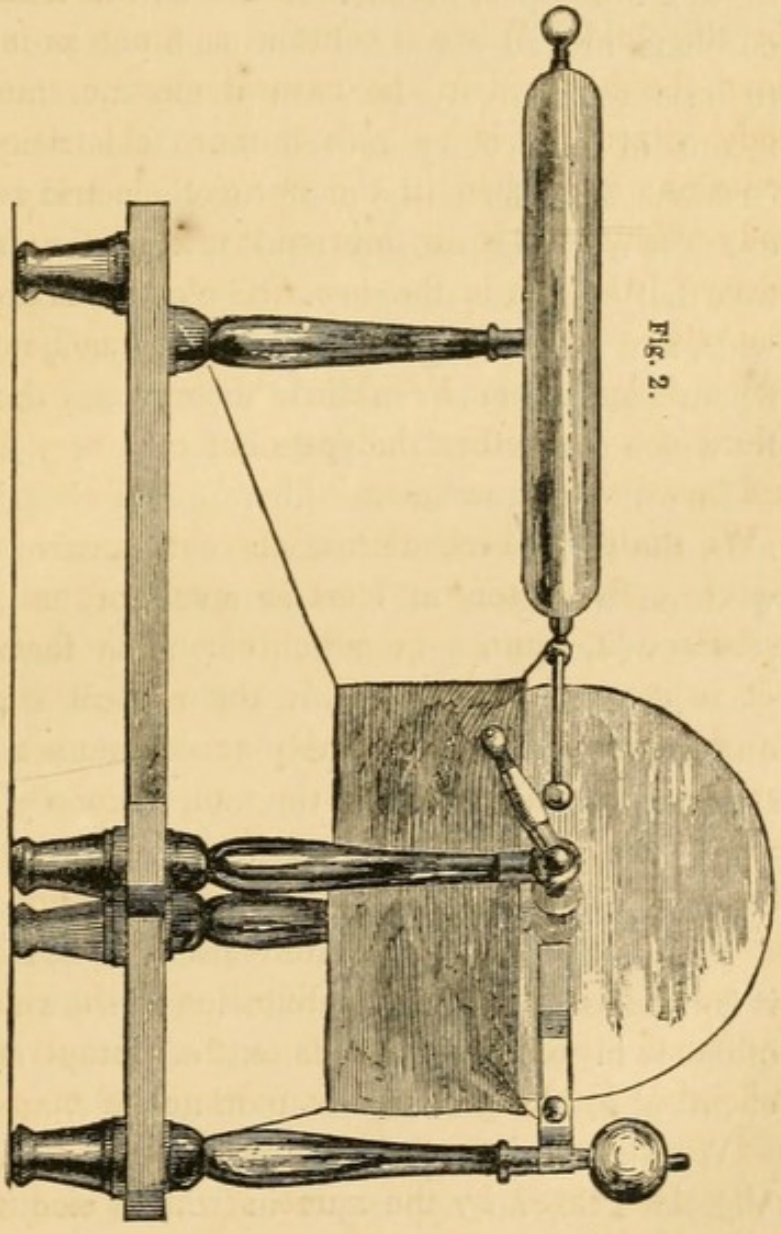


Fig. 2.

An electrical machine (Fig. 2) consists of a circular glass plate, from one twelfth to one eighth of an inch in thickness, and the diameter of which is equally various: being generally about two feet. The

plate is traversed at its centre by a metal axis, fixed firmly to the glass by means of two ferules; this axis rests upon two wooden supports, fixed vertically at the end of a solid table, and is so placed that the glass plate is situated between the two supports, and at an equal distance from either. A handle fixed to the extremity of the axis that is situated on the outer side of the table serves to give a rotary movement to the plate. The greater portion of this handle is commonly of glass, so that the electricity of the part of the plate nearest to the axis may not be conducted into the ground by the hand and body of the person who is working the machine. Two pairs of horse-hair cushions covered with leather are placed, one in the upper part, the other in the lower part of each of the two vertical supports. These cushions are so arranged that each portion of the plate is made to pass successively between them, first above, then below, by means of the rotary movement. It is also necessary that the cushions be sufficiently near together, and sufficiently elastic, to exercise a strong pressure against the plate; this produces a friction that electrizes the glass. The cushions are four or five inches wide, and are as long as possible; always, however, leaving a sufficient interval between their extremities and the metal ferules by which the axis of the plate is fixed.

In order to render the liberation of electricity more considerable, the surface of the leather of the cushion must be covered with an amalgam of zinc or a coat of mosaic gold (deuto-sulphuret of tin). The vitreous electricity that is acquired by the glass plate from the effect of friction is collected by cylindrical conductors of brass, which are placed horizontally on vertical glass stems, themselves fixed on the table, at one of the extremities of which the supports are placed by which the glass plate and the cushions are sustained.

We have seen above how electricity is obtained by friction, but it is not the only mode of producing this development: there exist others; in particular, elevation of temperature, and also the chemical action of one body upon another.

We shall confine ourselves here to a brief description of the Voltaic Pile, an apparatus in which electricity is developed,

according to some by the contact of two metals of a different nature, and according to others by the chemical action of the liquids with which it is charged upon one of the two metals that enter into its formation. The pile devised by Volta owed its origin to the interpretation which this celebrated philosopher gave to a remarkable experiment made by Galvani; namely, that a frog undergoes a violent commotion when one of its nerves, being exposed, is touched with one metal, and its muscles with another metal, the two metals being themselves in close contact in one or more points of their surface. This effect, which is due to a liberation of electricity, has caused the electricity thus liberated to be called *galvanic*, and the part of physical science concerned in it to be called *galvanism;* but the name Voltaic must remain to the pile, since it truly originated with Volta.

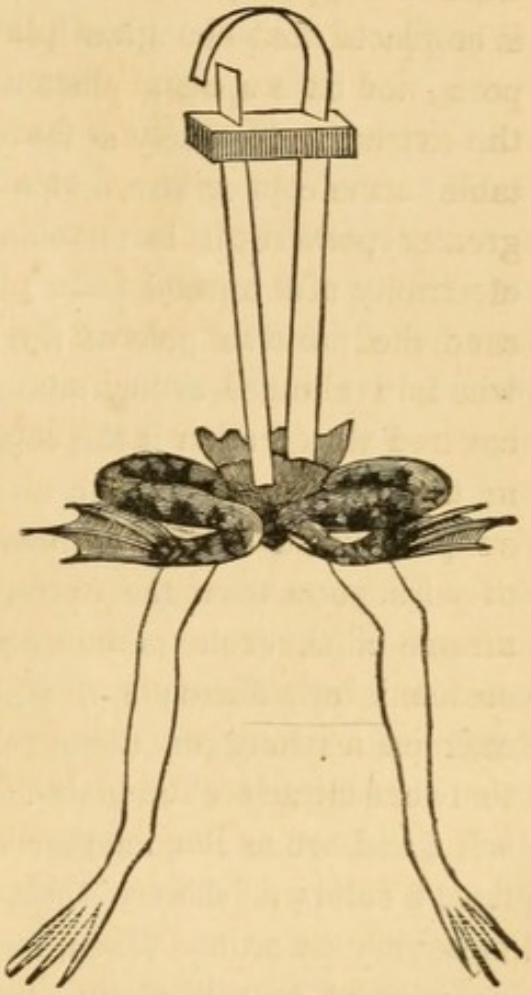


Fig. 3.

The form first given by Volta to the pile is that of a vertical column, formed of discs of copper and zinc, from $1\frac{1}{2}$ to $2\frac{1}{2}$ inches in diameter, arranged as follows. The base of the column is a copper disc, upon which is placed a zinc disc; the composition of these two superposed discs forms a pair. Over this first pair a second similar pair is placed, care being taken that the copper is always below the zinc: the second pair is separated from the first by a circular piece of cloth or pasteboard, well moistened with water, or, which is better, with salt water, or acid water. Upon the second pair is placed a third, arranged in the same manner, and separated also by a moistened circular piece,

similar to that which preceded. In this manner a greater or less number of pairs are superposed one upon another, care being taken to retain them in their position by means of vertical rods of brass; if the precaution has been taken to insulate the pile by resting its base upon a plate of glass, it is found to be charged with negative electricity at its lower extremity, where it is terminated by the copper disc, and with positive electricity at its upper extremity, where it is terminated by the disc of zinc. These extremities are termed *poles;* the former the negative, and the latter the positive pole of the pile. Had the two metals been placed in another order, namely, had we commenced with the zinc, and placed upon it the copper disc, then the moistened cloth, and then again zinc, copper, and moist cloth, and so on, the positive pole would have been below, and the negative above. Two wires lead, one from the extreme copper, and the other from the extreme zinc, each communicating the electricity of the pole whence it originates; and when they are brought together, a spark passes between them, resulting from the neutralization of the two contrary electricities. If these wires are held one in each hand, when the number of pairs in the pile is sufficiently great, a series of shocks is felt, the sensation of which is sometimes very painful. When, instead of the human body, a very fine wire of iron, platinum, or any other metal, an inch or two in length, is employed to connect the two conductors, the neutralization of the two kinds of electricities is brought about through this wire, which rises in temperature and becomes incandescent. The length and diameter of the wire that can be heated are greater in proportion as the pile is more powerful. The most remarkable circumstance is, that the incandescent condition of the wire is permanent, because the neutralization of the two electricities is continued, the pile liberating them at each of its poles, in proportion and as rapidly as they are neutralized.

The form of a column, which Volta gave to his apparatus, was soon abandoned; it had many inconveniences, among the principal of which was the rapid drying up of the pieces of moistened cloth or pasteboard, whence arose a great diminution in the power of the pile.

To remedy this, it was proposed to substitute for these discs a bed of liquid, which necessarily required that what was a vertical pile should be rendered horizontal, and that each pair should then be composed, not of two circular discs, but of two rectangular plates in contact, and should be cemented one after the other in the grooves of a wooden trough, so as to leave between them vacant spaces, or cells, to be filled with liquid. This mode of construction, which was first pointed out by Cruikshanks, was adopted in establishing the great voltaic pile that was given to the Polytechnic School by the Emperor Napoleon, and with which MM. Gay-Lussac and Thénard made their experiments in 1808.

This form, however, proved unsatisfactory, and a return was made to a form that Volta had previously pointed out, in constructing his pile called *Couronne de Tasses*, — a pile in which the liquids are placed in vessels independent of the metal plates, and the sides of which, of glass, porcelain, or pipe-clay, allow them to be placed one after the other, and even in contact, without any communication arising between the liquid strata contained in them. With this in view, either a series of ordinary cylindrical glasses is employed, as in the *couronne de tasses* pile, or a porcelain trough, divided off, by partitions made with the trough, into a certain number of cells (generally ten), in equal and successive compartments of a rectangular form, into each of which the liquid is poured, care being taken not to fill them completely. The liquids are thus totally insulated from each other. With regard to the metal plates, as it was very quickly perceived that it was not necessary for the zinc and copper to be in contact throughout their surface, but that it sufficed for them to be so in certain points only, it was enough to plunge into the liquid of each compartment a zinc and a copper plate, and to make a communication by means of a small plate of copper, in the form of an arc, between the zinc of one compartment and the copper of the following one, and so on. This is done in the *couronne de tasses*. By this method the liquid stratum, as in the primitive pile, occurs between the zinc on the one hand, and the copper on the other; and the zinc and copper that are plunged into the same

liquid are never in metallic contact, which is as it should be. But to facilitate operations, care is taken in the trough piles to fix the pairs, which are the same in number as the compartments of the trough, to a rod of glass or varnished wood: they are held there by means of the copper arc, which forms the means of communication between the metals of the pair. The metal plates must be arranged one after the other in the proper order, and at such distances that, by holding in the hands the two ends of the rod to which they are fixed, they may be plunged all together into their respective troughs, and so that each occupies the place prescribed for it; i. e. so that there shall be found in the same liquid only the zinc of the preceding couple, and the copper of the following one, or reciprocally.

Daniell's, Grove's, and Smee's Constant Batteries.

The piles, or batteries, that we have been describing, and which were for a long time exclusively used, all possess one inconvenience, which is, that after a short time they lose their power; and, in general, their force is very variable during the progress of the same experiment, even when the duration does not extend beyond ten or fifteen minutes. This gradual, and, in the majority of cases, rapid diminution, is due to several causes, the principal of which is that the liquid placed between the pairs is decomposed when the poles of the piles are connected by a conductor, in the same manner as the liquid is decomposed that is interposed between the poles themselves; it hence results that the copper of each pair is covered with hydrogen, and even with oxide of zinc, arising from the decomposition of the water, and from that of the sulphate of zinc which is constantly formed from the action of the sulphuric acid upon the zinc. This deposit, by altering the surface of the copper, and rendering it almost similar to that of zinc, which latter, on its own part, is very rapidly oxidized, destroys in great part one of the conditions essential in the construction of a battery, the heterogeneity of the two metals; and consequently very notably reduces its power. Hence it was necessary to clean the plates of a pile every time it was used, before putting it in action again.

In 1836, Daniell, in order to avoid the inconvenience that we have just pointed out, conceived the idea of plunging the copper of each pair into a different liquid from that in which the zinc was plunged; he placed the former of these metals in a solution of sulphate of copper, and the latter in a diluted solution of water and sulphuric acid, or in a solution of sea-salt. The difficulty was to separate these two liquids by a substance which, while preventing the mixture, should not alter the conductibility of the heterogeneous liquid conductor interposed between the plates of the pairs. A metal diaphragm could not be thought of, for this would have violated one of the fundamental conditions of the construction of the battery, which requires that there should be a conductor totally moist between the pairs. Daniell had recourse to an organic substance, according to the method which Becquérel had first pointed out; and he made some diaphragms with bladder, with stout paper, with very thin wood, or with very closely woven linen cloth. Experience has given the preference to diaphragms of thin wood, — lime-tree wood, for example, — and those of bladder; but care must be taken to preserve them from flaws, or in general from all solution of continuity. With this in view, it is necessary to keep the wooden diaphragms constantly in water when they are not in use, and to place those made of bladder under protection from the attacks of insects and from the contact of every foreign body. The difficulty experienced in taking these precautions has induced several philosophers to adopt, as indeed Daniell himself did, diaphragms of unglazed, porous earth; but the battery loses much of its power, especially for calorific and chemical effects. It answers, however, an excellent purpose in connection with the electric telegraph, and is very extensively used upon all lines in this country, as we shall see further on. Daniell gave the cylindrical form to the pairs of his battery, on account of the greater facility of procuring diaphragms of this form. In his battery (Fig. 4) a hollow copper cylinder is plunged into a glass vessel filled with a solution of sulphate of copper; in the interior of the cylinder is placed either a bag made of bladder, or a wooden tube, or a hollow cylinder of porous earth (the latter is the universal form

used at present), which is filled with either acidulated or saline water; finally, in this water is plunged a zinc cylinder, which is in metallic communication with the copper of the succeeding pairs by means of a wire attached to a screw-cup upon the copper cylinder. The zinc cylinder may be solid or hollow; in the latter case it is cast with a small projection at the top, to which is attached a screw-cup similar to the one upon the copper cylinder. Some prefer the latter mode, because the zinc presents more points of contact with the liquid; but it is consumed more rapidly. We prefer, however, a solid cylinder, considerably larger in diameter at the middle than at either end, on account of the greater action which takes place in the centre of the cup than at either extremity. This mode was first used by Mr. J. B. Stearns, Superintendent of the Fire Alarm Telegraph in Boston, who arrived at this result after a large number of observations upon the various batteries in use upon the circuits of his districts.

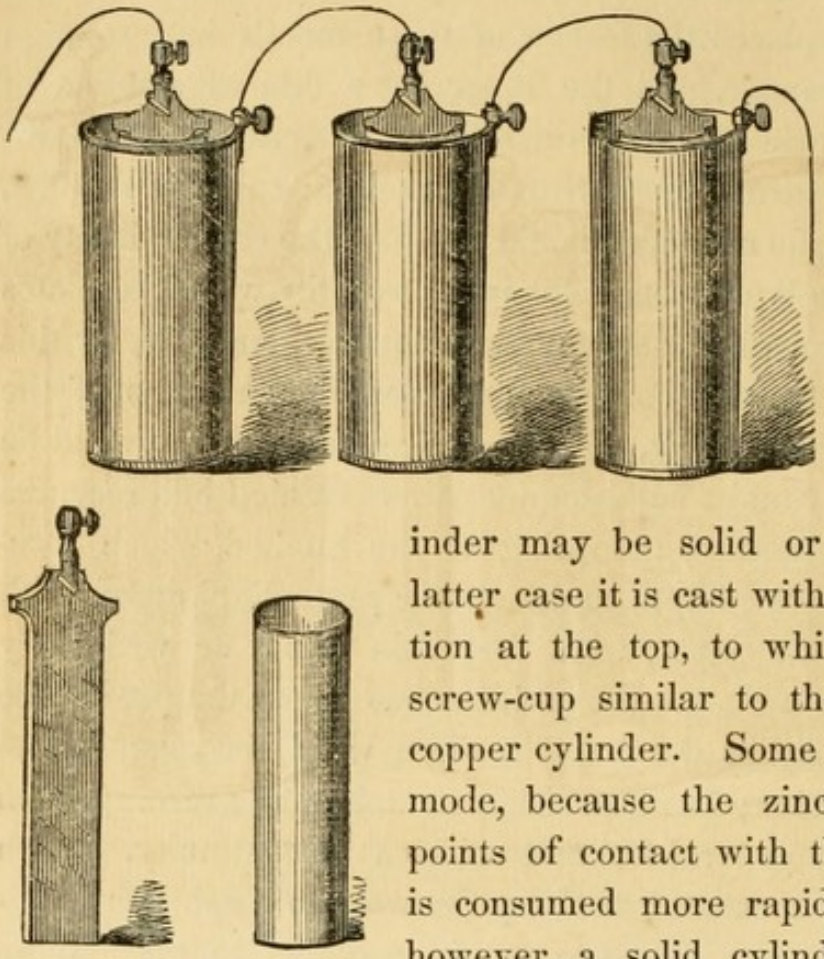


Fig. 4.

The Daniell battery is used upon nearly all telegraph lines in the United States for a local current. They have been substituted for the Grove, which was formerly exclusively used for local as well as main circuits. They are much superior to the Grove in that they require less attention, are not offensive in smell nor injurious to health, and furnish a steady, reliable current. Two cups are generally sufficient to work a Morse register or sounder. These batteries have also been introduced with good success

upon some lines for working main circuits. The following form (Fig. 5) was designed by Messrs. C. T. & J. N. Chester, of New

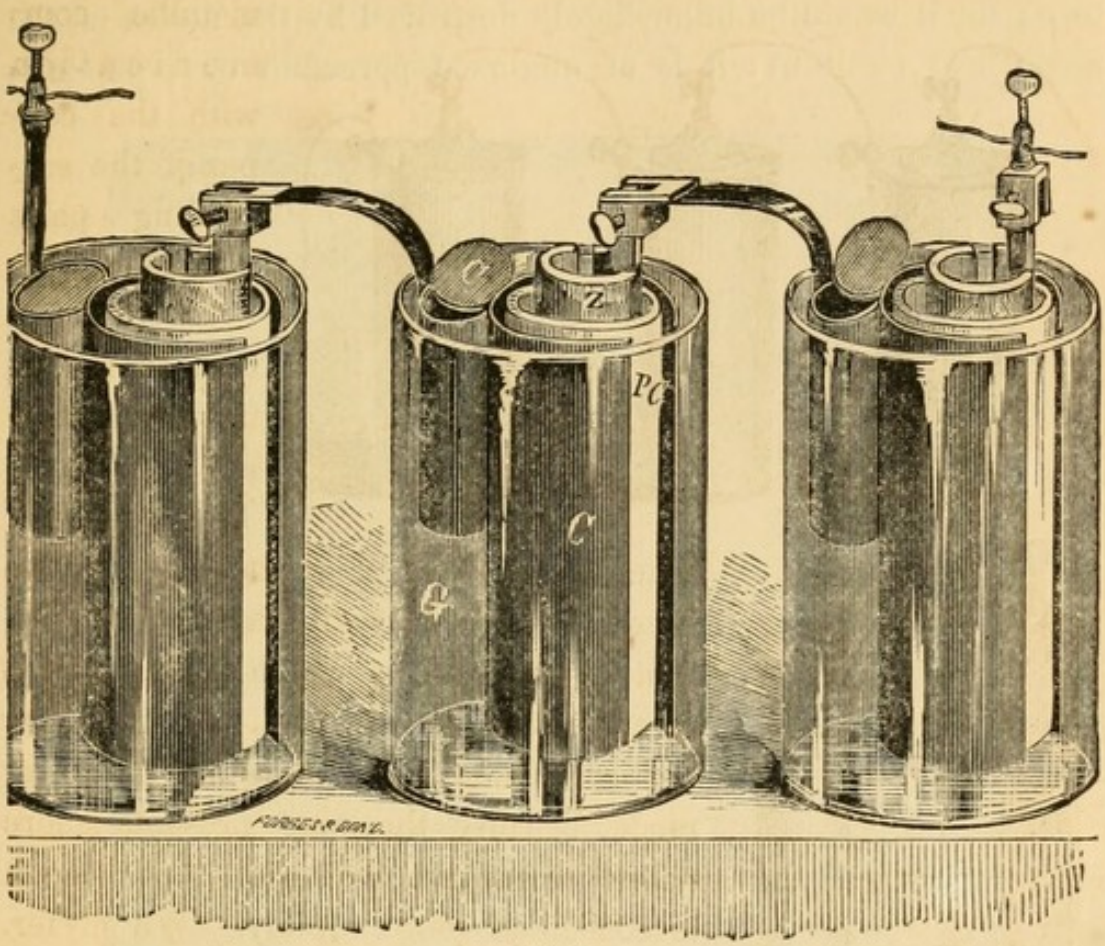


Fig. 5.

York, especially for local circuits upon telegraph lines. *Z* is a cylinder of zinc; *PC*, porous, or unglazed earthen cup; *C*, copper cell, with perforated copper chamber attached; *G*, glass tumbler. This form of the Daniell battery, and that represented in Fig. 4, designed by Mr. Thomas Hall, of Boston, are most generally preferred, although many others have been devised by candidates anxious to obtain the fame of a new invention, and who have accordingly varied the form of the battery in a diversity of ways, without any real advantage.

A second constant pile, and one in which two different liquids are also employed, is that of Grove. In this battery the zinc is amalgamated, and is plunged into sulphuric acid diluted with ten or twenty times its volume of water. The other metal is platinum, and not copper, and is plunged into nitric acid, either pure of 40°, or diluted with half its volume of water, or mixed with

one fourth concentrated sulphuric acid. The diaphragm by which the two liquids are separated is not in this case of an organic nature; for it would be immediately destroyed by the action of the nitric acid (Fig. 6): it is of unglazed porcelain or pipe-clay;

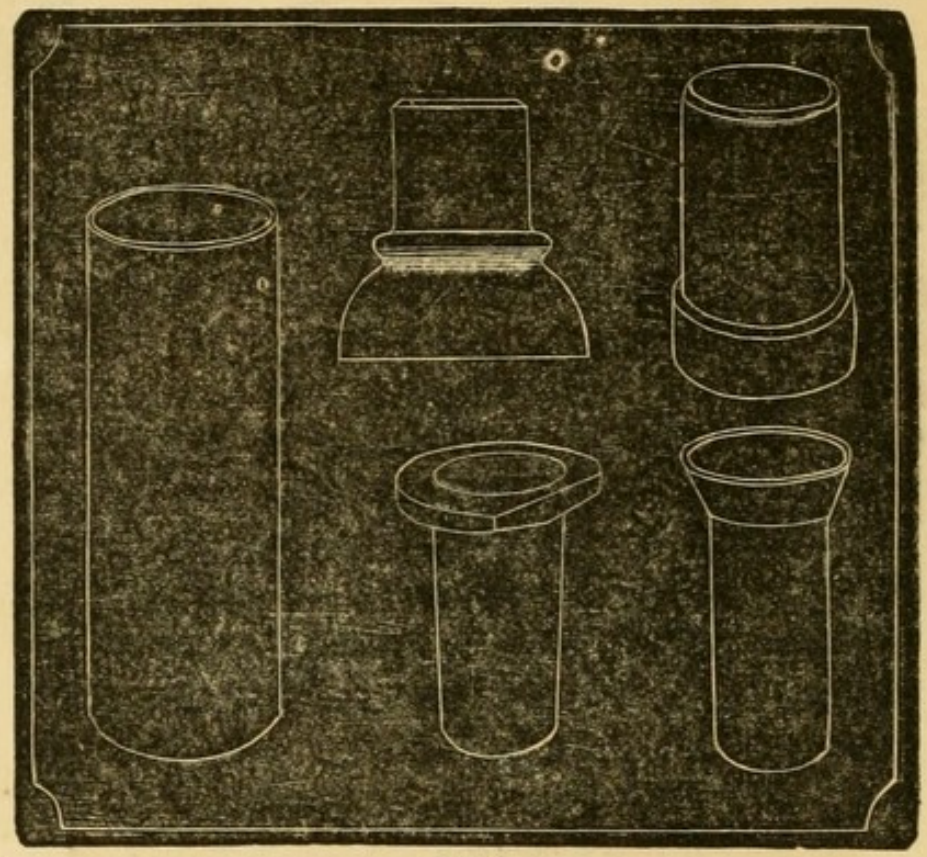


Fig. 6.

in this state these substances have the advantage of being sufficiently porous to permit communication between the liquids, and at the same time of entirely preventing their mixture.

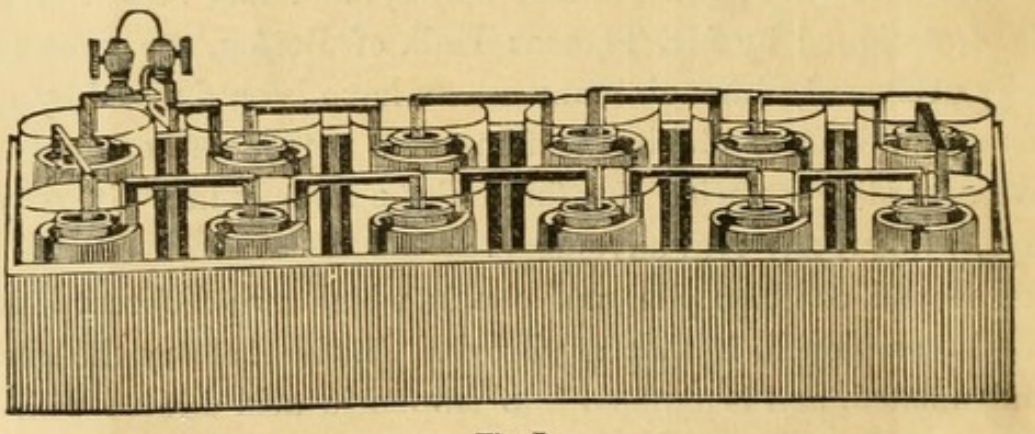


Fig. 7.

In Grove's battery (Fig. 7) the pairs are generally of a cylindrical form; they are cylinders of zinc (Fig. 8) and plates of

platinum plunged into cups of porcelain or glass. Each cell contains dilute sulphuric acid, in which the zinc is immersed, and a small cell of porous earth filled within with nitric acid. In this acid is placed the platinum plate, in metallic contact with the zinc of the succeeding or following cell. This contact is established between the arm of the zinc cylinder (Fig. 9) and the platinum plate, which are soldered together. Experiment has shown that the power of these batteries is much increased by giving to the zinc plates a very large surface in respect to the platinum plates. With

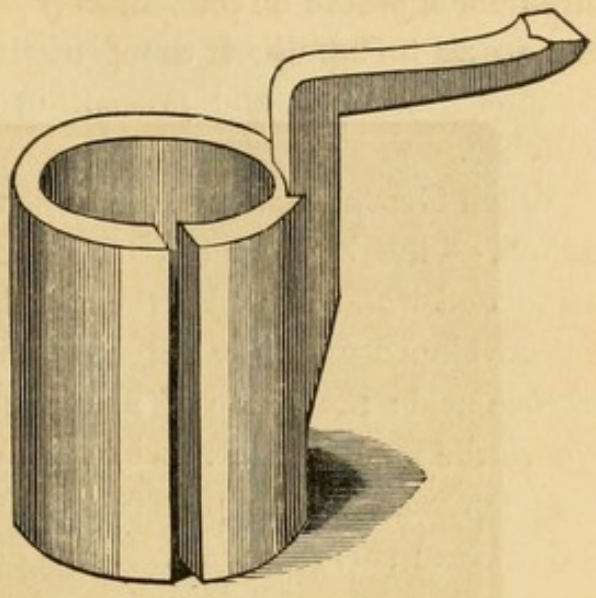


Fig. 8.

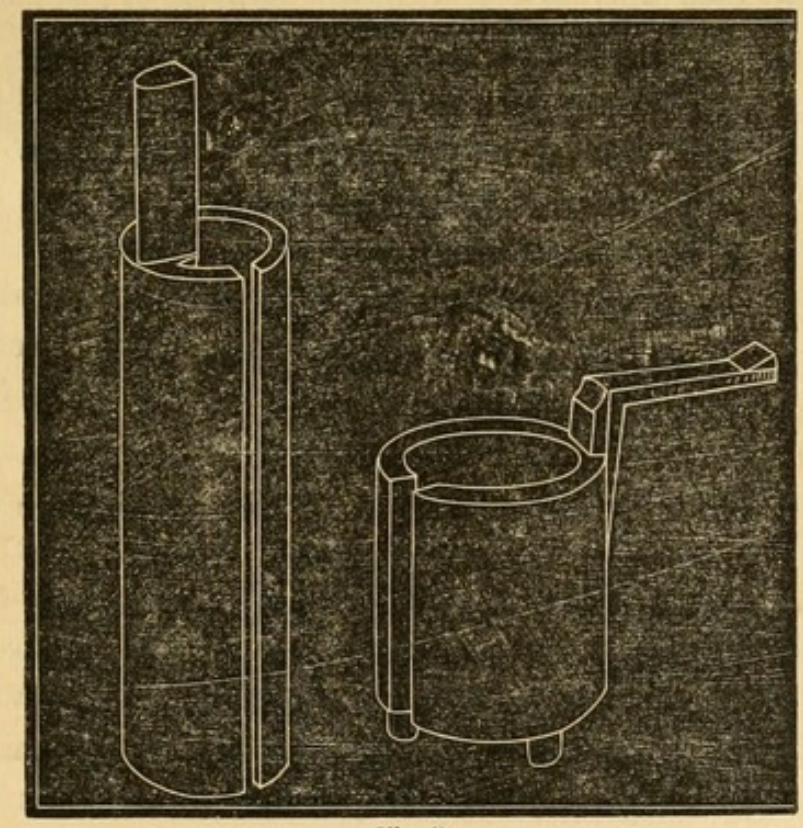


Fig 9.

this in view, the zinc cylinder is made hollow, and encloses

the porous unglazed earthen cylinder, into which passes a thin strip of platinum, one inch in width by three in length; the arm of the zinc of the preceding cup projects over the porous cylinder so as to admit of the platinum strip occupying a vertical position in the cell, and presenting a parallel surface to the zinc cylinder.

When Grove's battery is in action, — that is, when its poles are united, — the hydrogen arising from the decomposition of the acidulated water in which the metals of the pairs are plunged is not developed upon the platinum, but changes the nitric acid into nitrous acid; the oxide of zinc remains, as before, in the liquid, where the zinc itself is, and does not penetrate through the porous partition to the platinum. The latter then retains a perfectly clean surface; and it is this circumstance which contributes essentially to this pile's maintaining for a greater or less length of time, according to the use that is made of it, that power which is at once so constant and so energetic, and which renders it so valuable in practice. The nitric acid, however, as it changes into nitrous acid by the action of the hydrogen, passes into reddish-brown, and then into green, and finally acquires a temperature so elevated that it enters into ebullition; in this case, it is necessary immediately to arrest the action of the pile.

Fig. 10 represents the platina terminal to a Grove series, — heavy metallic base and binding screw attachment.

Bunsen's battery differs from Grove's only in that carbon supplies the place of platinum. This substitution arose essentially from the high price of platinum, which on this account is used in narrow strips, so thin that they are frequently torn. Bunsen's pile has also the cylindrical form of Daniell's; in fact, if in the latter a hollow cylinder of carbon be put in the place of the hollow copper cylinder, and pure or diluted nitric acid in place of the solution of sulphate of copper, and a cylinder of porous earth in place of the porous cylinder of organic matter in which are contained the diluted sulphuric acid and the cylinder of zinc, we obtain Bunsen's pile. Each carbon cylinder carries at its upper part a collar of copper, furnished with an appendix, which is placed in contact, by means of pincers, with a similar appendix

carried by each zinc cylinder; care, however, must be taken that the carbon cylinder is sufficiently high, that the part which car-

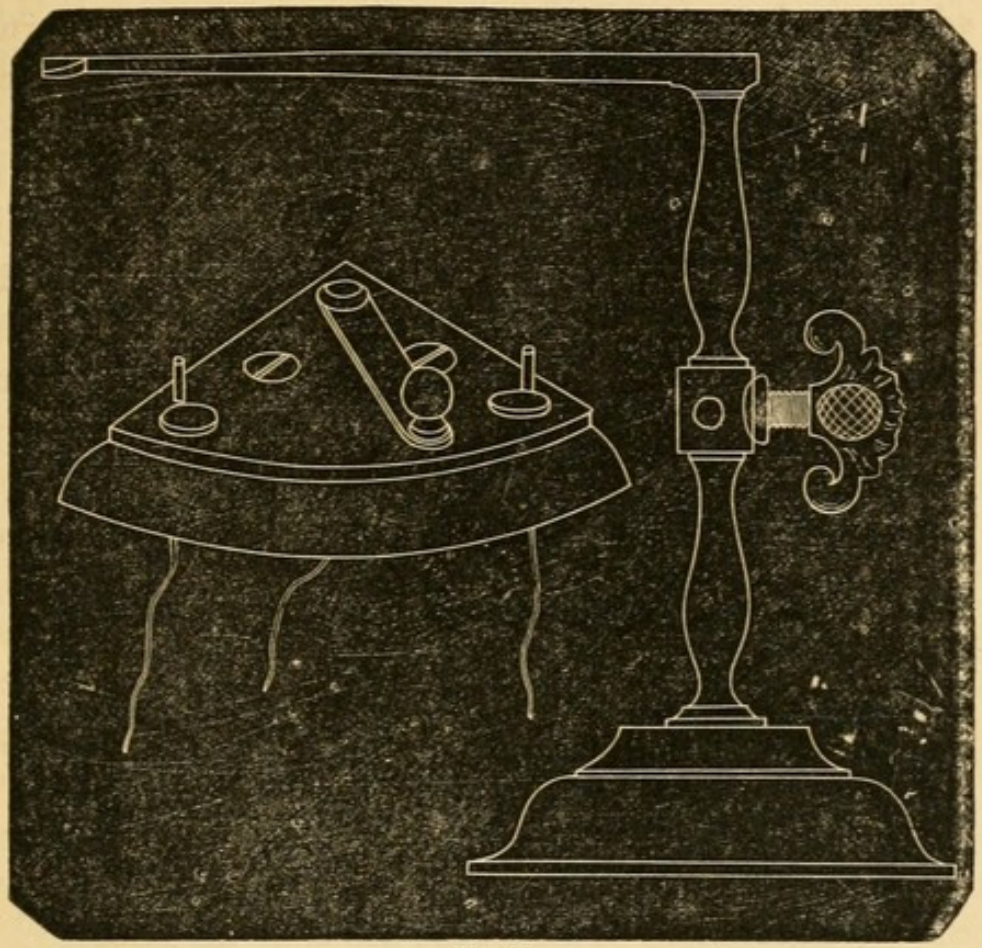


Fig. 10.

ries the copper ring shall rise above the glass vessel, and consequently shall in no way be in contact with the nitric acid. However, as the charcoal is very porous, the capillarity causes the acid finally to attain to the top of the cylinder, and to alter interiorly the copper ring. Therefore, every time this pile is used, it is necessary to move these rings and wash and carefully clean them.

A more convenient arrangement, inasmuch as it is free from the kind of inconvenience that we have just pointed out, is that contrived by M. Bonijal, who employs, instead of hollow cylinders, solid cylinders of carbon, in the top of which is thrust a stout copper rod, bent so as to be put into communication with a screw cup upon the zinc. The top of the carbon cylinder around the place in which the copper rod is inserted is covered with a

coating made of wax, prepared so as to penetrate to a sufficient depth into the pores of the portion of the carbon which it covers, and to which it adheres strongly. The consequence of this is that the nitric acid cannot ascend as far as the copper rod. It is evident that in this pile the amalgamated zinc is outside the carbon; it is a hollow cylinder plunged into the glass vessel that is filled with diluted sulphuric acid; the porous tube is placed in the interior of the zinc cylinder, and itself receives the carbon and the nitric acid into which the latter must be plunged.

The Smee battery (Fig. 11), invented by Alfred Smee, of London, has been used somewhat extensively upon telegraph

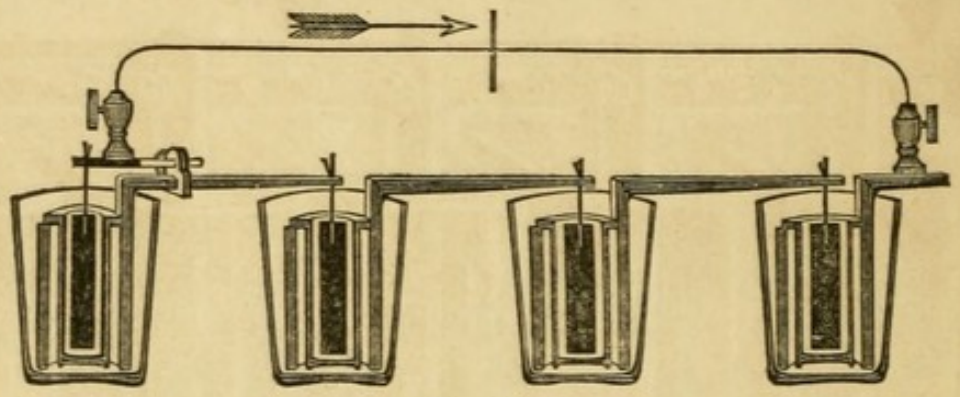


Fig. 11.

lines in this country during the past five years, having been designed, however, more particularly for use in electro-metallurgy.

This battery was made upon noticing the property which rough surfaces possess of evolving the hydrogen, and smooth surfaces of favoring its adhesion. Thus, whatever metal is used for a negative plate is roughened, either by a corrosive acid or mechanically, by rubbing the surface with sand-paper. The liquid generally used to charge this battery is one part sulphuric acid to ten of water. The form of the battery used for telegraphic purposes consists of a strip of platinum, one inch wide by ten in length, fastened to a beam of wood, upon the opposite side of which is a plate of zinc mercurialized, and both plunged into a glass tumbler. In arranging a series of cells, the zinc of the one cup is attached to the platinum of the next.

The electro-motive force of this battery is about half that of Daniell, and one fourth that of Grove.

Chester's telegraph battery for main circuit is represented in Fig. 12. *A* is an insulated wood-piece; *B*, brass clamps; *Z*,

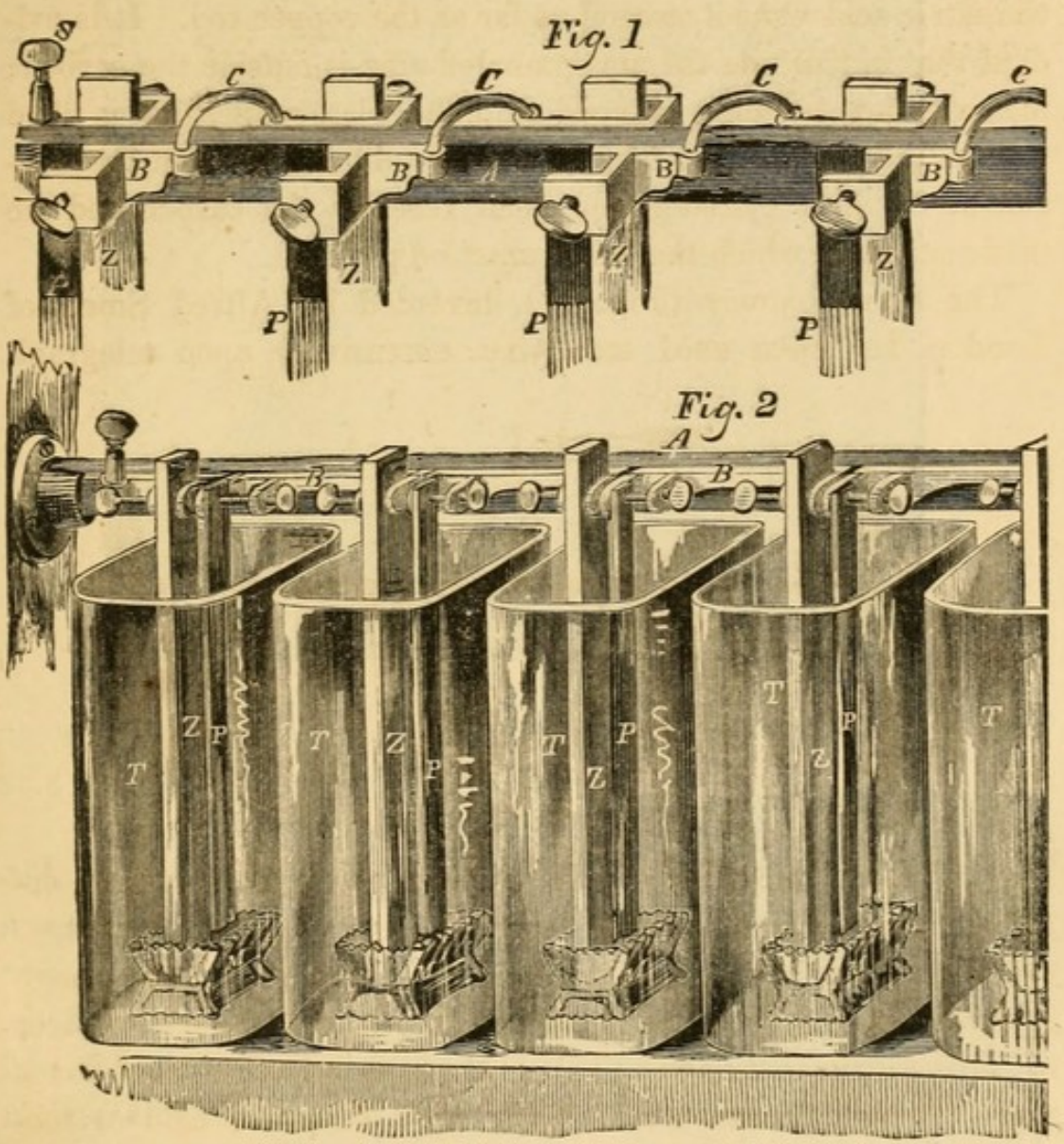


Fig. 12.

zinc plates; *P*, platinized plates; *T*, tumblers. In battery Fig. 1, the wooden pieces rest upon the glasses. In battery Fig. 2, they rest on iron brackets against supports.

This battery is based upon the principles of the Smee pile, but is an improvement in form and in the mode of connecting the cells. They have been in extensive use for about five years, and are much liked for their constancy and cleanliness.

Fig. 13 shows another method of connecting the plates, dis-

pensing entirely with wood-work. The uprights shown are of

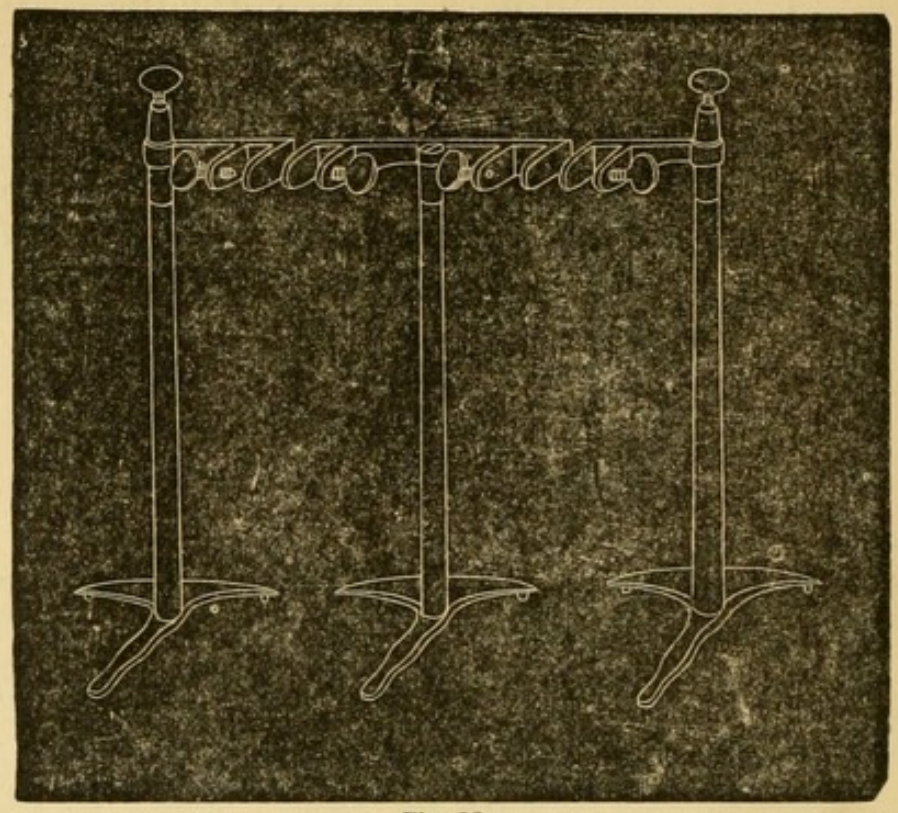


Fig. 13

cast iron, insulated at the top from the plate clamps with Protean rubber. Fig. 14 represents zinc plates for the above battery.

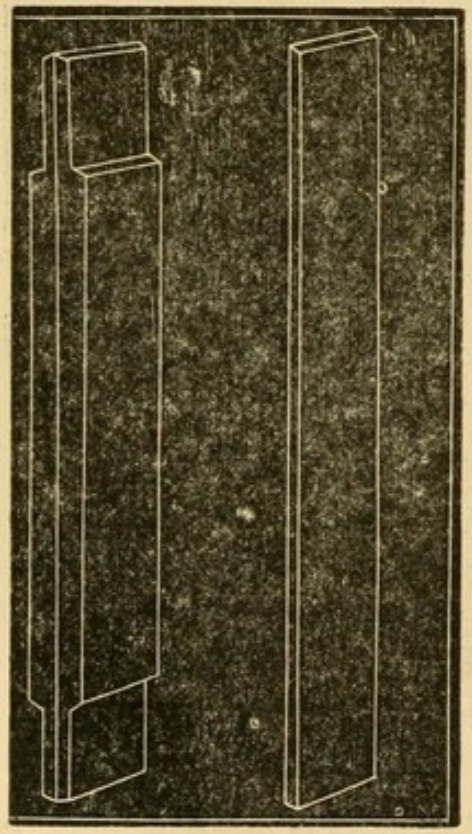


Fig. 14.

Fig 15 represents a *pocket battery* in its case, which occupies a space only eight inches long, five inches high, and two inches deep. It is charged in twenty seconds, and discharged in one. It will work a line five miles long with ease for ten hours, and is invaluable in making tests in places where the transportation and care of a large battery would be troublesome.

Another source whence currents of electricity may be obtained is to be found in certain animals. In the bodies of certain fishes a very fertile source of electricity is found,

independently of friction. This power is often very intense, so much so as to deprive smaller animals of their life, and to stun

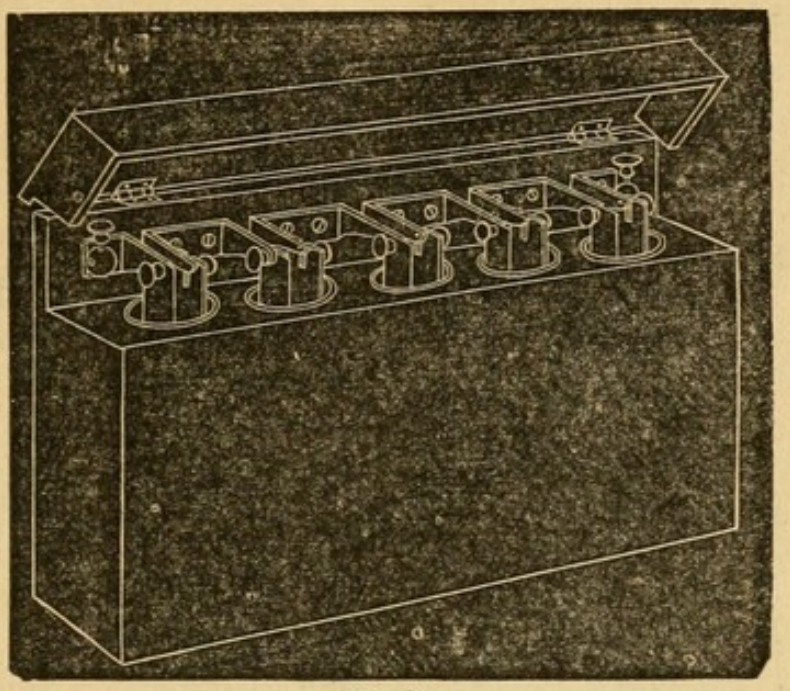


Fig. 15.

or render powerless for the time being even larger animals, such as the horse.

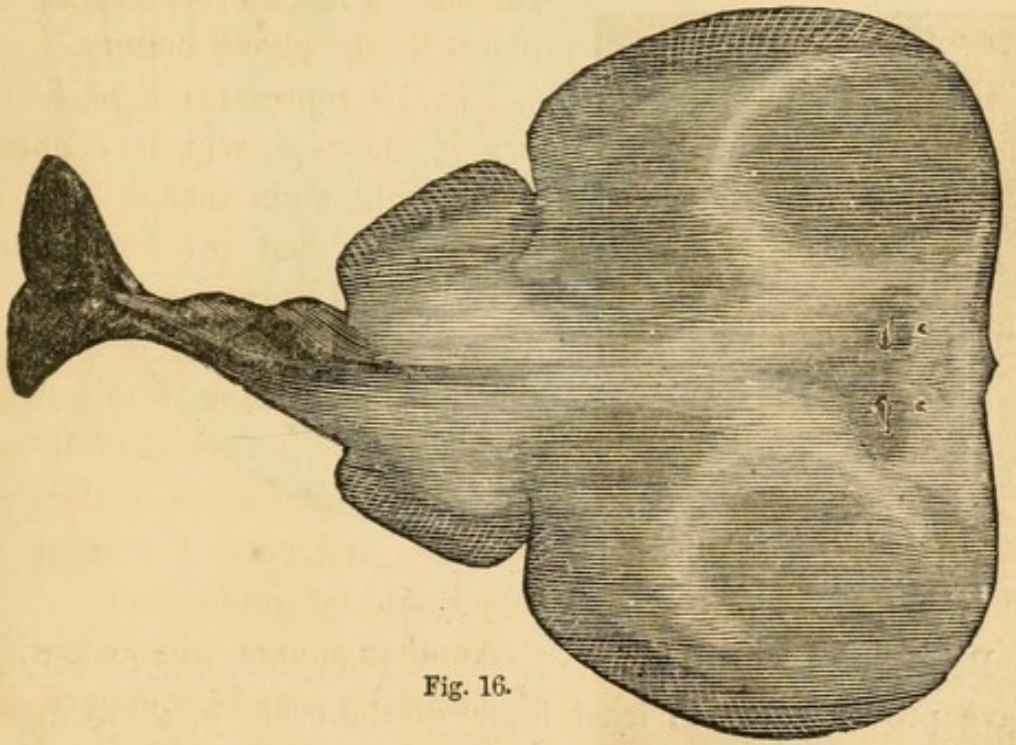


Fig. 16.

Among the most remarkable of this class of animals may be enumerated the *Raia torpedo* (Fig. 16), the *Gymnotus electricus*,

or electric eel (Fig. 17), the *Silurus electricus*, the *Trichiurus electricus*, and the *Tetraodon electricus*.

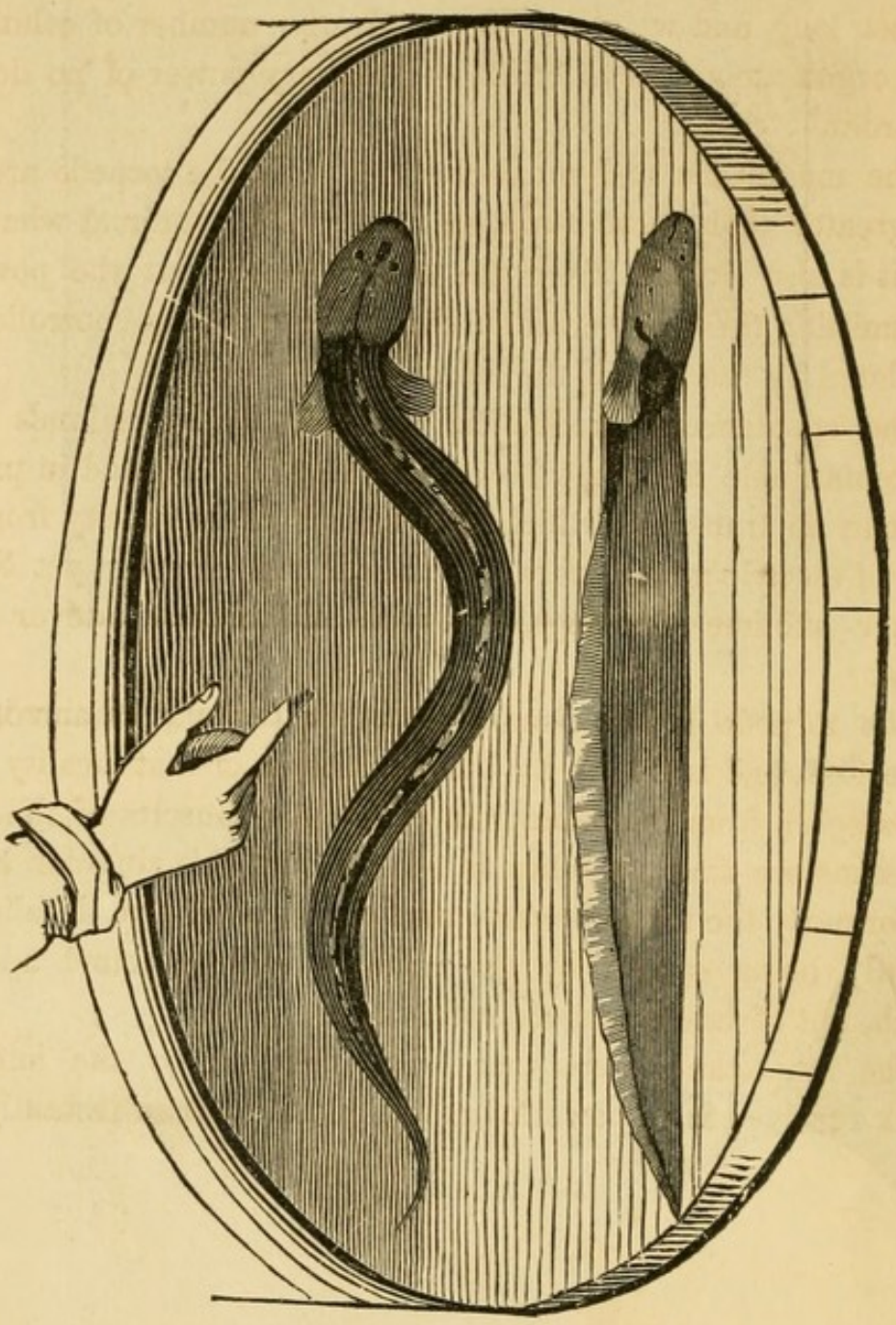


Fig. 17.

Recent experiments made by MM. Humboldt and Gay-Lussac have proved that the least injury to the brain of these animals destroys at once their power of producing these shocks.

In 1773, the celebrated Hunter published the anatomical structure of the torpedo, showing the position of the electric organs.

In a fish eighteen inches long, it was found that the number of columns composing each organ amounted to 470.

In a very large torpedo, which was found on the British coast, 4½ feet long, and weighing 73 pounds, the number of columns in each organ amounted to 1,182, — a battery power of no despicable order.

The magnitude and number of nerves in the torpedo are very far greater than those supplied to any other animal whatever; and it is also evident from the experiments, that the power of transmitting these powerful shocks of electricity is controlled and regulated by the will of the animal.

The spontaneous production of electricity by animals shows the remarkable fact, that, however difficult it is found in practice for man to transmit, artificially, currents of electricity from any kind of electric apparatus wholly submersed in water, yet Nature, in her sublime workings, finds no difficulty whatever in so doing.

The torpedo is occasionally found in the waters surrounding Cape Cod, and is known by the inhabitants of that locality as the *Cramp-fish*, from the manner in which the muscles of the hands and arms are cramped when in contact with this singular animal.

Formerly the torpedo was quite common in that locality, frequently being caught by the hook, as well as found upon the beach, but of late it is more rarely seen.

The inhabitants state that, when touched by the hand, the shock received is so powerful as to prostrate a man instantly.

CHAPTER III.

MAGNETISM.

THERE exists in nature a mineral named *Loadstone*, known from all antiquity, which possesses the property of attracting particles of iron which are placed near it, in certain points of its surface which are called *poles*. This mineral is a compound of iron and oxygen. The ancients called it μάγνης, from the city of Magnesia in Lydia, where it was found in abundance; hence arose the name of *magnetism* for that part of physics which treats of the phenomena of which it is the origin, and the name of *magnetic* for the phenomena themselves.

One of the most remarkable properties of the loadstone is that by virtue of which it communicates its property of attracting iron to a needle or a steel bar (Fig. 18) which is rubbed several times consecutively in the same direction against one of its poles. This needle or bar thus becomes capable of attracting towards its extremities a considerable quantity of filings or pieces of iron. The needle is then said to be magnetized, and its poles are at its extremities. If the steel bar exceed six or eight inches in length, we sometimes find two, or even four, poles beside those at its ends.

Fig. 18.

If, after having magnetized a steel needle, we suspend it by its centre of gravity to a thread, or place it on a point by means of a cap, it is found to take a determinate direction towards a point of the horizon which is very nearly north and south (Fig. 19). The point of the needle that is directed towards the north has been termed the *north pole*, and that which is directed towards the south, the *south pole*.

For a long time philosophers were struck with the analogy

that seemed to exist between electric and magnetic phenomena: two magnetisms, as there are two electricities; attraction and repulsion exercised between the contrary magnetisms as between the electricities, according to similar laws.

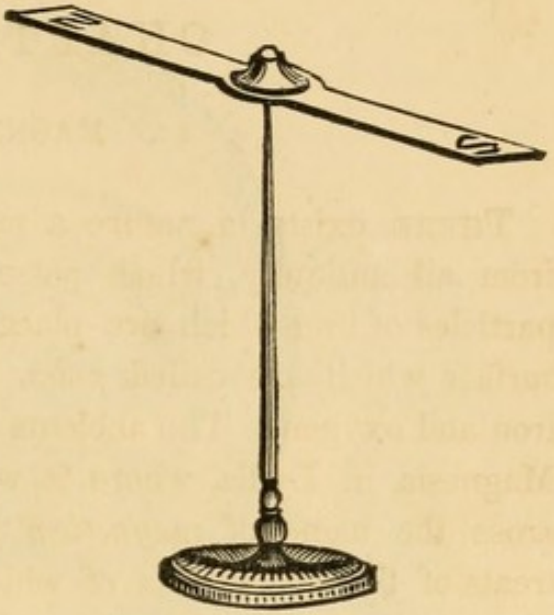


Fig. 19.

In 1820, Oersted, a Danish philosopher, succeeded in discovering the relation between magnetism and electricity. Electricity acts upon a magnet; and a magnet in its turn acts upon electricity; but only when the electricity is in motion, that is to say, in the condition that we term *dynamic;* there is no action when the electricity is in the *static* or *tension* state.

The following is Oersted's fundamental experiment: —

Unite the two poles of a battery by a wire. Place above or below this wire a magnetized needle, freely suspended, and parallel to its direction (Fig. 20). The needle immediately suffers a deviation, which is the more considerable as the voltaic pile is the more powerful; and it tends to place itself perpendicularly to the conjunctive wire, a position which it succeeds in obtaining when the electricity developed by the pile is very strong (Fig. 21). The direction of the

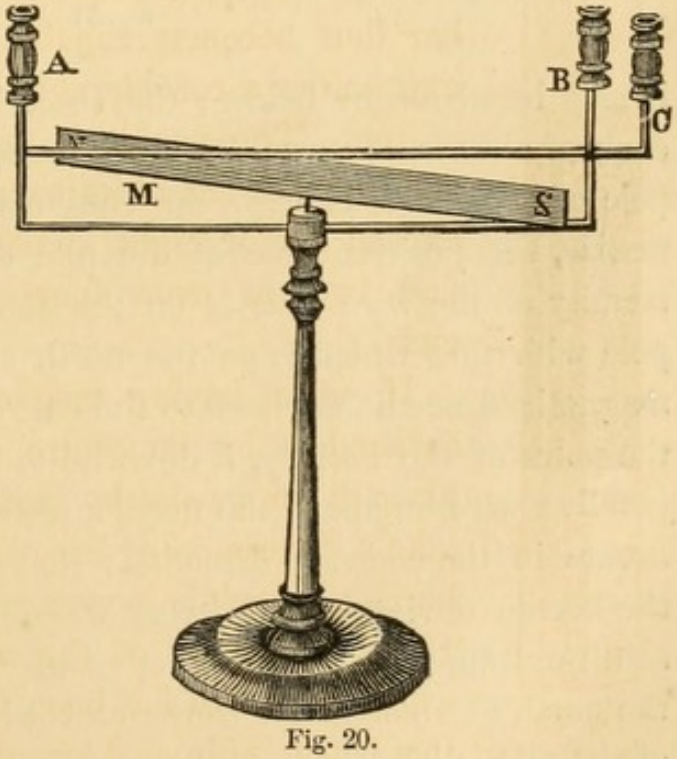


Fig. 20.

deviation depends upon two circumstances: the first is the position of the conjunctive wire in relation to the magnetized needle, —

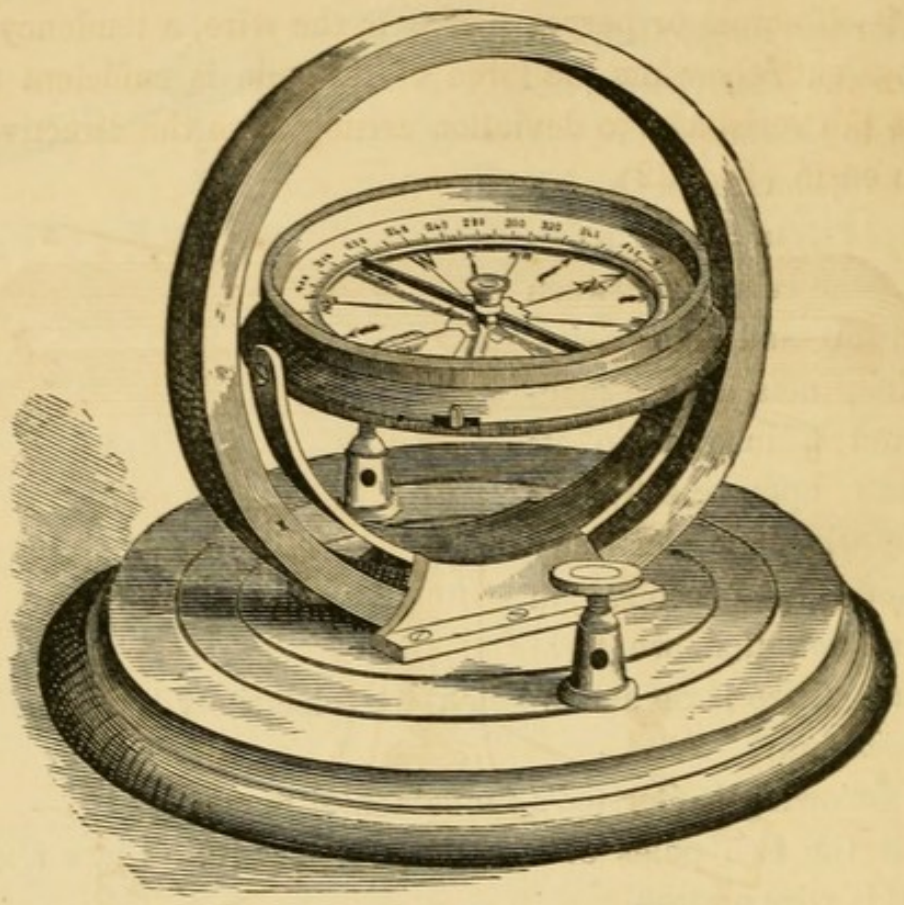


Fig. 21.

it may be above or below; the second is the communication of each of the two extremities of the conjunctive wire with either pole of the pile. Thus, if, the conjunctive wire being below the needle, the positive pole of the pile communicate with the extremity of the wire that is on the south side, and the negative pole with that which is on the north side, the north pole of the magnetized needle deviates to the east; if we change the place of the poles of the battery, it deviates to the west. But if the conjunctive wire be above the needle, instead of below, the deviation occurs in the contrary direction; that is to say, the north pole of the needle deviates to the west when the positive pole is at the south extremity of the conjunctive wire, and the negative pole at the north extremity, and to the east when the place of the poles of the pile is inverted.

If the conjunctive wire be not placed parallel to the needle, but

in such a manner that its direction forms, with that of the needle, either above or below it, a greater or less angle, the action is still the same; the needle in like manner manifests its tendency to place itself across or perpendicular to the wire, a tendency which it obeys entirely when the force of the pile is sufficient to surmount the resistance to deviation arising from the directive force of the earth (Fig. 22).

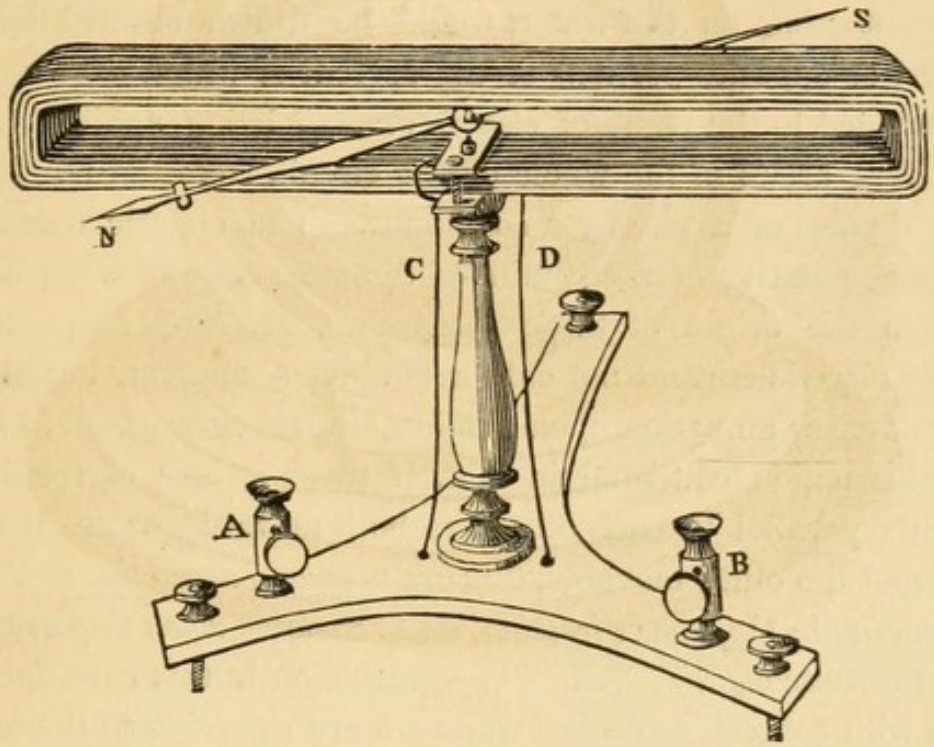


Fig. 22.

M. Ampère was not long in taking up this experiment, and deducing from it many theoretical and experimental consequences of the highest interest, which, under the name of *electro-dynamics*, have formed an entirely new part of physics. He observed that the action discovered by Oersted not only took place in the vicinity of the conjunctive wire, but that it was in like manner exercised by all parts of the conductor by which the two poles of a pile are united, and by the pile itself; but only when its poles communicate together.

Ampère drew some important conclusions from this experiment; namely, that the force, whatever it may be, that acts upon the magnetized needle, emanates equally from all parts of a *voltaic circuit*, designating by these words the pile and the whole of the conductors, whatever they may be, by which the poles are connected.

The second conclusion is, that the force in question is circulating; for how can we otherwise explain why it acts in contrary directions when it emanates from the two opposite or parallel portions of the circuit, this opposition being the only circumstance that establishes the conditions of the experiment? We may compare its action with that which a current of water would exercise, if circulating in an annular canal. In this case, small, light bodies, floating on the water, would be drawn onward by two parallel or opposite portions of the current of water. This analogy has led to the name of *electric current* being applied to the force that arises in the whole of the circuit, from the reunion of the two poles of a pile by a conductor. The electric current is the representative of the continued dynamic state of electricity.

From the origin of these researches, M. Ampère perceived that an electric current not only acts upon a magnet, but that it also exercises an action upon another electric current. He found that this action consisted in that, if two portions of rectilinear currents parallel to each other are both movable, or are the one fixed and the other movable, *they are mutually attractive when they are moving in the same direction, and repulsive when they are moving in a contrary direction.* The attraction in this case does not cease with contact, as occurs when we are referring to the attraction of electric bodies in static electricity; it remains so long as the current continues to traverse the conductors.

Immediately after Oersted's discovery, M. Arago showed that an electric current attracts iron filings (Fig. 23) and pro-

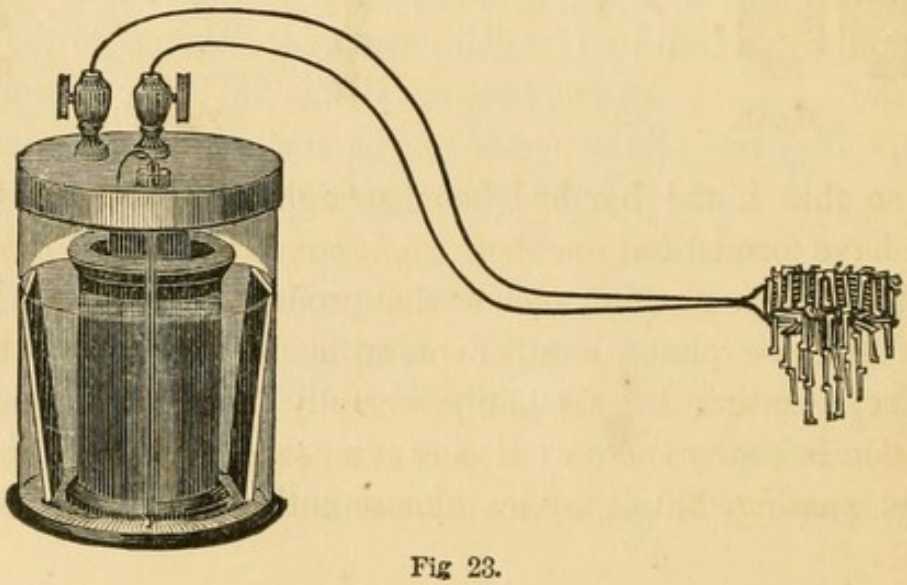


Fig 23.

duces magnetization just as a magnet would do. He always found that, in order to impress a more decided magnetism upon a steel needle, it was necessary to employ a conductor bent into a helix, within the axis of which he placed the needle, instead of using the rectilinear current (Fig. 24). In the experiment of the electric current upon iron filings, it was observed that, as soon as the current ceases to pass through the wire, the mass immediately falls. This phenomenon proves the susceptibility of the particles of iron to acquire a powerful magnetism under the influence of a current, and to lose it as soon as this influence ceases. Subsequently experiments were made by surrounding a bar of soft iron, bent into the form of a horse-shoe (Fig. 25), with copper wire covered with silk, and wound into a helix, care being taken that the helix of the second branch should be the continuation of the helix of the

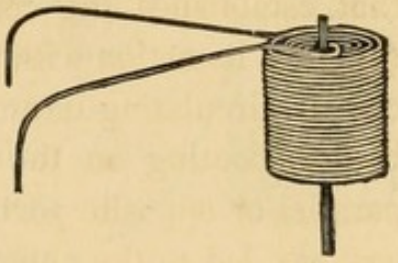


Fig. 24.

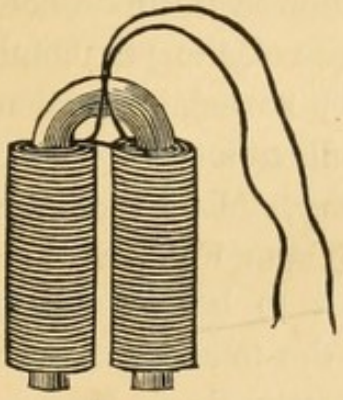


Fig. 25.

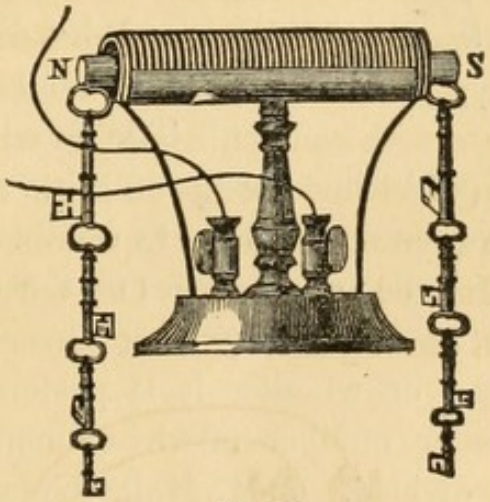


Fig. 26.

first; so that if the bar had been straightened, the two helices would have formed but one, both *right-handed*, or both *left-handed*. A feeble electric current, such as that produced by a single pair of copper and zinc plates, is sufficient, on being transmitted through the wire, to magnetize the bar powerfully (Fig. 26). The magnetization is instantaneous; it occurs as soon as the current commences passing, but it ceases almost entirely with the current.

It is so energetic that, with a suitable pile, we can make a bar of soft iron sustain a weight of a ton (Fig. 27). These temporary magnets are called *electro-magnets*, to distinguish them from permanent magnets of steel, and electric helices or solenoids. The discovery of electro-magnets has given a very great advance to magnetism, by furnishing us with a means of acquiring immense, and we may say almost unlimited, magnetic power. We shall see, farther on the immense advantages which mankind has derived from it in its application to electric telegraphy.

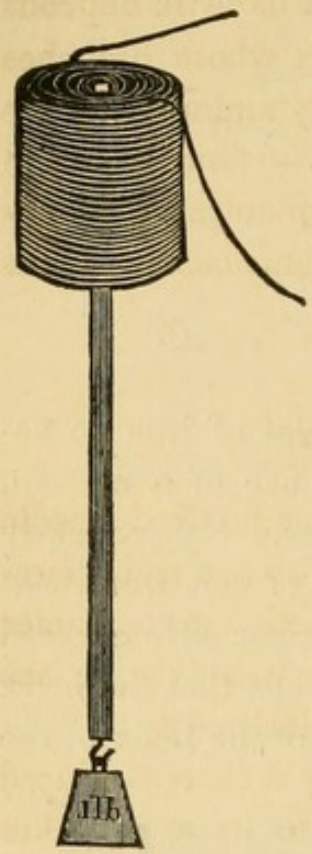


Fig. 27.

Many experiments have been made to determine the conditions most favorable for the development of powerful magnetism in electro-magnets. The length and diameter of the branches of the horse-shoe, the number of convolutions of the conducting wire, and its diameter, have successively been the subjects of numerous investigations. The force and nature of the pile employed for producing the current have also been varied, and researches have been made as to whether it is better that the wire coiled round the two branches of the electro-magnet should be continuous, so as to be traversed successively by the whole of the current; or whether it is preferable for it to be divided into a greater number of wires, among which the total current should be divided. MM. Moll, Liphaus, Quetelet, Prof. Henry, and many others, are still engaged upon this subject. With a current of a certain intensity, or developed by a certain pile, one kind of electro-magnet is preferable, whilst with another current, of a different intensity or origin, another kind would be preferable.

The quality of the iron exercises a great influence over the power of the electro-magnet; it must be as soft as possible: thus old iron, and especially Swedish iron, is preferable to all others.

It is not a bad plan to anneal it several times, in order to soften it, taking care to allow it to cool very slowly. The rapidity with which iron loses its magnetism, as soon as the current ceases, depends essentially upon its nature; however, it likewise depends upon the dimensions of the bar. Horse-shoes whose branches are long lose their magnetism much less easily and much more slowly than those whose branches are short, — four inches in length, for example. The presence of the armature at the extremities of the branches of an electro-magnet contributes towards its preserving its magnetism.

Electro-magnetic Galvanometers.

The action exercised by a current upon a magnetized needle has furnished a means for determining the existence and appreciating the force of an electric current. This action accompanies in all cases the presence of dynamic electricity, whatever be the nature of the circuit and the feebleness of the electricity.

We have seen that a conductor traversed by a current placed *above* a needle, but very near it, and parallel to its axis, makes this needle deviate to the east or to the west, according as it is moving in a direction from north to south, or from south to north. If it be *below*, it makes it deviate to the east when it is moving in the direction from south to north, and to the west when it is moving in the direction from north to south. It follows from this, that, if the conductor which transmits the current, passing first above the needle, be bent so as to return below, and so form two parallel branches between which the needle is suspended, the current that traverses the upper branch tends to make the needle deviate in the same direction as the current that traverses the lower one, precisely because it has in the former a contrary direction to what it has in the latter. By thus arranging the wire by which the current is transmitted, we obtain an action upon the needle twice as powerful as if, being kept rectilinear, instead of being bent, it had acted only above or below. But, instead of bending it once only, we may bend it twice, which doubles the effect; three times, which trebles it; — in a word, we

can cause the wire to make a very great number of convolutions, and can so multiply by a considerable quantity the action of the current upon the magnetized needle. A very feeble current, whose action would be scarcely visible if the wire by which it is transmitted made but one convolution, is able to exert a very marked action when the number of convolutions becomes considerable. This apparatus has therefore been named the *galvanometer-multiplier* (Fig. 28).

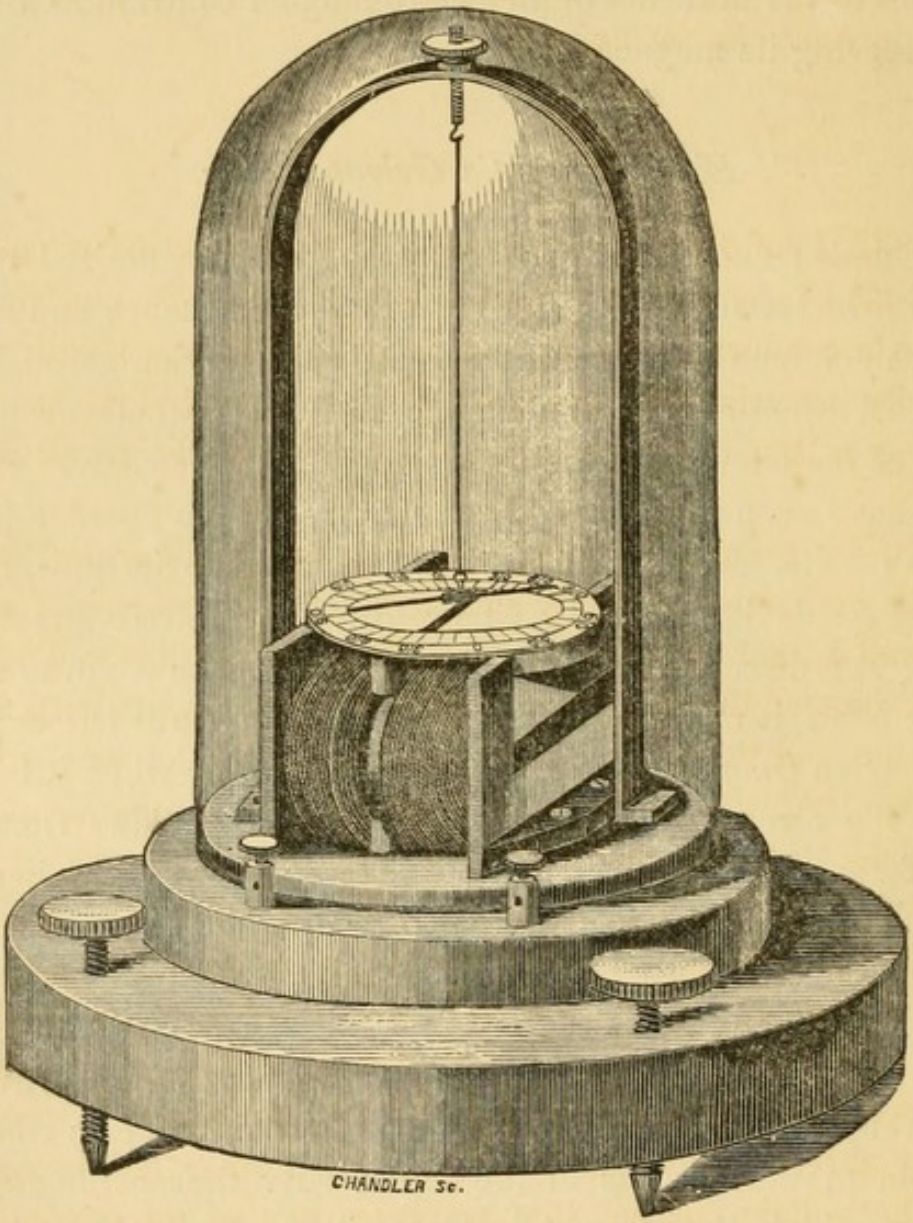


Fig. 28.

In constructing it we employ a copper wire covered with silk, which we coil round a wooden frame solidly fixed upon a stand, and which leaves between its lower and upper surface the

smallest possible space; it is in the interior of this space that the magnetized needle is suspended: the two ends of the wire, which are carefully deprived of the silk that covers them, serve to place the galvanometer, that is to say, the wire of the instrument, in the circuit. At the moment when a circuit is thus closed, providing that a current is propagated in it, we see the needle move; the direction in which it moves indicates the *direction* of the current, the *presence* of which is detected by this movement; and the number of degrees, or the size of the arc of deviation, enables us to appreciate its *intensity*.

Induced Currents.

In 1832, Prof. Faraday discovered that an electric current or a magnet is able by induction to develop at a distance electric currents in a conducting wire; just as a body charged with static electricity electrizes an insulated conductor by induction. The following is the mode by which this remarkable result is obtained.

We wind round a wooden cylinder two silk-covered wires, so as to make two perfectly similar helices, the spirals of which are parallel, and as near to each other as possible. The two ends of one of the wires are made to communicate with a galvanometer, and the two ends of the other with the two poles of a battery. At the moment when this latter communication is established, the first having been established previously, the needle of the galvanometer is seen to deviate; but this deviation immediately ceases, even though the current of the battery continues to circulate. As soon as this current is interrupted, the needle of the galvanometer a second time experiences a sudden and more permanent deviation; but this deviation occurs in a contrary direction to that in which the former had occurred. Thus the voltaic current that traverses one of the wires determines in the other an instantaneous current at the moment when it commences to pass, and determines it in a second at the moment when it ceases to pass. These two currents are called *induced currents*, and the current of the battery the *inducing current;*

the induced currents, as we see, are instantaneous: let us further add, that the former has a direction contrary to that of the inducing current, and the latter a similar direction.

This experiment proves that, when we suddenly bring near to a part of a conductor, forming a closed circuit, a conductor traversed by a current, we determine in the former an instantaneous current, moving in a direction contrary to that of the current brought near to it; and that when we remove it, we determine a second instantaneous current, moving in the same direction with the current that is removed.

The intensity of the induced currrent depends on many circumstances: first, on the length and diameter of the wires of the helices; and then on the energy of the inducing current, or the strength of the magnet. In general, it is advantageous to take very long wires, and even to add several helices end to end, one after the other; but if we are not producing the induction with a magnet, it is necessary to employ an inducing current arising from a battery of a great many pairs.

Magneto-Electric Machines.

We have just seen that magneto-electric induction is a remarkable source of dynamic electricity. We may therefore take advantage of this in order to produce electric currents, as we use friction in the electrical machine for developing static electricity.

The first magneto-electric machine was constructed by Faraday; but the one in general use at the present time was designed by Saxton, and perfected by Clarke. This apparatus (Fig. 29) consists of a powerful horseshoe magnet, fixed horizontally; an armature of soft iron having the form of a horseshoe, and each branch of which is surrounded by a wire covered with silk, is set in rotation before the magnetic poles by means of a horizontal axis passing between the branches of the magnet, and which is itself moved by means of a wheel. An endless cord, passing at once round the circumference of the wheel and the groove of a pulley fixed on the axis by its centre, serves to communicate motion. The two branches of the armature, which is fixed trans-

versely to the extremity of the axis, are, for each turn of the wheel, both made to pass successively before the two poles of the magnet.

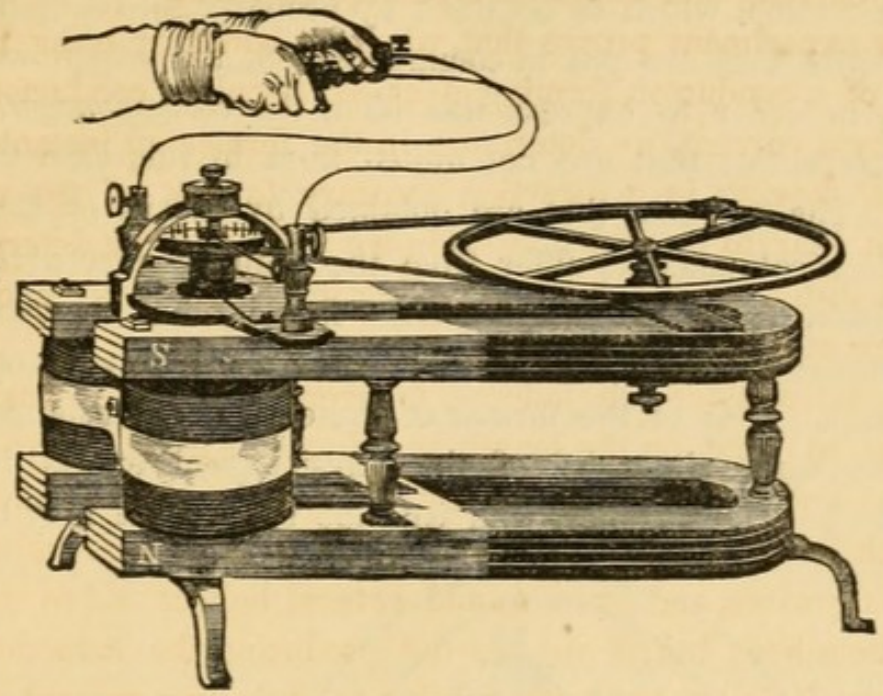


Fig. 29.

At each passage there is magnetization, and consequently a development in the ambient wire of two induced currents in contrary directions. Hence it follows, that in all there are four currents in each of the two wires for one complete rotation of the wheel. If we compare each induced current in one of the wires with the current induced in the other at the same instant, — that is to say, at the instant of magnetization or at the instant of demagnetization, — we shall remark that these currents must be moving in contrary directions, because the poles of the magnet to whose influence they are due are of a contrary name. In order that they may add to, instead of neutralizing, each other, we must connect together the two ends of each of the wires whence the current seems to proceed, and the two ends at which it seems at the same time to enter. These four ends, thus united two and two, present now only two extremities, which are like species of poles, and which are to be united by the body destined to be placed in the route of the induced currents. We may also unite one of the extremities of one wire with the corresponding extremity of the other, so that the two wires shall form but a single one, traversed entirely by each of the induced cur-

rents developed in both wires. It is necessary that, in the same instant, the two currents simultaneously induced should have the same direction, which is obtained by properly selecting the two extremities that are put in communication, and which we have called, in order to express this idea, the *correspondent*. The two extremities that are not united form in this case the two poles. The currents that are obtained by means of the magneto-electrical machine differ from the ordinary currents of voltaic electricity in two respects: the first is, that they are discontinuous; the second, that they move alternately in opposite directions. It is to the former of these two circumstances that the remarkable intensity of the physiological effects is due. (Fig. 30.) The chemical and calorific effects that may be pro-

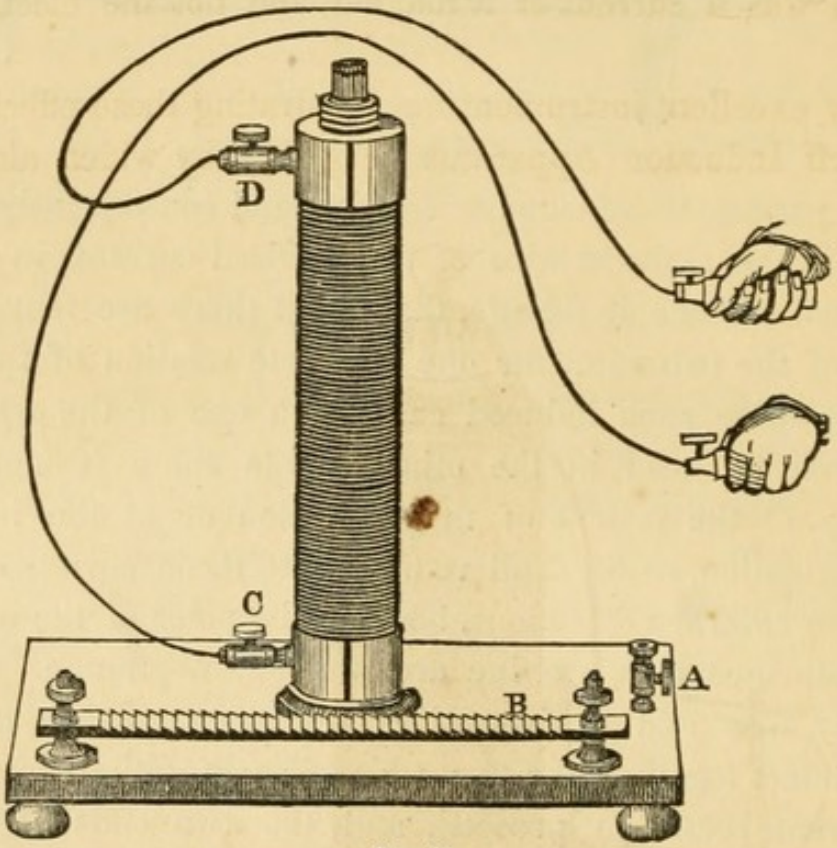


Fig. 30.

duced by means of these induced currents, by one as well as by the others, are very energetic. We can ignite a platinum wire, and can even obtain a small luminous arc between two points of coke. The chemical effects are very decided at the first instant; but the two gases liberated alternately at the two wires of the voltameter very soon re-combine, and the chemical power is in appearance diminished.

Electro-Static Effects of Electro-Dynamic Induction.

Induction by currents and magnets not only gives rise to dynamic electricity, but produces the electro-statical effects of tension; induced currents may themselves become inducing currents, and give rise to induced currents of another order. *A current of magnetic induction is able to produce sparks at a distance in the air, and powerfully to charge a condenser; consequently, a current of induction can be entirely transformed into static electricity.*

This important principle, which Faraday discovered, has been verified by experiments made upon a very large scale by MM. Masson and Bréguet, and which are the more conclusive as the source of the electricity which they employed for producing the induction was a current or a magnet, and not the electricity of tension.

A very excellent instrument for illustrating these effects is the Ruhmkorff Induction Apparatus (Fig. 31), by which almost all

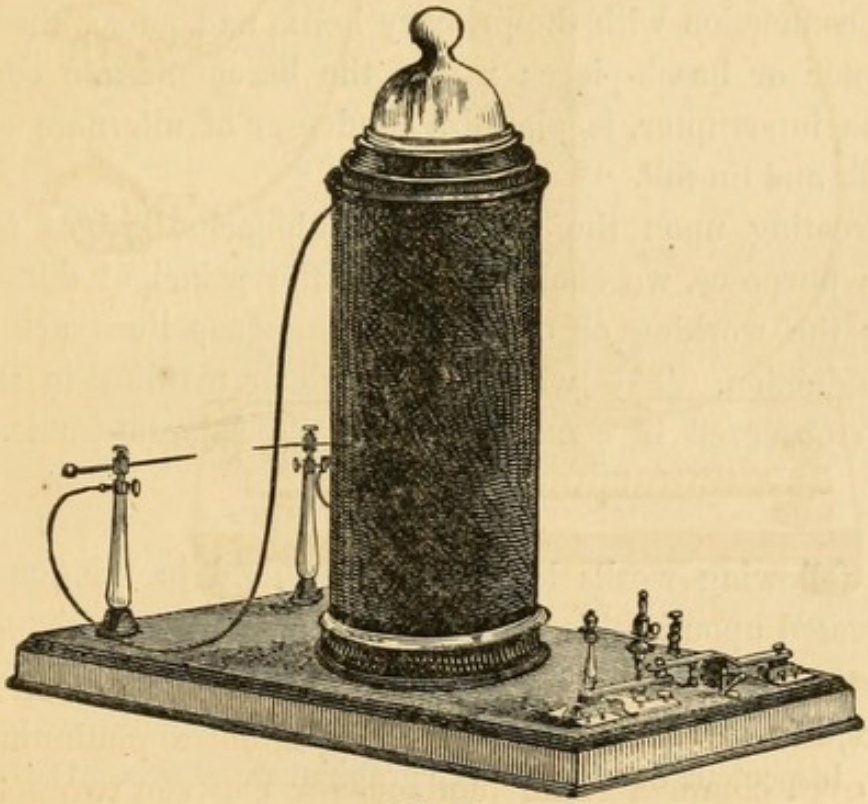


Fig. 31.

the effects of static or frictional electricity are produced from the galvanic battery.

The power of this instrument is immensely greater than that of the largest electrical machine; one sufficient to throw the spark three inches has been found to evolve a quantity of electricity equal to that which could be produced by *eight hundred* machines of twenty-four inches' diameter. It is not affected by the state of the atmosphere. The battery used is Grove's or Bunsen's, of one to four cells.

The apparatus consists of a primary coil of large copper wire, surrounding a bundle of iron wires, mounted upon a basement. A secondary coil or helix, of fine silk-covered wire, from one to ten miles in length, is wound upon a cylinder of thick gutta-percha (each layer of which is insulated), which surrounds a glass bell or cylinder, closed at the top. The glass bell, with the coil, is placed over the primary coil; the terminals of the wire, enclosed in rubber tubes, lead to insulated pillars, and the discharges pass between platina points; or the current is conducted by wires to other apparatus to show its effects.

The current from the battery is received through wires by pole cups in connection with the primary helix, and passes through an interrupter or break-piece; within the basement, and connected with the interrupter, is placed a condenser of alternate strata of oiled silk and tin-foil.

In treating upon the subject of submarine cables for telegraphic purposes, we shall show that the principal difficulty attending the working of extended subaqueous lines arises from static induction. This will be particularly manifest in the phenomena observed in connection with the Atlantic Cable.

The following works have been consulted in relation to subjects treated upon in this part of the work:—

Treatise on Electricity, by Aug. de la Rive. Vols. I., II., and III.

Cours théorique et pratique de Telegraphie Electrique, par E. E. Blavier, Inspecteur des Lignes Telegraphiques. Paris. 1857.

PART II.

GENERAL PRINCIPLES OF THE ELECTRIC TELEGRAPH.

CHAPTER IV.

THE rapid communication of intelligence between points more or less distant is the object to be attained in constructing the Electric Telegraph.

A single signal repeated at intervals from one station, and which can be easily observed at another, suffices to compose an alphabet or vocabulary.

The electric current can be transmitted upon an insulated conductor to a great distance, with sufficient intensity to produce marked effects, thus fulfilling marvellously all the anticipations of ancient and modern times for the instantaneous communication of thought.

A system of electric telegraph consists of an insulated wire conductor uniting two stations; a galvanic battery to generate the electric fluid; an apparatus to transmit the current upon the line, called a key or manipulator; and an instrument to observe the passage of the current, called a receiver.

We have seen, in a previous chapter, that, in order to have an electric or galvanic current, it is necessary that both poles of the battery should be united by a conductor. In the preceding illustrations, this conductor has been a metallic one; and, in order to have both poles of the battery united which should be employed to communicate between distant points, it is evident that there must be two wires, — one connecting with the positive pole, for

example, which should extend to a distant point, and a return wire connecting with the negative pole. This establishes the circuit; and the two electricities are obliged to traverse the entire length of the wire in order to be neutralized by each other. The first telegraph lines were constructed in this manner; that built between Baltimore and Washington, in 1844, contained an entire metallic circuit.

However, it was subsequently ascertained that the earth itself formed an excellent substitute for the return wire, and that it was only necessary to bury the two ends of the wire at the termini of the lines at a suitable depth in the earth, to form an excellent circuit.

This important discovery, as far as voltaic electricity is concerned, was made in the following manner.

M. Gauss had conceived the idea that the two rails of a railway might be employed as conductors of the current for the electric telegraph. Steinheil, having made some experiments, with a view to realizing Gauss's idea, upon the railroad from Nuremberg to Fürth, was unable to obtain an insulation of the rails sufficiently perfect for the current to reach from one station to the other; the great conductibility with which on this occasion he remarked that the earth was endowed, caused him to presume that it would be possible to employ it as a conductor, which would enable him to dispense with one of the conducting-wires between the two stations. The trials that he made to test the accuracy of this conclusion were followed by perfect success; and he then introduced into electric telegraphy one of its greatest improvements, both in regard of the economy produced by the suppression of one of the conducting-wires, and of the facility resulting from it for the establishment of great telegraphic lines.

The transmission of electricity by the earth had already been accomplished by a great number of philosophers, but M. Steinheil was the first who proved the fact for voltaic electricity, and with the view of its application to telegraphy. The conductor of the telegraph constructed at Munich in 1837 consisted of a copper wire, terminated at its extremities by two plates of copper buried in the earth; the current traversed this distance with the

greater facility in proportion as the surface of the buried plates was increased. Mr. Alexander Bain, of Edinburgh, in 1842, made a great number of experiments upon the conductibility of the ground, chiefly with a view to employing the earth as a moist conduction interposed between the zinc and copper plates of a pair; he satisfied himself that a tolerably strong and very constant current was thus obtained. Mr. Bain afterwards succeeded in employing this current in order to make electric clocks go. M. Gauss had before this observed the appearance of an electric current in a wire placed in communication with the ground by large metal surfaces fixed at its extremities. Mr. Wheatstone made also, at very nearly the same period, a great number of experiments upon the same subject, by studying the propagation of the current through the water of the Thames. The philosopher who first contributed by his labors, as ingenious as they were persevering, to give to electric telegraphy its present practical character, is without doubt Mr. Wheatstone. This illustrious philosopher was led to this result by the researches that he had made in 1834 upon the velocity of electricity, — researches in which he had employed insulated wires of several miles in length, and which had demonstrated to him the possibility of making voltaic and magneto-electric currents pass through circuits of this length. In 1837, in the month of June, Mr. Wheatstone took out his first patent. He first employed five conducting-wires between two distant stations, acting upon five magnetized needles, the movements of which, being combined two and two, enabled him to produce several different signs. Mr. Wheatstone at this time entered into partnership with Mr. Cooke, who had likewise devised an ingenious telegraphic apparatus founded upon the same principles. The English philosophers, from the very first, had added to the telegraph, properly so called, an apparatus intended to call the attention of the observers, and designated by the name of *alarum*. It is a bell that sounds under a hammer, the detent of which is suddenly released by the action of a temporary magnet of soft iron, upon which the electric current is made to act. Here the current no longer acts in an immediate manner in order

to produce the motion, but it is confined to magnetizing by its passage a piece of soft iron; this temporary magnet attracts another small piece of soft iron, which prevented the action of a permanent spring; the scapement thus becomes free, and a clock movement causes the hammer to move which strikes the bell. Great service has been likewise derived from this very ingenious process for telegraphy itself. The principle upon which it is founded includes an immense number of applications, for it enables man to put in action at any distance whatever all the forces of mechanics, instantaneously. Indeed, more recently Mr. Wheatstone applied it to the construction of his dial telegraph; and it is the same principle which serves as the basis of Morse's telegraph, invented at nearly the same period.

Before passing on to the detailed study of those telegraphs, the merits of which have been sanctioned by practice, and which are universally adopted, we will just refer to the electro-physiological telegraph of M. Vorselmann de Heer, founded upon the employment of the shocks which the passage of the current brings about in one or other of the ten fingers of an observer. The latter, at a given signal, must place the fingers of both his hands upon the ten keys of a finger-board, which, by means of ten wires, communicate with the keys of another finger-board, upon which a second observer makes his fingers to act. The observer who transmits the signals takes the precaution of protecting his fingers with gloves, in order not to receive the shock, which is to be detected only by the other observer. The advantage of this system is to require the employment merely of fine wires; but ten are necessary, which is a great inconvenience. There is also another disadvantage, which is that the force of the current employed for transmitting the signals must necessarily vary with the sensibility of the observer who receives them.

We are now about to pass on to the examination of the principal electric telegraphs, dwelling upon those only which are now in use upon the principal telegraphic lines. We have previously remarked, that in every telegraphic system there are three distinct parts: the apparatus intended for transmitting and regis-

tering the despatches, or the telegraphic instruments; the conductors intended for establishing the desired communications between the *transmitting* and *receiving* apparatus; and, finally, the batteries which produce the electricity, which are almost exclusively voltaic piles, but in some cases magneto-electric induction-machines, after the manner of those of Clarke, which we have described in the First Part (page 48). We shall not dwell upon this matter here, but confine ourselves to mentioning, in reference to each telegraphic system that we shall be called upon to describe, what the apparatus is that produces the electricity employed to set it in action.

There are three grand divisions into which the manifestations of the electric current may be separated, each of which gives us several different methods of telegraphing; namely, the electro-magnetic, the electro-thermal, and the electro-chemical.

Upon the first of these three divisions — the electro-magnetic — are based the Morse, House, Hughes, Combination, and all dial and printing systems. Upon the second, that of Horne's igniting telegraph; and upon the third, Bain's chemical.

The needle telegraph, so extensively used in Great Britain, is founded upon the deviating action exercised by the current upon the magnetized needle.

Although all systems of the electric telegraph which have been put in successful operation belong to one of the three grand divisions of magnetic, thermal, or chemical, yet they are subdivided by the several distinct principles upon which they work into the timing, for the Morse; the step-by-step printing, for the House, and the several dial instruments, which will be described hereafter; and the synchronous printing, for the Hughes and Combination.

As the Morse system is, after Steinheil's, the first *recording* telegraph invented, and is at the present time the most extensively used in this country and throughout the world, it should of course be the first to claim our attention in an article treating upon the history and progress of the invention.

There has been much controversy, for many years past, between men of science and others, upon the question whether Pro-

fessor Morse is entitled to the credit of originating and perfecting the instrument which bears his name. It seems to be generally conceded that Dr. Charles T. Jackson, of Boston, gave Professor Morse the first ideas respecting an electric telegraph, during a voyage at sea in the packet-ship Sully, in 1832. Nothing practical resulted, however, from Professor Morse's experiments until 1837; and it was not until Daniell's and Grove's batteries were perfected, in 1843, that sufficient galvanic force could be obtained to work the telegraph to any distance.

Although there is in Morse's system very little which can really be justly claimed as invented by him, yet he has the merit of having, by inflexible perseverance, combined and improved upon the invention of others to such a degree that, in 1837, out of upwards of sixty competitors in the discovery of the electric telegraph, he seems to have reached the most desirable result for public and private use. And it is certain that, whatever opinion may be formed in this country respecting the merits of the several rival inventions which have been brought before the public within the past twelve years, there has certainly been nothing invented in Europe to equal the Morse system, either in simplicity, rapidity, or reliability. To verify this assertion, we will simply mention the fact that the Morse instrument has superseded all others in France, Germany, Denmark, Sweden, Turkey, Russia, and to a great extent in England. It is also used exclusively in Australia, India, South America, California, Canada, and all the British Provinces; and has recently been introduced into the royal palace of the Emperor of Japan. It may, therefore, justly claim to be considered the universal telegraphic system of the world.

Electricity exercises the power of attraction and repulsion.
Produces a spark.
Gives a shock.
Charges a Leyden jar.
Has a heating power.
Produces chemical decomposition.
Deflects a magnetic needle.
Produces magnetism.

By nearly all of these manifestations of the imponderable fluid it is possible to construct an electric telegraph.

Thus, in 1816, Ronalds constructed, at Hammersmith, in England, a telegraph, which depended for its action upon the deflection of a pith-ball by the electric discharge.

Lesage, in 1774, employed a pith-ball electrometer, as the basis of his telegraph.

Lomond, in 1787, employed a pith-ball electrometer as a receiver for his system of electric telegraph.

Betancourt, in 1787, used a battery of Leyden jars.

Reizen, in 1794, employed the power of the electric current to produce sparks, by which the letters of the alphabet, cut upon tinfoil, were rendered visible.

Cavallo, in 1795, used the number of sparks to designate the various signals, and the explosion of gas for an alarum.

Soemmering employed, in 1809, the electric current to decompose water, by which letters were designated.

Dr. Coxe, in 1810, proposed both the decomposition of water and of metallic salts.

Ampère, in 1820, employed the magnetic needle, the deflections of which by the electric current indicated letters. He proposed to have, at every station from which intelligence was to be sent, a galvanic battery, with all necessary keys for putting the battery in communication with the wires, and to have at the points where intelligence was to be received as many magnetic needles as there were letters required to be denoted. Each letter was placed upon a different needle, and the needles were surrounded with coils of wire in metallic communication with the wires extending between the stations. It is evident, therefore, that upon the transmission of a current of electricity through any one of these coils, the needle would move, and with it the letter, and thus letter after letter would be denoted.

Dyar, in 1827, used litmus-paper, which was decomposed by electric sparks.

Schilling, in 1832, employed the deflective power of the current upon magnetic needles.

Gauss and Weber, in 1833, used magneto-electricity to deflect a needle.

Vorselmann de Heer constructed an electro-physiological telegraph, founded upon the employment of the shocks which the passage of the current brings about in the fingers of an observer.

Steinheil, in 1837, invented an electric telegraph, using but one wire, and one or two magnetic needles.

Masson's telegraph, invented in 1837, employed magneto-electricity in conjunction with magnetic needles.

Morse's telegraph, invented in 1837, makes use of the direct magnetic effects of the electric current.

Bain's telegraph, invented in 1840, uses the electro-chemical effects of the current.

Horn's telegraph uses the electro-thermal, or heating power of the current.

Thus, we perceive, eight separate and distinct manifestations of the effects of the electric fluid have been made use of in constructing electric telegraphs. We shall see, however, in the succeeding chapters, that only two of these, namely, the deviating influence exercised by the electric current upon a magnetized needle, and the electro-magnetic influence exercised upon soft iron, are used to any extent in any part of the world at the present time. The electro-chemical telegraph has been extensively used in this country, and competed successfully with the magnetic for several years, but it has been withdrawn in consequence of the consolidation of the rival companies.

The electric telegraph is the most wonderful application of that science by which man is gradually extending his control over nature. Electricity is a very familiar agent, — in the lightning, in the hair of animals, in the crackling of silk. It is also, where unseen, a central power, endowing matter with a large proportion of its chemical and mechanical properties. Electricity is also itself capable of assuming a variety of forms, as in the electrical machine, the galvanic battery, and the electro-magnet.

The telegraph is made possible by three remarkable properties or laws of electricity, viz.: —

First. Electricity seeks always an equilibrium in its distribution through matter. If there is an excess in one place, it always seeks to transfer itself to other places, where there is less, or a deficiency.

Second. The production of electricity, from whatever source, is always twofold, or in two directions, one surface or part of our apparatus becoming always *positive*, while another becomes *negative;* thus suggesting the idea of a gain on one side, and loss on the other, of a corresponding amount of electricity, — in other words, of a *disturbance of equilibrium.* Thus the rubber and prime conductor of the electrical machine, the platina and zinc plates of the battery, and the antimony and bismuth of the thermo-electric pair, become respectively electro-positive and electro-negative, as the first condition and fact of electrical excitement.

Third. Different substances have very different conducting powers for electricity, some permitting its passage with slight resistance, while others, called *insulators*, completely bar its progress. The effect of this law, applied to the preceding ones, is to make it possible to insulate electricity in our apparatus in its two opposite conditions of positive and negative; when, by its tendency to equilibrium, a current, according to our common modes of expression, will pass from the positively excited body to the negatively excited body, by means of any conductor, as, for example, the telegraph wire, which we may please to interpose between the two.

The practical utility of the telegraph will depend upon the completeness of the insulation and the conduction in different parts of the apparatus, upon the quantity, force, and rate of travel of the electricity employed, and the means which we have of observing and registering its passage.

The Leyden jar illustrates well the possible extremes of conduction and insulation which we may employ. It consists of glass, perhaps not more than a sixteenth of an inch thick, which is coated on the outside and inside with tin-foil. When charged, these coatings become excited — one electro-positive, the other electro-negative — to an intense degree. If a conductor, of a

length almost without limit, be made to form a circuit connecting these, the electricity will traverse its whole extent, rather than cross the slight barrier interposed by the thickness of the glass.

In the galvanic battery we have the same contrast between insulation and conduction in a less degree. A platina plate may be placed at half an inch distance from a zinc plate, in an acid or saline solution; and yet the current excited will traverse a metallic conductor of hundreds of miles, disposed in a circuit so as to connect the plates, rather than cross the solution of only half an inch which intervenes. In this case, however, the obstacle to the passage of the electricity is not only, or chiefly, the bad conducting power of the solution compared with that of the wire, but an electrical relation of the liquid to the plates, which is the original occasion of the current, and which resists its passage in the opposite direction to that originally imposed upon it. Indeed, the energy of the current which flows through the long conductor is increased, rather than diminished, by approximating the plates until they are separated only by a slight film of fluid. A saline solution is a much better conductor for electricity than water; but a recent estimate of the conducting power of pure water, compared with an equal area of copper wire for galvanic electricity, places it at the enormous disproportion of one to a million.

Electricity from different sources is characterized by peculiarities which affect materially its application to the telegraph. The electricity from the common machine, by which the Leyden jar is charged, is called free electricity, and is in the same condition as lightning. It is accumulated only on the *surface* of insulated bodies; its tension is so great that it will pass off to a neighboring conductor through a considerable interval of air, thus producing the phenomenon of the spark; the quantity of its current is so small as to produce comparatively slight chemical or mechanical effects; it is insulated with difficulty, and conducted by a metal with hardly appreciable loss. In the galvanic battery, on the other hand, the current is conducted by the whole mass of the conducting material or wire; its tension, or force, may be so low as to be resisted and rapidly overcome by the best

conductors, while it is insulated by almost all non-metallic substances in the solid state, such as wood. Meanwhile, its *quantity* is so great as to be capable of producing the most powerful mechanical and chemical effects. As will be mentioned hereafter, means exist of multiplying to a certain extent the intensity or force of the single galvanic pair, by which it becomes the most efficient means of exciting electricity for the purposes of the telegraph.

Another condition of the practical usefulnesss of the telegraph is the rate of travel of electricity, which, on examination, proves to be an almost instantaneous transfer of influence. Thus, Wheatstone determined the rate of free electricity to be 288,000 miles a second. This would require about six minutes to traverse the space between the earth and the sun, or a somewhat shorter period than that required by light to perform the same journey. It may be observed here, that in the transmission of messages we are apt to consider the distance traversed by electricity as that existing between the two stations of the telegraph, whereas it is double that distance; a *circuit*, as it is technically called, being always necessary, — two conductors being required, one upon which the electricity goes out, the other upon which it returns.

The mode by which the rate of motion of electricity was obtained by Wheatstone is so curious, that it deserves to be described. He caused the electricity from the common machine to pass through a long coil of insulated wire, in which were two or more breaks across which sparks must necessarily pass. A mirror was made to revolve with immense rapidity before this coil. The reflection of the sparks was thus thrown occasionally, when the mirror was in the right position, upon a canopy above, graduated in equal divisions. The reflection of one of the sparks was found always to lag behind the other, on account of the time occupied by the electricity in passing through the intervening portion of the coil, the effect of which was multiplied by the revolving mirror. The length of the coil between the breaks and the rate of revolution of the mirror being known, and the distance of the reflected sparks from each other being observed, the rate of motion of the electricity was easily calculated.

It will be observed that this determination applies only to free electricity. The electricity of the galvanic battery, which involves in its passage a change or vibration in all the particles of the conductor, may easily have a different rate, and in the course of the brilliant experiments of the United States Coast Survey of the last two years it has been found that in reality its velocity is much less. It is stated by Mr. Sears C. Walker that the rate of galvanic electricity, obtained by simultaneous observations at New York and Philadelphia, with the astronomical clock, in connection with the telegraph, and subsequently on the line between Washington and St. Louis, is approximately 18,700 miles in a second. It would, therefore, require one and one third seconds for the galvanic current to traverse a wire extending round the earth. In our ordinary telegraphic communications, the time occupied by the passage of the current would be wholly imperceptible.

The general principles on which the electric telegraph depends have thus been considered. They involve no new facts or discoveries in science. Not only so, but, as will be seen in tracing its history, the idea of the telegraph was deduced from these principles at a very early period, and a conclusive experiment was tried before the close of the last century. The improvement which has been made by modern science, by which the telegraph has become more extensively useful and applicable, has been the indicating or registering apparatus, by which the passage of the electricity at the distant station is noted.

It is evident that the power of sending a current of electricity through a wire of a hundred miles in length, however surprising, could be of no practical use unless the means existed of observing the passage of the current in distant parts of the circuit. Several of the reactions of electricity have been employed for this purpose, which will be described hereafter in detail. The decomposition of water into its constituent gases by the passage of electricity; the decomposition of saline solutions in the same manner, giving rise to a change of color; the passage of the spark across a short interval made in the circuit; the deflection of the needle by the passage of a current of electricity in its neigh-

borhood; the charging of an electro-magnet, or the influence exerted on a bar of iron in the axis of a coil, by which mechanical motion is produced, have been severally resorted to.

The mode of transmitting intelligible signals by this agency has always consisted in sending either a succession of instantaneous electrical impulses, or a current prolonged for some instants, measured by its effects or by its duration. A combination of these signals, according to previous arrangement, may be made to indicate all the letters of the alphabet, or even, by an ingenious contrivance, with only a single circuit, to print each letter separately.

To produce the effects by which the telegraphic messages are expressed, it is necessary that the electric current shall have a certain intensity. Now, the intensity of the current transmitted by a given voltaic battery along a given line of wire will decrease, other things being the same, in the same proportion as the length of the wire increases. Thus, if the wire be continued for ten miles, the current will have twice the intensity which it would have if the wire had been extended to a distance of twenty miles. It is evident, therefore, that the wire may be continued to such a length that the current will no longer have sufficient intensity to produce at the station to which the despatch is transmitted those effects by which the language of the despatch is signified. The intensity of the current transmitted by a given voltaic battery upon a wire of given length will be increased in the same proportion as the area of the section of the wire is augmented. Thus, if the diameter of the wire be doubled, the area of its section being increased in a fourfold proportion, the intensity of the current transmitted along the wire will be increased in the same ratio. The intensity of the current may also be augmented by increasing the number of pairs of the generating plates or cylinders composing the galvanic battery.

Since it has been found most convenient generally to use iron as the material for the conducting-wires, it is of no practical importance to take into account the influence which the quality of the metal may produce upon the intensity of the current. Other things being the same, the intensity of the current will be in the

proportion of the conducting power of the metal of which the wire is formed. Copper is the best conductor of the metals, it being seven times better than iron; but, as explained above, the conducting power of the metal being increased in the same proportion as the area of the section of the wire is augmented, it becomes perfectly easy, by increasing the size of the iron wire, to obtain as good a conductor as is required.

M. Pouillet found, by well-conducted experiments, that the current supplied by a voltaic battery of ten pairs of plates, transmitted upon a copper wire having a diameter of four thousandths of an inch, and a length of six tenths of a mile, was sufficiently intense for all the common telegraphic purposes. Now, if we suppose that the wire, instead of being four thousandths of an inch in diameter, has a diameter of a quarter of an inch, its diameter being greater in the ratio of $62\frac{1}{2}$ to 1, its section will be greater in the ratio of nearly 4,000 to 1, and it will consequently carry a current of equal intensity over a length of wire 4,000 times greater, that is, over 2,400 miles of wire.

But in practice it is needless to push the powers of transmission to any such extreme limits. To reinforce and maintain the intensity of the current, it is only necessary to establish at convenient intervals along the line of wires intermediate batteries, by which fresh supplies of the electric fluid shall be produced; and this may in all cases be easily accomplished, the intermediate telegraphic stations being at distances one from another much less than the limit which would injuriously impair the intensity of the current.

Having thus explained the means by which an electric current can be conducted from any one place upon the earth's surface to any other, no matter what the distance between them, and how all the necessary or desired intensity may be imparted to it, we shall now proceed to explain the expedients by which such a current may enable a person at one place to convey instantaneously to another place, no matter how distant, signs serving the purpose of written language, and even language printed in legible Roman letters!

It may be briefly stated, that the production of such signs de-

pends on the power of the agent transmitting the current to transmit, suspend, intermit, divert, and reverse it at pleasure. These changes in the state of the current take place, for all practical purposes, simultaneously upon all parts of the conducting-wire, to whatever distance that wire may extend; for although strictly speaking there is an interval depending on the time which the current takes to pass from one point to another, that interval cannot in any case exceed a small fraction of a second.

Although there is some discordance in the results of experiments made to determine the velocity of the current, they all agree in proving it to be prodigious. It varies according to the conducting power of the metal of which the wire is composed, but is not dependent on the thickness of the wire. On copper wire, its velocity, according to Professor Wheatstone's experiments, is 288,000 miles, and according to MM. Figeau and Gonelle, 112,680 miles per second. On the iron wire, used for telegraphic purposes, its velocity is 62,000 miles per second, according to Figeau and Gonelle; 28,500, according to Professor Mitchell of Cincinnati; and about 16,000, according to Professor Walker of the United States Coast Survey. It is therefore evident that the interval which must elapse between the production of any change in the state of the current at one telegraphic station and the production of the same change at any other, however distant, cannot exceed a very minute portion of a second; and since the transmission of signals depends exclusively on the production of such changes, it follows that such transmission must be practically instantaneous.

We will here say a few words upon the important part played by the earth when it is employed as a conductor in the operations of electric telegraphy. We have already seen that the idea of employing the earth as a conductor between two telegraphic stations, realized for the first time by Steinheil, had permitted the suppression of one of the conducting-wires, and thus the realization of great economy and simplicity in practice. It was at first supposed that the ground played the same part as the conductor for which it was substituted, and that there was established between the two poles of the battery placed in communication

with the earth, even when they were at a great distance apart, a veritable electric current, transmitted through all the interposed conducting matters, and which the earth always contains in greater or less proportion. The terrestrial globe cannot be considered as being in its nature so perfect a conductor as a metal; but its bad conductibility is found to be more than compensated by the immensity of its section. We may therefore consider the earth as presenting a null resistance to conductibility. MM. Bréguet and Matteucci, by various experiments, found that where the current went by the copper wire from Pisa to Pontedera, and returned by the earth, its intensity was the same as when the two poles of the battery were immediately united by a single copper wire as long as that by which the two stations were connected. This experiment, and a great number of other similar ones, enable us, therefore, to admit that the resistance of the earth to electric conductibility is null.

Electric currents, we must admit, are able to cross each other in all directions, and at every instant, without affecting each other; and we must suppose that, between two stations very far apart, such as New York and Buffalo, there is a series of decompositions and recompositions of all the interposed molecules of water; and that the positive electricity, for example, that is introduced into the ground at New York cannot be neutralized except by the negative arising from the same battery, but brought by the telegraph wire into the ground at Buffalo; a neutralization going on from molecule to molecule through all the conducting sections that are found in the terrestrial globe between these two stations. It is likewise necessary to admit, when the positive and negative poles of several batteries are plunged at the same time in the ground at great distances from each other, that the positive electricity of each pole, in order to become neutralized, seeks for the negative electricity of the pole belonging to the same battery, even though this pole might be much more distant than the negative of another battery. This hypothesis of the predisposition of the two electricities to neutralize each other only when they arise from the same source, appears to us equally contrary to logic and to observation.

We must therefore have recourse to another explanation of the part played by the earth in the phenomena of electric conductibility, — an explanation which flows very naturally from the fact observed by Faraday and Wheatstone with electric cables. This fact is that of a vast reservoir, — of a species of drain, — which sucks up and absorbs at the two extremities of the wire the free electricities which the battery, or any apparatus that is the generator of electricity, sends into it. By the very fact that this electricity is lost or escapes, there is an electric movement, and consequently a production of a current. M. Magrini, in experiments made with long, well-insulated telegraph-wires extending from Milan to Menza, had already shown that an electric current might be obtained in a wire of which only one of the ends communicated with a source of electricity, whilst the other remained insulated. But in this mode of operating some defect of insulation might be feared. This fear disappears in the experiments of Faraday and Wheatstone. These latter very clearly show us that it is enough to put into communication with one of the poles of a battery the end of a conductor of very great dimensions, the other extremity of which is insulated, in order that this conductor, in becoming charged, may be traversed by an electric current, the presence of which is indicated by the deviation of the needle of a galvanometer. The same phenomenon takes place with the earth, with this difference, that, the terrestrial globe being a conductor of infinite dimensions, the current is able to endure as long as the communication of the pole with the ground takes place.

M. Matteucci, who has greatly directed his attention to the conductibility of the earth, had made the curious remark, that, when the electrodes are plunged into the ground to a suitable depth, the resistance of the interposed layer increases exactly with its length, according to the recognized law for ordinary conductors; there is not even any difference, when the layer is very thin, between its resistance and that of the same layer of earth or water contained in an insulated vessel. But if the distance between the electrodes becomes considerable, the resistance of the terrestrial bed diminishes very rapidly; even at the distance of

from sixty to one hundred yards, the current ceases to diminish; at greater distances its intensity increases until it becomes equal to that which would be found with the circuit entirely metallic. This result is always verified for distances of ten or twelve miles. The increase of the current with the length of the terrestrial bed is independent of the nature and form of this bed; it was before having arrived at the length of the bed at which the resistance ceases, that the influence was observed of the nature and form of this bed over this same resistance. This observation of M. Matteucci clearly shows us that the earth is able to play two very different parts in the transmission of currents. It is able to discharge the function of an ordinary conductor when the electrodes are very near to each other, — and then the resistance which it opposes to the current increases with the length of the interposed terrestrial bed; but when the distance between the electrodes attains to a certain limited dimension, the earth acts as a reservoir which absorbs the electricities liberated at each of the poles; its resistance then disappears, and the intensity of the current depends on nothing more than the resistance of the conducting-wire alone; — so that the intervention of the terrestrial globe presents the double advantage of permitting the economy of one line wire, and of rendering the current twice as strong as it would be were it made to return by the second suppressed wire.

The results obtained by Matteucci in his experiments have been verified by our own, in a somewhat different manner.

A telegraph line of one mile in length, extending from the counting-room of the Bridgewater Iron Works to the works themselves, furnished with a current of five Daniell's cells, had never worked well, — the current being always weak and shaky. We were finally called upon to solve the difficulty, and after satisfying ourselves that the connections were perfect, decided that the earth termini must be imperfect, not being of sufficient depth to overcome resistance. We accordingly attached a copper wire and ran it into the canal, when the intensity of the current at once increased to the full amount desired.

Subsequently, upon our explaining to Mr. Sprague, the opera-

tor, the laws of transmission and resistance, — that the resistance of the earth was in the inverse ratio to the surface of the metal buried, — he attached a plate of copper to the wire and placed that in the canal, when he was able to reduce the intensity of his battery one fifth, and still have a stronger current than before.

The difference between what takes place when the electrodes are near together, and what takes place when they are far apart, may seem extraordinary at the first moment; but upon reflection we easily conceive that in the former case the molecules interposed between the two electrodes, not being so numerous, may constitute the electric chain by the effect of the mutual neutralization of their opposite electricities, which is preceded by their polarization. When the electrodes are very distant, this communication between them can no longer take place; and they are then discharged, by means of the bed with which they are in contact, into the entire mass of the terrestrial globe.

Besides, many other facts of a different kind demonstrate that it is not necessary, in order to obtain a current, to reunite the two contrary electricities produced by the same electrical apparatus; but that it is sufficient that one of the two electricities be absorbed. Thus it is that, when the outer coating of a Leyden jar is placed in communication with the ground, we are able to obtain a discharge in the air similar to a current, by furnishing its inner coating with a point.

The part played by the earth in the transmission of telegraphic despatches is, therefore, in accordance with a very great number of phenomena of the same kind, which have demonstrated to us that the propagation of electricity, and consequently the production of an electric current, may take place in a conducting body, as well when this body is placed in communication with another, charged with an excess of one of the electricities only, as when it is found placed between two excesses of contrary electricities.

When the terrestrial globe is employed for bringing about the circulation of a current in an insulated conductor, one of the extremities of which communicates with one of the poles of a battery and the other with the ground, whilst the second pole of

the battery also communicates with the ground, care must be taken to establish these communications well. With this view, the conducting-wires that go to the earth terminate in large metal plates, generally of copper, which are also buried as deep as is convenient in wells, or in the most moist parts of the ground that can be found. The gas and water pipes of towns are advantageously employed for obtaining good communication with the earth; and iron fish-jointed rails are valuable in country stations especially.

Upon nearly all telegraph lines where an intermediate office puts on a ground, — that is, puts the main wire in communication with the earth, without separating the main line, — other stations may, by adjusting their armatures very closely, obtain what is being communicated upon the portion of the line intercepted by the ground.

This is owing to the imperfect contact between the ground wire and the earth, a part of the electric current passing by the ground-wire sufficient to work a delicate relay magnet.

List of the principal works consulted in the preparation of this chapter : —

Treatise on Electricity. Vol. III. By A. De la Rive. London. 1858.

Museum of Science and Art. Vol. III. By Dionysius Lardner. London. 1854.

The Electric Telegraph, its History and Progress. By Edward Highton. London.

The Electro-Magnetic Telegraph. By Laurence Turnbull. Philadelphia. 1853.

Book of the Telegraph. By W. F. Channing. Boston. 1858.

PART III.

ELECTRIC TELEGRAPH APPARATUS.

CHAPTER V.

THE MORSE SYSTEM.

In 1837, Prof. S. F. B. Morse made known to the public his recording telegraph, which justly retains his name, and of which it appears that he had conceived the idea as far back as 1832. Its principle is very simple. It requires but a single circuit; consequently but a single insulated wire, and the return by the earth. At the extremity of the circuit, where the despatch is to be received, is an electro-magnet (Fig. 32), the wire of which communicates by one of its extremities with the ground, and by the other with the insulated wire that serves as a conductor between the two stations. A small soft iron

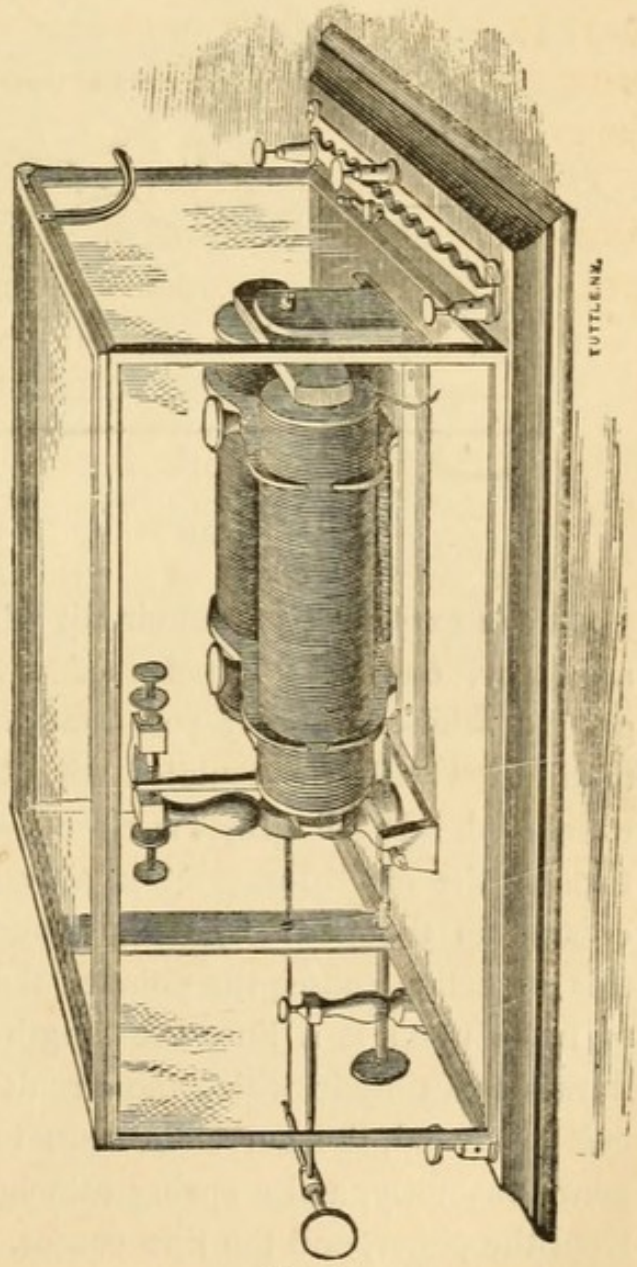


Fig. 32.

bar, called an armature, is attached to a brass lever sustained in a horizontal position by two pivots. The soft iron armature is attached to one end of this lever, while the other end is armed with a steel point, which is called a pen. Under the point of the pen travels on, with a uniform motion, a band of paper, which is moved by means of mechanism analogous to clock-work (Fig. 33).

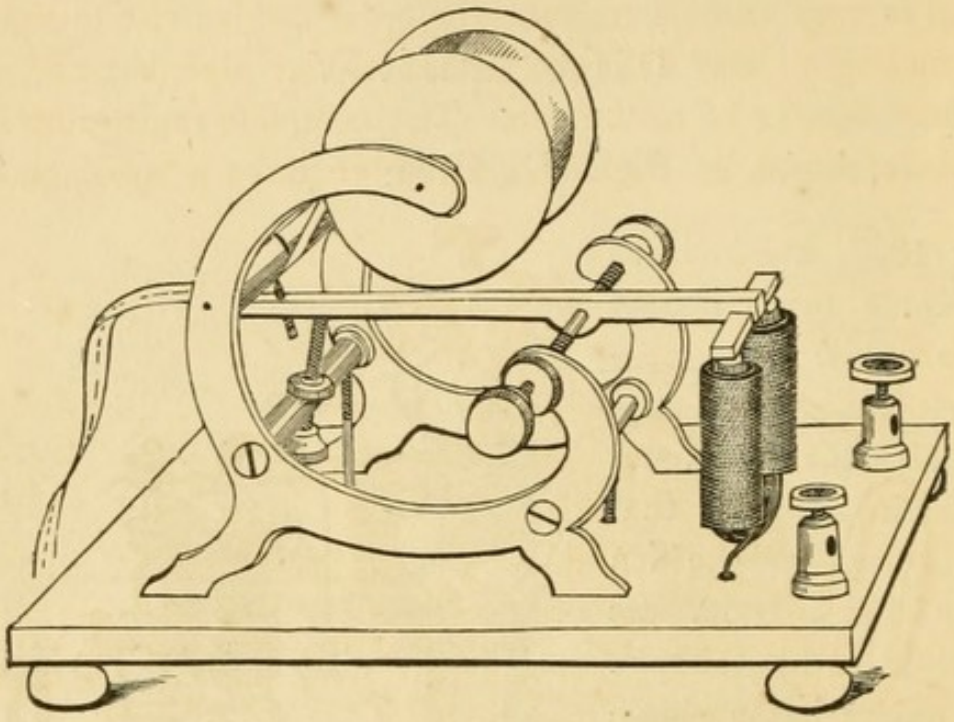


Fig. 33.

At the extremity of the circuit whence the despatch sets out is a battery, one of the poles of which communicates with the ground, whilst the other pole may be put at pleasure into communication with the insulated wire, by which the two stations are connected. If the circuit is closed — that is, whole — the armature of the electro-magnet is attracted, through the magnetism created in the helix by the passage of the electric current; and this attraction causes the point of the pen to touch the paper, and to trace upon it a line, the length of which depends upon the duration of time in which the circuit remains whole. If the circuit is opened, the current ceases to flow, the magnetism disappears instantly, and a spring attached to the lever draws it away from the paper, and the line ceases. If the circuit is opened and closed rapidly, there are produced upon the paper simple dots,

the number of which depends upon the number of times that the circuit is interrupted and established. The blank space by which the points and the lines are separated is greater in proportion as the circuit remains open for a longer time. We therefore see that we may at pleasure, by acting at one of the stations, trace upon the paper which is unrolled at the other, a succession of points or lines, separated by blank intervals, which may be combined in very various manners, in order to give rise to signs corresponding to the different letters of the alphabet, and to the various figures of arithmetic. The complete registering instrument is shown in Fig. 34. Here we have a spool, on which

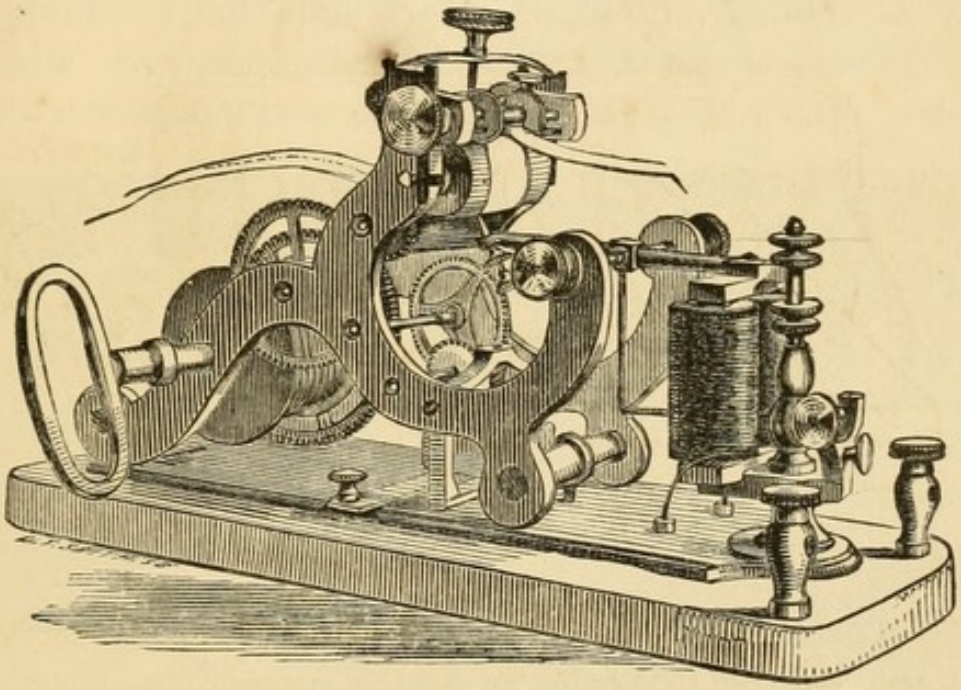


Fig. 34.

the strip of paper is wound, and clock-work, with rollers, which give the strip a steady motion onwards under the pen upon the lever of the electro-magnet.

The recording apparatus depends upon the combination of two essentially different parts; one consists of a lever, which, when it is lowered, presses upon a sheet of paper a steel point (Fig. 35) with which it is furnished. This lever is depressed by means of the electro-magnet, which attracts the armature fixed to the levers; every time that the current passes in the wire of the electro-magnet, the armature draws the lever to which it is fixed, and thus produces the pressure of the point against the

paper. A screw under the end of the lever projecting beyond the electro-magnet serves to limit the play of the armature, and

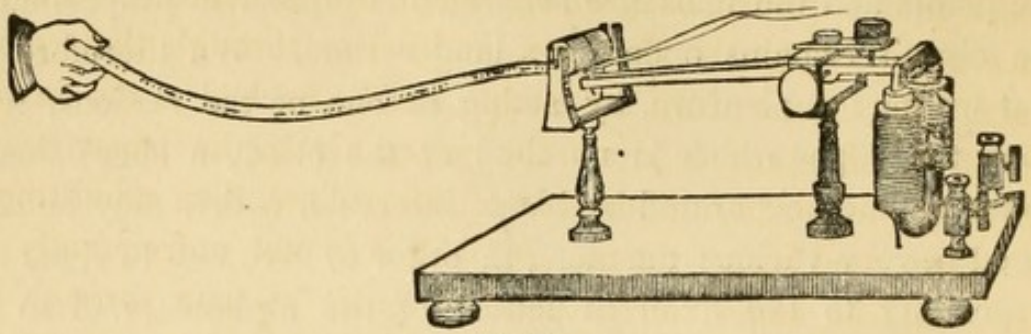


Fig. 35.

a helical spring attached to the under side of the lever compels it, by its elasticity, to separate itself from the electro-magnet, when the current ceases to act, which causes the point no longer to press. The other part of the apparatus is intended to cause a

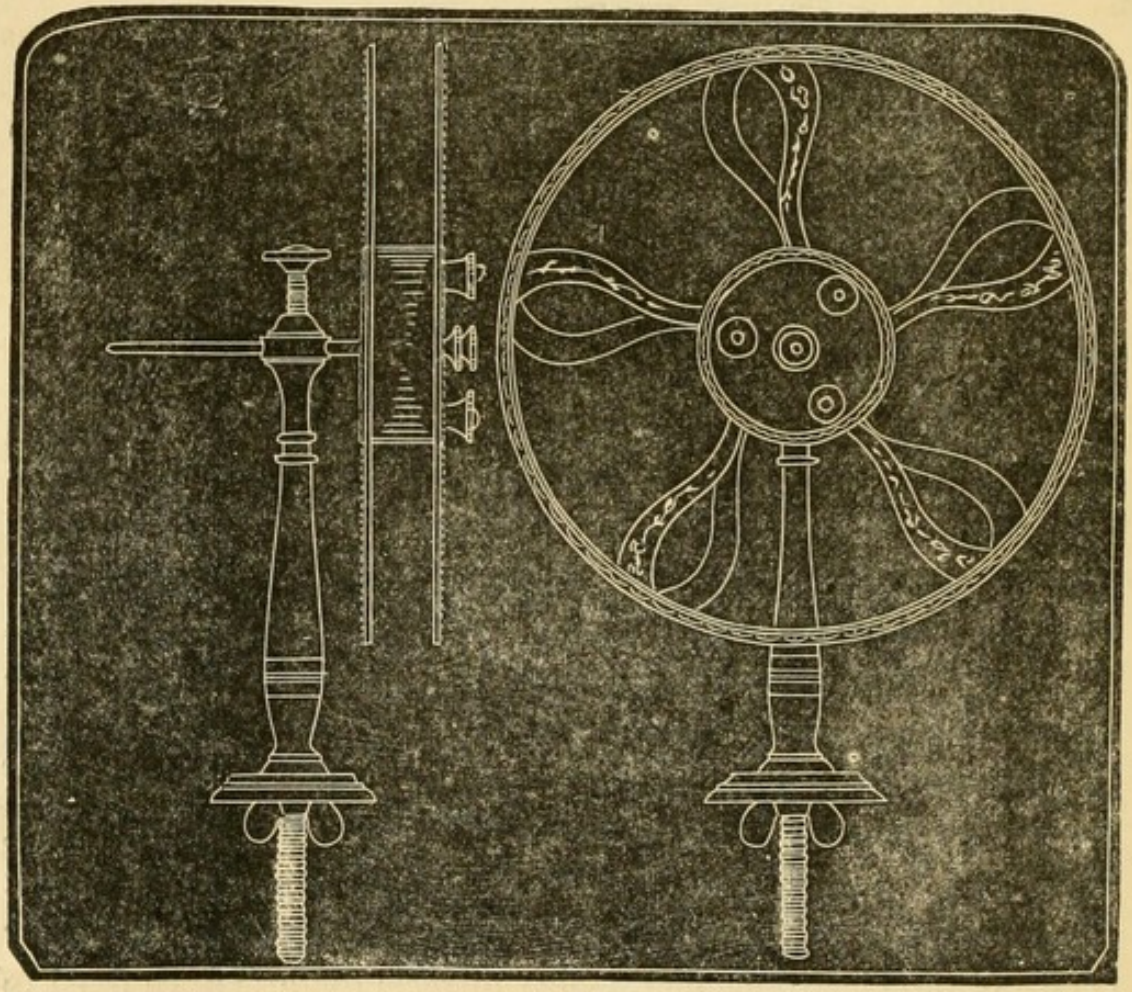


Fig. 36.

long band of paper to pass under the point with a uniform velocity, which paper is rolled upon a cylinder (Fig. 36), or, as is

generally the case in the telegraph offices, it is put into a long narrow box, and after passing through the instrument, or register, passes into a similar box, which, when full, is transferred to the place occupied by the first box, and is run through the register again. By means of an adjustable slide, attached to the feeding rollers, which serve to draw the paper along, the paper can be moved at pleasure to either side of the rollers, thus admitting of its being used many times. In fact, it is not unfrequently the case that the same roll of paper is made to pass through the register as many as twenty times, thus making a large saving, in the course of the year, in the matter of paper. Two springs retain the upper cylinder pressed against the lower cylinder, which is set in motion by a clock-movement, by means of a weight, for which, in some cases, an ordinary spring has been substituted with advantage. The paper is drawn on between the two cylinders by the motion of the lower cylinder, and thus passes under the point. In order that this point may leave a proper mark upon the paper, one of the rollers is grooved, to correspond with the steel point; therefore, when the lever is attracted by the electro-magnet, the pen, reaching the paper, presses it against the groove, which produces a distinct mark. If the pen presses upon the paper for a short time only, it produces a dot merely; if it acts for a longer time, it makes a dash; it is able therefore to mark dots and dashes, which, as we have said, is sufficient for forming a complete alphabet.

The transmitting apparatus is a very simple contrivance of a lever and anvil (Fig. 37), designed simply for the more easy opening and closing the circuit than could be done by holding the ends of a wire in the hand, which, however, is often resorted to when despatches are sent from places where there happens to be no apparatus. Fig. 38 represents a signal key, as usually used upon the

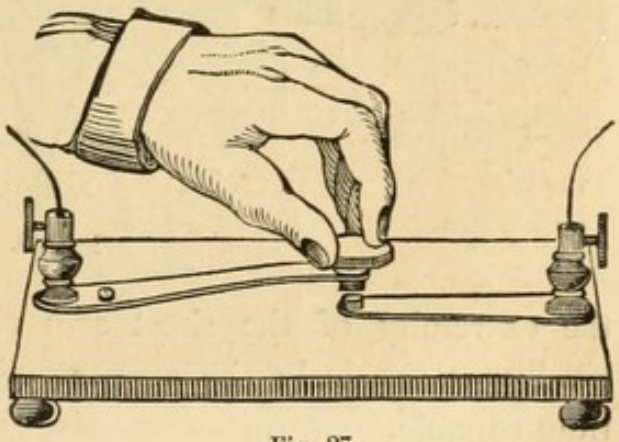


Fig. 37.

lines in this country. It consists of a lever mounted on a horizontal axis, with a knob of ivory for the hand at the extremity of

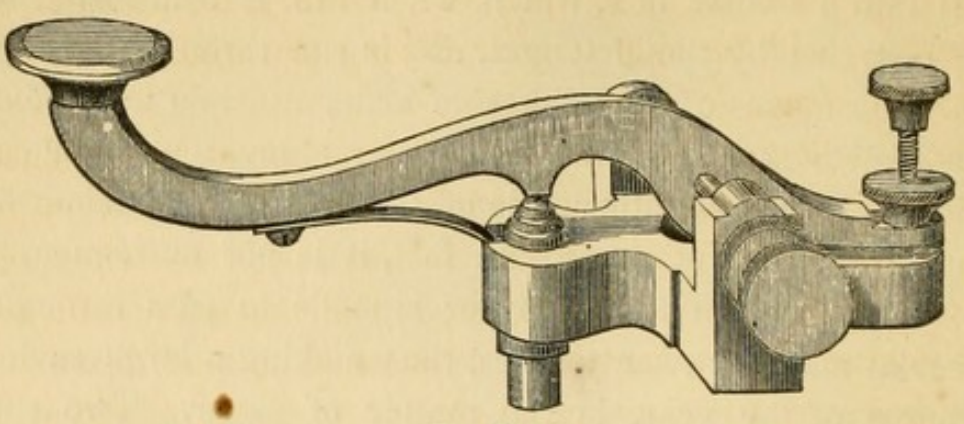


Fig. 38.

the long arm, which is at the left in the cut. This lever is thrown up by a spring, so as to avoid contact with the button on the frame below, except when the lever is depressed for the purpose of completing the circuit. A regulating screw is seen at

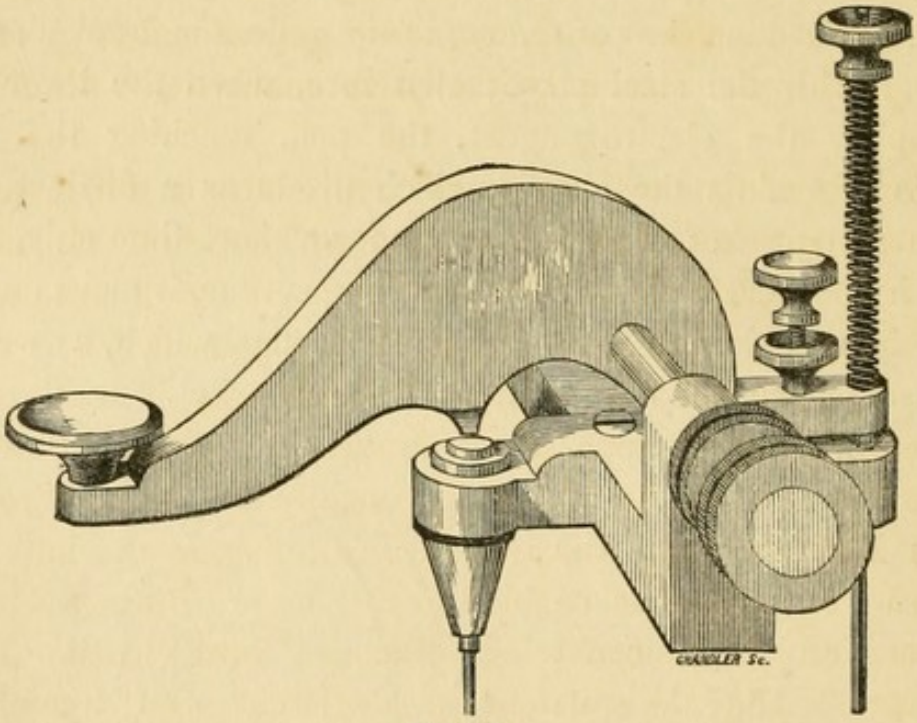


Fig. 39.

the extremity of the short arm of the lever (Fig. 39) which graduates precisely the amount of motion of which it is at any time capable.

We are thus able, by resting with the finger upon the ivory knob, to close or break the circuit at pleasure; if the contact

between the hammer and the anvil is produced for a very short time only, the current will pass in the circuit only during this instant; by maintaining it, upon the contrary, for a longer time, the current will be able to pass during the whole time in the telegraphic wire.

Where a long circuit is used, the resistance to conduction, measured by the amount of electricity which passes, is very great. The diminution of the current is most sensible when tested through the first few miles of wire, the amount which subsequently passes appearing nearly constant for a long distance. It is not, however, sufficient, in its electro-magnetic effects, to work one of Morse's registers directly. The current, which has traversed a great length of wire, can only move the lever of the electro-magnet sufficiently to bring a platina point in contact with a little platina disc placed opposite to it, so as to complete the circuit of a local battery, which works the register with energy. This is the principle of *combination of circuits*, and constitutes the important invention of the *receiving magnet* and *relay* or *local battery*, as they are familiarly known in connection with Morse's telegraph.

The effect of the combination of circuits is to enable a weak or exhausted current to bring into action and substitute for itself a fresh and powerful one. This is an essential condition to obtaining useful mechanical results from electricity itself, where a long circuit of conductors is used, and accordingly it received the attention of early experimenters with the telegraph. This principle seems to have been first successfully applied by Professor Joseph Henry, of the Smithsonian Institution, in the latter part of 1836. He was thus enabled to ring large bells at a distance, by means of a combined telegraphic and local circuit. In the early part of 1837, Wheatstone, in England,* used a combining instrument, which consisted of a magnetic needle, so arranged as to dip an arch of wire into two mercury cups, when deflected by a feeble current, thus completing the circuit of a local battery, which struck a signal-bell. Davy patented in England, in 1838,

* London Repertory of Patent Inventions, 1839, Vol. XI.

a system of combined circuits, for four different purposes connected with his telegraph. He brought into action a local circuit,

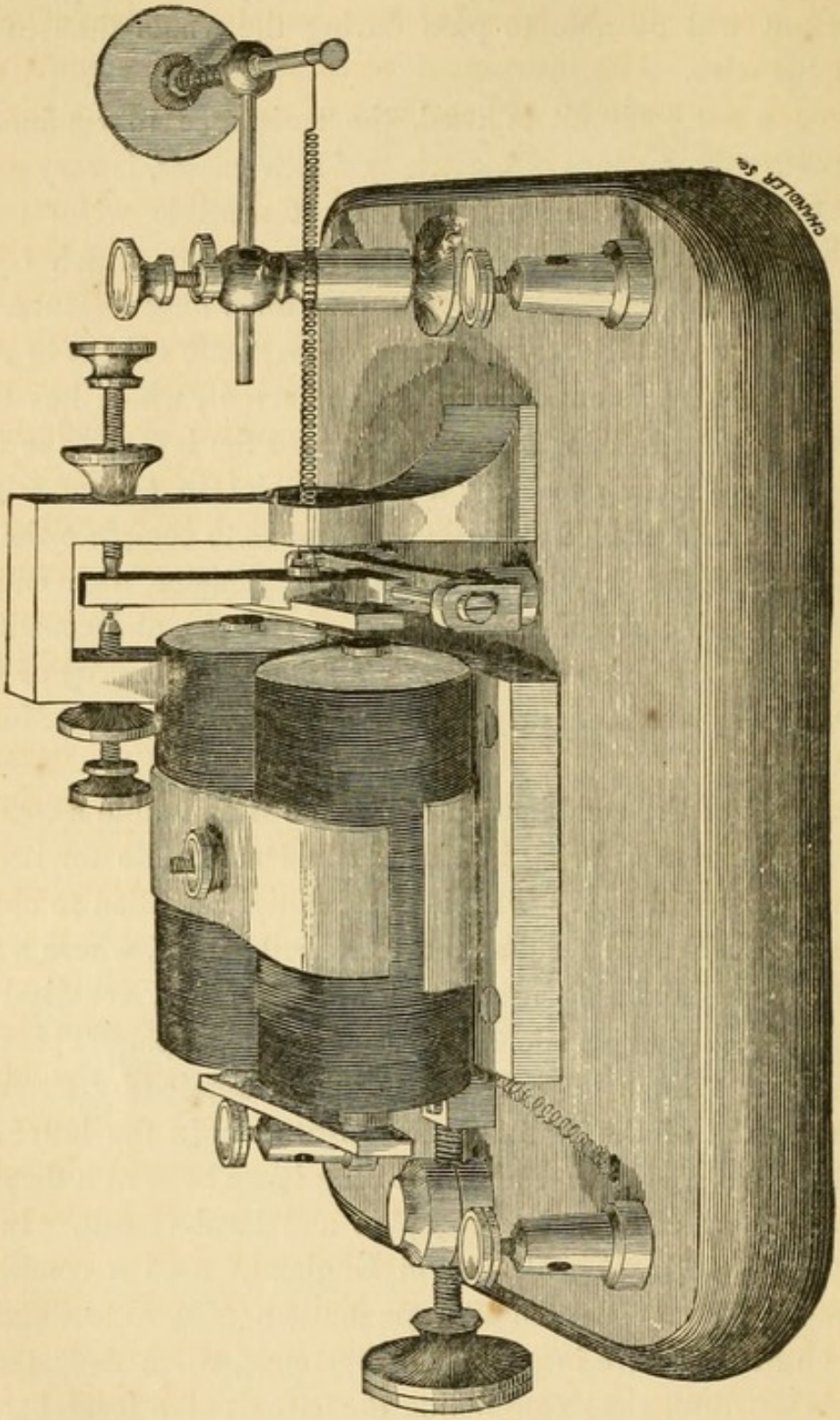


Fig. 40.

1st, to discolor or dye, by electro-decomposition, the calico on which he registered his signs; 2d, to actuate an electro-magnet

regulating the motion of the calico; 3d, to direct the long or telegraphic circuit to either of two branches, by means of a receiving instrument placed at their point of meeting, and operated upon from a distance; 4th, he provided for a complete system of relays of long circuits. His instrument resembled Wheatstone's, only the contact was made by two surfaces of metal, without the use of mercury.

The receiving magnet (Fig. 40) used by Professor Morse is a very slight modification of his register, the platina point for completing the local circuit being substituted for the marking point. The magnet is surrounded with helices of fine wire, which multiply the effects of the feeble current, and the whole instrument is constructed with delicacy. By Morse's patent of 1840, this is applied to the combination of long circuits, or the *relay* of currents; and by his patent of 1846, it is applied to operating the register by a local or office circuit. The electro-magnet, armature, and lever, constituting the chief part of both these instruments, is simply the electro-magnet of Professor Henry, described by him in 1831.

The relay is a very essential apparatus in Morse's telegraphic system, and is also applied to many other purposes of a similar kind. The object of the relay is, when the current of a battery transmitted to a great distance by a telegraphic wire is too feeble to cause the receiving apparatus to act in a direct manner, to employ this current to cause the more powerful current of a local battery to act upon the apparatus, — a function which requires but very little force in the current. Now the receiver in the Morse telegraph requires, in order to its acting, a very energetic current, and at least the employment of very powerful batteries, which would be very expensive, and frequently very troublesome; it cannot be made to act by a current transmitted from one station to the other. Recourse is therefore had to the relay (Fig. 41), which consists of an electro-magnet, the wire of which is placed by the extremities in communication with the telegraphic line; so that this electro-magnet operates under the action of the current transmitted from one station to the other. The soft iron armature is attached to a lever movable around the axis; the

extremity is moved between two screws, one of which is terminated by an ivory point, and the other, entirely metallic, commu-

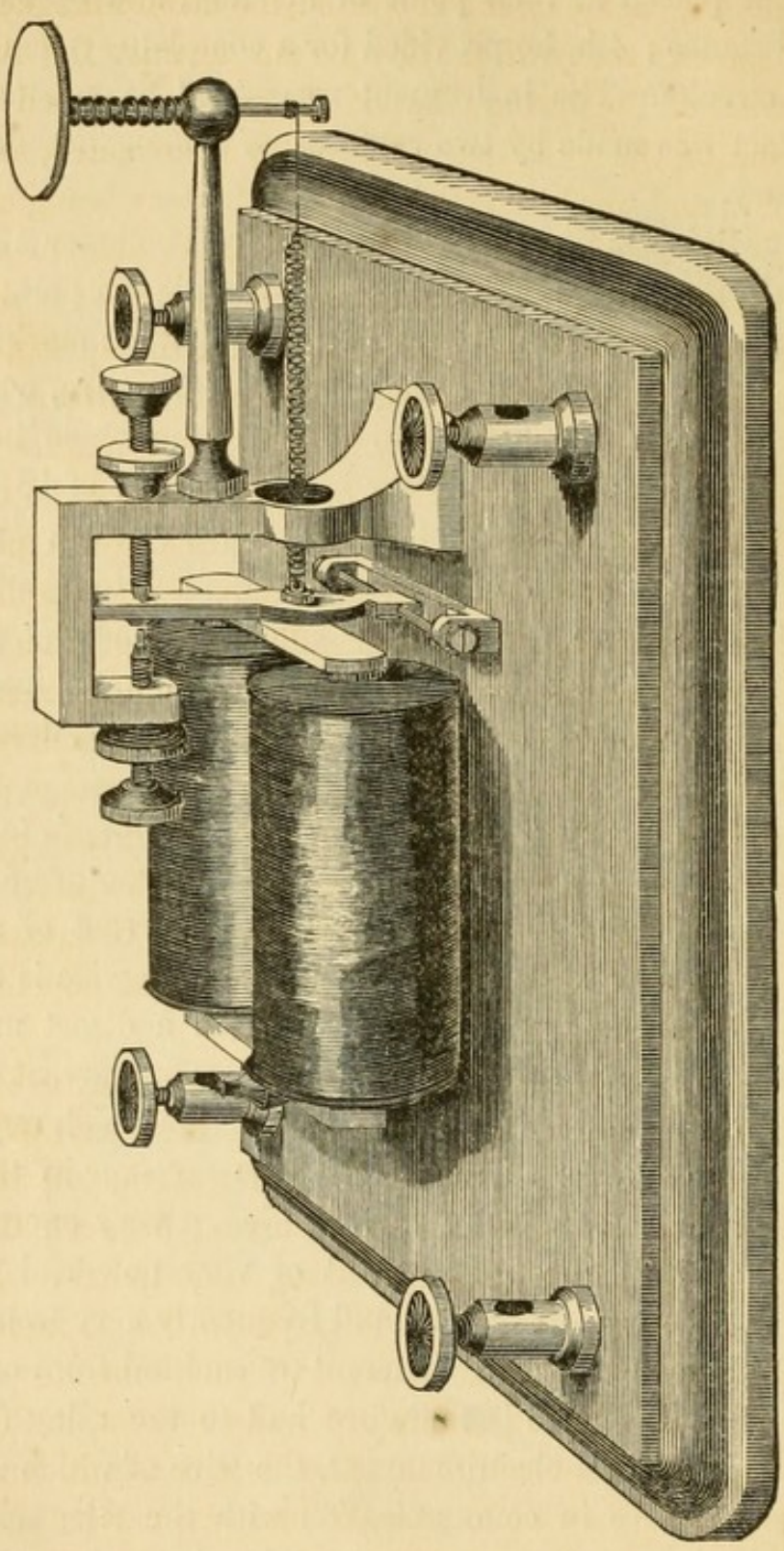


Fig. 41.

nicates by means of a metal column and a wire conductor with one pole of a local battery; the other pole of this battery commu-

nicates, by the intervention of the wire of the electro-magnet of the registering apparatus and of the spring, with the metal lever. When the telegraphic circuit is opened, the electro-magnet does not act, and the extremity of the lever rests against the ivory point by the effect of the spring; but if the circuit is closed at the departing station the armature of the relay is attracted, touches the metal point, and, the circuit of the local battery being closed, the receiving apparatus of the arrival station is able to act. The screws, between which the armature vibrates, as it is alternately drawn forward by the magnet or back by the spring, serve as adjusters, also, to the armature. When the current upon the line is very feeble, it is necessary to place the armature very near the poles of the electro-magnet in order that it may be influenced by it. When the current is strong, the armature is placed farther off. There is also another contrivance for accomplishing the same object, namely, the proper adjustment of the armature. This consists of a carriage, upon which the helices rest; a long screw running under the carriage, and projecting underneath and in the rear of the helices, serves to draw the carriage backward and forward, and, of course, by this means to increase or decrease the distance between the armature and the poles of the electro-magnet, at pleasure. This improvement has been made within the past few years in this country, but does not appear to have been adopted in Europe as yet.

The object of these "adjusting screws," as they are called, is to bring about a proper adjustment; that is to say, to place the armature at that distance from the poles of the electro-magnet where it is under the control of the current between the station receiving and the station transmitting a despatch. Now, the resistance of a telegraphic wire is in proportion to its length and size, and the earth being a conductor of such immense surface as to present no resistance whatever to the current, it follows that upon a long telegraphic circuit there is a constant tendency for the current upon the line to pass off into the earth; this passage of the current into the earth we call "escape." There are no lines in the world, probably, — certainly none in the United States, — whose insulation is so perfect as not to be more or

less affected by this escape. It is much greater during wet weather; but all lines are more or less affected at all times. We shall have occasion to treat upon this subject at length, when we come to discuss the very important subject of insulation; we only allude to it here in order to explain more fully the uses of the adjusting apparatus, and what constitutes a proper adjustment for all conditions of the line.

The strength of a telegraphic current depends upon the intensity of the battery employed and the amount of resistance which the conductor presents. Thus, if we have a battery of fifty Grove cups, with a line well insulated, we can work a relay, or sensitive electro-magnet, a distance of eight hundred miles, with considerable force, or at least with sufficient power to close a local circuit with ease; but if we apply this battery to a line of fifty miles in length, we obtain sufficient power to work the register. The discrepancy between the force with which it operates the two electro-magnets is due to the resistance which the two lines present, the resistance being in proportion to the length of the circuit. During very wet weather, however, unless the line be very well insulated, a great portion of the current escapes; and it sometimes happens that a battery of fifty cups of Grove can scarcely affect the armature of a sensitive electro-magnet at a distance of even one hundred miles, the remainder of the current escaping, a little at each pole, during this entire length of line. The usual arrangement upon telegraph lines is to have relays of batteries distributed at intervals of about one hundred miles, in order the more equally to distribute the current.

We will now suppose a telegraph line of one hundred miles in length, with four stations at equal distances of twenty-five miles. The batteries are placed at both termini, twenty-five cups at each. During dry weather, when the line is tolerably well insulated, one adjustment of the armature serves for all the stations upon the line, and does not require alteration during the entire day; but if there comes up a rain, causing considerable escape, the attraction of the electro-magnet increases, because there is *less resistance*, the current finding a shorter cut, through the earth, to its starting-point. Now, as the magnetism increases from this

escape, the armature must be adjusted farther from the poles of the magnet, — far enough, in fact, to allow for all the magnetism which arises from this escape, — in order to be affected by the breaking of the circuit at the second station. If the escape is equal upon the whole length of the line, it follows that the armature would have to be adjusted from the poles of the electro-magnet as much farther for the second station as the escape was more than usual, double the distance for the third, and three times the distance for the fourth. An operator requires experience and skill in working a line during a heavy escape, and it is not unfrequently the case that two good operators will do a large amount of business over a telegraph line during a heavy storm, when inferior operators would be unable to transmit a single despatch.

In a line of telegraph of several hundred or a thousand miles, any number of receiving magnets may be interspersed, as they do not interrupt the circuit; but the introduction of a large number of these fine-wire electro-magnets increases the resistance, thereby requiring batteries of greater intensity (greater number of pairs), and also a more thorough system of insulation. Each one of these relay magnets may work a local register, and thus the same message may be recorded at a multitude of places practically at the same moment of time. If the receiving magnet is to effect a relay of currents, the motion of its lever brings into action a powerful battery on the spot, which works the next receiving magnet in succession, and so on.

The use of the receiving magnet, however, for the purpose of *relay* of the galvanic force, may be dispensed with by simply increasing the number of pairs and distributing them in groups along the line. Thus Mr. Sears C. Walker, of the Coast Survey, writes: "We have made abundant experiments on the line from Philadelphia to Louisville, a distance in the air of *nine* hundred miles, and in circuit of *eighteen* hundred miles. The performance of this long line was better than that of any of the shorter lines has hitherto been. I learn from an authentic source, that the same success attends the work from Philadelphia to St. Louis, A DISTANCE IN CIRCUIT OF ONE TWELFTH OF THE EARTH'S CIRCUMFERENCE. The number of Grove's pint cups

used is about one for every twenty miles. It is natural to conclude from this experiment, that, if a telegraph line round the earth were practicable, *twelve hundred* Grove's pint cups, in equidistant groups of fifties, would suffice for the galvanic power for the whole line. The expense of acids for maintaining this line would be about five mills per day for each cup, or six dollars per day for the whole line." This distribution of the galvanic agency is frequently adopted in the mode of placing one half of the necessary number of pairs at each extremity of the line.

It is easy for us now to represent the manner in which communication is made between two stations. It is necessary that there should be at each, — 1st, a principal battery, called a main battery, and a local battery; 2d, a writing apparatus; 3d, a relay; 4th, a lever-key. The lever-key at each station communicates in a permanent manner with the ground, by means of a conductor; it communicates also, by another conductor connected with the anvil, with one of the extremities of the wire of the electro-magnet of the relay, the other extremity of which is connected with one of the poles of a battery, whose other pole connects with a line wire. It follows from this arrangement, that if the lever-key of the second station is lowered, the principal current of this station causes the relay of the former to act, since its circuit is complete. The current, indeed, coming from one of the poles of the principal battery, arrives at the metal piece of the relay, where it finds the end of the line wire, traverses this wire, then arrives at the metallic piece of the relay of the former station, traverses the wire of the electro-magnet of this relay, arrives at the screw of the lever-key, thence goes into the ground, whence, returning to the second station, it penetrates by the earth wire into the lever-key of this station, which, being depressed, leads to the screw which is in communication with the other pole of the battery.

M. Steinheil, of Munich, who has so ably contributed to the perfecting of the Electric Telegraph, has found it convenient to join to the principal batteries of each of the stations a considerable resistance, the extent of which might be changed without interrupting the current. He has accomplished this by means of

a *rheostat*, consisting of a very fine brass wire. By so selecting this wire that a length of 40 feet presents very nearly the same resistance as 16,000 feet, or three miles of the conductor, he succeeds, by brass wire of from 400 to 600 feet in length, in producing resistances equal to those of the conductors comprised between two consecutive stations, or those which we call partial lines. This rheostat is so arranged that, in a very brief space of time, one is able to introduce into the circuit resistances equal to one, two, three, and up to eleven *leagues* of the line wire; a second rheostat added to the former allows of introducing likewise very promptly resistances equivalent to one tenth of those of the former, that is to say to $\frac{1}{10}$, $\frac{2}{10}$, &c., of a league of the line wire. The necessity of this introduction of a variable resistance into the circuit is due to the importance of having a current of constant force, in order to act upon the relay; seeing that the apparatus, when once adjusted by the tension of the spring, ceases to act well, if the current becomes more or less intense than that under the influence of which it has been adjusted. Now, the current which sets the apparatus in motion is variable, for its intensity depends upon the state of the battery, which, even in the most constant batteries, may vary, and especially on the insulation of the line wire, which changes with the degree of humidity of the air and of the supports. Every day, therefore, it is necessary to vary the additional resistance arising from the introduction of the rheostat into the circuit, so as to have, as much as possible, a current always of the same intensity, which is determined by means of a compass, surrounded with a galvanometric wire, which forms part of the principal circuit, and with which each station is provided.

The adjustment of the force of the current regulates the action of the apparatus; and it furthermore enables us to know the condition of the whole of the line; for the losses of current are more powerful, and consequently the insulation of the line wire more imperfect, in proportion as it is necessary to increase the deviation of the compass at the departure station by diminishing its resistance, in order to obtain at the other station the deviation that corresponds to the normal current, under the action of which

the apparatus ought to work. Notwithstanding the incontestable advantages of the rheostat, we shall however see, in a moment, that experience has shown that it might be dispensed with without inconvenience; and that it is more simple and convenient to adjust the apparatus every day, according to the variable intensity of the current, by putting more or less tension upon the springs of the relays, and by adjusting the armatures by means of the adjusting screws and the adjusting carriage.

Before going farther and pointing out by certain practical details the manner of using Morse's telegraph, it is time to make known the nature of the signs, or alphabet, which it has been arranged to employ. As we have already said, the signs are two in number, a dot and a dash; and it is by numbering them two and two, three and three, and four and four, that they have succeeded in obtaining in all forty-one indications, corresponding to the letters in the alphabet, the numerals, and punctuation-marks. The alphabet is the same in principle as that employed by Harrison Gray Dyar in 1828, and Prof. Steinheil in 1837. On the opposite page is given the table of these combinations, placed side by side with the letters, numerals, and punctuation-marks which they represent.

We have seen that the pen of the recording instrument is in contact with the paper, as long as the lever-key is held down; the length of the marks traced by the pen is proportional to the time of the depression of the lever-key, and the interval between two marks depends upon the duration of the pauses between two successive depressions. But the successive production of dots and dashes by the depression of the key requires a measured rhythmic movement, without which it is impossible to trace in a regular manner the successive signs; for time is the measure of the length of each sign, and it is consequently necessary to employ the natural measure that we possess for time, which is rhythm. In order, therefore, fairly to comprehend the action of the lever-key, it is necessary to exercise one's self to depress it in time. With this view we strike upon a table with the tip of the forefinger of the right hand in two different methods: — 1st. By drawing back the finger with rapidity, so that it rests upon the

Letters.	Signs.	Ciphers and Punctuation-Marks.	Signs.
a	·—	1	·———·
b	—···	2	··——··
c	·—·—	3	···——·
d	—··	4	····—
e	·	5	—————
f	··—·	6	····—··
g	——·	7	——···
h	····	8	—····
i	··	9	—··—·
j	—·——·	0	———
k	—·—	.	··——·—··
l	———	,	·—·—·—
m	——	?	——··——·
n	—·	!	——·——·
o	· ·	“ ”	·—·—·—·—·—
p	····—·	( )	·—··—·
q	··—·		
r	·—··		
s	···		
t	—		
u	··—		
v	···—		
w	·——		
x	·——··		
y	··——		
z	···—·		
&	·—···		

table for an instant only, and by raising it only half an inch. 2d. By leaving the finger resting upon the table for the time that separates two blows of the first kind, and by raising it for an equal time. Each beat of the first kind is measured by the syllable *di*, which is pronounced while making the beat; with regard to the beats of the second kind, they are measured by pronouncing the syllables *do-o*. The beats that are made while pronouncing the *di* would produce dots, and those which are made while pronouncing *do-o* would give dashes, if the finger had been rested on the lever-key that sets Morse's writing-apparatus

in action; but it is better first to learn the use of the telegraph without apparatus, and by merely accustoming one's self to strike upon a table in the manner that we have pointed out. We must then practise producing a dash and two dots, then two dots and a dash, and so on, always pronouncing during these movements of the finger the syllables *di* and *do-o*, each syllable requiring to be pronounced at an equal distance from the following. We see that intervals of equal times elapse between two dots, from one dot to the following dash, from the commencement of the dash to the end, and from the end of the dash to the first following sign. Each dot requires only a single interval of time, while the dash requires two. In the formation of the groups that result from the combination of dots with dashes for the representation of different signs, regard has been had to the number of intervals of time, so as to have the fewest possible.

After a little practice, one easily succeeds in writing distinctly twenty or twenty-five words in a minute, and in reading with the greatest facility. It is essential that the lever-key shall have but a very limited play in order that the *do-o*, or beats of the lever-key, when it is lowered and raised, shall follow each other at equal intervals. We succeed very quickly in distinguishing by the ear the dashes from the dots, the lever-key making a noise similar to *tri tri tri* for the dots, and to *do-o* for the dashes; we succeed also in distinguishing them, as well by the action of the relay as by the action of the lever of the recording apparatus.

It will be obvious from the above description of the mode by which the letters are made in this system, that a good appreciation of time is required for a skilful operator; indeed, there is very little use in any one's endeavoring to excel as a manipulator unless he possess an accurate appreciation of time. We have known many persons to attempt to become operators, who have failed from a want of the proper development of this faculty. We have in our recollection now, one who, after many months' application, was obliged to translate his despatch into the arbitrary characters of the telegraphic alphabet, upon a slate or a piece of paper, and then count for the dashes and dots as he

depressed the key, and in this laborious manner to transmit his despatch!

The description which we have given of the apparatus of the Morse system is a correct one, as it was used in all the offices for

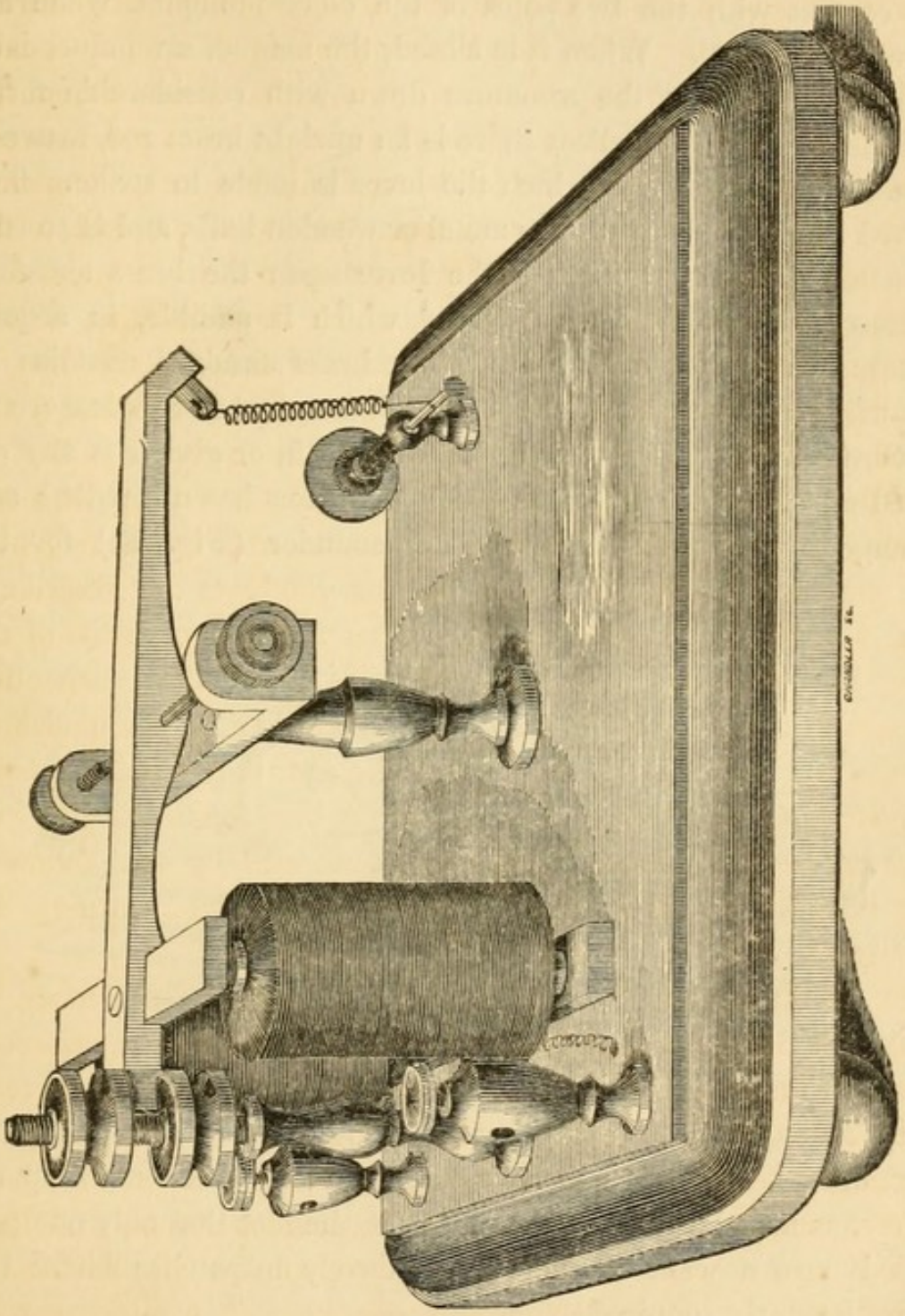


Fig. 42.

many years; but since the adoption of the method of reading by sound, another apparatus has taken the place of the register, or recording apparatus, called the *sounder* (Fig. 42).

This is simply an electro-magnet attached to a rosewood or mahogany base, with an armature attached to a lever; the lever is supported upon the centre of its axis by two pivots. A spring at one extremity of the lever serves to draw the armature from its contact with the two poles of the electro-magnet, when the circuit is broken. When it is closed, the magnetism induced by the current draws the armature down with considerable force. At the rear of the helices there is an upright brass rod, fastened also to the board, upon which the lever is made to strike. The board itself stands upon four metal or wooden balls, and is so constructed that the striking of the lever upon the brass standard causes a loud and distinct sound, which is audible, in a quiet place, a couple of rods distant. The brass standard contains an adjusting apparatus, which enables the operator at pleasure to govern the sound, — making it loud or soft, or giving it any desired pitch. No other part of the apparatus has undergone any change by the substitution of the sounder (Fig. 43) for the

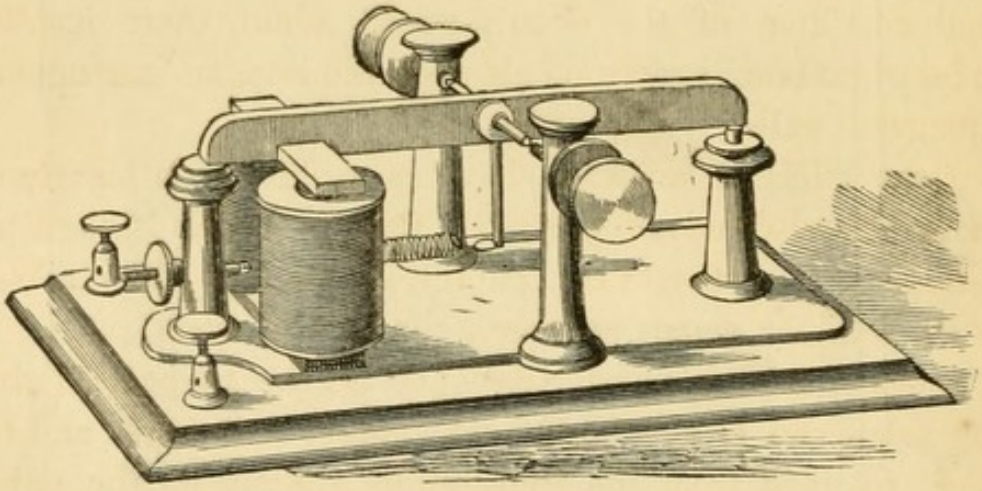


Fig 43.

recording apparatus. But there has arisen from this a great saving in the force necessary for doing a large business over the wires, as may be easily imagined from the fact that only one person is now necessary to receive and copy despatches where two were formerly required.

It was soon discovered, after the introduction of the Morse system of telegraph, that words could be read by the click of the magnet; but paper was used, upon which the arbitrary alphabet

of dots and lines was indented by the instruments, for all matters of business up to 1852, and by many lines even later; but at the present time there is scarcely an office of any importance in the United States where the paper is used to receive the record.

Ten years ago the practice was, almost invariably, in the principal offices, to employ an operator to read the despatch from the long strips of paper, as it came from the instrument; and a copyist who stood by his side took it down. Now, the system is entirely changed. The operator reads by the click, and copies the messages himself. By this means the expense is lessened nearly one half, and the risk of errors in a far greater ratio.

Repeaters. — Although a telegraphic circuit of one thousand miles works quite as well as a shorter one, provided it be well insulated, still it has proved so difficult to accomplish the latter condition during all states of our variable weather, that shorter circuits have been resorted to; and where it has been found desirable to transmit despatches to points more distant than the normal condition of the circuit would admit, there has been introduced, at one or more points upon the line, an instrument or an apparatus called a *Repeater*.

Various kinds of repeaters have been devised, all possessing advantages and disadvantages; but the one which is used upon the lines in this section of the country, invented by Messrs. Woodman and Farmer, seems to answer the purpose well.

A repeater is an apparatus designed for the purpose of duplicating from one electric circuit to another the breaks and completions received from the transmitting station, for the purpose of renewing the power lost by the escape of the electric fluid into the earth through bad insulation.

In the earlier repeaters, the armature of the receiving magnet is made to perform the functions of a circuit breaker and closer to another circuit, the two circuits being entirely independent of each other, excepting that the breaks and completions on one are made by the armature of the electro-magnet which is in the other, and this armature is controlled by the operator's key at the transmitting station. This repeating arrangement requires

the attendance of an operator to turn a switch to keep the points electrically connected that form a portion of the circuit from which despatches are being sent. Woodman and Farmer's repeater obviates this and other objections by an ingenious arrangement of detents and frictions.

The electro-magnetic part of this apparatus is worked by local circuits; consequently the relay in the circuit on the left operates by a local battery the electro-magnet on the left of the repeater, and the relay in the circuit on the right operates the electro-magnet on the right of the repeater.

The main circuit on the left runs through the relay, thence to the front right screw-cup, thence by the spiral wire to the binding screw-head by the standard, but insulated from it excepting at the point where it supports a flat brass spring; then by means of the spring, which is supported a short distance above the armature of the electro-magnet, to the standard and back screw-cup on the right; thence to the battery and ground.

The circuit on the right may be traced in the same manner at the opposite side of the repeater.

If the flat spring on the left be lifted from the binding screw, which supports it, the circuit upon the right will be opened, and *vice versa.*

The local circuits are similar in arrangement to the usual combination, — the armature and standard of the relay in the left circuit forming a part of the local circuit which works the left electro-magnet on the repeater, and the armature and standard of the relay in the right circuit forming a part of the local circuit which works the electro-magnet on the right.

The switch on the back of the base board, at the right, is designed to break the local circuit which works the sounder, and close another with the same battery through the helix on the right of the repeater; and the switch on the left performs the same office for that part.

At the top and near the middle of the framework are two detents, projecting beneath the armature of the electro-magnets.

Projecting from the shaft of each detent is an arm, situated immediately over another arm in connection with the armature of the electro-magnet on the opposite side of the repeater.

Having given an idea of the construction of the repeater, we will now explain its *modus operandi*.

The switches on the front being thrown off to allow the armatures to break the circuits, and those on the back being switched so as to form the two local circuits through helices on the repeater, — now if the main circuit on the left be opened, the local circuit is broken by the relay, and the armature of the electro-magnet on the left, being released, is drawn up against the flat spring, which it lifts from the binding-screw, breaking the main circuit on the right. Before, however, the armature reaches the spring, the arm attached to it strikes the arm which projects from the shaft of the detent on the opposite side, throwing the detent under the armature on the right, which is thus prevented from reaching the flat spring on the right, and breaking the left circuit.

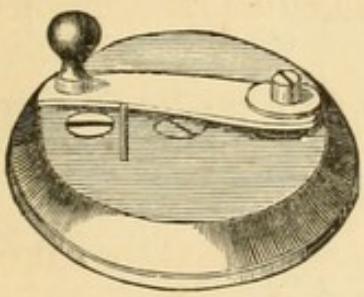


Fig. 44.

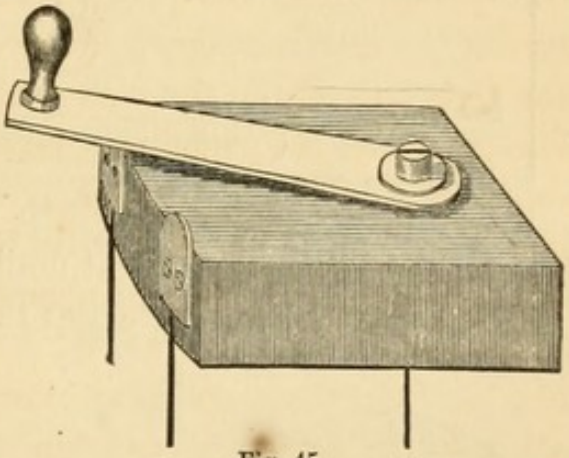


Fig. 45.

Now if the circuit on the left be again closed, the armature of the repeating magnet on that side will also close by the action of

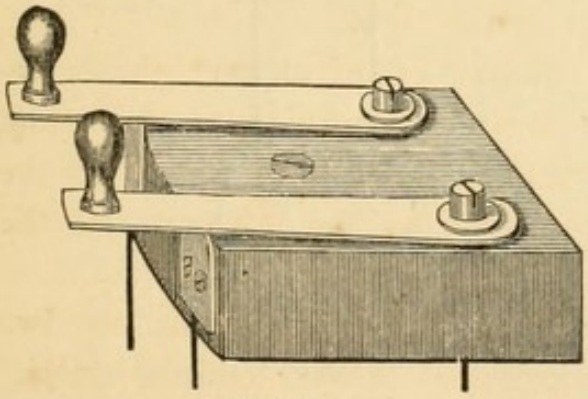


Fig. 46.

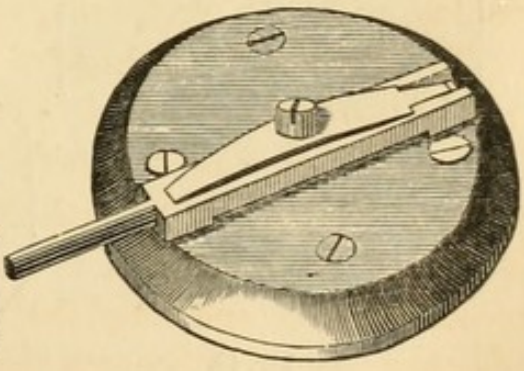


Fig. 47.

the relay, but the detent which it threw under the opposite arma-

ture is held there by friction until the relay on the right has time to operate. The circuit on the right in closing closes the local circuit, and releases the detent, which is drawn into its original place by a spring. Thus the armature of the right electro-magnet is prevented from making false breaks in the circuit on the

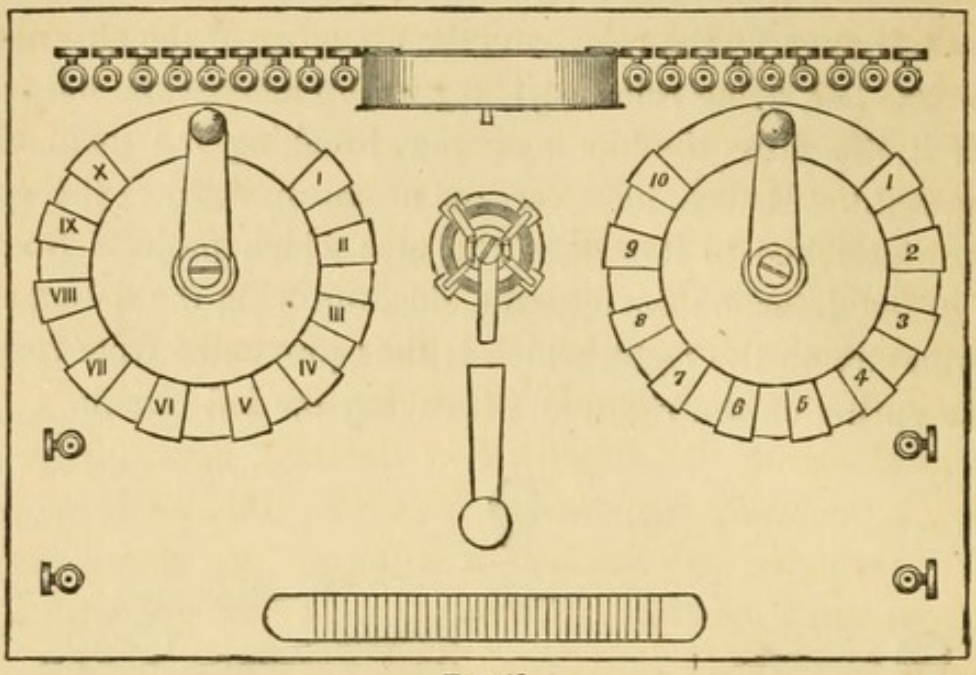


Fig. 48.

left, it being held by the detent until it is released by the closing of its own relay, which also closes the repeating armature.

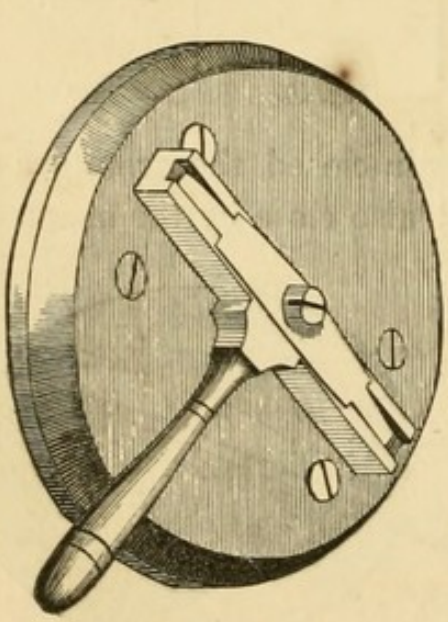


Fig. 49.

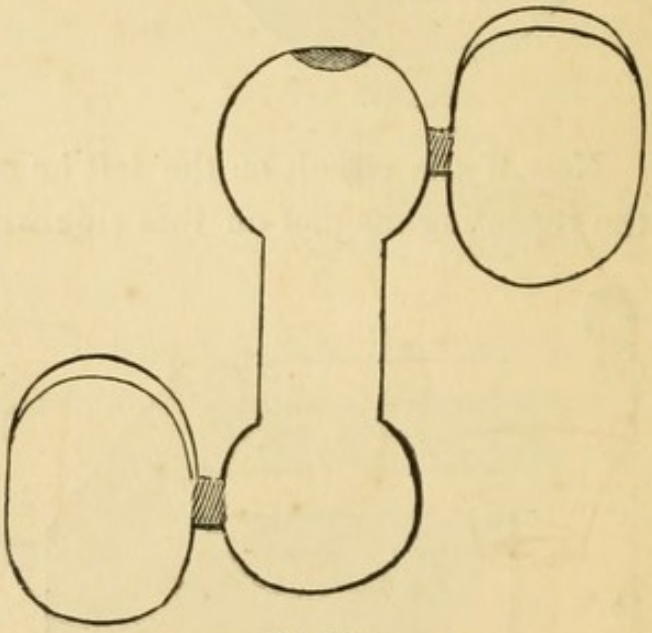


Fig. 50.

If both circuits are closed, the armature that first opens throws a detent under the other before opening the other circuit, and

when the circuit is to be closed, instead of depending upon the prompt action of the relay in closing to prevent a false break, the armature is held by the detent until the relay has actually closed, which, closing the repeating armature, lifts it from the detent, which, being before held by friction with the armature, is now drawn from under it.

Various apparatus used in telegraph offices, such as switches, screw-cups, thumb-screws, &c., require a passing notice. Fig. 44 represents a simple switch used for closing the circuit, with the key raised. Fig. 45 is a switch for throwing on a ground at an intermediate office, for testing the line or for closing the main circuit when the line is broken beyond. Fig. 46 is a double switch for the purpose of changing the directions of different lines. Fig. 47 is used for the same purposes as Fig. 44. Fig. 48 is an instrument for bringing any number of batteries into circuit at pleasure, from one to one hundred cups. It is arranged with a pole-changer, break-piece, key, and clock-work electrotome. It is called a manipulator. Fig. 49 is a switch, designed for throwing portions of the apparatus out of the circuit at pleasure. Figs. 50, 51, and 52 are thumb-screws, designed for uniting wires tempo-

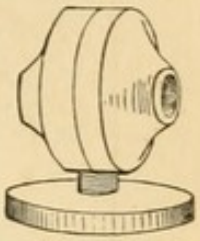


Fig. 51.

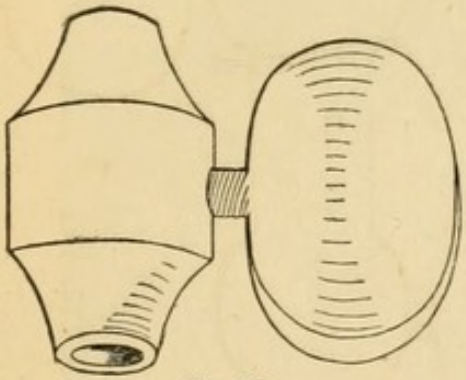


Fig. 52.

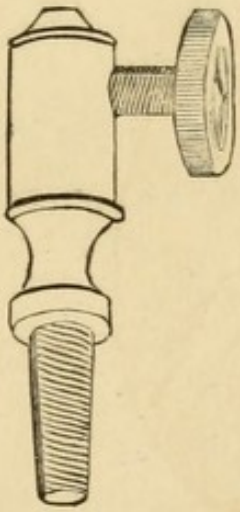


Fig. 53.

Fig. 54.

rarily in the offices, or for connecting wires upon the line at testing places. Fig. 53 is a screw-cup, used upon the copper end of a Daniell battery, for the purpose of connecting the line

wire. Figs. 54 and 55 perform the same office for the zinc pole of a Grove battery.

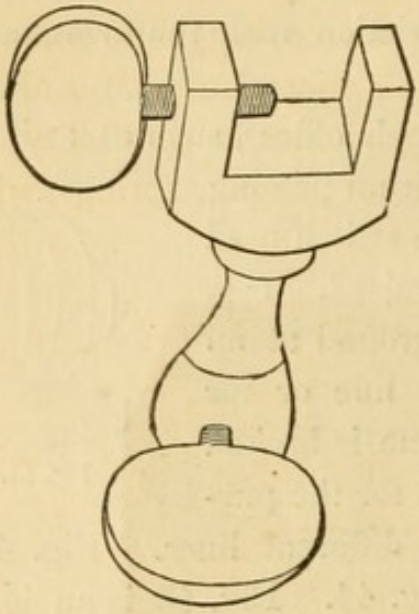


Fig. 55.

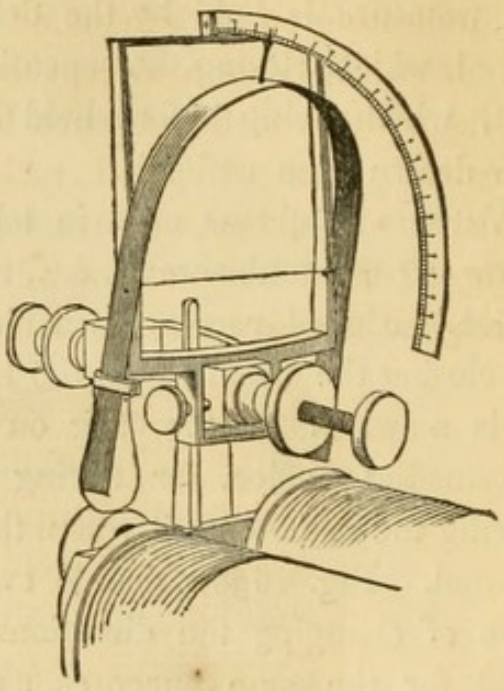


Fig. 56.

Fig. 56 represents a galvanometer attached to an electro-mag-

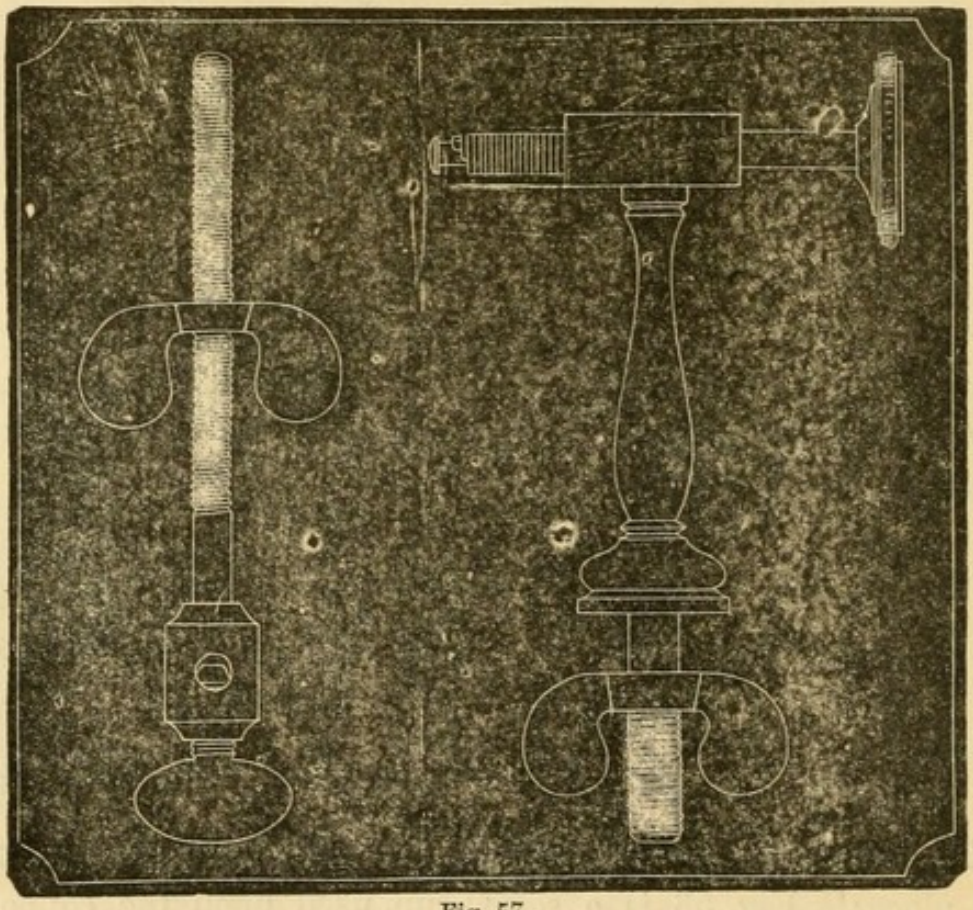


Fig. 57.

net. This is an exceedingly delicate permanent magnet. The

electro-magnetism induced in the magnet cores repels the poles of this magnet; it swings on its centre towards a horizontal position, indicating on the graduated arc the force of electro-magnetism. It will indicate a current too feeble to vibrate the armature, and its position with reference to the electro-magnetic poles can be instantly changed, so as to make their operation upon it always repulsive. A sliding weight upon it graduates its sensibility.

Fig. 57 is an independent adjuster for magnet springs, which is designed to screw into the table.

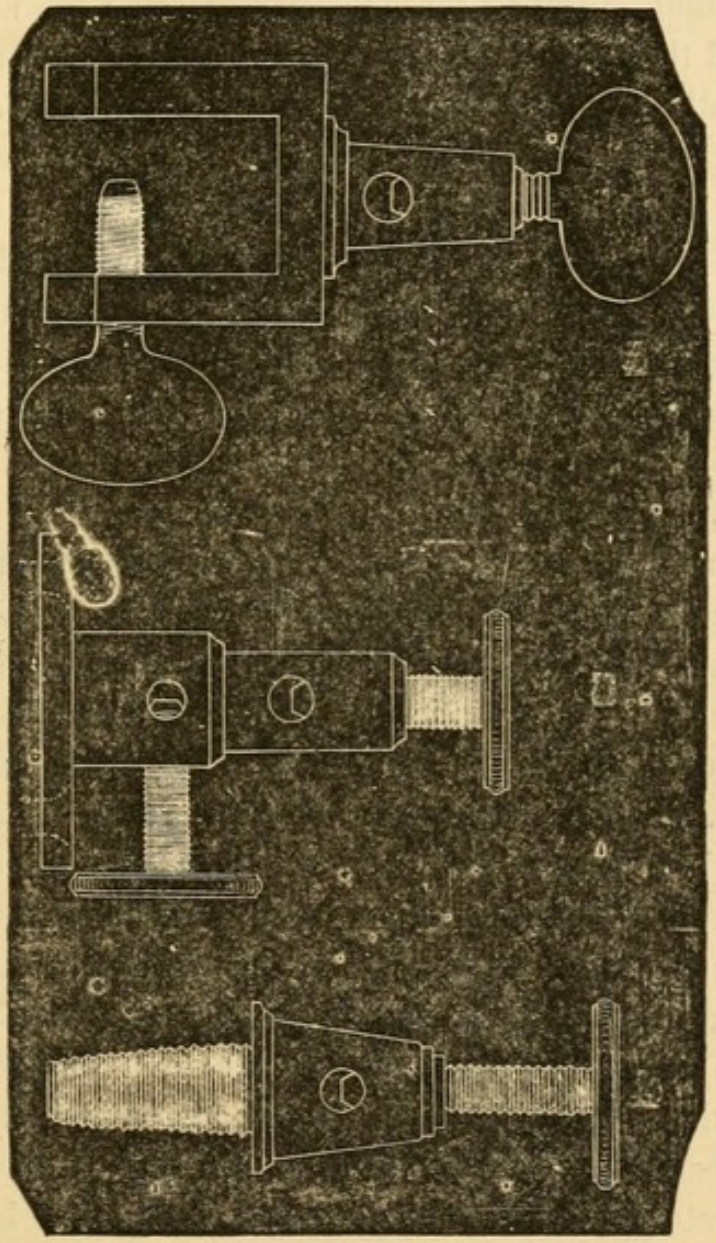


Fig. 58.

Fig. 58 represents binding-screws, connectors, &c., for screwing to zincs of local or main batteries as pole connections.

CHAPTER VI.

THE NEEDLE SYSTEM.

THE essential part of the needle telegraph is the multiplier, the needle of which, fixed vertically upon a horizontal axis, moves in front of a dial. Among these telegraphs, some are single-needle; others, and they are the more numerous, are double-needle. The single-needle telegraph has an alphabet engraved on the right and left of the needle; some letters require as many as four movements, which may be either all on the same side, or some on one side and some on the other; but it is necessary that the last movement of a letter placed on the right shall always be to the right, and that of a letter placed to the left, always to the left. Thus W is indicated by four movements, three to the left, and the fourth to the right; L, by four movements, to the right, to the left, to the right, to the left. Beneath each letter there is a sign, formed of one or more right lines, inclined toward the right or toward the left; some of these diagonal lines are entire, the others have only half the length; the direction of the diagonal is that of the deviation, and one deviation is required for each diagonal; the deviation indicated by the demi-diagonal is first made. In order to simplify the matter, it has been agreed to proceed in the following manner: one, two, three, four deviations to the left are first employed for the first four signals; then one to the right, with one, two, three deviations to the left, for the three following signals; then two to the right, with one to the left; then to the left, the right, the left; and finally to the right and left, the right and left; which leads as far as the letter L, and thus completes the first half of the series. The second half is the counterpart of the first; the deviations to the left are simply replaced by deviations to the right, and reciprocally. The numerals are inscribed under the needle; and they are indicated by the movements of the lower part. Thus, in order to show 4,

the lower extremity of the needle is carried once to the right, and once to the left.

The double-needle telegraph differs from the preceding only inasmuch as it is composed of two multipliers, instead of having but a single one. The two needles are likewise arranged vertically, each on a horizontal axis. The upper case is occupied by the bell, or alarum. The letters of the alphabet are arranged upon several lines, commencing at the left and finishing at the right, as in ordinary writing. The first series, from A to P, appears above the points of the needles; the second series, from R to Y, appears below the points of the needles. Each letter is indicated by *one*, *two*, or *three* movements. The letters of the upper series are formed by the nearest needle, which is made to deviate once, twice, or thrice on the side where the letter is, so as to point towards it. For the letters of the lower series, both needles are moved together, by directing their lower ends towards the letter. Six letters, C, D, L, M, U, V, require two contrary movements of the needle, or of both needles; first to the right, then to the left, for C, L, and U; and first to the left, then to the right, for D, M, and V. These letters are engraved in small capitals, and separated by double arrows.

It remains for us now to make known the internal arrangements of the needle telegraph (Fig. 59). We shall content ourselves, for the sake of simplicity, with describing that of the single-needle telegraph, the arrangement of the double-needle telegraph being, with a slight modification, almost entirely similar. The multiplier in these telegraphs carries, as in ordinary multipliers, two needles; the one, called *diamond needle*, when made in the form of a lozenge, very short and very wide; the other, exterior, rather longer, and similar to ordinary needles. Mr. Walker found advantage in substituting for the diamond needle, a needle formed of several very short needles of thin steel and strongly magnetized, fixed upon an ivory disc of 1¼ inches in diameter. A single narrow, coffin-shaped rhomb makes a good needle. The outer needle is three inches in length. The frame of the bobbin, *A*, Fig. 59, is of brass, or, better still, of wood or ivory; it is fixed by screws to a brass plate, often var-

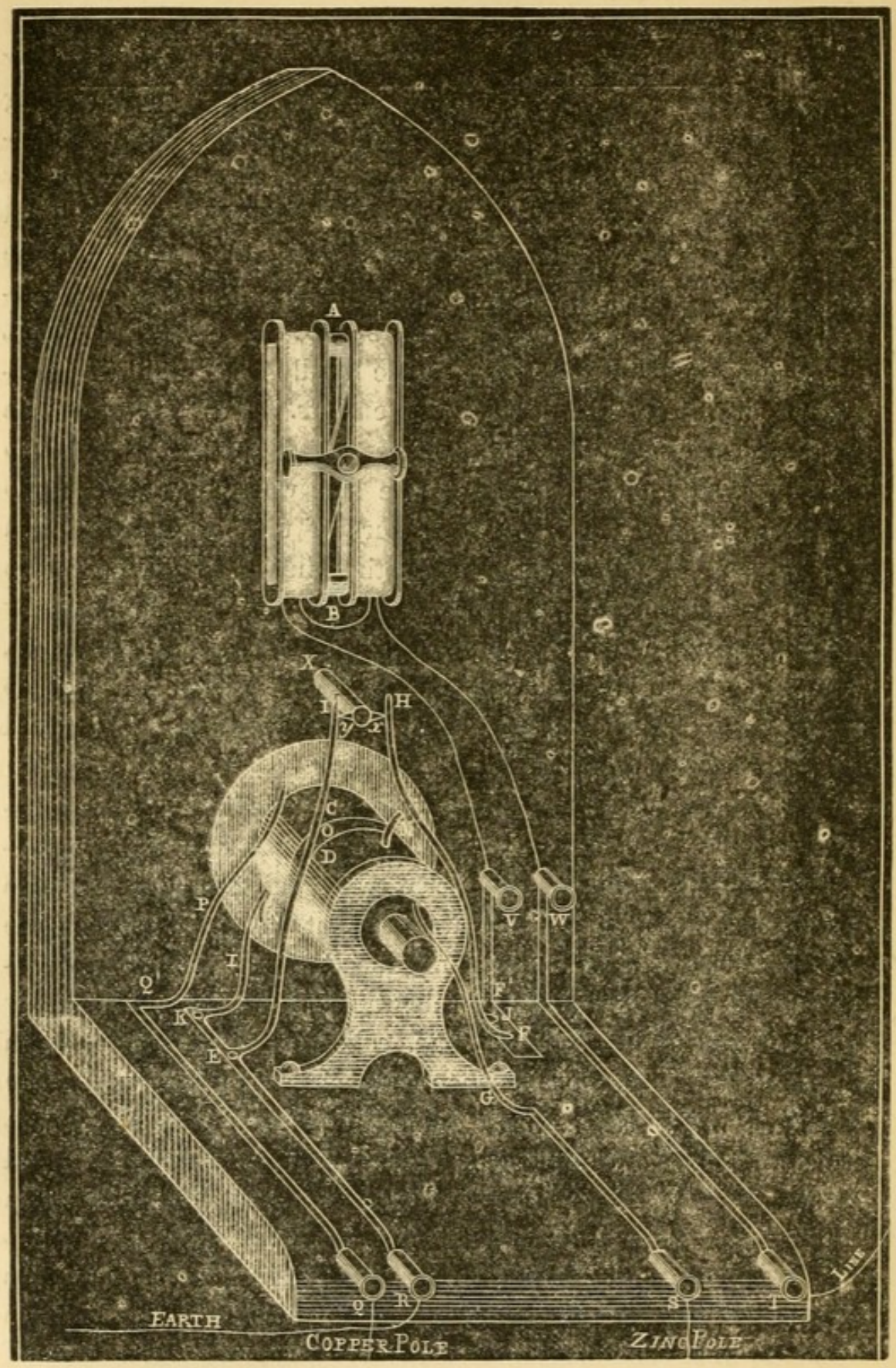

A
B
X
I
H
y
x
C
O
D
P
V
W
I
Q
K
E
F
N
F
G
Q
R
S
T
LINE
EARTH
COPPER POLE
ZINC POLE

Fig. 59.

nished on the side towards the case, and supported against its frame; or it is made in halves, and slides into grooves at the back of the case, independently of the dial. The wire of the bobbin is less than a hundredth of an inch in diameter; its two extremities abut upon binding-screws, *V*, *W*; a slip of metal unites the extremity *W* with another binding-screw, *T*; *V* communicates in like manner, by a metal slip from *V*, by the spring *H*, the stud *a*, and the spring *E*, with the binding-screw *R*. The springs *H*, *I*, which are of steel, press strongly against two points fixed into a brass stem, *X*, cemented into the wooden case of the instrument. A conducting-wire connects the binding-screw *T* with *R* (when the instrument is being tried on a short circuit in a room); and the circuit is completed in the following manner between *T* and *R*. The current, arrived at *T*, passes into the bobbin by the right side, returns by the left, ascends the steel spring *H*, passes by the studs in the stem to the other spring, *I*, descends to *R*, and completes the circuit by the earth wire. Let us now conceive that the conducting-wire of a first station communicates with *T*, and the wire of a second station with *R*, the apparatus will be in the circuit of the telegraphic line, and quite ready to receive (as above described) the signals manifested by the deviations of the needle or needles; since two similar apparatus are connected with each other, and their bobbins are traversed at the same time by the current that goes from *T* to *R*. In order to obtain greater regularity, it has been agreed always to place the conducting-wire that leads *up* the line in communication with *T*, and the wire that leads *down* the line with *R*.

The above is the manner in which signals are received; let us now state how they are transmitted. The commutator is a cylinder of boxwood, mounted as shown in the figure, and which is able to turn upon itself by means of a handle; its extremities, *Z*, *N*, are fitted with brass collars, with studs standing out, and insulated from each other by the wood which separates them. Two strong steel springs, *G*, *K*, fixed at the right and the left upon the brass slips, rest with friction, one upon the brass drum *Z*, and cause the extremities of the commutator to communicate with the binding-screws *S* and *Q*, and by their means with the

poles of the battery. If the commutator is made to turn, the stud *M* causes one of the springs *H*, *I*, to rise, which, by this act, will no longer communicate with each other by the stem *Q*. In the figure, it is the right spring *H* that is raised; but a little further motion imparted to the commutator causes the block *o* to be touched by the stud *M*, which places it in communication with the drum *y*; the current of the battery then circulates through the apparatus, and in the whole of the telegraphic circuit. In fact, when arrived at *S*, it will pass by *G* into the drum *Z*, will enter by the upper stud *M* into the spring *H*, and thence by *V* into the bobbin; it will come out by *W*, will come on to *V*, will pass along into the conducting-wire of the telegraphic line, will come to *R*, will pass by *E* to the stud *I*, and thence by the drum *y* and the spring *Q* along the slip to the copper pole *Q*. If the manipulator is turned in the opposite direction, the current transmitted from *S* to the drum *Z* will arrive at *R* by the spring *H* and the plate *E*; will go into the conductor of the telegraphic line; will come to *T*, enter into the multipliers by *W*, and come by the plate and block to the stud *K*, to the drum *Z*, and by the spring *Q'* to the copper pole *Q*. The internal arrangements of the multipliers are so arranged, that, when the handle is turned to the right, the needle is deviated towards the right. The needle *A*, placed at the outside of the apparatus, has always its north pole upwards; the inside needle has always its north pole downwards; so that, in virtue of the law of the action of currents upon magnets, if on looking at the instrument in front we see the upper point of the needle move towards the right, we may be sure that in the half of the wire nearest to the spectator the current is ascending. We have merely, therefore, to turn the handle now to the right, now to the left, in order to make all the needles of the telegraphs deviate to the right and left, and transmit signals.

The alarum, or bell, intended for giving notice that a despatch is about to be sent, and which is placed upon the top of the case, presents a very simple mechanism; it consists of an electro-magnet, and a movable armature of soft iron, attracted by the electro-magnet every time that, and also for as long a time as, the cur-

rent passes; two small brass screws, tipped with ivory, and fixed into the armature, prevent its coming into absolute contact with the poles of the electro-magnet, while still permitting it to approach very near to it. The object of this arrangement is to prevent the adherence of the armature of the electro-magnet, an adherence which too often would continue even after the rupture of the circuit. The armature is terminated by a lever, arranged as a detent, in such a manner that when it is drawn up by the current the detent is released, and thus sets in motion a train of clock-work which causes a hammer to strike a bell.

In concluding the description of the double-needle telegraph, let us now recall to mind the manner in which it is employed. The following is, first, the complete vocabulary: —

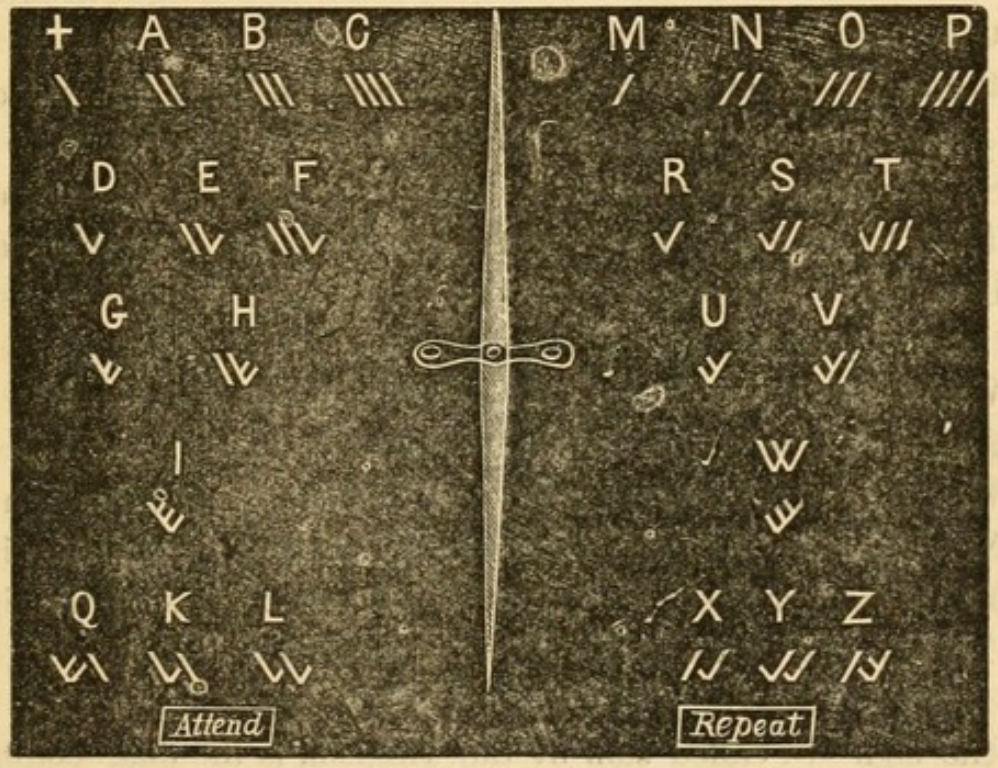


Fig. 60.

A. Two movements towards the left of the left needle.

B. Three movements toward the left of the left needle.

C and 1. Two movements of the left needle; the first to the right, the second to the left.

D and 2. Two movements of the left needle; the first to the left, the second to the right.

E and 3. A single movement of the left needle toward the right.

F. Two movements to the right of the left needle.

G. Three movements of the left needle toward the right.

H and 4. A movement toward the left of the right needle.

I. Two movements toward the left of the right needle.

J is omitted, and G substituted for it.

K. Three movements toward the left of the right needle.

L and 5. Two movements of the right needle; the first to the right, the second to the left.

M and 6. Two movements of the right needle; the first to the left, the second to the right.

N and 7. A single movement toward the right of the right needle.

O. Two movements toward the right of the right needle.

P. Three movements toward the right of the right needle.

Q is omitted; K is substituted for it.

R and 8. A parallel movement toward the left of both needles. The lower end is read in this and the two following signals.

S. Two parallel movements toward the left of both needles.

T. Three parallel movements toward the left of both needles.

U and 9. Two parallel movements of both needles; the first to the right, the second to the left.

V and 0. Two parallel movements of both needles; the first to the left, the second to the right.

W. A parallel movement of both needles toward the right.

X. Two parallel movements of both needles toward the right.

Y. Three parallel movements of both needles toward the right.

Z is omitted, unless made with one beat more than Y; or S is substituted.

The sign +, called *stop* by the English, is the final point, by which the person who sends the despatch announces that the word is finished; it is indicated by the movement of the left needle toward the left. This sign serves also for him who receives the despatch to indicate that he does not understand; when he understands, he shows the letter E; two E's, or rather two movements of the left needle, are employed for saying *yes*.

The words, *wait*, *go on*, engraven upon the instruments, are useful signals. If London addresses Dover, when Dover is occu-

pied and is unable to lend attention to the correspondence that London is about to open, Dover directs the lower end of the needles to the letter R, and says by this act, *wait.* When he has become at liberty again, and ready to receive the message, he directs his needles to W, which means, *go on.*

It is especially important for the two stations that are opening a correspondence to understand each other well before commencing. It is necessary that the one who receives should know well who is sending to him; and that the one who sends a message should know clearly if it is the station with which he desires to correspond that really receives it. Above the six large letters, +, E, H, N, R, W, are engraved the names of the stations of the group: and these stations will henceforth be always designated by these letters. In the apparatus, R is London; E, Tunbridge; H, Ashford; N, Folkestone; W, Dover. If, now, London desire to correspond with Tunbridge, he directs his needle to E for a few moments; each movement causes the Tunbridge bell to ring, should it be in circuit, which, as we have seen, would be situated on the same wire as the left needle. The attention of the clerk is roused; he puts his alarum out of circuit, and transmits to London the same signal, which is equivalent to saying, *All right, I am at my post.* London is then sure of being understood at Tunbridge. He then directs the needles upon the letter R, which indicates London, and Tunbridge, in his turn, knows that it is London that is speaking to him, and by repeating this same signal, R, he says that he has received it. London then goes on with Tunbridge; the correspondence commences, and Tunbridge after each letter says E, *understand*, or the stop +, *not understand.* When the despatch is completed, London makes two deviations of the left needle towards the left; the clerk at Tunbridge repeats them, if he has nothing to add, and proceeds to the transmission of the despatch to its ulterior destination.

Two telegraph clerks are able to modify their vocabulary in such a manner that the intermediate stations seeing their signals are unable to decipher them. They can agree, for example, that the right directions shall be read to the left, and reciprocally, for one of the needles, or for both; secondly, that the left needle

shall become a second right needle, or the right needle a second left one; or, thirdly, that the right needle shall become the left needle, and the left the right, &c., &c.

The figures are written under certain letters; and the sign H followed by the + shows that a figure is about to be indicated, and not the corresponding letter. In order to avoid all errors, the correspondent immediately repeats the same H +, indicating by this that he expects a figure, and not a letter. The letter W, interposed among the figures, serves to separate compound figures or decimal fractions. Thus, H, E, W, N, means 43*l.* 7*s.*, or 43 ft. 7 in., or 43 h. 7 m., &c. Special signals indicate periods, paragraphs, words underlined, or other important circumstances; the clerks have invented a signal for laughing, and for expressing their astonishment, &c., &c. The English clerks are so well skilled, that they are able to send the most difficult despatches, even when no letter or figure or signal may be engraved upon the dial of their apparatus.

As may be supposed, the double-needle telegraph may easily be arranged so that it shall act as a single-needle telegraph only, which is very valuable in many cases; as, for example, when one of the two wires necessary to the double-needle telegraph has become deranged or broken; or when the two wires, by the effect of a violent storm or an accident, have come into contact, so as to constitute one only. Moreover, the single-needle telegraph, although its manipulation requires a little more time, is able to render great service; it is not unfrequently employed for the notices to be given on railways between the various stations.

The double-needle telegraph is perhaps the most perfect of all in theory; and although it requires the employment of two wires, it merits the preference in the majority of cases, both on account of its simplicity, the action upon which it depends being a direct action, which does not require any intermediate mechanism, and also on account of its infallibility, which is due to the same cause, since it is less susceptible than any other of becoming deranged and giving rise to errors. The facility with which the handles lend themselves to the movements to be executed, and the rapidity which results from it in the transmission of despatches, are

equally remarkable. Mr. Walker, as the result of his long experience, has observed that, in ordinary cases, from fifteen to twenty words per minute are easily transmitted; that very frequently, when all is in order and the insulation is good, twenty-five or more are transmitted. These considerations explain why the double-needle telegraph is generally adopted in Great Britain, and why it is retained, notwithstanding the evident superiority in many respects, as we shall see, presented by Morse's telegraph; they will likewise serve as our justification for the extended description we have given of it.

There remains another needle telegraph, contrived by Mr. Bain, which was set up in 1846, upon the line from Edinburgh to Glasgow. This telegraph is a single-needle one; but the number of movements necessary for forming a signal never exceeds four; this is only one more than in the double-needle telegraph, and the same number as in Cooke and Wheatstone's single-needle; it has the same advantage as the latter in requiring only one wire. This telegraph, like the preceding one, depends upon the action that is exercised upon the magnet by the current that traverses the wire of a bobbin; but the arrangement of the different pieces of the apparatus is very different; the two permanent magnets of a semicircular form are connected together by means of a brass rod in the diameter of their circle, upon which is fixed, perpendicularly to this diameter, the indicating-needle, which comes from its centre, through which also passes the axis of rotation. The two semicircular magnets have their poles of the same name near to each other, there being between them an interval of not more than a sixth of an inch; two bobbins are so placed that, in the state of inaction, the two neighboring poles of the magnets are likewise in the interior of the same bobbin. It follows from this that, as soon as a current penetrates into the wire of the bobbin, one of the poles is driven from the interior of the bobbin, whilst the other penetrates into it; which produces, according to the direction of the current, a movement of the indicating-needle, either to the left or to the right. The same effect takes place upon the other two poles of the two semicircular magnets, which likewise penetrate into the interior of a second bobbin.

It is now easy to comprehend that, by means of a commutator, we are able to produce movements of the indicating-needle as numerous as we desire, and which rapidly succeed each other, either to the right or to the left, and the direction of which deviations is carefully made to coincide with that of the motion imparted by the hand to the arm with which the handle is furnished, by which the commutator is made to move.

CHAPTER VII.

HOUSE'S PRINTING TELEGRAPH.

THIS magnificent instrument (Fig. 61), in which the application of the electric science to the art of telegraphy seems carried

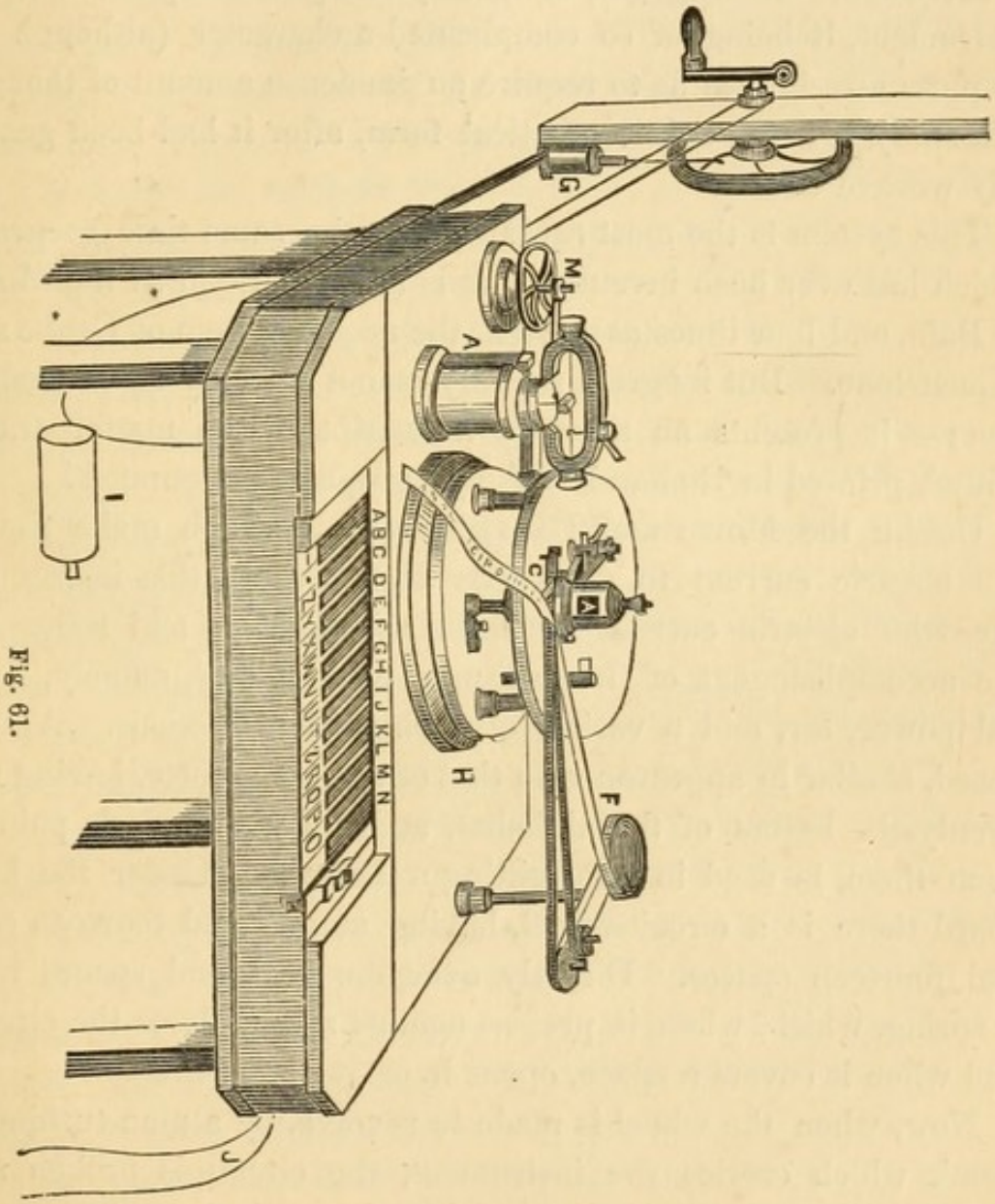


Fig. 61.

to its highest perfection, — which works at the astonishing rate of sixty or seventy strokes or breaks in a second, and at once

records the information by its own machinery in plain Roman letters, and literally gives letters to lightning, as well as "lightning to letters," — was invented by Royal E. House, a native of Vermont.

A patent was applied for in 1846, but, owing to some supposed infringement upon the Morse patent, it was not granted. Subsequently, however, the instrument was changed by the substitution of air in the place of an electro-magnet and a local circuit for carrying the escapement, and a patent was issued in 1848.

Mr. House was engaged for nearly six years in perfecting the instrument, it being of so complicated a character (although all its parts are simple) as to require an immense amount of thought and study to bring it into practical form, after it had been generally worked out.

This system is the most rapid, and at the same time accurate, which has ever been invented. It is twice as rapid as the Morse or Bain, and four times as rapid as the needle system of Cooke and Wheatstone. But its great rapidity is not its only recommendation; — it presents an accurate transcript of the matter transmitted, printed in Roman letters and properly punctuated!

Unlike the Morse and Bain instruments, which make use of the electric current to do nearly all the work, this instrument uses the electric current as little as possible, and relies for the accomplishment of its work upon other forces, namely, manual power, air, and a variety of springs and frictions. A keyboard, similar in appearance to that of the piano-forte, having the twenty-six letters of the alphabet, and a dot and dash painted upon them, is used in transmitting a message. Under the keyboard there is a circuit-wheel, having at one end fourteen cogs and fourteen spaces. Directly over the cogs and spaces rests a spring, which, when it presses against a cog, closes the circuit, and when it covers a space, opens it.

Now, when the wheel is made to revolve, by a man turning a crank which carries the instrument, the circuit is broken and closed just twenty-eight times for each revolution. There are pins set around the surface of the circuit-wheel shaft corresponding to the cogs and spaces upon the circuit-wheel, so that, by

pressing down any of the keys, the wheel can be arrested at any moment.

The paper receives its impression from the steel type cut in the surface of the type-wheel (situated upon the top of the instrument), which, by an ingenious contrivance of a miniature press, forces the paper against a blackened silk ribbon, pressing it upon the type-wheel with sufficient force to make a legible impression.

The press can only work when the type-wheel is at rest, and we will now show how the keys control the movements of the type-wheel. Connected with the circuit-wheel is an electro-axial magnet, which connects at the upper end with a tightly fitting air-valve. From the air-chamber lead two pipes, through only one of which the air is forced at a time. If the valve be drawn down by the magnet, it passes through the right-hand pipe; if the valve be raised by the spring, it passes through the left. At the extremity of the air-pipes there is a double-headed cylinder, which, when the air is forced into the right end, forces the valve to the left, and when forced into the left end, forces the valve to the right. In the centre of this cylinder there is placed an arm of an escapement whose two prongs embrace the under part of the type-wheel in such a manner that, if the escapement be forced either to the left or the right by the cylinder, the type-wheel must stop. The type-wheel contains as many cogs as the circuit-wheel, and when the circuit-wheel is set in motion the type-wheel can make just as many revolutions as the circuit-wheel, and no more. The circuit-wheel controls the magnet; the magnet controls the valve; the valve controls the double-headed cylinder; the cylinder controls the escapement; and the escapement controls the type-wheel. All the instruments commence from the dash. There are, upon an average, seven breaks and closes for every letter, although some may not require more than one, while others require twenty-eight.

To operate this instrument two persons are necessary, — one to furnish the motive power, the other to use it in transmitting the despatch.

English writers have failed to understand this instrument, and

English mechanics have failed to duplicate it. It is described in several British works upon the telegraph as being almost the slowest kind in use, while in fact it is *altogether the most rapid*, — being twice as fast as the Morse, and four times as fast as the needle telegraph in use in Great Britain.

The first line using the House system was completed in March, 1849, between New York and Philadelphia. The second line, between New York and Boston, was completed in the autumn of the same year, and was followed by a line to Buffalo, Cleveland, and Chicago; one from Philadelphia to Washington; and one from New York city to Sandy Hook. In 1853, the government of Cuba contracted with parties in this country for the construction of lines of telegraph 1,200 miles in length, with 51 stations, to use the House instrument. American operators were employed to teach the Spaniards, to whose management the lines were surrendered; but we are not aware how well they have succeeded with the business. No despatches are allowed to be sent over the Cuban wires except they are written in Spanish, and the government exercises a close surveillance over the whole business.

About the same time that the Cuban government was introducing the House system into that island, one of the English companies decided to give it a trial. They bought one of the instruments in this country, and endeavored to manufacture others by it, but after two or three attempts relinquished the idea as a fruitless one. They then sent to this country for two more instruments, and operators to work them, and attempted to use them upon the subterranean lines between London and Liverpool; but it was found that the underground lines did not discharge themselves rapidly enough, on account of the static induction, for the necessary vibrations of this instrument, and therefore the enterprise was abandoned.

This is much to be regretted, for this system is peculiarly adapted to the short circuits of the English lines, and, were it once established upon the open-air lines, would undoubtedly be generally adopted.

For the past seven years, House's printing telegraph between Boston and New York has transmitted a large proportion of the

private telegrams between these two important points, as well as the entire report of the press. The work, we need hardly say, has been done eminently to the satisfaction of the business public, with whom the printed slips are highly popular.

House's printing telegraph is a step-by-step, axial-magnetic, letter-printing instrument. Like most other systems, there are two distinct parts to the apparatus; namely, the composing, and the registering or printing apparatus. Some of the instruments are provided with treadles for the purpose of producing the necessary motive power to supply the machines with air, and to carry the composing and printing apparatus; but the greater number, and indeed all in the larger offices, are turned by crank, by a man especially employed for this service, called the *grinder*.

We will now endeavor to describe the instrument fully, so that all its parts may be clear to the reader, and its *modus operandi* correctly understood.

The reader has already the general idea that the action of the composing apparatus, namely, the breaks and closes of the circuit-wheel, controls the movements of the type-wheel, and thus designates the letter to be printed. The reader must not, however, confound this action with that of the Morse machine, which is totally unlike it. In that system, the same number of breaks always produces the same letter, provided they are made in the same length of time; while in this the number of breaks which are required for a letter is made dependent upon what letter was made before it. Thus, when we have made A, it requires only one break to make B, and one close for C, and then a break for D; and so on through the alphabet; but if, after making A, we wish to make another A, we must allow the wheel to perform an entire revolution, or to break and close the circuit just twenty-eight times; and the same is true of any other letter, which, having just printed, we wish to print again. This is owing to the step-by-step motion, and is doubtless the reason why English writers have got the impression that the instrument is slow.

A composing and a printing machine are both required at every station; the printing apparatus is entirely distinct from the circuit, but all the composing machines are included in and form

part of it. The circuit commences in the galvanic battery of one station, passes along the conductor to another station, through the coil of the axial magnet to an insulated iron frame of the composing machine, thence to a circuit wheel revolving in this frame; it then enters a spring that rubs on the edge of this circuit-wheel, and has a connection with the return wire, along which the electricity goes through another battery back to the station whence it started, to pursue the same course through the composing machine and magnet there, and all others upon the line. Thus the circuit is confined to the composing machines, axial magnets, conducting-wires, and batteries.

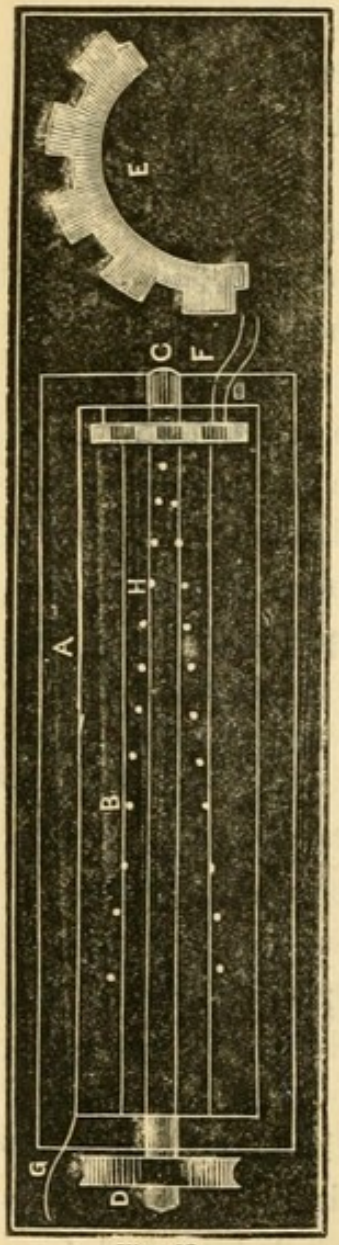


Fig. 62.

The composing machine is arranged within a mahogany frame, *H* (Fig. 61), three feet in length, two in width, and six to ten inches deep; the various parts of the printing machine are seen on the top of the same case. Both are propelled by the same manual power, which is distinct from the electric current; it is simply a crank, with a pulley carrying a band to drive the machine, and a balance-wheel to give stable motion. One of the spokes of the balance-wheel has fixed to it an axis for the end of a vertical shaft to revolve on, which moves the piston of an air-condenser, *G*, fastened to the floor; the air is compressed in the chamber *I*, fourteen inches long, and six in diameter, lying beneath the mahogany case *H;* it is furnished with a safety-valve, to permit the escape of redundant air not needed in the economy of the machine.

The composing system has an insulated iron frame, *A* (Fig. 62), placed immediately below the keys, parallel with the long diameter of the case; this has within it a revolving shaft, *C;* the shaft is enclosed for the greater part of its length by the iron

cylinder *B;* it is made to revolve by a band playing over the pulley *D*, fixed to the left extremity of it. The cylinder, *B*, is detached from the shaft, but made to revolve with it by a friction contrivance, consisting of a brass flange fastened permanently to the revolving shaft; the face of the flange and the inner face of the circuit-wheel are in contact, with a piece of oiled leather interposed; the friction is regulated by a spring pressing against the end of the revolving shaft, *C*. The object of this friction apparatus is to allow the shaft to revolve while the cylinder can be arrested.

On the right end of the cylinder is fixed the brass wheel, *E*, four or five inches in diameter, called the circuit-wheel or break; the outer edge or circumference of it is divided into twenty-eight equal spaces, each alternate space being cut away to the depth of one fourth of an inch, leaving fourteen teeth or segments, and fourteen spaces. The revolving shaft and cylinder form part of the electric circuit; one point of connection being where the shaft rests on the frame, the other through a spring, *F*, having connection with the other end of the circuit, pressing on the periphery of the break-wheel, *E; G*, the other part of the circuit, coming from the axial magnet to the frame *A*. When the shaft, cylinder, and circuit-wheel revolve, the spring will alternately strike a tooth and pass into an open space; in the former case, the circuit is closed, in the latter it is open.

For the purpose of arresting the motion of the circuit-wheel and cylinder, the latter has two spiral lines of teeth (*H*, Fig. 62) extending along its opposite sides, fourteen in each line, making twenty-eight, one for each tooth and one for each space on the circuit wheel. The cylinder extends the whole width of the key-board above it; the latter is like that of a pianoforte, containing twenty-eight keys, which correspond with the twenty-eight projections on the cylinder, and have marked on them, in order, the alphabet, a dot, and dash, or rather a space of the length of a dash (Fig. 61); they are kept in a horizontal position by springs; there is a cam or stop fixed to the under surface of each key, directly over one of the projections on the cylinder; these stops do not meet the teeth unless the key is pressed down, which being

done, the motion of the cylinder is stopped by their contact. By making the circuit-wheel revolve, the circuit is rapidly broken and closed, which continues until a key is depressed; that key being released, the revolution continues until the depression of another key, and so on; the depression of a key either keeps the circuit broken or closed, as it may happen to be at the time, so that the operator does not break and close the circuit, but merely keeps it stationary for a moment. From one to twenty-eight openings and closings of the circuit take place between the depression of two different keys, or the repetition of the depression of the same one; the object of the composing machine is to rapidly break and close the circuit as many times as there are spaces from any given letter to the next one which it is desired to transmit, counting in alphabetical order.

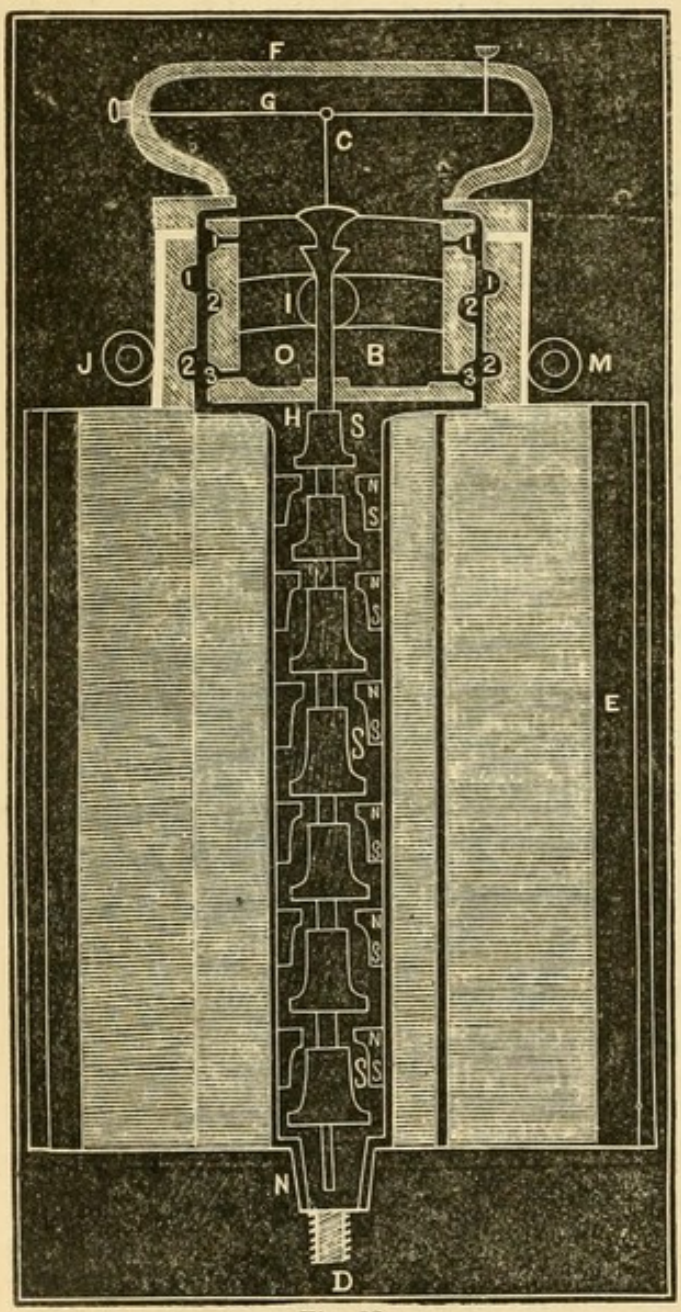


Fig. 63.

The rapid pulsations are transmitted by the circuit of conductors to the magnet and printing machine at another station, through the wire *I*, Fig. 61. The helix of this magnet is an intensity coil, contained in the steel cylinder, *A*, Fig. 61, in the upper surface of the mahogany case; its axis is vertical.

A, Fig. 63, is a brass tube, eight or ten inches long, placed within the

helix, and fastened at the bottom by the screw *D*. To the inner surface of this tube are soldered six or eight soft iron tubes, separated from each other at regular intervals. Above the iron cylinder is an elliptical ring, *F*, through the axis of which is extended an elastic wire, *G;* two screws are attached to the wire, by which it is made lax or tense, to suit the intensity of the electric current. From this is suspended the brass rod, *C*, that passes down within the small iron tubes before mentioned, and has strung on it six or eight small iron tubes; these are fastened at equal intervals, and have their lower extremity expanded into a bell-like flange; the surrounding fixed ones have their upper ends enlarged inwardly in the same manner. The tubes and the wire to which they are fastened are movable, so as to come in contact with the small exterior iron tubes, *K*, but are kept separate by the elastic spring above. At *E* is the brass covering. On the transmission of an electric current through the helix, the tubes become magnetic. Such is the arrangement of their polarities, that they act by attraction and repulsion, overcome the elasticity of the spring, and bring the movable magnets down to the fixed ones; — the current being broken, the spring separates them. The two flanges do not come in direct contact, though the movable one acts responsive to magnetic influence. Most of the magnetism exists at the flanges, and the order is such that the lower end of the inner tube has south polarity, the surrounding one above, the same, which repels it, while the top of the surrounding one below has north polarity, and attracts it; this movement is through a space of only one sixty-fourth part of an inch.

On the same rod, above the movable magnets, is fixed a hollow cylindrical valve, having on its outer circumference the grooves 1, 2, 3, Fig. 63. The plate represents a longitudinal half-section of the valve, magnets, and helix. The valve slides in an air-chamber, *H*, which has two grooves, 1, 2, on its inner surface. Air is admitted through the orifice 1, by means of a pipe from the air-chamber beneath the case, into the middle groove of the valve. The grooves of the chamber open into the side passages *I* and *M*, which connect at right angles with a second chamber,

in which a piston moves. The movement of the magnets changes the apposition of the grooves in the first chamber, by which air enters from the supply pipe, through one of the side passages, into the second chamber, at the same time that air on the other side of the piston, in the second chamber, escapes back into the grooves 1 and 2 of the valve, through the other side passage, and thence into the atmosphere. This causes the piston to slide backward and forward with every upward and downward motion of the valve.

This piston moves horizontally, and is connected with the lever 8, Fig. 64, of an escapement, the pallets of which alternately

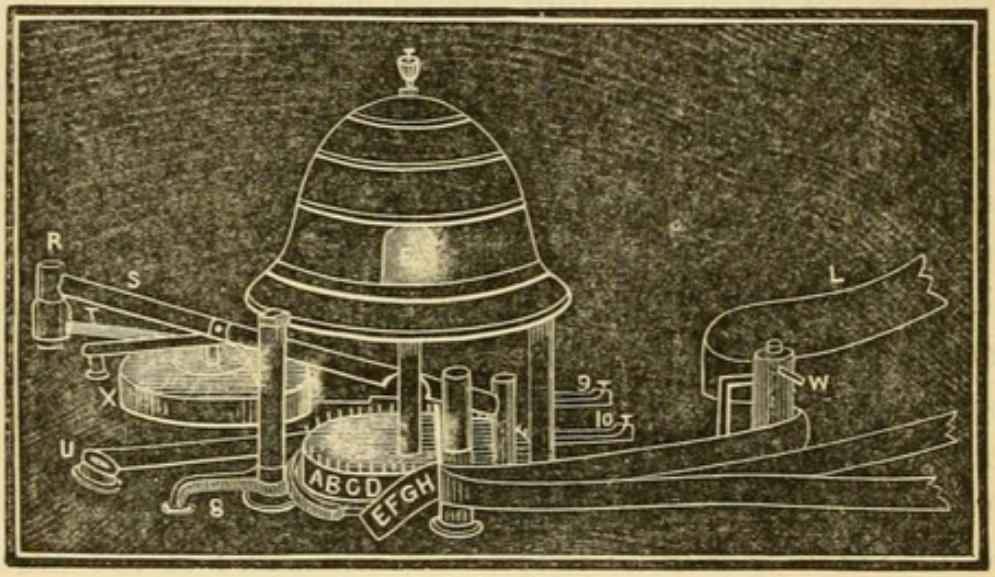


Fig. 64.

rest on the teeth of an escapement-wheel of the printing machine, *A*. This part of the apparatus is arranged on a circular iron plate, twelve or fourteen inches in diameter, supported by standards on the mahogany frame, *H*, Fig. 61. The escapement-wheel revolves on a vertical shaft, which passes through the iron plate, and has fixed on it there a hollow pulley. This pulley contains within it a friction apparatus, consisting of two brass clamps enclosing two pieces of leather moistened with oil, which being pressed against the shaft by the clamps, and carried around by the pulley, acts upon the escapement-wheel, causing it to revolve constantly, while the shaft and escapement-wheel may be stopped.

Fig. 65.

The escapement-wheel has fourteen teeth, each one of which causes two motions of the escapement, which will make twenty-eight for a single revolution of the wheel, which is shown in Fig. 65.

When in operation, the piston to which is attached the escapement arm 8, Fig. 64, is subjected, on one side or the other, to a pressure of condensed air; therefore the piston and escapement will only be moved by the escapement-wheel when the air is removed from one side or the other of the piston. The position of the valve, Fig. 63, attached to the magnet, regulates the pressure of air on either side of the piston, by opening one or the other of the side-passages into the second chamber. By breaking and closing the circuit, therefore, the piston and escapement move backward and forward; thus a single revolution of the circuit-wheel at one station opens and closes the circuit twenty-eight times, causing an equal number of movements of the magnets in another station; they carry the valve which alternately changes the air on either side of the piston. This permits the escapement-wheel to move the escapement and piston twenty-eight times, and allows one revolution of the escapement-wheel for one of the circuit-wheel at the transmitting station.

A steel type-wheel, *A B C D*, Fig. 64, two inches in diameter, is fixed above, and revolves on the same shaft with the escapement-wheel; it has on its circumference twenty-eight equidistant projections, on which are engraved, in order, the alphabet, a dot, and a dash. The fourteen notches of the escapement-wheel cause twenty-eight vibrations of the escapement in a revolution, which correspond to the characters on the type-wheel. Every vibration of the escapement, therefore, makes the type-wheel advance one letter; these letters correspond to those on the keys on the composing machine. If any desired letter on the type-wheel is placed in a certain position, and a corresponding key in the composing machine is depressed, by raising that key and again depressing it, the circuit-wheel at one station, and the escapement and type-wheel at the other station, all make a single revolution, which brings that letter to its former position. Any other letter is brought to this position by pressing down its key

in the composing machine, the circuit being broken and closed as many times as there are letters between the last one taken and the letter desired.

To form the letters into words, it is necessary that the printing and composing machines should correspond, and for this purpose a small break and thumb-screw, 9 and 10, Fig. 64, can be made to stop the type-wheel at any letter. In sending messages they usually commence at the dash, or space; if, by accident, the type-wheel ceases to coincide with the distant composing machine, the printing becomes confused, the operator stops the type-wheel, sets it at the dash, and the printing goes on as before.

Above the type-wheel, on the same shaft, is the letter-wheel *E*, Fig. 64, on the circumference of which the letters are painted in the same order with those on the type-wheel below. It is encased in a steel hood, having an aperture in it directly over where the letters are printed, so that when the type-wheel stops to print a letter, the same letter is made stationary for a moment at the aperture, and is readily distinguished; hence messages can be read, thus making it a visual as well as printing telegraph.

Of late years the hood has been discarded, the operator finding no difficulty in reading from the wheel, with nothing to guide the eye except the habit, which long practice has rendered very acute, of fixing the eye upon an imaginary point, which when the wheel stops always reveals the proper letter. An operator will read a despatch coming at the rate of 2,800 words an hour in this manner, while an inexperienced person could see nothing but a confused mass of revolving letters.

The type-wheel has twenty-eight teeth arranged on the outer edge of its upper surface; near it, on the opposite side from where the printing is done, is the shaft *T*, Fig. 64, revolving in an opposite direction. A steel cap, *X*, two inches in diameter, is so attached to the top of this shaft that friction carries it along with it, but it can be moved in the opposite direction; it has a small steel arm, three fourths of an inch long, projecting from its side, and playing against the teeth on the type-wheel; while the latter is revolving, its teeth strike this arm, and give the cap a contrary motion to its shaft. There is a pulley on this

shaft, below the plate, connected by a band to *M*, Fig. 61; its speed is less than that of the type-wheel. When the type-wheel comes to rest, the arm falls between the teeth, but it has not time to do so when they are in motion. On the opposite side of the cap to where the arm is attached are two raised edges, called detent pins, against which the detent arm *U*, Fig. 64, alternately rests, as the position of the cap is altered by the small arm that plays on the teeth of the type-wheel.

Between the type-wheel and cap is a small lever and thumb-screw, 9, Fig. 64, which acts as a break on the cap; its motion can be stopped by it while the type-wheel revolves; it is used merely to arrest the printing, though the message may be read from the letter-wheel.

The detent arm revolves in a horizontal direction about the vertical shaft, which is also driven by a pulley beneath the steel plate; when the type-wheel is at rest, the detent arm rests on one of the detent pins, but when it moves, the teeth on its upper surface give the arm and cap a reverse direction to its shaft, which alters the position of the detent points, so that the detent arm is liberated from this first pin and falls upon the second, where it remains until the escapement and type-wheels again come to rest; when this happens, the arm falls between two of the teeth, the cap resumes its first position, the detent is let loose, makes a revolution, and stops again on the first pin.

The shaft that carries the detent arm has on it, above the arm, an eccentric wheel, *R*, Fig. 64; that is, a wheel having its axis of motion nearer one side than the other, and which while revolving operates like a crank; from this eccentric is a connecting-rod, *S*, which draws a toothed wheel against the type; this toothed wheel is supported in an elastic steel arm (shut out of view by the coloring-band), on the opposite side of the type-wheel from that of the eccentric, and revolves in a vertical direction; the band *E*, Fig. 61, carrying the coloring matter to print with, passes between this and the type; the dots seen represent small teeth that catch the paper and draw it along as the wheel revolves, between itself and a steel clasp operated by a spring, which presses the paper against the teeth and keeps it smooth;

the clasp is perforated in such a manner that the type print through it; there are two rows of teeth, one above, the other below the orifice.

The vertical wheel, Fig. 64, is embraced in a ring by the connecting-shaft *S*, and a rotary motion is imparted to it by a ratchet fixed to its lower surface, moving with it, and catching against two poles fastened to the steel plate below it; the poles are pressed against the ratchet by springs, as shown in Fig. 66; the wheel is octagonal, and every revolution of the eccentric turns it through one eighth of a revolution, and therefore presents a firm, flat surface to push the paper against the type, and advances sufficiently for every letter, one being printed each time the detent arm revolves.

Fig. 66.

When the type-wheel stops, the detent arm revolves, carrying with it the eccentric, which, through the connecting-rod, draws the toothed wheel, having the paper and coloring-band before it, against the type, and an impression is made upon the paper; a letter is printed if the circuit remains broken or closed longer than one tenth of a second; three hundred letters, in the form of Roman capitals, can be accurately printed per minute; the roll of paper, *L*, Fig. 63, is supported on a loose revolving wire framework; on the same standard is a small pulley, *W*, around which one end of the coloring-band runs.

In transmitting a message, the machine is set in motion, a signal is given (which is simply one break of the circuit), and then, with the communication before him, the operator commences to play like a pianist on his key-board, touching in rapid succession those keys which are marked with the consecutive letters of the information to be transmitted. On hearing the signal, the operator at the receiving station sets his machine in motion; then, setting his type at the dash, sends back signal that he is ready, and the communication is transmitted. He can leave his machine, and it will print in his absence; in fact, the receiving operator has nothing to do but look occasionally at the strip of paper, and see that no false break has occurred to interrupt the synchronism of the two instruments. When the printing is finished, he tears off

the strip which contains it, and folds it in an envelope, ready to be sent to any place desired. The Governor's Message, containing 5,000 words, has been transmitted by this instrument, and published entire in New York, two hours after its delivery in Albany. Over 3,000 words an hour of press news, partly abbreviated, are frequently sent over the House wires with a single instrument. No other instrument in the world has ever accomplished this.

The function of the electric current in this machine, together with the condensed air, is to preserve equal time in the printing and composing apparatus, that the letters in one may correspond with the other; the electrical pulsations determine the number of spaces or letters which the type-wheel is permitted to advance; they must be at least twenty-five per second, to prevent the printing apparatus from acting. The intervals of time the electric currents are allowed to flow unbroken are equal, and the number of magnetic pulsations necessary to indicate a different succession of letters is exceedingly unequal; from A to B will require one twenty-eighth of a revolution of the type-wheel, and one magnetic pulsation; from A to A will require an entire revolution of the type-wheel, and twenty-eight magnetic pulsations.

We presume it will hardly be expected that the pulsations of the House apparatus should furnish an audible means of communication, and yet there are operators possessed of such a wonderful power of memory and combination as to be able to read with facility from this instrument by the sound of the type-wheel. Most, and indeed all operators, can distinguish a few words in this manner; but Mr. Rufus Bollock stands alone, we believe, in the possession of the wonderful power of reading long communications from the House apparatus by ear.

We have heard one operator, Mr. Luby, play tunes upon this instrument with very great success, which, coming over the wire a distance of some hundreds of miles, possessed a peculiar interest from their novelty.

The House instruments cannot work upon very long circuits, because the helices contain so large a quantity of fine wire as to offer, upon long lines, too much resistance to be overcome by the batteries used.

This might be remedied by cutting out the coils at the intermediate offices, and this is sometimes done with advantage; but upon our main lines, where the press news is dropped at every station, it is desirable to have all the offices receive the news at the same time, so that it has been found better to divide the lines into partial circuits of about one hundred miles each, and repeat the communications at the several termini of the partial lines.

A Morse electro-magnet contains about half a mile of fine silk-wound copper wire, while a House electro-magnet contains from four to six miles of fine wire, thus offering from eight to twelve times the resistance that a Morse magnet does.

When we take into account that upon the line between Boston and New York there are fifteen stations, and seventy-five miles of fine resistance wire (equal to twelve hundred miles of No. 8 iron wire), while the Morse line would give but five and a half, we see at once the disadvantage the House system labors under in this respect.

In concluding this chapter upon the House system, we cannot forbear expressing our affection for it, which is like that entertained for an old friend. Indeed, the instrument seems almost human; for its operation is so rapid that we can express our thoughts as freely, and almost as rapidly, as by word of mouth; and then the response comes back to us in an instant, printed in plain Roman letters, — our companions in childhood! Altogether, it seems a thing of life, and speaks to us in a language as familiar as household words.

CHAPTER VIII.

BAIN'S ELECTRO-CHEMICAL TELEGRAPH.

THE next system of telegraphing in the order of its invention and introduction in this country is the Chemical, invented by Alexander Bain, of Edinburgh.

Mr. Bain obtained a patent for his system in England, in 1846, and applied for one in this country in 1849; but was refused, upon the ground of infringement upon the Morse patent. It seems to have been the opinion of the Patent Commissioner that Mr. Morse held the exclusive right to electricity in any form in which it could be used for telegraphic purposes, and that he was placed at the head of the Patent Department solely to maintain it for him.

Supposing this decision final, Mr. Bain left Washington to return to England, but was met in New York by Mr. Henry O'Reilly, who induced him to appeal to the Supreme Court. He did so, and the decision of the Commissioner was overruled, and Judge Cranch ordered a patent to be issued to him.

Immediately upon the granting of this patent, a number of public-spirited and enterprising merchants of New York and Boston set themselves at work to build an opposition line between New York and Boston, to be worked upon this system. The monopoly which had existed since the telegraph lines had been first established was so unpopular, that the construction of this line was hailed as a public blessing.

The line was completed in the autumn of 1849, and the tariff between the two cities reduced from fifty to thirty cents for ten words.

The line worked admirably, — better than any had previously worked in this country, — and business increased so fast, that it was necessary to put up a second wire at once. In the mean time, lines working upon this system were constructed between New York and Buffalo, between New York and Washington, between

New Orleans, Louisville, and Cincinnati, between Boston and Montreal, and between Boston and Portland.

From this date a new era seemed to open in the telegraphic world. Business increased rapidly; tariffs were reduced; lines improved in reliability, and public confidence began to be secured for the first time.

Early in the winter of 1849, the proprietors of the Morse patent commenced suits for the infringement of their patent against the New York and Boston, and the New York and Washington, Bain lines. These suits were kept in court for nearly three years, when it was clearly evident, if they were pressed for decision upon the merits of the case, the Morse patent would be destroyed, and the system thrown open to the world. This result was, of course, not to be desired by either party, and they therefore agreed to consolidate their lines and use but one patent. The lines thus consolidated between New York and Boston were called the Union Lines. They now use the Morse system, as they also do upon all the other consolidated lines. There is at present but one Bain line in operation in this country, — the one from Boston to Montreal.

The Bain system, if not the simplest, is one of the simplest forms of telegraphy ever worked. No magnetism is used, and only the chemical effects of the electric current are necessary. A metallic disc, carried at a regular uniform rate of speed by clock-work, receives a sheet of prepared paper (Fig. 67). Upon the paper rests a screw-plate, which serves to guide a pen in regular spiral lines from the inner to the outer surface of the disc. The circuit is what is known as the "open circuit," — that is, the key which throws the current from the battery upon the line is always open when a message is being received from a distant station, and the current passed through the chemically prepared paper to the earth, without uniting with the home battery. Each station is furnished with its own battery, the negative pole of which is invariably connected with the earth, and the positive pole, by the depression of the key, with the line.

The paper is prepared with a solution of *cyanide of potassium*, made after the following recipe: Six parts prussiate of potash,

dissolved in water, two nitric acid, two ammonia. This solution will scarcely color the paper, while it will render it quite sensitive to the electric current. The stylus, or pen, is made of No. 30 iron wire. A battery of ten cups Grove, with the line

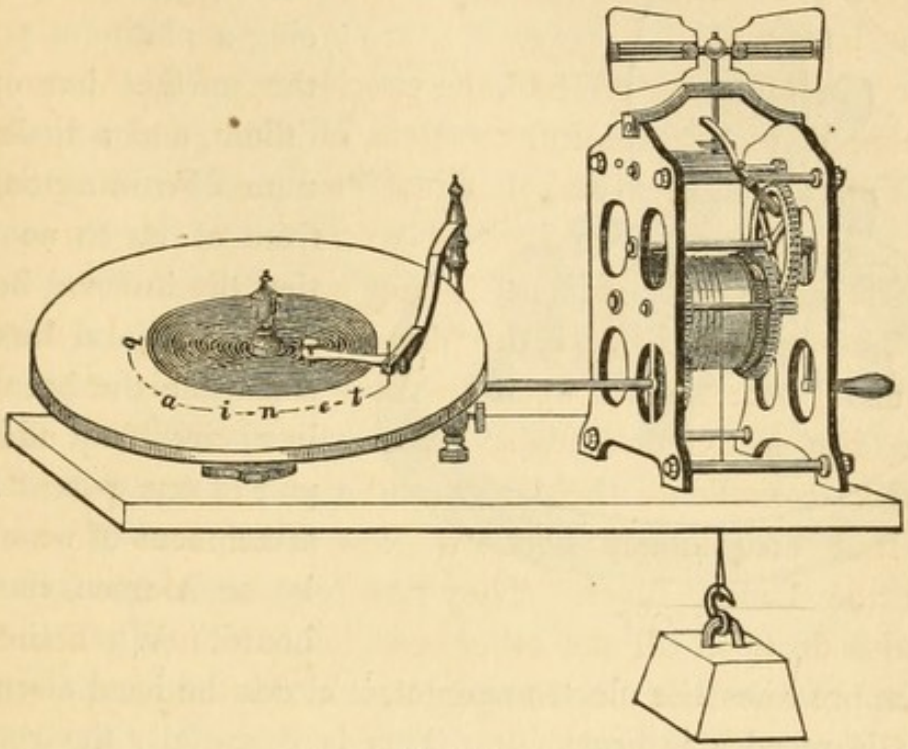


Fig. 67.

well insulated, will decompose the salts, and, uniting with the iron stylus, leave a light blue mark upon the paper at a distance of two hundred and thirty miles. The positive pole only produces a colored mark; the negative bleaches the paper.

The *call*, or *alarum*, commonly used on the Bain lines, is represented in Fig. 68. It consists of a U-shaped receiving magnet, placed horizontally on the board, with two helices of wire surrounding the legs. An armature, supported on an upright bar, so as to form a cross, is seen in the figure before the poles of the magnet. This is held back by a delicate spiral spring, graduated by a screw, which is also seen to the left. Above are two circular plates of glass. The upright bar, armed with two little knobs, to perform the part of a hammer, rises between these plates. When the armature is drawn to the magnet, it strikes one of them, and on being drawn back it strikes the other. As they are of different tone, the repetition of this signal at once

draws attention to the register. The duty of the operator is then to set the clock-work in motion, and receive the message communicated. This instrument can be used also as a receiving magnet, by placing a platinum point on the upright bar or pendulum, and a little platinum disc immediately in front of it, so connected that the interval between the point and disc shall constitute the break in a local circuit, an additional pair of screw-cups for the attachment of which may be seen upon the base-board. When the armature approaches the electro-magnet, it closes the local circuit, and when it recedes it breaks it. This is essentially the receiving instrument of Morse and others.

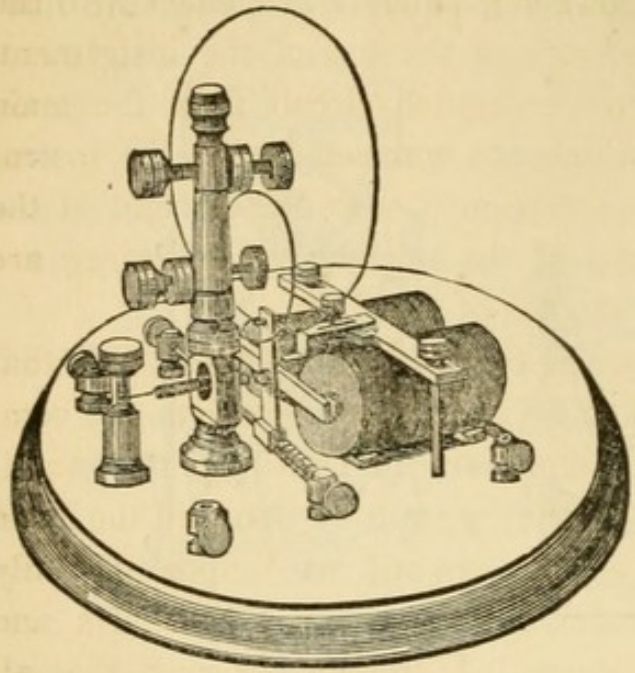


Fig. 68.

This call is similar in purpose or principle to those used by Soemmering in 1811, Schilling in 1831, and Henry, Steinheil, and Wheatsone in 1836 and 1837.

The receiving magnet, in its improved form (Fig. 69), used for the purpose of combining or connecting circuits, is closely allied in its construction to the call, and may therefore be described here, though already referred to in connection with Morse's telegraph. The armature is mounted on an upright bar, and is seen forming part of the cross just in front of the poles of the horizontal electro-magnet, sur-

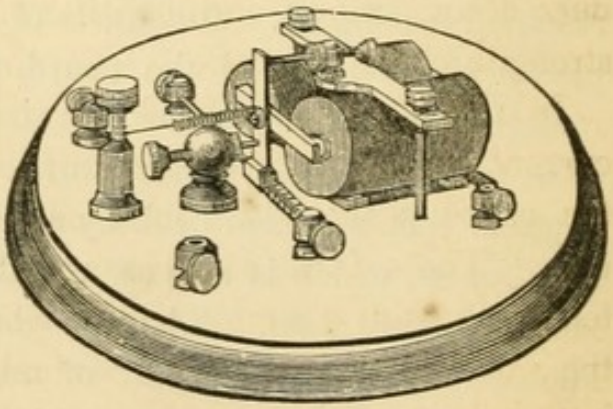


Fig. 69.

rounded with helices of fine wire. The long or telegraphic circuit is connected with these helices by means of two of the screw-cups on the board. When the current flows, the armature is attracted to the magnet, and the upright bar is brought in contact with the end of the horizontal screw, seen at the top of the instrument. This completes a local circuit, or branch circuit from the main battery, the conductors of which are connected with the instrument by means of two other screw-cups, seen on the right of the board. The points of contact of the upright bar and screw are protected from oxidation by the use of platinum.

The alphabet used by Bain is the same in principle with that employed by Dyar, Steinheil, and also by Morse, consisting of combinations of dots and lines. We give on the next page the combination of the dots and lines as they were used upon all the Bain lines in this country; and as they are still used upon the only remaining line using this system, and upon the Fire Alarm and police telegraph system of Boston. It will be observed that all the letters begin with dots from A to O, at which point they commence with a line, and so continue to the end of the alphabet. The numerals also possess the same peculiarity, and, it will also be noticed, each numeral contains exactly five characters; thus, a dot and four lines for 1; two dots and three lines for 2; three dots and two lines for 3; four dots and one line for 4; five dots for 5, &c.

When there is no electric current upon the wires, the pen leaves no impression upon the paper; but the slightest current will produce decomposition, and the color of the mark depends upon the strength of the current.

In this system no local circuits are necessary, the battery current which traverses the long line doing its own work upon the paper, without the intervention of any other force whatever. There is a disadvantage, however, in the use of this telegraph, with a simple circuit, where it is desirable to register the same communication at a number of different places, as the interposition of the paper, moistened with a saline solution, somewhat obstructs the current. The receiving magnet and register used by Morse present a metallic conductor for the current

Letters.	Characters.	Numerals.	Characters.
a	·—	1	·————
b	·—·	2	··——
c	···	3	···—
d	··—	4	····—
e	·	5	·····
f	·———	6	——— —·
g	·——··	7	——— ··
h	·——	8	——···
i	··	9	—····
j	···—	0	——·——
k	·——·	.	··——··
l	····	?	——··—·
m	·—·—		
n	··——		
o	—		
p	—·—		
q	—·—·		
r	——·		
s	—··		
t	—···		
u	—·		
v	———·		
w	——··		
y	——		
z	———		
&	————		

throughout, and they can therefore be multiplied without serious loss. To compensate this disadvantage, a system of branch circuits at way stations has been devised in connection with the Bain telegraph, by which communications can be received at various places at the same time. Morse's instrument requires the time taken by the motion of the armature to make each mark. The decomposition in Bain's instrument is instantaneous. This is an advantage where mechanical means are used to complete and break the circuit with great rapidity for the purpose of rapid communication.

This system has some advantages over any other which has

ever been used in this country, not the least among which is its ability to work through a heavy thunder-storm, which none of the other systems can do without considerable danger both to the operators and the instruments. Another very considerable advantage which it possesses, is its ability to work over a greater "escape" than any other. We have known the line between Boston and New York to do business during a heavy rain-storm, with the wire actually lying upon the ground! This was accomplished in the following manner. Each station transmits with its own battery without aid from any other; therefore, there being no intermediate battery, if New York got any current, it must come from Boston; and by putting on a battery of one hundred and thirty Grove cups, intelligible signals could be produced upon the New York instrument, notwithstanding there was a heavy northeast storm raging at the time, and the wire lay upon the ground.

This system is capable of working a greater distance, without the aid of relays, than any other, and of working with a smaller battery. We have worked well between Boston and New York with but ten cups of the Grove battery, all told; and have worked well between Boston and Buffalo, *via* New York city, without the intervention of repeaters or auxiliary batteries.

But with these numerous advantages over the other systems there are some disadvantages. No other system is so much troubled by magnetic storms, — such, for instance, as the aurora borealis, which always renders operation difficult, if it does not suspend it entirely. Then, again, the prepared paper is unhealthy to breathe, and the fine spiral lines upon the paper are injurious to the eyes. But it must be conceded that no other system of telegraphing, or at least no other lines, ever possessed the confidence and good-will of the public to such an extent as these. It is, doubtless, as much owing to the result of good management upon the part of the proprietors of these lines, as of any peculiar excellence in the system.

In the above description of the electro-chemical telegraph, invented by Alexander Bain, we have confined ourselves to the form under which his admirable system worked upon the leading

lines in this country, from 1849 to 1852; but it would be doing Mr. Bain a manifest injustice not to mention his method for rapid writing, which, in theory, could transmit intelligence with the greatest accuracy at the astonishing rate of five thousand words per hour; or, to compare the system with other recording systems in use, twice as fast as the House, over three times as fast as the Morse and Hughes, and eight times as fast as the needle telegraph of Cooke and Wheatstone!

To accomplish this wonderful result, he caused long strips of narrow paper to be perforated with arbitrary characters, resembling those used upon the Morse lines. A small hand-punch fastened to a table enabled the operator to prepare the paper with great facility. When so prepared, it was passed between two insulated rollers, one of which connected with a battery, and the other with the earth. In connection with the upper roller is a small metallic comb, whose teeth pass through the perforations in the punched paper, and, coming in contact with the under roller, complete the circuit. It is only necessary to have, upon the receiving instrument, the paper prepared with the solution of *cyanide of potassium*, and the stylus resting upon its surface, the paper carried at the same rate of speed as the transmitting instrument, and you have, at the distant station, a correct *facsimile* of the copy to be transmitted. To show the importance of this invention, we will suppose the system to be in operation between Boston and Halifax. A steamer arrives from Europe, and a despatch of three thousand words has been made up on board, and the whole composed upon the slip of paper in these arbitrary characters. No sooner does the steamer arrive at the wharf than the despatch is handed into the telegraph office, and in a little over thirty minutes the entire despatch is in State Street.

This is no imaginary, fanciful sketch, but is what can be performed upon the arrival of every steamer, with just as much certainty, correctness, and ease as we can transmit a letter to New York through Uncle Sam's mail, or a telegram over the wires at the present rate. Or, we will suppose a speech to have been delivered at twelve o'clock in Washington; a *corps* of operators

prepare the copy, and, in thirty minutes, it is ready for the press in Boston. Let this system be introduced, and the imagination revel among marvellous accomplishments as it will, it cannot exceed the actual results which will be obtained.

The question which will be at once raised by the reader is, Why, if this is practicable, has it never been accomplished?

We will explain this seeming contradiction. At the time Mr. Bain introduced his rapid system to public notice, there was no governor capable of regulating the speed of an instrument which should make the number of revolutions necessary to accomplish this great result. Mr. Bain endeavored to use the pendulum and escapement, but these could not be made to vibrate with sufficient rapidity to accomplish the result. In 1855, Mr. Hughes invented a spring-governor, which, were it applied to the invention of Mr. Bain, would enable it to produce all the results which I have pointed out. In the succeeding year, 1856, Mr. G. M. Phelps, of Troy, an exceedingly intelligent mechanic, and well versed in the application of electricity to telegraphy, invented an electro-magnetic governor, which can be applied to a machine so as to regulate the speed at from one hundred to two hundred revolutions per minute. Two machines, with these governors attached, will run together for hours without the variation of a second! In describing the combination instrument, at present very successfully worked upon the wires of the American Telegraph Company, we shall have occasion to describe the *modus operandi* of this beautiful invention of Mr. Phelps. For our present purpose it is enough to show, that, were Mr. Phelps's invention applied to this instrument of Mr. Bain, it would enable it to take the lead of every other system in the world for correctness, rapidity, and economy in the transmission of intelligence by the electric telegraph.

A great number of chemical telegraphs, based upon the principle of Mr. Bain's, have been devised, two of which we will briefly mention.

Mr. F. C. Bakewell, of London, brought out, in 1850, an apparatus called the Copying Telegraph, by which despatches were transmitted in the handwriting of correspondents. The

advantages of this mode of transmission are, that the communications may be authenticated by the recognized signatures of the parties by whom they are sent; and as the writing received is traced from the original message, there can be no errors of transmission; for every letter or mark made with the pen is transferred exactly to the other instrument, however distant.

The despatch is written on tinfoil, with a pen dipped in varnish. The letters thus written form on the conducting metal surface a number of non-conducting marks, sufficient to interrupt the electric current, though the deposit of resinous matter is so slight as not to be perceptible to the touch.

The message on tinfoil is fixed round a cylinder at the transmitting instrument, which instrument is a counterpart in its mechanical arrangements of the receiving one, and either of them may be used to transmit and receive messages. A metal style in connection with the battery presses on the tinfoil, and is carried along by an endless screw as the cylinder revolves, exactly in the same manner as the steel wire that draws lines on the paper on the receiving instrument. The varnish writing, when it interposes between the style and the tinfoil, stops the electric current; consequently, at every part where the electric current is stopped by the varnish at one instrument, the steel wire ceases to make marks upon the paper at the other station. Both cylinders are so regulated that they rotate exactly together; therefore the successive breaks of the electric current by the varnish letters cause corresponding gaps to be made in the lines on the paper; and the succession of these lines, with their successive gaps where the letters occur, produces on the paper of the receiving instrument the exact forms of the letters. The letters appear of a white or pale color on a ground of blue lines, there being about nine or ten lines drawn by the wire to make one line of writing.

M. Caselli of Florence has been engaged for some years upon a new electro-chemical telegraph, which he has named *Pantographic*. This instrument reproduces upon ordinary paper, in colored characters, a perfectly exact image (a *fac-simile*) of the writing, or of any design, that is required to be transmitted from one station to the other. The despatch is written upon tinfoil, as

in the case of Bakewell's, but the copy, instead of being white upon a blue ground, is blue upon a white ground. By means of a peculiar combination, which constitutes one of the most original and ingenious parts of M. Caselli's telegraphic system, the alteration in the intensity of the current, produced by the resistance of the ink to the passage of the electricity, — greater than that which is presented by the metallic surface of the paper, — brings about a reversal of polarity in the point of the receiver. From having been negative, it becomes positive, which produces upon the paper a coloring, whence there results an assemblage of colored lines and points, which reproduce the perfect image of the original despatch. The instantaneous reversal in the direction of the current produces a chemical effect so rapidly that the most delicate traces of writing and drawing may in this manner be reproduced immediately. The peculiar method by which M. Caselli accomplishes this instantaneous reversal of polarity he will not make known, and it has excited the interest of many philosophers in Europe, and among them De la Rive, who says: "It would be desirable that M. Caselli should make known the combination by means of which he obtains this result, by which he succeeds in so instantaneously reversing the direction of a current, in such a manner that no appreciable time elapses between the passage of the current in one direction and its passage in the contrary direction, as it might, in its application, lead to very interesting results, particularly as far as concerns the relations that exist between the molecular constitution of bodies, and the effects that are produced upon them by the transmission of electricity."

We do not know whether we have discovered M. Caselli's method or not, but we have accomplished the results obtained by him in the following manner. At the transmitting station we place in the circuit of a long telegraphic line a battery of twenty of Grove's cells, with the negative pole to the line; and at the receiving station a battery of three of Grove's cells, with the positive pole to the line. Now, when no obstacle intervenes, the larger battery neutralizes the smaller, and, its current being negative, leaves no mark upon the paper; but when the pen-wire, which forms a portion of the circuit, comes in contact with the

writing upon the cylinder, a great resistance is offered, which enables the small battery at the receiving station to come into action and record upon the paper just so long as the ink interposes the resistance to the large battery.

Dr. Lardner gives an account of a very remarkable telegraphic feat which he witnessed in Paris some years since, and which, we presume, must have been accomplished by Bain's fast method. The following experiment was prepared and performed at the suggestion of M. Leverrier and Dr. Lardner. Two wires, extending from the room in which they operated to Lille, were united at the latter place, so as to form one continuous wire, extending to Lille and back, making a total distance of 336 miles. This however, not being deemed sufficient for the purpose, several coils of wire wrapped with silk were obtained, measuring in their total length 746 miles, and were joined to the extremity of the wire returning from Lille, thus making one continuous wire, measuring 1,082 miles. A message consisting of 282 words was then transmitted from one end of the wire. A pen attached to the other end immediately began to write the message on a sheet of paper, moved under it by a simple mechanism, and the entire message was written in full in the presence of the committee, each word being spelled completely, and without abridgment, in *fifty-two seconds*, being at the average rate of *five words and four tenths per second!*

By this instrument, therefore, it is practicable to transmit intelligence to a distance of upwards of one thousand miles, at the rate of 19,500 words per hour!

CHAPTER IX.

THE HUGHES SYSTEM.

After ten years of persevering labor, Mr. David E. Hughes, of Kentucky, produced, in 1855, a printing instrument upon an entirely new principle, which, for simplicity and ability to work upon long circuits, is unrivalled. A patent was obtained in this country in 1855 and in 1858.

This instrument belongs to the synchronous class of electro-magnetic printing telegraphs. It is unlike any other recording telegraph, although in its general appearance it resembles the House. The resemblance, however, goes no further. There is also a resemblance, in the idea merely, to the telegraph invented by Francis Ronalds in 1817, which we have briefly described in a previous chapter. To avoid misapprehension, we will point out here in what the resemblance consists.

Ronalds's machines were carried by clock-work; set to the same time, and run together. The letters were placed upon the face of a dial, which contained an aperture through which one letter only could be seen. When the letter which it was desired to transmit appeared at the aperture, an electric discharge announced the fact by deflecting a small pith-ball. Magnetism was not, at that time, sufficiently developed in theory even to be made use of for telegraphic purposes. In fact, it was not until 1820 that Ampère proposed a system of telegraphy, which consisted in employing the instantaneous action that is exercised upon the magnetized needle by the current.

Now Mr. Hughes has made use of the synchronous idea of having the machines run together; only, instead of the plain clock-movement and the pendulum, which would be altogether too slow, he has invented a very ingenious contrivance, called a spring-governor. This is nothing more than a vibrating spring, which depends for its action upon a well-known law of acoustics; namely, that a certain number of vibrations per second pro-

duces a certain musical tone; consequently, if there are two or more springs of the same tone, they invariably give the same number of vibrations per second. These springs, by their vibrations, control an escapement, which regulates the speed of the instrument; and all springs of similar tone must revolve in the same time. Therefore, if all the instruments upon a telegraph line are set to the same tone, they will all run together, with almost as much accuracy as so many finely balanced chronometers. The type-wheel resembles that of the House instrument in form and fashion, but is entirely different in application and movement. Instead of stopping for the letter to be printed, as in the House instrument, it prints the letter while in motion, and while actually performing one hundred and thirty revolutions per minute! It also prints the letter with ink upon the paper itself, instead of, as in the House, pressing the blackened ribbon against the paper.

Like the House instrument, it has reduced the labor to be performed by the electric current to the lowest possible point; but, unlike the House, which requires seven vibrations upon an average for each letter, — or the Morse, which is based upon the number of waves sent, as well as the length of time occupied in sending them, and which upon an average requires three and a half, — this system requires but one. It had long been considered a desideratum to print a letter at every impulse; but nothing approaching it had ever been obtained until the production of this incomparable instrument by Mr. Hughes.

By a combination of the natural magnet and the electro-magnet, Mr. Hughes has obtained one of remarkable sensibility; the mere contact of a piece of zinc against a copper wire being found sufficiently powerful to work it with facility.

The vibrating spring has attached to it an adjusting bar, which can be set to make any number of vibrations; but the usual number for ordinary purposes of business allows one hundred and twenty revolutions of the type-wheel per minute. The type-wheel always starts from the dash; consequently, if the type-wheels all along the line are started from the same point, and run at precisely the same speed, making exactly the same number of revolutions per minute, it follows that the same letter

must present itself in the same place upon all the type-wheels in communication at the same moment. Behind the type-wheel there is a small press, so arranged that, when it is thrown in connection with the type-wheel by the projecting arm of a revolving cam, it allows but one letter to be made, and then falls back to its original position, until again thrown in connection by contact with another arm. The printing cam, which is propelled by friction, is held by a small detent attached to the keeper of the combination-magnet. The keeper, when released from the magnet, is carried back by a spring; and the only service performed by the electric current is to neutralize the magnetism in the natural magnet, by causing magnetism of an opposite polarity to be created in the poles of the electro-magnet. As we have mentioned above, so extremely sensitive is this magnet thus arranged, that a piece of zinc placed in contact with a copper wire has been found powerful enough to work it with ease.

This would seem to be reducing the necessary power of the electric current to a wonderful point; but when we come to add, that it takes but one wave of this exceedingly delicate battery to print a letter in plain Roman character, the feat becomes perfectly marvellous. Indeed, there is nothing in the whole range of electrical science so surprising as the accomplishment of this wonderful result. If the question had been asked of the best mechanic in the world, if he could make two machines which should perform one hundred and twenty revolutions per minute, and run together so as not to vary for two hours to the twentieth part of a second, we fear he would have replied that the thing was impossible; and yet Mr. Hughes has accomplished more than this, — he has run his instruments up to one hundred and forty revolutions per minute, and continued them in operation all day without a change of adjustment.

The key-board contains twenty-eight keys, like that of the House, and is operated upon in the same manner. Suppose a cylinder to contain twenty-eight spaces, arranged around the circumference at equal distances, and a peg upon the end of each key to be so arranged that, upon being depressed, it should be able to enter the space allotted to it once during each revolution; that, upon entering the space, it should close the circuit; that

by closing the circuit it should release the magnet-keeper, and that by such release the detent should become detached from the revolving cam, which in revolving should throw the press against the type-wheel, and take off a letter. By following out this supposition, you have the whole mystery of this wonderful instrument at once.

The armature, or keeper of the magnet, is restored to its place by means of a lever, which acts upon it at the moment it is pulled away from the electro-magnet poles by the spring.

This system requires but about one tenth of the battery power required to work the House system, and perhaps one third that of the Morse. The instruments are run by a weight, which is wound up by a treadle. It might, perhaps, be imagined that the machinery necessary to produce results so remarkable should be of a complicated character; such, however, is not the case. The machinery is very simple, consisting mainly of four clock-wheels used to turn the type-wheel, circuit-wheel, and printing-cam.

There is no other system capable of working upon so long a circuit of wire without the aid of repeaters, if all that is said of it by its friends is to be credited; but upon this point we confess we have not yet seen sufficient evidence.

We do not, however, see the practical benefit to be gained by a system which can be worked at a greater distance than the Morse. The business over any line, even in this extensive country, is mainly confined to points of less than three hundred miles apart. It would be desirable, doubtless, to have direct communication between Boston and California; but even if there were systems capable of reaching that distant point upon a single circuit, the insulation, unless greatly improved upon our present lines, would never allow a current to reach there upon one circuit. But this matter of insulation is one of vital importance, and will be treated upon in another chapter.

There is one more point in the splendid achievement of Mr. Hughes which should not be passed over in silence, although of no practical value; and that is his arrangement for working both ways over the same wire at the same time. This, however, has been accomplished in Europe by several ingenious electricians, namely, MM. Gintl, Wartmann, Siemens, Halske, and Edlung,

who have solved the problem of the transmission of two or more despatches over the same wire at the same time, by processes entirely different.

An ingenious electrician in this city prepared a modification of MM. Siemens and Halske's invention, which was designed to be used upon the Morse lines. It was tested between this city and Portland, and found to work well. The operator at this end of the line actually sent despatches to Portland at the same instant that the Portland operator was sending a despatch to Boston over the same wire! The despatches did not interfere with each other in the least. But, as we remarked before, there is no practical benefit to be derived from this. It would require, of course, a double force of operators to work a wire in this manner, and there are always questions to be asked back and forth, which would cause confusion if they had to pass from the sender to the receiver, and *vice versa*. Besides this, a finer balancing of batteries upon the line would be necessary, to accomplish this result, than could practically be obtained. The experiment, although extremely interesting, is of no practical utility.

The cost of a Hughes instrument is about one hundred and thirty dollars, — varying according to the maker. The cost has heretofore been augmented by the experiments which have been made, and the numerous improvements suggested. It will, of course, become cheaper whenever a settled plan shall be agreed upon.

The system is easily learned, — a man of quick apprehension becoming quite an expert operator in a few weeks.

Altogether, Hughes's printing telegraph is entitled to be considered one of the greatest inventions of the age, and, had he preceded Morse, House, and Bain, it would have entitled him to the first place among inventors.

Mr. Hughes is confident that his instrument would have worked through the Atlantic Cable. Had it accomplished this, it would have ranked as the first recording telegraph in the world, performing what no other recording instrument could possibly have achieved. It is, therefore, much to be regretted that Mr. Hughes did not have the opportunity to make the trial.

CHAPTER X.

THE AMERICAN PRINTING TELEGRAPH, OR THE COMBINATION SYSTEM.

THE last chapter gave a sketch of the printing instrument of Mr. Hughes, as it was used a few months ago in the Boston office, upon the lines of the American Telegraph Company. There have, however, been found some practical objections to this instrument, and among them some which were claimed by Mr. Hughes as among the chief excellences of his system. We allude now, particularly, to the use of the combined natural and electro-magnet, and the use of a weight for carrying the machine. Mr. Hughes, in conceiving that his instruments could be carried by weight, considered that he had accomplished a great saving in labor and expense. It has proved, however, upon the contrary, that this has not been an improvement. In order that the instruments should run with sufficient speed to answer their requirements, it was necessary to have a larger number of wheels, when carried by weight, than when carried by treadle. This will be obvious to any one at all acquainted with machinery. And, in order to accomplish both of these results, it was necessary to have the machinery made very light. Now, the machinery being light, and running with such rapidity, it was constantly breaking and giving out in one place or another all the time, and the consequence was that resort was again had to the treadle.

The second objection which we have alluded to was still more serious. The combination of the natural and electro-magnet, which produced results so sensitive, has come to be condemned on account of its very sensitiveness. But to make this clear to the reader, we will explain the matter briefly. If a line were constructed between this city and New York, for instance, perfectly insulated, (a circumstance that has never yet occurred,) and no atmospheric currents had any influence upon the line, it is

obvious that the system requiring the least battery — everything else being equal — would be the most desirable. But as none of these conditions are to be met with, it happens that it is not desirable to work a line with such feeble current. There is but a small part of the time, in any season of the year, when there are not more or less atmospheric currents to disturb the equilibrium of the lines; such, for instance, as the magnetic storm, or aurora borealis; and, therefore, the more sensitive the magnet, the more interruptions will it experience from such extraneous sources. The Hughes instrument was peculiarly liable to such interruptions; and, without trespassing too far upon the limits designed for this chapter, we will briefly allude to one or two of them.

During the magnetic storm which culminated in the aurora borealis of August 28 and September 2, 1859, the Hughes instrument at West Brookfield was unable to work for nearly a week. The operator, not being sufficiently versed in the theory of magnetic induction to ascribe the matter to its true cause, went over the line a great number of times in search of the trouble, but, of course, without success. Within the past few years, during which the Hughes instruments have been used upon the lines between Boston and New York, they have ceased to work during heavy rain-storms, owing to the "escape," and the business of the line has been done over the House wires; that system being able to work over a greater escape.

To obviate these difficulties, the company, through the aid of that ingenious mechanic and able electrician, Mr. G. M. Phelps, of Troy, has succeeded in producing an instrument which unites all the excellences of the Hughes system and that of Mr. House. This production has been very appropriately designated as the combination instrument.

This instrument (see Frontispiece) retains the synchronous movement of the type-wheel, the simple form of the press, the frictional movement of the cam, the correctors, and the detent, of the original Hughes invention; but borrows from the House system the double-headed cylinder or plunger, the air-pump, chamber,

and valve; and, in addition, contains the electro-magnetic governor invented by Mr. Phelps. It also uses the simple form of the U magnet invented by Professor Henry of the Smithsonian Institution, and which is used upon the Morse system.

Upon the combination lines the open circuit is used. The valve fits into an air-tight chamber, and, being made of soft iron, acts as a keeper to the U magnet situated under it. The valve is raised by a spring, and depressed by the passage of a current through the electro-magnet. The plunger, which is contiguous to the valve, has an air-passage from each end to the air-chamber of the valve, by the depression of which a current of air is forced into one end, and by the raising of which it is forced into the other extremity. In the centre of the plunger one end of the detent is placed. When the circuit is open, the plunger forces the detent against a projecting arm upon the cam; when it is closed, the plunger forces the detent away from the arm of the cam, which is then carried around by the friction until it comes into contact with the press, forcing it against the type-wheel, and taking off the letter which at that instant presents itself. Around the surface, and under the type-wheel, are twenty-eight cogs, corresponding to the twenty-six letters of the alphabet, and a dot and a dash. The press is composed of a tube an inch long, with cogs at the lower end, which, by being thrown forward by the movement of the liberated cam, locks into the cogs upon the type-wheel, and is made to revolve with it as long as the contact lasts; but as it takes but one wave to release the detent, which is again applied to the cam as soon as the circuit opens, it follows that the press is only kept in contact long enough to form one letter, and to pass one cog. A small, semicircular spring confines the strip of paper between it and the tube, and when the tube is carried around one notch, the paper is drawn along by friction. The press itself is thrown back from the type-wheel by a spring at the instant the arm of the liberated printing-cam releases it.

Under the cogs above described upon the type-wheel, there is a second set of cogs; and upon the cam there are six projecting cogs, which fit into the spaces between the cogs upon the type-

wheel, and serve as correctors. In this manner the instruments are prevented from varying to the hundredth part of an inch. There is a bell situated near the cam, designed as an alarm; not, however, to be used like the ordinary alarums upon English and other European systems, to call attention when a message is to be sent, but to announce to the operator who is transmitting a despatch when a break occurs. The use of this alarm might, however, be very safely dispensed with. A steel wire, with a small ball upon one end, and connected by the other with the detent, is made to vibrate with every movement of the detent, and strike the bell with considerable force.

In passing from this part of the instrument, we cannot forbear alluding to the important part which air plays as a motive power in this, as well as the House instrument. Without it the House instrument would hardly be practicable; with it this instrument is wonderfully improved. Air acts instantaneously, is never at fault (if the pumps and tubes are looked after), and is a powerful auxiliary motive power.

The key-board is similar in appearance to the House, and in principle is identical with the Hughes. The circuit-wheel is fifteen inches in length by three in diameter. It is in the form of a cylinder, and made of brass. Apertures one inch in length, running across the cylinder in a direct line with the keys upon the key-board, but having at the lower end a small aperture running longitudinally to the left, corresponding in number with the twenty-six letters of the alphabet and the dot and dash, receive the projecting arms at the extremity of the keys.

At the back part of the keys, and in a line with them, there is an iron band connecting with a key, or circuit-closer, in such a manner that by moving it to the right it closes the circuit instantly.

The projecting arms at the extremity of the keys, when the keys are depressed, are forced into the apertures of the cylinder, and, passing in a direct line until near the bottom of the aperture, are then carried in an oblique direction a space of an eighth of an inch, in doing which the iron band is moved the same distance, and closes the circuit. It follows from this, that as the

apertures are situated at equal distances upon the circumference of the circuit-wheel, and as the circuit is closed whenever a key drops into its aperture (no key can drop into the aperture of another), the circuit must always be closed in that part of the arc of the type-wheel corresponding to the key depressed. That is to say, supposing the circuit-wheel and type-wheel to be making 120 revolutions each per minute, and that they be both started alike from the dash, it follows, if you close the circuit at M, that M will be printed from the type-wheel, because that letter represents just one half a revolution of the type-wheel as well as one half of the circuit-wheel. The circuit-wheel, as soon as the key reaches the oblique aperture by the movement of which the circuit is closed, drops the key, and the circuit opens again.

Six letters may be printed at every revolution, and as the instruments can be run up to 140 revolutions per minute, we have the astonishing rate of 50,400 letters, or 10,080 words, per hour, which this instrument is able to produce; but as there are no words in the English language so peculiarly constructed as to include every fourth letter from A to Z, it follows that this result is not practicable from this single fact, as well as from the fact that there are no operators of sufficient dexterity to be able to touch the keys at this rate.

It remains for us now to describe the electro-magnetic governor of Mr. Phelps's invention. This governor is made of iron, three inches in depth by four in width, in the form of a hollow cylinder. It runs upon a shaft connecting with the principal wheel in the machine. Through the centre of the shaft there is an aperture, through which passes a spring, connected at one end with a lever and at the other with a balance, which a rapid revolution of the cylinder causes to fly out, and at the same time raise the lever at the other end. Upon the end of this lever there is a small iron wire, which is raised by the lever whenever the balance flies out, by the rapid revolution of the instrument, until it strikes a brass pin at the top, by which it closes a local circuit, and thereby brings an armature, containing a leather friction attached to a keeper of an electro-magnet, into connection with the

sides of the cylinder of the governor. This checks the speed of the governor, and causes the needle to drop, by which the local circuit is opened and the friction removed. The governor then regains its speed, causing the balance again to fly out, the lever to rise, and again brings the wire into contact with the brass pin, again throwing on the friction of the electro-magnet, which again checks the speed, and so on.

It will be observed that there are here two forces in direct opposition. The natural speed of the instrument causes the balance to fly out, and raise the lever, by which a local circuit is closed, which brings into action a friction which checks the speed of the governor. By raising the brass pin over the wire, the instruments can be increased in speed to any desired amount; and by lowering it, they can be decreased. Three cups of Daniell's (sulphate of copper) battery furnishes the necessary current for the local battery.

The ordinary rate of speed of this instrument is about 2,000 words per hour, or about twice as rapid as the Morse, and about equal to the House; for although the Morse instruments can be worked as high as 1,500 words per hour, and the House as high as 2,800, still neither of them is ordinarily operated at this rate. The usual rate upon the Morse lines does not exceed 1,000 words, and that of the House 1,800 words per hour. Mr. Walker, the Superintendent of the Electric Telegraph Company between London and Dover, states the rate of transmission upon the lines under his charge, which employ the needle system, to be about 15 words per minute, or 900 words per hour. This is, doubtless, setting the rate pretty high, and we may therefore conclude that, from all the testimony we can gather upon the subject, the needle system is about one half as fast as the Morse, and one fourth as fast as our American printing system. The combination instrument as a whole is, without question, far in advance of any and all other instruments ever devised, in this country or Europe. It is simple in construction, and therefore not expensive in manufacture. Only one wave is necessary to produce a letter, while it requires, upon an average, three and a half upon the Morse, seven upon the House, three and a quar-

ter upon the needle telegraph of Cooke and Wheatstone, seven upon Froment's dial system, and the same upon Siemens's.

The breaking and closing of the circuit is done by machinery, and is therefore much more accurately and firmly done than if performed by hand, as is the case upon the Morse, Bain, and needle systems; for, although some operators touch the key firmly and steadily, making a good contact between the lever and anvil, there are many who, from nervousness or carelessness, close the circuit in an imperfect manner, causing, particularly in wet weather, when there is considerable escape, a shaky, unreliable movement to the armature of the electro-magnet. From this cause it often happens, upon all Morse lines, that messages can be received from some operators when it would be impossible to receive from others, over the same wires. This goes to show how essential it is that the contact should be made properly, — that is, firmly, and of sufficiently long continuance. At the *exact* instant that the contact is made, the full force of the current does not flow, but increases in volume for a perceptible time, as has been observed from minute experiments. Now the contact is made upon this instrument, not only by machinery, but by a direct movement, and the contact continues a sufficient length of time for the current to develop its full force. The contact is an exact one also, — the placing together of two flat surfaces of brass. In this particular it is superior to the arrangement upon the House instrument for closing the circuit; for upon that a spring is used, made of steel, divided through the middle, one end of which presses upon the surface of a cog-wheel, divided into twenty-eight parts, and which revolves sixty-two times a minute, thus opening and closing the circuit 1,750 times per minute, or 29 times per second!

To print 2,000 words per hour with the combination instrument, it is only necessary to break and close the circuit 166 times a minute, or not quite three times per second.

Printing systems possess great advantages over the needle, the dial, or the arbitrary recording instruments, in that *they perform double the work*, and thereby reduce the chances for error in the same proportion. We all know that man is always liable to error,

and that the more we can accomplish by exact machinery, the less liable are we to be annoyed with mistakes.

Then, again, the printed slips are more satisfactory to the patrons of the telegraph, because they are more easily read than ordinary writing; and this, again, is a matter of more importance than it would at first seem, because the rapidly written copy of even the best operator is often far from legible, and requires to be studied, and sometimes returned to the office to be deciphered.

This instrument, then, standing at the head of all which have been devised for transmitting intelligence by the wonderful agency of the electric fluid, and seemingly fulfilling all the requirements of a perfect system, deserves a brief consideration, at least, to determine the question as to whom belongs the credit of its devisement. We cannot, properly speaking, call it an invention separate and distinct from any other, and its very name suggests the impropriety of doing so. It is simply a combination instrument, and it remains for us to state from what it is combined.

We have seen above, that it is composed of a portion of the instrument invented by Hughes, a portion of that of House, and the governor of Mr. Phelps. The union of these systems is unquestionably due to Mr. Phelps; and if such a combination were patentable, he would undoubtedly be entitled to the patent. But the leading principle upon which the instrument operates is that invented by Mr. Hughes, or, I should say, first successfully applied to a printing instrument by him; namely, the synchronous movements of the type-wheels, and the application of the one wave, or impulse, of the current for signalizing a letter. The portion of the apparatus borrowed from the House invention, though important, is secondary. It consists, mainly, in the application of air in conveying the impulse of the electric current for the purpose of releasing the detent at the proper moment, in order that the cam may force the press into contact with the type-wheel.

It would be proper, it strikes us, that the credit of this incomparable instrument should be divided between Messrs. Hughes, House, and Phelps, as inventors; but there is also much credit due to the American Telegraph Company, for the liberality with which it has expended its money in the large number of experi-

ments which it has been necessary to make, extending over a period of four years, in order to bring to a successful termination the valuable but imperfect invention of Mr. Hughes.

A patent has recently been awarded to Mr. Phelps for the following: —

"GEORGE M. PHELPS, *of Troy, N. Y.* (*Assignor to the American Telegraph Company*), *for an Improvement in Telegraphing Machines*: —

"I claim, first, producing from a magneto-electric battery the momentary electric currents required for actuating the printing-mechanism by giving momentary motion to the armature or other current-inducing part of the magneto-electric battery, by means of a set of finger-keys, which, when depressed, are controlled in their action upon the current-inducing part of the magneto-electric battery by a mechanical contrivance which constantly moves in harmony with the unintermittingly revolving type-wheel, substantially as described.

"I also claim increasing the capability of the instruments for telegraphing, by so increasing the speed of the transmitting-device and type-wheel, in relation to the motion of the parts which perform the printing, that two or more types shall pass the platen while the printing-mechanism is acting once, as described.

"I also claim turning the cylindrical platen while each impression is being made, by means of rings of teeth, *R* and *T*, upon the type-wheel and platen, as and for the purpose set forth.

"And, finally, I claim making a revolving wheel or shaft, *U* or *i*, turn the corrector, *M*, armature, *C*, or another wheel or shaft, a certain fixed distance, with the same speed as itself, at any time and any desired number of times, by the use of a ratchet-wheel, *V* or *h*, catch, *W* or *f*, guide, *X* or *k*, and detent, *K* or *e*, all arranged together, and, with the said driving and driven wheel or shaft, for conjoint operation, as set forth."

A valuable auxiliary to the combination instrument in its practical operations during rainy and foggy weather, when there is always considerable escape, from defective insulation, is found in

an apparatus which is being perfected by Mr. W. T. Eddy, of New York.

This apparatus consists of an induction coil, two relay magnets, and a local and primary circuit. The induction coil (discovered by Faraday) is applied in such a manner as to produce an instantaneous but momentary impulse upon the electro-magnets along a telegraphic wire, in addition to, and independent of, the main current upon the line.

We have described the principles of the induction coils on page 47, and we shall therefore only briefly describe the construction of the one in question.

The induction coils used by Mr. Eddy contain about ten miles of silk-wound copper wire, $\frac{1}{100}$ of an inch in diameter, for the *secondary* or *induced current*, and of about half a mile of insulated copper wire of No. 20 gauge for the *primary* or *inducing current*. The coils are fourteen inches in length by three in diameter, and enclose a bundle of about 150 iron rods or wires in the centre.

The manner of connecting this apparatus in the circuit is as follows. The main wire which extends between the distant stations is connected with the two poles of the secondary helix. A relay magnet placed in the same circuit operates a second relay, by means of a local battery, and this second relay opens and closes the *primary circuit*, the current of which induces a momentary and instantaneous current in the *secondary coil* at the moment of breaking or closing the primary.

The primary helix is made in sections, so that a part or the whole of the wire composing it may be in the circuit, as circumstances may require.

The utility of the local circuit and second relay may not at first be obvious. The object is to have the first relay work with a very delicate adjustment, which would not be practicable if it had to close a powerful primary circuit, such as is used for charging the secondary coil. The primary battery is composed of eight of Grove's cells.

During a heavy rain-storm, recently, two of these instruments were placed in the circuit of the line extending between Boston

and New York, and aided very materially in working the line through. In this case, one of the coils was placed in the circuit at Worcester, and the other at Waterbury. Before they were put in, Boston and New York operators could not get each other's breaks, but by their aid they were enabled to work with facility.

Should these coils prove, upon further trial, to accomplish all that is expected of them, the science of electric telegraphy will have received a very great help through the skill and perseverance of Mr. Eddy.

Owing to the momentary action of the induced current, it was not supposed that the coils could be used in connection with the Morse apparatus; but recent experiments seem to indicate that they may, with advantage, aid that system also.

Mr. Milliken worked between Boston and Portland by the aid of one of these coils, and was able to correspond intelligently with the operator at Portland, by simply breaking and closing the primary circuit, without disturbing the main circuit. The explanation of the success attained in this experiment is, that it requires more power to bring the armature up to the magnets than to hold it there; and the momentary impulse imparted by the induction coil being sufficient to bring the armature up, the voltaic current is able to perform the office of holding it there.

With the aid of permanent magnets, it is probable, therefore, that the Morse apparatus might be worked over a long circuit, without the aid of other battery power than that furnished by the primary current and the induction coils; but it would not probably result economically in practice, as the primary battery is consumed very rapidly.

The combination instrument has now been in use about a year, and, since the first of January last, has done nearly all the private business between Boston and New York. An ordinarily expert operator can easily transmit 2,000 words an hour by it, and those better skilled much more. Mr. Barrett, one of the Boston operators, has sent news for the press at the rate of 2,800 words an hour, partially abbreviated, and at the rate of 2,500 when printed in full, which is equal to the best speed attained by the House system.

The operation of this instrument becomes more and more satisfactory every day, and it is looked upon by all who have become familiar with its performances as the best telegraphic apparatus which has yet been produced. Its leading characteristics are rapidity of operation, simplicity in construction, and great accuracy. It might very justly adopt for its motto that used by its predecessor, the House printing instrument, and with even greater propriety, namely, *Prompt, accurate, and reliable.*

CHAPTER XI.

HORNE'S ELECTRO-THERMAL TELEGRAPH.

THIS system applies a new principle in electro-dynamics. The electric current, instead of being used to produce magnetism, as we have seen in the Morse, House, and Hughes inventions, or to decompose salts, as we have seen in the Bain, is employed in this instrument to produce heat, and, by burning holes in the paper, to produce a set of arbitrary signs composed of dots and dashes similar to the Morse alphabet.

The instrument (Fig. 70) is mainly composed of simple clock-

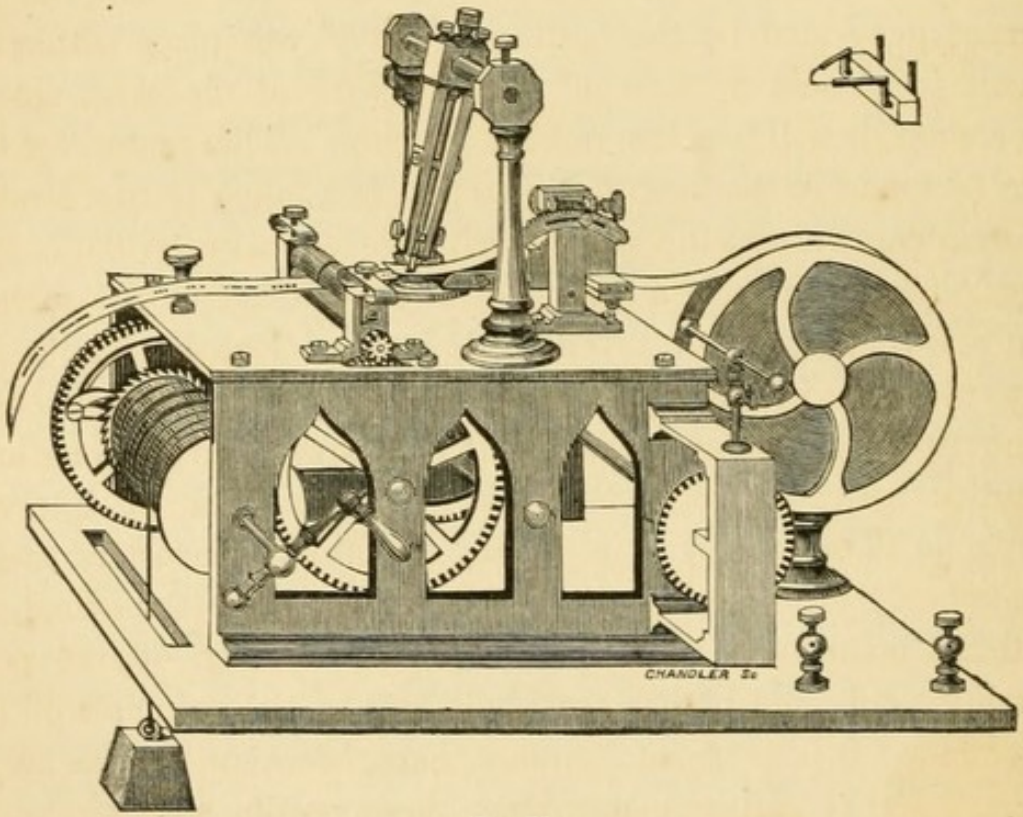


Fig. 70.

work, designed to carry along strips of paper at a uniform rate of speed. Above the clock-work are two pillars, supporting an axis, upon which is the adjustable wire-holder, the lower extremity of which touches the strip of paper. By means of the con-

nections and insulations of the pillars, axis, and wire-holder, the platinum wire, which passes over a little slip of porcelain at the end of the wire-holder, becomes part of the circuit, with which the two screw-cups upon the right of the instrument are connected. When the wire needs adjustment, the wire-holder can be turned up on its axis. The bed supporting the strip of paper is also adjustable, so as to regulate the contact between the wire and the paper.

This instrument derives its practical value from its application of the law, that resistance of metals, under certain conditions, to the passage of the electric current, generates heat. If you take, for example, an ordinary Morse "relay" magnet, composed of a large number of convolutions of fine silk-wound copper wire, and pass a heavy quantity current through it, you will find the helix to grow very hot, in a short space of time. Now this is owing to the resistance which the fine wire offers to the passage of the current generated by the battery. But if you place within the circuit so formed a piece of platinum-wire of the same size as the copper, it will become red-hot at once. The reason for this is to be found in the fact, that platinum is a much poorer conductor than copper, and the small piece inserted between the copper wires, offering so great a resistance to the passage of the current, is at once made red-hot. With this explanation, the reader has only to conceive the platinum wire, bent, so as to present a pointed place of contact with the strip of paper, and a strong local quantity battery thrown upon the platinum wire at intervals similar to those employed in making the Morse characters, and to remember that, when the battery is thrown upon the wires, the platinum point burns a hole, and when it is thrown off, the point instantly cools, and he has the whole idea of the principle of this invention. It is proper to remark here, however, that as only a strong quantity battery can produce these results, and that quantity batteries cannot produce such effects at the termini of a long telegraph line, it becomes necessary to use a local circuit, a relay magnet, and a local quantity battery; and here is where the invention runs against an insurmountable difficulty, for the relay magnet, local battery, and local circuit are particularly claimed

in Morse's patent as his invention. This instrument cannot therefore work without the permission of the owners of the Morse patent. It has no points of superiority over the Morse, and as it cannot be used as a substitute, owing to the above disability, the result has been that it has never been put into practical operation at all.

An instrument which might, perhaps, be construed into somewhat of a resemblance to the above, was constructed by Messrs. Farmer and Batchelder of this city. They used, however, a large cylinder, upon which were placed sheets of variously tinted tissue-paper. A platina point connected by an armature with the keeper of an electro-magnet was brought in contact with the tissue-paper by the opening and closing of the circuit. A spirit-lamp, situated under the platina point, kept it at a red heat, and when it touched the tissue-paper it discolored it, causing a distinct mark. The instrument was carried by clock-work. The system is practicable, and could be used upon a line to advantage; but it will be obvious that it presents the same difficulty as the Horne instrument, namely, infringement upon Mr. Morse's patent.

In 1848, Messrs. Zooke and Barnes, of Mississippi, brought out a new telegraph instrument, which they called the Columbian Instrument. It recorded similar to the Morse, but used, instead of the simple electro-magnet, a combination of the natural and electro-magnet, such as Mr. Hughes uses upon his new printing instrument. They formed a new combination of characters for an alphabet, but differing in principle not a particle from the Morse. They used a local circuit, a key, and, in fact, nearly everything else, like it.

Mr. Henry O'Reilly, who at this time was having some serious difficulties with the Morse patentees, took up this instrument and introduced it upon the extensive range of lines he was then constructing throughout the Southwestern States; it was, however, proceeded against by the owners of the Morse patent as an infringement, and an injunction was granted by the United States District Court for the District of Kentucky, in 1849.

Notwithstanding the infringement was most palpable to every one, there were not wanting plenty of "experts" to testify that

the instrument was entirely dissimilar in principle and practice, — thus showing the value of these professional experts, whose services can be bought over to either side for a small compensation. Public safety lies in the scientific knowledge and ability of our judges, and it unfortunately often happens that they possess little science, however much general knowledge they may have.

In 1850, Mr. Henry J. Rogers, of Baltimore, devised a modification of Bain's electro-chemical telegraph; using, instead of the iron stylus and the moistened paper, a pen containing a liquid solution of salts, which left, through the action of the electric current, a colored mark upon a smooth brass disc.

We saw this telegraph in operation in Philadelphia, in 1851, and were informed by the operator that it was liked very much. However, it did not strike us as being any improvement upon the Bain system, but, upon the contrary, as far inferior to it. The New York, Philadelphia, and Washington Bain line never did operate their line upon the Bain principle strictly; but used the local circuit, which, as we have said, is claimed as Morse's invention, although there are few well posted in the history of the invention who think him entitled to it.

The use of this circuit operated upon the company disastrously in their suit with Morse in 1852, and was, doubtless, the primary cause of the disuse of the Bain system in America; although, as we stated in our chapter upon the Bain system, it is the opinion of some of the best electricians and experts in this country, — among others, Dr. William F. Channing, — that the cause of Judge Kane's decision against the Bain line, in 1852, was owing to an understanding previously arrived at between the managers of the Morse and Bain companies to that effect, they having agreed to consolidate their lines and join their interests, which would be better subserved by keeping the Morse patent intact.

CHAPTER XII.

THE DIAL TELEGRAPHS.

The Dial Telegraphs (Fig. 71) are those in which a needle traverses a dial, upon the margin of which are placed the letters of the alphabet, by a succession of elementary impulses, and is enabled to stop during a short space of time upon any point, and to show, consequently, any of the letters of the alphabet, or any signs, which might be placed there. Sometimes it is the dial which is movable. The only advantage of the dial telegraphs is that each sign is shown directly to the clerk, and that its perception is the result of a single instant of attention; the transmitter of the message has only to impart one simple rotary motion, more or less prolonged, in order to bring the indicating-needle upon the sign to be shown at a distance, or the movable dial to the place where the sign is to be found.

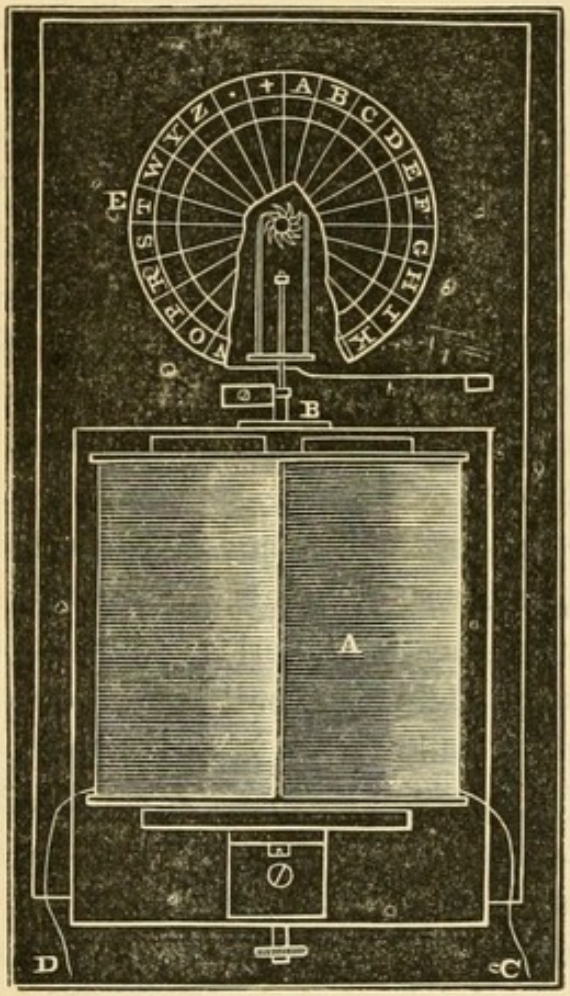


Fig. 71.

In the dial telegraphs there is always an electro-magnet, *A*, which, acting upon an armature, or, as it is called, a contact of soft iron, *B*, produces by means of this piece of soft iron a movement in a system of wheels more or less complicated, — a movement which is imparted directly by the piece in question, or which results from a mechanism foreign to

the electro-magnet, the action of which is arrested and liberated according to the position of the piece. The inconvenience of some of the dial telegraphs is, that, in general, each signal in them being dependent upon those which go before it, errors are liable to accumulate; their mechanism is also more or less complicated, which renders them more susceptible of derangement, and consequently very difficult to regulate and maintain regulated.

Wheatstone, who was the inventor of the first dial telegraph, has constructed a great many kinds in the endeavor to perfect them; and there have been a multitude devised by other inventors in England, France, and Germany. We shall only describe one of these dial instruments, and that the simplest in form, rather to illustrate the principle than the best mode in practice.

The instrument, like all others designed for telegraphing, is composed of two parts, the manipulator and the receiver. The needle of the receiver is mounted upon a wheel, which possesses twenty-seven teeth, corresponding to the twenty-six letters of the alphabet, and to the sign +, called *final*, which serves as the starting-point. A pallet connected by a lever in connection with the keeper of an electro-magnet, is made to advance one tooth in the index-wheel for every break and close in the circuit. Suppose the needle to rest upon the *final*, it will take one opening and closing of the circuit to bring it upon the letter A; by repeating the breaking and closing twice, starting from the final, it will be brought upon the letter B; and so on for all the letters. The manipulator carries a dial precisely similar to the preceding; only its needle, which is stronger, is moved by the hand, and in its motion draws on the wheel upon which it is mounted. The latter possesses twenty-seven teeth; two springs are placed to the right and left, one of which performs the office of the catch in the ratchet-wheel, by preventing the wheel from turning backwards, and is always found in contact with it; the other touches it by a projecting terminal only, when one tooth passes before it. Two connecting-wires, each of which is attached to one of the extremities of the wire of the electro-magnet of the receiver, are attached, the former to the positive pole of the battery, the latter

to the catch-spring, whilst the other spring connects with the negative pole. It follows from this arrangement, that, each time a tooth passes before the second spring, the circuit is closed, and that it is interrupted when this spring is situated in the interval that exists between two teeth. Thus, when the needle of the manipulator is made to pass from one letter to the following, there is produced successively a closing and an interruption of the circuit, which causes also the needle of the receiver to pass precisely in the same manner from one letter to the following. Consequently, if the two needles are in accordance, (and it is for this purpose that the + is employed, upon which the needles of both apparatus must always be stopped when they are not acting,) they will pass on together to all the letters, indicating them simultaneously; and in order to transmit a word, we have merely to stop the needle of the manipulator for an instant at each of the letters of which it is composed. Each station must have a battery, a manipulator, and a receiver; the operator who receives the despatch keeps his battery and manipulator out of the circuit; there is nothing else to do than to follow with his eyes the needle of the receiver, in order to read what it indicates. When it is his turn to transmit a despatch, he takes his receiver out of the circuit by means of a commutator, and at the same time introduces into it his battery and his transmitter; he causes the alarum of the station to which he addresses himself to ring, his correspondent performs a reverse operation, and the communication is established.

The apparatus above described, excellent for demonstration, is inferior to others of the same kind in respect to velocity and safety in the transmission of despatches; the derangements to which it is liable arise from the circumstance that the pallet of the escapement of the receiver is sometimes liable to allow a tooth, instead of a half-tooth, to pass, on account of the velocity of the impulse, and from the fact that the hand of the person that causes the needle of the transmitter to turn has nothing to guide, and especially to stop it exactly where it ought to be done; the least irregularity it may suffer, either onward or backward, may produce some want of agreement between the needles.

Mr. Wheatstone has devised many methods of transforming

the alternate motion of the armature into an intermittent circular motion of the dial. The direct mode above described requires too strong a current to be employed when the distance to be traversed by the despatch is considerable. Thus, in the improved apparatus intended for long lines, Mr. Wheatstone has connected the signal dial with a clock movement, set in action by a spring or a weight, which, when there is no preventing cause, communicates to the wheel to which the dial is fixed a rapid rotation. But mechanism analogous to a scape-wheel and pallets does not allow of the wheel advancing more than the distance of a half-tooth each time that the armature is attracted by the electro-magnet, or repelled by means of the spring to which it is connected when the magnetization ceases.

M. Bréguet has also devised an improved dial telegraph, in which he uses the clock movement to carry the needle, and the electric current to act simply as an interrupter. That which particularly distinguishes this machine is the employment of an escapement which is placed in dependence upon an electro-magnet, in order that the latter may enable one half-tooth to escape at each vibration. The escapement acts by means of two pallets mounted upon an oscillatory axis, and arranged at such a distance and manner that the tooth of the wheel cannot pass without encountering them.

M. Froment has also designed one of the best of the dial systems. His improvements are particularly in the transmitters, which greatly resemble those used upon the House instruments. He uses twenty-eight keys, arranged upon a board similar to the House plan. He also uses a straight, steel arbor, upon which there are placed twenty-eight pins, arranged in regular order and at equal distances, and which also divide its circumference into twenty-eight equal parts, forming the complete revolution of a helix. This arbor is situated under the key-board, the keys of which are provided with corresponding pins, which pass freely when in their natural position, but, when the keys are depressed, cause the arbor, which is moved by clock-work, to stop. At the end of the arbor there is a break-wheel, by which the circuit is broken and closed twenty-eight times for each revolution. The

needle of the receiver moves synchronously with the arbor of the type-wheel, through the action of the circuit-breaker. The instrument is very rapid, the last wheel of the movement which carries the arbor making three revolutions per second. Four letters can be made at each revolution upon an average. This, like all other dial systems, belongs to the class of step-by-step electro-magnetic telegraphs. There can be little question that the leading ideas of this instrument were borrowed from the House, which is, however, vastly superior to it, from the fact that it actually prints in plain Roman letters, while this simply has the power of indicating them. House's instrument possesses this indicating power also, and operators in conversing with each other never set the press in motion, but simply read from the signal-wheel, which long practice enables them to do with great facility. In fact, there have been made numerous signal-instruments upon House's plan, for small offices and railway stations, which do not possess the printing apparatus, but simply depend for their usefulness upon the signal. These instruments are of course far less complicated than the printing instrument, and much less costly, being made for about $150 apiece, in a very substantial manner.

Bréguet's and Froment's systems have been largely used in France, but are being superseded by Morse's and Bain's instruments.

We cannot dwell upon all the very numerous modifications which the dial telegraph has undergone, such as the employment of clock-movements moving synchronously at the two stations, and which are stopped by the aid of electro-magnetic actions at the same instant; or such as the substitution of pieces of magnetized steel for the ordinary armatures of soft iron, which enables us to do without the spring employed for restoring the armature to its former position. In fact, in this case the electro-magnets act upon the armature already magnetized of itself, by repulsion as well as by attraction, according to the direction of the current; the sensibility of the apparatus is thus increased, and it is independent of the variable intensity of the current, which requires that the spring be regulated, when the armatures are of soft iron, for each particular intensity.

M. Glösener, who has employed magnetized armatures in the construction of the different systems of telegraphs, has found in it the advantage that is likewise presented, as we shall see, by the employment of magneto-electric machines instead of piles, — that of destroying more rapidly, by the production of induced currents, the magnetization of electro-magnets, which remains sometimes for some instants after the current has ceased to pass. But, notwithstanding these various advantages, we think that, if magnetized armatures have not been generally adopted, it is because their magnetization must alter very rapidly under the intermittent action of electro-magnets.

All alphabetical telegraphs, both those which we have been describing, as well as those which resemble them, may be characterized in a general manner, by saying that they have necessarily a manipulator, which is moved by the hand of the person who sends the despatch, and that, consequently, he who receives the despatch is obliged to remain passive until his correspondent gives him the liberty of speaking in his turn. With regard to the differences that exist between the various apparatus, they depend only upon the mechanism that serves to transform the backward and forward movement into a rotary motion, or upon the arrangement of the dial, or upon the form of the interrupter, or, finally, upon the number of the divisions, both conducting and non-conducting, of which it is composed. It is not the same with the telegraph devised by Mr. Siemens, which differs totally from others in that it maintains to the operator who is receiving the despatch, even while he is receiving and writing it, his direct and immediate action over the operator who is sending it to him, and this without having recourse to a second wire, without disturbing the agreement of the dials and of the apparatus, and without introducing the smallest disturbance into the series of signs, the transmission of which is commenced.

In order to realize this advantage, Mr. Siemens suppresses the interrupter, and arranges his dial apparatus so that it may act in the same manner when sending or receiving a despatch.

The armature of the electro-magnet carries a lever of about four inches in length, which performs two separate actions. By

the first, at each double vibration, it causes one tooth of the wheel to pass, upon the axis of which is mounted the indicating-needle of the dial; and thus carries this needle step by step from one letter to the letter that follows.

By the second, it breaks the circuit, and arrests the current from which it has itself received motion; but it does not arrest it until the moment when it is itself arrested by a stop in its *onward* excursion, that is to say, when the armature, attracted by the electro-magnet, has arrived as near to the poles as it ought to go; then, the circuit being broken, the armature ceases to be attracted, and, finding itself immediately drawn back by its spring, the lever accomplishes its *return*. Scarcely does it touch this other limit of its excursion, than it completes the circuit afresh, re-establishes the current, and instantly is found to be carried on anew by the armature in order to accomplish its second onward movement, which from the same cause is followed by a second return. These isochronous vibrations will thus be accomplished indefinitely, as long as the battery furnishes a current of the same intensity.

In order that communications may be sent by this instrument, it is necessary that the needle be arrested in its course for a longer or shorter time. In order to obtain this result, Mr. Siemens adjusts circularly around his dial as many keys as it carries signs, and upon each key is repeated, in a very conspicuous character, the sign to which it corresponds. On placing the finger upon a key, a small vertical end, of the tenth or twentieth of an inch in diameter, is depressed, which then stops the passage to a horizontal lever, parallel with the needle, and mounted upon its axis. It is exactly as if the needle itself were stopped; but the mechanism is concealed beneath the dial, in order not to confuse its appearance, and not to fatigue the attention of the operator. It is not only necessary that the needle be stopped opposite to the sign that it should indicate; it is also important that the motor lever, connected with the armature, the vibration of which is also arrested by the same obstacle, shall be then situated toward the middle of its return; that is to say, towards the middle of the excursion it makes under the influence of the spring which brings

it back. In fact, at this instant, the circuit being broken for a certain time, and the effects of the current having ceased, there is less chance that the armature should contract a magnetic polarity capable of disturbing the regular action of the apparatus. These conditions are very skilfully fulfilled by Mr. Siemens.

The person sending the despatch has only one operation to perform,—to place his fingers successively upon all the keys corresponding to the signs he wishes to make. He depresses a key, and the indicating-needle of his apparatus, carried on by the regular motion by which it is actuated, does not yet suffer anything; it continues its course till the moment when it arrives at the sign whose key is depressed, when it stops. The needle of the other station, moved by the same force, and subject to the same synchronism, cannot, however, stop mathematically at the same instant; for the lever which causes it to move, brought back also by its spring, accomplishes its return with force, since it does not encounter, like its homologue of the first station, a material obstacle which stops it; it therefore accomplishes its return, and takes the position in which, as far as it is concerned, it completes the circuit and re-establishes the current. What it then does cannot have its full effect at the very instant, since its homologue of the first station is then retained in a point where it breaks the circuit. Thus the operator, sending the despatch by placing his finger upon a key for a certain fraction of a second, brings about a moment of similar stopping in the needle of the second station; but we must particularly remark, that the two needles cannot stop at the same instant; the second does not stop until after a time which is equivalent to nearly a quarter of the duration of a complete vibration.

The operator sending the despatch, by raising his finger placed upon the first key, in order to carry it on to the second and make the second sign, produces the following results. The lever of his apparatus, obeying the action of the spring which draws it, is finally free to accomplish its return, and, in fact, it does accomplish it. Then, the circuit being everywhere closed, the current is re-established; the armatures of the two stations are simultaneously attracted, and the needles recover their concordant pro-

gress, until the moment when that of the first station marks the second sign; the needle of the second station repeats it in its turn, and the same phenomena are reproduced until the end of the despatch. If everything goes on well, the operator of the receiving station has only to follow the movements of his indicating needle, to write or to dictate the signs that it points out to him. If he has a doubt, he places his finger upon a key; then the needle of the first station stops at that signal, and the person who sends the despatch is thus warned that his correspondent wishes to speak; the conversation goes on, explanations are exchanged, and the original operation soon resumes its course.

Mr. Siemens, when desired, joins to his apparatus a printing-press, which operates by electro-magnetic action; but the mechanism of the apparatus is very complicated, and has not been generally used.

Mr. Siemens's telegraph requires, in order to its acting well, a perfection of execution, which has been realized by Mr. Halske, a skilful mechanician of Berlin, but which in general can only be obtained with difficulty. This circumstance, added to the complication, and consequently to the high cost, of the apparatus, has rendered the employment of it not very general.

PART IV.

SUBTERRANEAN AND SUBMARINE LINES.

CHAPTER XIII.

As soon as the fact was established that a telegraph could be constructed through the aid of electricity, the attention of discoverers, both in this country and in Europe, was turned to the invention of some perfect insulating substance by which the wires could be enveloped and buried in the earth. It was not deemed desirable, or in fact practicable, to place them in the open air upon poles, from the fear, in the first place, that they would be constantly broken by accident, or from malicious motives; and, secondly, it was supposed necessary to insulate them from the atmosphere, which, as I have before observed, is now known to be a valuable auxiliary in the passage of the current. Tarred yarn, with a preparation of asphaltum, was among the first insulators used for covering the wires. The lines constructed at government expense, between Washington and Baltimore, were covered in this manner. A plough was also invented by Mr. Cornell — one of Professor Morse's earliest assistants — for the purpose of opening a trench in the earth for burying the wires; but on account of the expense and the difficulty of obtaining anything like good insulation, the idea of laying them under ground was for the present, at least, abandoned. Still, if it was decided to relinquish the idea of building subterranean lines in this country, the fact was apparent to all, that perfect insulation, or something approaching it, was imperatively demanded for crossing straits or wide rivers, where masts

could not be erected upon which to carry the wires out of reach of shipping.

For this purpose copper wire, wound with several layers of cotton yarn dipped in asphaltum varnish, and the whole enclosed in a lead tube, was used. Mr. Alexander Jones of New York designed a submarine cable, the covering of which was to be glass, in the form of a ball-and-socket joint. The object was to get something which would unite both strength and flexibility, and at the same time furnish the best insulation. We do not know whether Mr. Jones ever had any of this cable manufactured, but he was endeavoring, in the winter of 1847, to get some of the telegraph managers to engage in the manufacture of it. It is probable, however, that nothing was done about it, for about this time that wonderful substance, gutta-percha, was discovered, which was destined to work a great change in international telegraphing.

This substance was applied to submarine telegraphing at once, it proving to be one of the best non-conductors known. In this country wires covered with a thin layer of gutta-percha were used for connections about the offices, and were also run through the branches of trees, where it was difficult to prevent the wires from touching the moist leaves, and thereby losing much of the current through the ground. But in this respect the experiment proved a decided failure; for the gutta-percha, being a comparatively soft substance, was soon rubbed off against the twigs of the trees, and exposed the wires to much worse escape than they would have been subject to without it. Owing to this blunder, — for it can be called nothing else, — one line between this city and New York was rendered useless for nearly two months, and these pieces of covered wire had to be taken out, and the line taken out of the trees, before it could be worked.

For river-crossing, the gutta-percha covered wires were encased in lead tubes. In this manner the Bain line crossed the Connecticut River at Middletown, in 1849, in the most satisfactory manner.

Gutta-percha, when exposed to the atmosphere, undergoes a change, which in a very short time renders it of no use as an

insulator; a thousand minute cracks being perceptible upon the surface, which allow the moisture to penetrate to the conducting-wire, and thus, of course, to form a connection by which the current is carried off upon the surrounding moist substances. From our observation, however, we are of the opinion, that, where gutta-percha is kept constantly covered with water, or entirely secluded from the atmosphere, no change of this kind can take place. We have examined a cable recently, which has been manufactured seven years, and has been laid for half that time, which is as perfect as on the day it was made. Therefore we cannot understand why the subterranean telegraph system should have failed so signally in Prussia, where it was originally exclusively adopted, and has since been abandoned. De la Rive says:—

"The subterranean system, employed in Prussia, was obliged to be abandoned on account of the molecular changes which the gutta-percha then employed underwent in the course of time, and which, by permitting moisture to infiltrate into it, establish a communication between the interior wire and the ground, and thus cause the current to be diverted from the desired direction. Ingenious methods had been well devised, which were founded upon Ohm's law, in order to discover the points of rupture; but the frequency of accident, joined to the difficulty of repairing them, has appeared to present greater inconveniences than those which are presented by the aerial lines, the establishment of which is, besides, much more economical. However, in towns, where the length of the circuits is never very considerable, the employment of subterranean conductors presents in so many respects such great advantages, that they have been generally adopted; only, in some cases, simple iron wires, deposited in a bed of bitumen, and covered with a layer of the same substance, have been preferred to copper wires covered with gutta-percha. These wires are so large, that the current does not suffer any resistance; and actual experiments have proved that their insulation is sufficient. However, wires covered with gutta-percha, carefully prepared, serve the same purpose; and they are employed with advantage in the passage of telegraphic lines through tunnels, against the sides of which

they are fixed, without fear of any defect of insulation resulting from it. All the telegraph lines in England have very long lines of subterranean gutta-percha wire laid, in some cases along the railway, and in others along turnpike-roads, which serve well. The wires of the Magnetic Telegraph Company, which extend from London to the English coast, *en route* to Ireland, are exclusively of this kind."

De la Rive is excellent authority upon all matters relating to the application of electricity, but we must differ with him in his conclusions respecting subterranean lines, and the value of gutta-percha as an insulating substance when exposed to the atmosphere.

We think it will strike any one as singular that the subterranean lines should have failed so signally in Prussia, owing to molecular changes and the consequent infiltration of moisture, when the same system has been adopted by many of the telegraph companies in England, and serves well. The explanation of this seeming contradiction is, we presume, to be found in the fact that the wires in Prussia were not laid deep enough in the earth to be out of the influence of the atmosphere, and were consequently open to the same objection which is made to the use of gutta-percha in the open air. The English lines, upon the contrary, it is to be presumed, are laid down below all atmospheric influence. It is not, however, so easy to explain how he should have committed the error of stating that the simple gutta-percha covering should have proved an excellent insulator in running lines through tunnels, to the sides of which they are fixed, without other insulators, unless, which is quite likely, he got the idea from some publication made directly after the trial was made, and before sufficient time had elapsed to destroy the insulating properties of the gutta-percha.

We have in this country but one subterranean line, and that is of short extent. The line extends from Nantucket to Martha's Vineyard, a distance of thirty-five miles, and is divided into eleven miles of aerial, thirteen miles of submarine, and eleven miles of subterranean wire. Starting from Nantucket, the line runs for ten miles upon posts, and then for three miles under the

sand to the extremity of Smith's Point, where it is attached to an iron covered cable, and runs under the channel to the island of Tuckernuck, across Tuckernuck under ground, and thence under water to the island of Muskeget, where it again runs under ground to the other side of the island, and there connects with an iron-protected cable eight miles in length crossing the channel between Muskeget and Chappaquidic; it crosses Chappaquidic, a distance of three miles, and connects with a cable one mile in length across the "Swimming Ground," to a point one mile distant from Edgartown, and thence runs in upon poles.

This line has been built three years. The line extending across the island of Chappaquidic, three miles long, is laid about two feet under ground, without any other covering than a thin coat of gutta-percha. After it had been down two years, we tested it with a delicate instrument, and found the insulation perfect. The subterranean line, three miles in length, upon Smith's Point, was laid out originally in the same manner; but owing to the sand absorbing the rays of the sun, and becoming very hot, the gutta-percha covering cracked and peeled off in immense quantities, entirely destroying the insulation. The proprietor of the line has since laid down gutta-percha wire enclosed within a small lead tube; we presume, however, he will never get a line to stand any length of time there, unless he trenches several feet below the surface. The submarine lines have all stood the test with the exception of the longest one, across Muskeget Channel. This has several times been hooked up by anchors, and communication destroyed.

The cable between Nantucket and the Vineyard was put in operation on the first of November, 1859, and remains in good working condition up to the present time. The Cape Cod Telegraph Company will shortly relay their cable between the mainland and the Vineyard, and thus place Nantucket in communication with the rest of the world.

While upon this subject, and before treating upon the matter of cables at length, which we propose doing, we will say a few words in reference to other cables which have been laid in the same vicinity.

The Cape Cod Telegraph Company constructed a branch between Wood's Hole and Edgartown, upon Martha's Vineyard. A cable was laid between Nobsque and West Chop, the two nearest points respectively upon Cape Cod and the Vineyard. They also laid one between Wood's Hole and Naushon, one of the Elizabethan group of islands. The cable between Nobsque and West Chop was five miles in length; the one between Wood's Hole and Naushon not quite a mile.

The cable used was about three times as large as the Atlantic cable. It worked for a few weeks, and then parted. It has since been twice repaired, with the same result, except that it did not stand so long as the first time. The tidal current between these two points is exceedingly rapid. One of the principal causes of the failure in the cable, and the immediate one, was the great quantity of sea-weed constantly drifting in the Sound, and which, collecting in huge masses upon the cable, forming in some cases balls of the size of a hogshead, offered such resistance to the immense body of water flowing through the Sound, that the cable was snapped asunder.

It is hardly probable that any cable can be found of sufficient strength to stand in this place for any length of time; but if there can, it must be such an one as was devised for the shore ends of the Atlantic cable. The cable across the smaller strait, between Wood's Hole and Naushon, stood the test until the beginning of the past summer, when, without parting, it had become injured in some manner so as to produce so much escape that it was found necessary to lay another, which was done about the first of July, and it has continued to work well since.

The English were the first to lay submarine cables, and are now far in advance of the rest of the world in their manufacture, and in machinery for laying them.

On January 10, 1849, Mr. Walker submerged an experimental gutta-percha covered wire, two miles in length, in the sea off Folkestone Harbor, one end being connected with a wire leading to London, the other with a telegraph instrument on board a steamship. The first message was sent to London at 12.49 P.M., and communication was maintained during the day, until the wire

was collected in. On August 28, 1850, Mr. Jacob Brett ran out temporary gutta-percha covered wire from Dover to Calais; signals were passed from coast to coast; but the wire, being unprotected, was cut by the rocks, and failed next morning. In September, 1851, he submerged the first permanent cable between Dover and Calais, which is still in use. It was once broken by anchors, but was repaired.

Since this period several submarine lines have been established: three are already in existence between England and the Continent, one abutting at Calais, another at Ostend, and the other at the Hague.

Besides two between England and Ireland, others exist in the seas which wash Denmark and Sweden, as well as in the Bosphorus. During the war with Russia, a line about four hundred miles in length was established in the Black Sea, between Varna and Balaklava.

Two others have also been undertaken, the extent of which will be immense.

One of these is intended to place Europe in communication with Africa, and consequently, by way of Egypt, with the East Indies, and probably Australia. Two attempts were made to accomplish this, which failed. In September, 1855, after submerging sixty-five miles, on entering the great depths, the cable ran out with such violence, that it was necessary to cut it adrift and sacrifice it to save the ship and crew. In August, 1856, after submerging sixty miles, a similar run took place, and the cable was cut adrift; eighteen miles of the shore-end were fished up and joined to the hundred and twenty-six miles still on board. This was safely run out; but the hundred and forty-four miles were just exhausted when the ship was still in deep water, and while the remnant on board was a few miles short in quantity. The cable was now lashed to the ship, which lay by in hopes to hold her own till another length of cable, for which a telegraphic message had been sent from the ship, should arrive from London. Rough weather came, and on the fifth day the cable snapped.

A less heavy cable, containing four conducting-wires, was deposited safely between Bona, in Sardinia, and Cape Telenda, in

Algeria, on September 9, 1857; but as it did not quite reach an extra piece was sent out. The total distance is 125 miles; more than three fourths of this distance presents a depth of from 1,600 to 1,700 fathoms, — nearly two miles.

Fig. 72 represents several kinds of submarine cable. The conducting-wires employed are generally of copper, about one

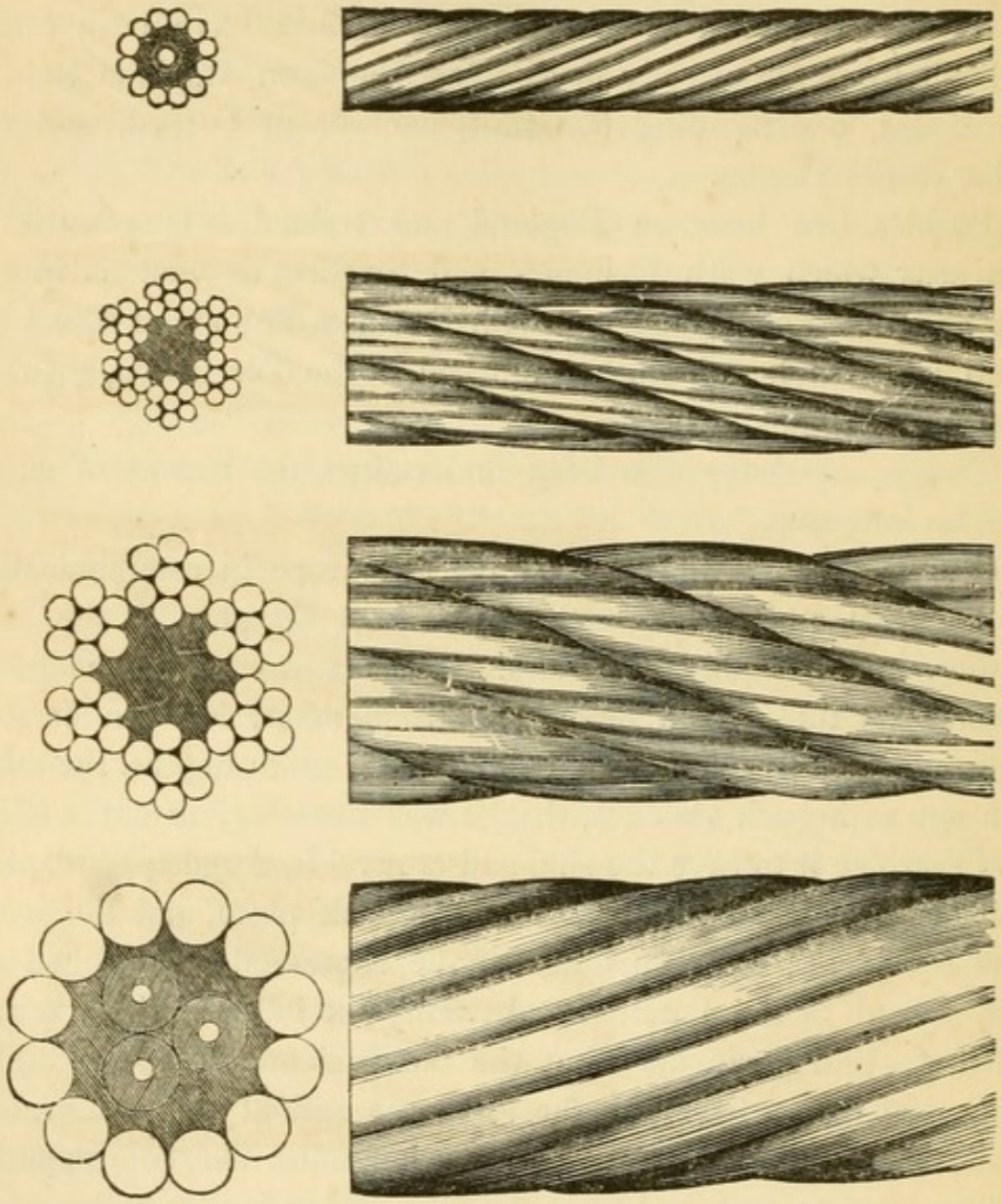


Fig. 72.

sixteenth of an inch in diameter; more than one may be placed in the same cable, and from one to six have been included, according to the multiplicity of correspondences to be transmitted. The wire, or each of the wires if there are more than one, is

covered with a coat or sheath of gutta-percha one twelfth of an inch in thickness, and placed on in two layers, in order the better to insure the insulation; for if one of the layers presented a solution of continuity, it is probable that it would not encounter a similar defect in the same point of the superposed layer. When there are several wires, they are arranged one after another as

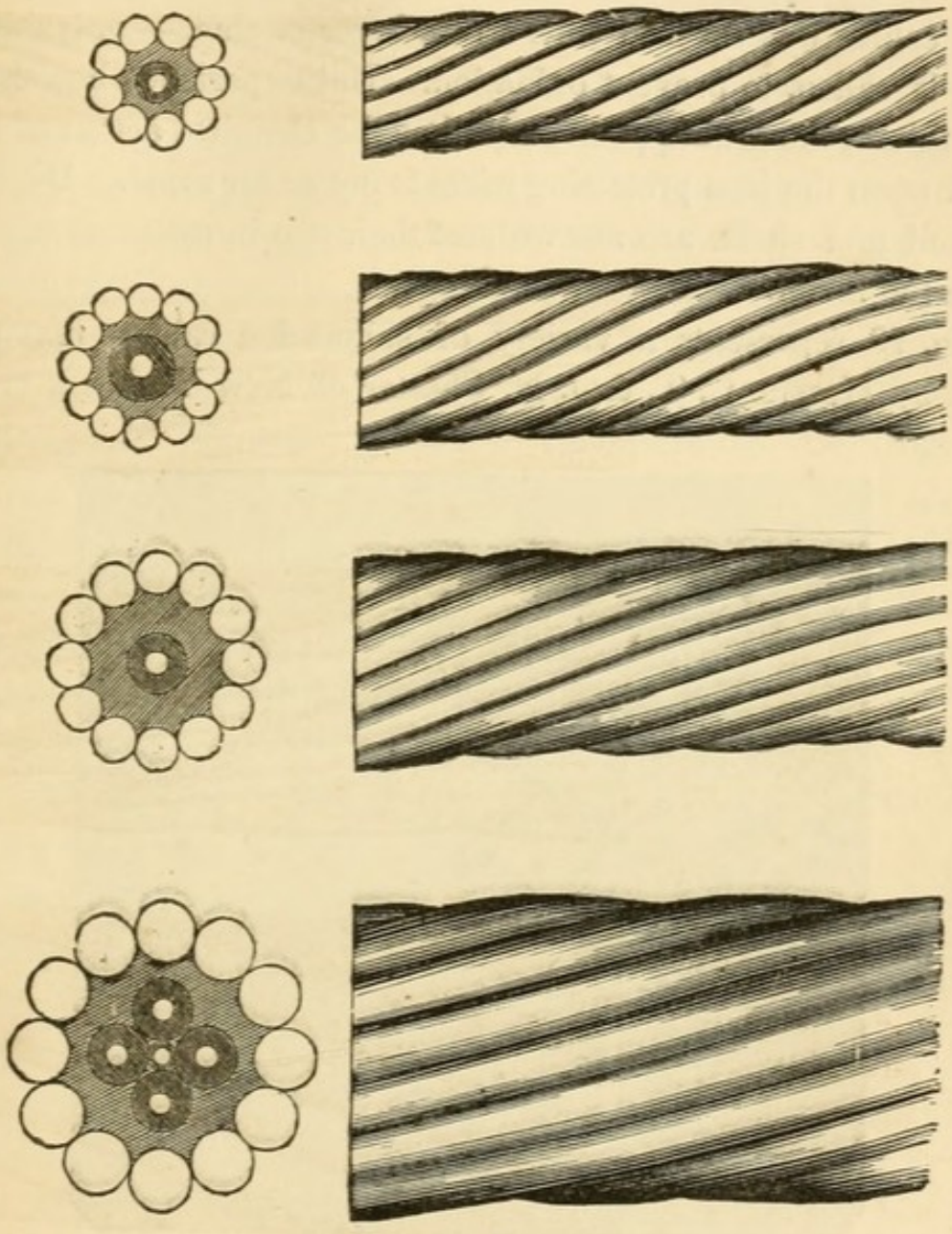


Fig. 73.

the elements of a cylinder and tangent in respect to their gutta-percha envelope. The placing one of them in the centre is avoided, except in the case where there is but one, when the single wire is necessarily in the centre. The outer circumference, as well as the wires themselves, are furnished with tarred yarn, a

material which is not a bad insulator, and which yields to pressure without altering the form of the conducting-wires. But that which is essential is the external protecting envelope, which is formed of a variable number of large iron wires, coiled helicoidally, so that the cable, notwithstanding its strength, is able to bend according to the exigencies of the bottom of the sea, when it is deposited therein. This exterior iron envelope in early cables was covered with a thin layer of zinc, — galvanized, as it is called, to prevent oxidation. But experience has shown that this erelong disappears, and that the chemical action of sea-water upon the iron protecting wires is not at all rapid. Deposits of sand and shells are not without their use in assisting to preserve the metal.

Fig. 73 represents a variety of submarine cables, manufactured by Messrs. C. T. & J. N. Chester of New York.

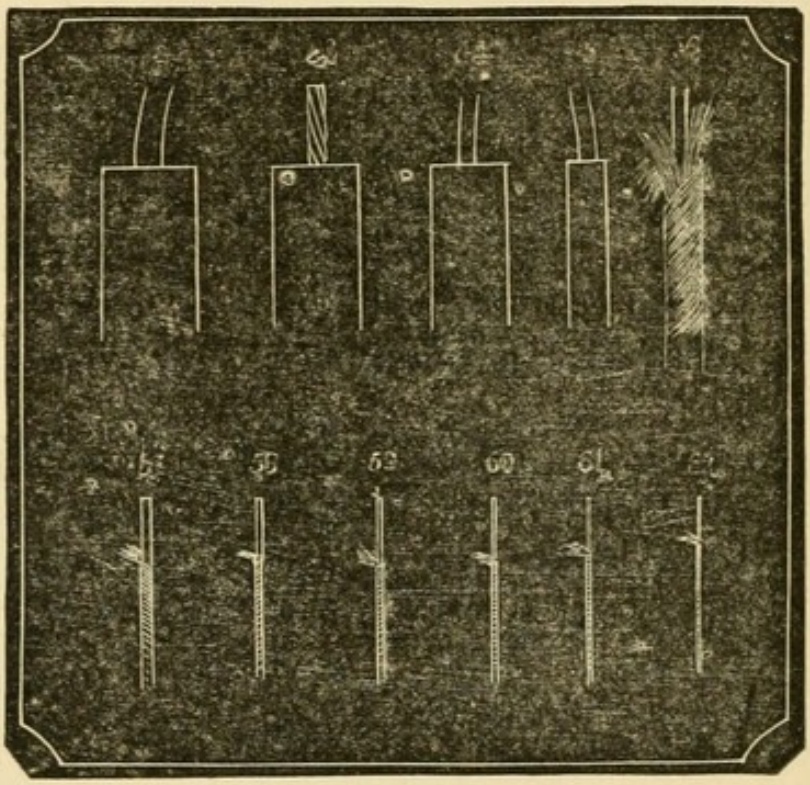


Fig. 74.

Fig. 74 represents a variety of insulated copper wire designed for office connections,—partly covered with gutta-percha and partly with a double coating of cotton, and twice coated with hot shellac varnish.

CHAPTER XIV.

THE ATLANTIC CABLE.

THE other and still more marvellous undertaking, alluded to in the foregoing chapter, was with the view of connecting Ireland with Newfoundland and New York, and of thus permitting Europe to communicate telegraphically with America.

Lieutenant Maury, of the United States Navy, so well known for his hydrographical researches, caused a series of regular soundings to be made, with the view of determining the form and condition of the bed of the ocean between the coasts of British America and Ireland. He found that, between Newfoundland and the west coast of Ireland, the bottom consists of a plateau, which, as he says, seems to have been placed there especially for the purpose of holding the wires of a submarine telegraph, and of keeping them out of harm's way. It is neither too deep nor too shallow; yet it is so deep that the wires but once landed will remain forever beyond the reach of vessels, anchors, icebergs, and drifts of any kind, and so shallow that the wires may be readily lodged upon the bottom.

The depth of this plateau is quite regular, gradually increasing from the shores of Newfoundland to the depth of 1,500 to 2,000 fathoms as you approach the other side. All the specimens of the bottom brought up have been found to consist of microscopic shells, without the admixture of a single particle of gravel or sand. Had there been currents at those depths, these shells would have been thrown about and abraded, and mixed more or less with the *débris* of the natural bed of the ocean, such as ooze, sand, gravel, and other matter. Consequently, a telegraphic cable once laid there, it would remain as completely beyond the reach of accident as if it were buried in air-tight cases.

Twelve hundred and fifty miles of cable were coiled on board the Agamemnon, an English screw-ship of war, and a like length

on board the Niagara, an American ship of war. On the evening of August 7, 1857, the Niagara commenced paying out the cable from Valentia, on the west coast of Ireland, and at 3.45 A. M., on August 11, 335 miles had been successfully laid, when the cable parted, while in 2,000 fathoms, on account of the amount of retarding strain put upon it in order to check its too rapid run, which had become considerably in excess of the speed of the ship

On Saturday, May 29, 1858, the Niagara and Agamemnon sailed from Queenstown, on an experimental trip, for the purpose of testing the cable. On the 31st of May, in lat. 47° 12′ north, long. 9° 32′ west, the depth of water being 2,530 fathoms, a series of deep-sea experiments was commenced.

The Niagara and Agamemnon were connected by hawser, stern to stern, distant from each other some twelve hundred feet. The cable was paid out and spliced on board the Agamemnon, and the first experiment began. Two miles of cable were paid out, when the wire parted. On the following day the cable was respliced, and three miles were paid out; but in the attempt to haul in, the wire again parted. On Wednesday the cable was again spliced, but in a few minutes parted on board the Agamemnon. After various experiments in splicing, lowering, and heaving in, the squadron returned to Plymouth.

On Thursday, June 10, the fleet again started from Plymouth, with the Atlantic Cable on board.

After having been three days at sea, the expedition was overtaken by a fearful gale, which continued without intermission for nine days. On the seventh day of this heavy weather, the ships, which continued to keep together, had to part company, and the Agamemnon was obliged to scud before the wind for thirty-six hours. The coals got adrift and a coil of the cable shifted, so that her captain for some time entertained serious apprehensions for her safety, and, from the immense strain, her water-ways were forced open, and one of her ports was broken. Two of the sailors were severely injured, and one of the marines lost his reason from fright. Yet such was the consummate skill, good seamanship, and intrepidity of her commander, Captain Priddle,

that he was enabled to bring her to the appointed rendezvous, lat. 52° 2′, long. 33° 18′. The Niagara rode out the storm gallantly, having only carried away her jib-boom and one wing of her figure-head, — the American eagle.

All the vessels having arrived at their central point of junction, the first splice of the cable was made on the 26th. After paying out two and a half miles each, owing to an accident on board the Niagara, the cable parted. The ships having again met, the splice was made good, and they commenced to pay out the cable a second time; but after they had each paid out forty miles, the current was broken, and no communication could take place between the ships. Unfortunately, in this instance the breakage must have occurred at the bottom, as the electricians, from the fine calculations which their sensitive instruments allowed them to make, were able to declare such to have been the fact, even before the vessels came together again.

The vessels met for the third time on the 28th, and started afresh. Having paid out over 300 miles, the most sanguine anticipations of success were entertained upon both vessels, when the fatal announcement was made upon the 29th, at 9 P. M., that the electric current had ceased to flow. Both vessels returned to Queenstown, the Niagara arriving July 5th, the Agamemnon July 12th.

Saturday, July 17th, the fleet was again under weigh, bound to the mid-ocean rendezvous. The fleet consisted of the Agamemnon, Valorous, and Gorgon, British ships of war, and of the United States steamship Niagara.

The several vessels met in mid-ocean on Wednesday, the 28th, made the splice at 1 P. M. on Thursday, the 29th, and then separated, the Agamemnon and Valorous bound to Valentia, Ireland, and the Niagara and Gorgon for Trinity Bay, Newfoundland.

The machinery for paying out the cable worked in the most satisfactory manner, and was not stopped for a single moment from the time the splice was made until the arrival of the Niagara at Trinity Bay, and the Agamemnon at Valentia, August 6th.

On the morning of August 7th, the whole country was electri-

fied by the announcement from Mr. Cyrus W. Field, — to whom the success of the enterprise is mainly due, — that the cable was successfully laid, and the electrical signals through the cable were perfect.

Although the cable was successfully landed upon the 6th of August, the first public despatch — that of the Queen to the President of the United States — was not received until the 17th. The cable worked until the 1st of September, when, owing to abrasion upon the rocks in the ocean, or through some other injury not yet determined, there occurred so strong an "earth current" as to prevent the obtaining of intelligible signals.

The people all over the country appear to have fully estimated the importance of the great telegraphic undertaking, which seemed successfully accomplished upon the 6th of August, 1858. Everywhere, in an impromptu manner, they gave vent to their joy by the discharge of artillery, illuminations, display of flags, &c.; and even in inland places, distant from the sea-shore, the town bells rung out, in melodious tones, the announcement of the union, by the strongest ties, of the Old and the New World.

The following poem upon the Atlantic Cable, written by E. J. O'Reilly, Esq., appeared in the journals of the day.

Six thousand years have passed o'er earth,
  While Science, like a stripling, bore
The trophies of its timid birth,
  In various forms, from shore to shore;
But now her latest, mightiest child,
  Which Franklin viewed and Morse caressed,
With glory ripe and undefiled,
  Is laid within the ocean's breast!

The mighty lightning herald sleeps,
  Till human touch awakes its fires,
To send beyond the morning reach
  New tidings ere a pulse expires!
'T is laid! Old Ocean feels a thrill
  Throughout his time-sealed bosom now,
And yields to man's victorious will,
  The crown long placed on Neptune's brow.

Calm as the deep in summer's reign
And wild, as in its wintry wrath,
Shall be, with varied joy or pain,
Each message through its ocean path!
Within its grave, beneath the storm,
It lives, a breathing thing of life,
As they shall live who gave it form,
In fame, when called from mortal strife!

Soon, like Orion's belt of fire,
Its broad electric arm shall hold,
With all a monarch's strong desire,
The world and all its varied fold!
And from its tongue through every sphere,
Till Time and Earth together cease,
Mankind the glorious tale shall hear
Of commerce, brotherhood, and peace!

In regard to the passage of the electrical current through the wire when submerged in the ocean, which has been a controverted question, the Atlantic Telegraph Company instituted experiments before the manufacture of the cable, which are said to have established the following principles and facts: —

That gutta-percha covered submarine wires do not transmit as simple insulated conductors, but that they have to be charged as Leyden jars before they can transmit at all; —

That consequently such wires transmit with a velocity that is in no way accordant with the movement of the electrical current in an unembarrassed way along the simple conductors; —

That magneto-electric currents travel more quickly along such wires than simple voltaic currents; —

That magneto-electric currents travel more quickly when in high energy than when in low, although voltaic currents of large intensity do not travel more quickly than voltaic currents of small intensity; —

That the velocity of the transmission of signals along insulated submerged wires can be enormously increased, — from the rate, indeed, of one in two seconds, to the rate of eight in a single second, — by making each alternate signal with a current of different quality, positive following negative, and negative following positive; —

That the diminution of the velocity of the transmission of a magneto-electric current in induction embarrassed coated wires, is not in the inverse ratio of the squares of the distance traversed, but much more nearly in the ratio of simple arithmetical progression; —

That several distinct waves of electricity may be travelling along different parts of a long wire simultaneously, and within certain limits, without interference; —

That large coated wires used beneath the water or earth are worse conductors, so far as velocity of transmission is concerned, than small ones, and therefore are not so well suited as small ones for the purpose of submarine transmission of telegraphic signals; — and

That by the use of comparatively small coated wires, and of electro-magnetic induction-coils for the exciting agents, telegraphic signals can be transmitted through two thousand miles with a speed amply sufficient for all commercial and economical purposes.

The cost of the cable laid between Ireland and Newfoundland is given below: —

Price deep-sea wire per mile, ...	$ 200.00
Price spun-yarn and iron wire, per mile, . . .	265.00
Price outside tar, per mile, ...	20.00
Total per mile, ...	$ 485.00
Price as above for 2,500 miles, . . .	$ 1,212,500.00
Price 10 miles deep-sea cable at $ 1,450 per mile, .	14,500.00
For 25 miles shore-end, at $ 1,450 per mile, . .	36,250.00
Total cost, ...	$ 1,263,250.00

The United States steam-frigate Niagara, which was employed in laying the cable, is the largest ship of war in the world. She is 345 feet long, with 55 feet breadth of beam, and 31 feet 6 inches depth of hold, and measures 5,800 tons.

The British steamship Agamemnon, associated with the Niagara, measures only 3,102 tons. She is 230 feet between perpendiculars, with 55½ feet breadth of beam, and 24½ feet depth of hold.

As there has been considerable scepticism manifested in regard to the actual transmission of communications through the Atlantic Cable, we have thought it advisable to present the following incontestable proofs of the fact. They consist of an abstract of the diaries kept at Newfoundland and Valentia, in which are recorded all the messages and conversations which passed through the cable during the period of its operation.

In these messages we have a complete history of the cable, — a history of which it is itself the narrator, — from the day in which it began to speak intelligibly, up to that on which it became silent.

It is the opinion of many, well qualified to judge, that the failure of the cable was owing to the bungling and mismanagement of both the engineers and electricians of the company who had charge of it; for it was owing to their negligence, in the first place, that the defects were produced in the insulation.

The first complete message in form received at Valentia from Newfoundland, through the Atlantic Cable, was on August 12, at 5.35 P. M., as follows: —

"Laws, Whitehouse received five minutes signal. Coil signals too weak work relay. Try drive slow and regular. I have put intermediate pulley. Reply by coils."

August 13, at 12.38 A. M., Newfoundland asks Valentia to "Send word Atlantic." Valentia responds, "Atlantic." This was the first word read in Newfoundland which came through the cable. During the day some additional intelligible signals were received.

August 14, at 1.53 A. M., Valentia sends to Newfoundland, "Send faster." These were the first words recorded in Newfoundland, and the manner in which the record was made is seen by Newfoundland's reply to Valentia, sent 2.55 A. M. "Understand. Send faster. Now try message. We get your signals on delicate detector by tapping and marking the paper with pencil, for the time the needle is held over on either side."

At 10.20 P. M., after much difficulty in transmitting intelligible signals, Valentia received the following from Newfoundland. "Saward, — E. M. Archibald, New York, telegraphs, 'Instructed

by Honorable Directors Atlantic Telegraph Company, and Directors New York, Newfoundland, and London Telegraph Company, to state that unexplained delay injures interests both companies. I replied, — 'Cause not passing messages, — that instruments require great care and adjustment. Doing fast possible. You should not look on cable as on ordinary short line, as we encounter many little difficulties, but think all soon overcome.' De Sauty."

August 15. Scarcely any intelligible signals received either way.

August 16. Some signals passed intelligibly each way to 11.12 A. M., when Valentia sent the following despatch to Newfoundland, which was correctly received: —

"Directors of Atlantic Telegraph Company, Great Britain, to Directors in America. Europe and America are united by telegraph. Glory to God in the highest; on earth peace, good-will towards men."

Newfoundland responded to Valentia: — "Directors: — All right. Will you receive one?"

At 4.15 P. M., Valentia commenced sending the Queen's message, but at 6.29 P. M., after sending as far as "greatest interest," the operator wrote, "Wait repairs to cable." And it was in consequence of his making this interruption, without signifying that the despatch was not finished, that the unfortunate error took place of forwarding that communication before completion.

The Queen's message was not completely finished until 6.48 A. M. of the 17th of August. During that time the repetitions in answer to questions from Newfoundland were very much embarrassed, probably by earth currents. It was raining very hard in Newfoundland during the whole time.

The Queen's Message.

"The Queen desires to congratulate the President upon the successful completion of this great international work, in which the Queen has taken the greatest interest. The Queen is convinced the President will join with her in fervently hoping that the electric cable which now connects Great Britain with the

United States will prove an additional link between the two nations, whose friendship is founded upon their common interest and reciprocal esteem. The Queen has much pleasure in thus directly communicating with the President, and in renewing to him her best wishes for the prosperity of the United States."

At 10.10 A. M., August 17, Newfoundland sent the following despatch: —

"Directors Atlantic Telegraph Company: — Entered Trinity Bay, noon, fourth. Landed cable at six, Thursday morning. Ship at once to St. John's two miles shore cable, with end ready for splicing. When was cable landed at Valentia? Answer by telegraph, and forward my letters to New York.

"CYRUS W. FIELD."

VALENTIA TO NEWFOUNDLAND.

"Acknowledged. Go on."

NEWFOUNDLAND TO VALENTIA.

"Have you more? Always give the signal 'Cleared out' when you finish."

"Saward to Whitehouse: — Mr. Cunard wishes telegraph McIver, Europa collision Arabia. Put into St. Johns. No lives lost. Will you do it? Stay anxiety, non-arrival.

"DE SAUTY."

After the transmission of this despatch, which Valentia received with the loss of but two letters in the address, Newfoundland was unable to receive anything during the remainder of the day.

August 18. Notwithstanding both stations made every exertion to restore communication by alternately sending and putting in instruments to receive, nothing more was read at Valentia, and not one word in Newfoundland during the whole day. It is proper to state, however, that from 6.40 A. M. until 9.08 P. M., operations which took place at Valentia prevented the possibility of transmission or reception. From 6.40 till noon, Mr. Canning was engaged in lifting the cable in the harbor. From noon until 1.30 P. M., efforts were made to communicate, and from this time till 9.08 P. M. operations obstructed electrical working.

August 19.

NEWFOUNDLAND TO VALENTIA.

"See to adjustment. Can you receive President's message? Been here since yesterday." "We can't read." "Currents too weak to read." "Very good currents, but can't read. Send C's."

VALENTIA TO NEWFOUNDLAND.

"C. C. C. Faster."

(This in answer to Newfoundland's request to send C's for adjustment.)

"Send message fast."

(These words came in very good signals. The deflections on galvanometer very strong.)

NEWFOUNDLAND TO VALENTIA.

"Have you received message for McIver? Send acknowledgment."

VALENTIA TO NEWFOUNDLAND.

"No."

NEWFOUNDLAND TO VALENTIA.

"D. C. McIver, Liverpool: — Arabia in collision with Europa, Cape Race, Saturday. Arabia on her way. Head slightly injured. Europa lost bowsprit, cutwater; stern sprung. Will remain in St. John's, Newfoundland, ten days from sixteenth. Persia calls at St. John's for mails and passengers. No loss of life or limb. CUNARD."

"New York, August 17."

VALENTIA TO NEWFOUNDLAND.

"Cunard. All right. Go on."

NEWFOUNDLAND TO VALENTIA.

THE PRESIDENT'S MESSAGE.

"Washington City. To Her Majesty, Victoria, Queen of Great Britain: — The President cordially reciprocates the congratulations of Her Majesty, the Queen, on the success of this great international enterprise, accomplished by the science, skill, and indomitable energy of the two countries. It is a triumph more glorious, because far more useful to mankind, than ever was won by con-

queror on the field of battle. May the Atlantic Telegraph, under the blessings of Heaven, prove to be a bond of perpetual peace and friendship between the kindred nations, and an instrument designed by Divine Providence to diffuse religion, civilization, liberty, and law throughout the world. In this view will not all the nations of Christendom spontaneously unite in the declaration, that it shall be forever neutral, and that its communications shall be held sacred in passing to the place of their destination, even in the midst of hostilities? JAMES BUCHANAN."

VALENTIA TO NEWFOUNDLAND.

"President's all right."

NEWFOUNDLAND TO VALENTIA.

"Your current much stronger; but cannot read your signals. Repeat." "Received. Send a few words." "Your currents very weak. Repeat."

VALENTIA TO NEWFOUNDLAND.

"How now, — can you read?"

NEWFOUNDLAND TO VALENTIA.

"Understand. Better than ever. Please always commence by attack and give final signals, as we receive on galvanometer. Relay won't work."

"To Whitehouse. Please send large circular galvanometer."

VALENTIA TO NEWFOUNDLAND.

"Can you take message for Field?"

(At 8 P. M., Valentia had finished message to Mr. Field. Currents were strong, but very irregular, and only the last five words were readable. This was the message commencing "Directors have just met.")

NEWFOUNDLAND TO VALENTIA.

"Strength of your current constantly varies. Send Field's message." "Repeat all from beginning to 'tariff.'" "You should never send more than a dozen words at a time in long messages. Repeat all of last message before 'tariff.'" "Can't read. Send dots and dashes." "After 'can you.'"

VALENTIA TO NEWFOUNDLAND.

"How now?"

NEWFOUNDLAND TO VALENTIA.

"Better. Repeat message to Field."

VALENTIA TO NEWFOUNDLAND.

"Try read on galvanometer."

NEWFOUNDLAND TO VALENTIA.

"Yes. Repeat Field's message." "All to word 'the.'" "Understand after 'met.'"

(The last ten messages refer to the following message to Mr. Field, which, although commenced at 3.55 P. M. on the 19th, was not finished until 1.45 A. M. of the 20th.)

August 20.

NEWFOUNDLAND TO VALENTIA.

"Now from Valentia to 'tariff.'" "End. Understand."

VALENTIA TO NEWFOUNDLAND.

"C. W. Field, Newfoundland. August 17, 3 P. M.:— The directors have just met. They heartily congratulate you on success. Agamemnon anchored at Valentia at 6 A. M. on Thursday, August 5. We are just on the point of chartering a ship to lay shore-end. No time will be lost in sending them out. All your letters have been posted to New York. Please write to me fully about tariff and other working arrangements."

(This message was repeated from Newfoundland to Valentia to show that it was understood.)

"Can we send faster?"

NEWFOUNDLAND TO VALENTIA.

"Yes. I have two messages since morning. Can I send one?"

VALENTIA TO NEWFOUNDLAND.

"Send faster."

NEWFOUNDLAND TO VALENTIA.

"How do you receive now?"

VALENTIA TO NEWFOUNDLAND.

"Splendid on Thomson's galvanometer, and print on Morse key. How do you?"

NEWFOUNDLAND TO VALENTIA.

"We work with Morse key and detector. Will you take message?"

VALENTIA TO NEWFOUNDLAND.

"We can't unless on Company's service."

NEWFOUNDLAND TO VALENTIA.

"New York, August 18. Directors of Atlantic Telegraph Company, London: — The Directors of New York, Newfoundland, and London Telegraph Company desire to express to the Directors of the Atlantic Telegraph Company their joy and gratitude for facilities and privileges on coming into closer union and fellowship with them and our fellow-men throughout the world. May the success which has crowned our labors secure to the nations of the earth a perpetual bond of peace and good fellowship.

"PETER COOPER, *President.*"

VALENTIA TO NEWFOUNDLAND.

"Directors all right."

NEWFOUNDLAND TO VALENTIA.

"New York, 18. Directors Atlantic Telegraph Company London: — Niagara arrived to-day. All well. Full reports by mail. I drew on you, from St. Johns, at three days' sight, £750 sterling, to pay laborers on Niagara. Great rejoicing all over country successful laying cable. Please request Admiralty to permit the Gorgon, Captain Dayman, accompany Niagara New York.

"C. W. FIELD."

VALENTIA TO NEWFOUNDLAND.

"Received acknowledgment of message, Field to Directors."

NEWFOUNDLAND TO VALENTIA.

"To Whitehouse: — Please send out a large circular galvanometer and another relay or two as soon as possible.

"DE SAUTY."

"If you have anything, go on."

VALENTIA TO NEWFOUNDLAND.

"Bartholomew to De Sauty: — Whitehouse in London. Your message about galvanometer gone there."

NEWFOUNDLAND TO VALENTIA.

"Cleared out."

The Newfoundland diary had in it the following words:— "First-rate signals from Valentia this morning." This was the first time the cleared-out signal was given by both stations at same time. All communications had been accurately got off to their destinations from both sides of the Atlantic. The operators then spent two or three hours in chatting, during which Newfoundland reports superintendent and staff quite well, and Bull's Arm Station henceforth to be called "Cyrus Station."

NEWFOUNDLAND TO VALENTIA.

"Saward: — Two cable-splicers and gutta-percha jointer here waiting to make a splice in shore-end. All well.

"DE SAUTY."

VALENTIA TO NEWFOUNDLAND.

"We will send coil currents. Say if you will receive."

NEWFOUNDLAND TO VALENTIA.

"Signals very good. Will you receive from Mayor Halifax to Lord Mayor of London?"

"Have you received my last service message?"

VALENTIA TO NEWFOUNDLAND.

"We can't take message."

NEWFOUNDLAND TO VALENTIA.

"The two messages are from Mayors Halifax and Toronto."

VALENTIA TO NEWFOUNDLAND.

"We have asked London. Wait."

NEWFOUNDLAND TO VALENTIA.

"Well, have you asked those messages of De Sauty?"

"Have you message."

VALENTIA TO NEWFOUNDLAND.

"No."

NEWFOUNDLAND TO VALENTIA.

"Was message about Europa made use of?"

VALENTIA TO NEWFOUNDLAND.

"Yes: it was sent for publication."

NEWFOUNDLAND TO VALENTIA.

"What weather have you?"

VALENTIA TO NEWFOUNDLAND.

"Very fine. Yours?"

NEWFOUNDLAND TO VALENTIA.

"Mosquitoes keep biting. This is a funny place to live in,— fearfully swampy."

All messages cleared out again from both stations.

August 21.

VALENTIA TO NEWFOUNDLAND.

"We wish you to send coil currents. Are you ready?"

NEWFOUNDLAND TO VALENTIA.

"Ready."

VALENTIA TO NEWFOUNDLAND.

"We send V's."

Good dots and V's were received at Newfoundland.

NEWFOUNDLAND TO VALENTIA.

"Yes, we read well."

VALENTIA TO NEWFOUNDLAND.

"Can you read? Send fast."

"I will send V's by coil currents. Say if you get them. Are you ready?"

NEWFOUNDLAND TO VALENTIA.

"Yes, quite ready." "Shall be glad to hear from you." (After an hour's intermission,) "Your signals not readable."

VALENTIA TO NEWFOUNDLAND.

"How now?"

NEWFOUNDLAND TO VALENTIA.

"Better."

"De Sauty to Bartholomew:— Ask Saward send 35 feet $\frac{3}{0}$ gutta-percha tube, and two gutta-percha siphons with tops, and fifteen pounds gutta-percha, $\frac{3}{8}$ sheet."

VALENTIA TO NEWFOUNDLAND.

"Bartholomew to De Sauty:— Understand. How signals now?"

NEWFOUNDLAND TO VALENTIA.

"Not very good. Repeat my last."

VALENTIA TO NEWFOUNDLAND.

"Bartholemew to De Sauty: — Understand. Can you take message?"

NEWFOUNDLAND TO VALENTIA.

"Yes, but repeat figures of my last."

VALENTIA TO NEWFOUNDLAND.

"Thirty-five, three eight, two fifteen, three eight."

NEWFOUNDLAND TO VALENTIA.

"Understand. Send message."

VALENTIA TO NEWFOUNDLAND.

"Thomson to De Sauty: — Order McFarlane to arrange a mirror galvanometer for receiving. Use the innermost coil and power steel magnetic adjustment. Say when will be ready."

NEWFOUNDLAND TO VALENTIA.

"Now ready. Go on."

"Land galvanometer in circuit. Signals beautiful."

VALENTIA TO NEWFOUNDLAND.

"Is this first time it is in circuit?"

NEWFOUNDLAND TO VALENTIA.

"No. Send thirty-five words as fast as you can."

VALENTIA TO NEWFOUNDLAND.

"Use hundred Daniell's, with reversing key in your next. We are going to test the cable, and only wait for a specimen of your battery signals. After receiving which, we shall explain what we want."

NEWFOUNDLAND TO VALENTIA.

"Understand. What reversing key do you mean? We are getting ready Daniell's. If you send again, send faster."

"Can't read." "Shall we send battery currents since everything ready?" "Please send something."

August 22.

NEWFOUNDLAND TO VALENTIA.

"Can you receive message?" (After an hour's intermission,)

"How do you receive?" (Seven hours' intermission,) "Do you receive this?"

VALENTIA TO NEWFOUNDLAND.

"Can you read this?"

NEWFOUNDLAND TO VALENTIA.

"Yes. Can you take message now?"

VALENTIA TO NEWFOUNDLAND.

"Yes."

NEWFOUNDLAND TO VALENTIA.

"August 21, New York. Right-Honorable Sir Walter Carden, Lord Mayor of London: — I congratulate your Lordship upon the successful laying of the Atlantic Cable, uniting continents Europe and America, cities London and New York, Great Britain and the United States. It is a triumph of science and energy over time and space, uniting more closely the bonds of peace and commercial prosperity, — introducing an era in the world's history pregnant with results beyond the conception of a finite mind.

"DANIEL F. TIEMANN, *Mayor*."

VALENTIA TO NEWFOUNDLAND.

"Mayor's message received."

"Insulate for two hours, and say when you commence. Repeat this."

NEWFOUNDLAND TO VALENTIA.

"Understand. Cable insulated."

"Have you finished testing?"

"Repeat. Send much slower."

"Signals are good, but your sending comes very bad. Repeat all."

"Please repeat service."

"Repeat service message."

"Repeat service now."

The above were all the signals read after the transmission of the Mayor's message at 2.15 P. M., until 10.19 P. M.

VALENTIA TO NEWFOUNDLAND.

"Thomson to De Sauty: — Put delicate detector in circuit, and

note weak currents from us, thirty minutes each way. Say if ready."

NEWFOUNDLAND TO VALENTIA.

"Repeat word after 'us.'"

VALENTIA TO NEWFOUNDLAND.

"Thirty."

NEWFOUNDLAND TO VALENTIA.

"Understand. Ready now."

August 23. It rained very hard in Newfoundland from midnight until six A. M.

NEWFOUNDLAND TO VALENTIA.

"Your currents very irregular. Repeat."

VALENTIA TO NEWFOUNDLAND.

"Signals weak. Will you take message from Lord Mayor?"

NEWFOUNDLAND TO VALENTIA.

"Yes; send little faster and better."

VALENTIA TO NEWFOUNDLAND.

"Give 'understand' every twenty words."

NEWFOUNDLAND TO VALENTIA.

"All right. Send much faster."

"Understand, faster."

Testing nearly the whole of the day at Valentia.

August 24.

VALENTIA TO NEWFOUNDLAND.

"The Lord-Mayor of London to the Hon. Daniel F. Tiemann, Mayor of New York: — The Lord Mayor of London most cordially reciprocates congratulations of Mayor New York upon the success of so important an undertaking as the completion of the Atlantic Telegraph Cable. It is indeed one of the most glorious triumphs of the age, and reflects the highest credit upon the energy, skill, and perseverance of all parties intrusted with so difficult a duty; and the Lord Mayor sincerely trusts, that, by the blessing of Almighty God, it may be the means of reuniting those kind feelings that now exist between the two countries.

"R. W. CARDEN, *Lord Mayor*."

NEWFOUNDLAND TO VALENTIA.

"Repeat between 'duty' and 'sincerely.'"

"Message all right, — understood."

VALENTIA TO NEWFOUNDLAND.

"Thomson to De Sauty: — On what instrument do you receive? How many divisions deflection do you get? What battery? How many cells? What key? Directors desire you send news, public interest, but none commercial. Have you any now?"

"Can you take a long message?"

NEWFOUNDLAND TO VALENTIA.

"Go on."

VALENTIA TO NEWFOUNDLAND.

"Saward to De Sauty: — Answer by telegraph what length shore-end you require, and if any small cable as a reserve. How much surplus had Niagara, and where is it? Have you splices and jointers enough? We have chartered the Bilboa to lay the end. Telegraph full particulars, and if you require anything beside gutta-percha articles I will send them by the Bilboa.

NEWFOUNDLAND TO VALENTIA.

"Repeat from 'shore-end' to 'small.'"

"Acknowledged Saward to De Sauty."

VALENTIA TO NEWFOUNDLAND.

"C. W. Field: — We desire you to place in America about £15,000 unappropriated £20 shares, authorized February last. Reply by telegraph. Soonest. C. M. SAMPSON."

NEWFOUNDLAND TO VALENTIA

"Acknowledged message."

VALENTIA TO NEWFOUNDLAND.

"Answer each question about instruments." (Refers to Thomson's message.)

"Your currents vary much. Very weak to-day. How ours to-day?" (This is in answer to Newfoundland's attempt to send message.)

NEWFOUNDLAND TO VALENTIA.

"To Thomson: — Receiving on your galvanometer, thirty divisions. Galvanometer seven degrees. Print local circuit by hand. The large Smee's. Whitehouse's reversing key. News Persia. DE SAUTY."

"Have you received message right? Service for Saward. Will you take it?"

VALENTIA TO NEWFOUNDLAND.

"Yes; and prepare after to receive Thomson's compensated currents."

NEWFOUNDLAND TO VALENTIA.

"De Sauty to Saward: — Two miles shore-end ample. Have half-mile small cable; plenty. It is stowed on beach. Two splicers and jointer here. Six gallons naphtha required. Please send authority to draw on Brooking. £100 required immediately for laborer's house in a wilderness. Roads to make and woods to cut down and clear. Ought to have some more relays. Have only one great difficulty in sending letters from here. Have written fully."

VALENTIA TO NEWFOUNDLAND.

"Understand. Give news of Persia. Also public news for morning papers. Send much faster."

August 25.

NEWFOUNDLAND TO VALENTIA.

"Persia takes Europa's passengers and mail. Great rejoicing everywhere at success of cable. Bonfires, fireworks, *feu de joies*, speeches, balls, etc., etc. Mr. Eddy, the first and best telegrapher in the States, died to-day. *Pray give some news for New York; they are mad for news.*"

VALENTIA TO NEWFOUNDLAND.

"Understand. *Sent to London for news.* Meantime take Thomson's currents. Say when ready."

NEWFOUNDLAND TO VALENTIA.

"Splendid sending. We are quite ready."

"Murray to Thomson: — Signals very weak. Send stronger acid."

"Can you receive?"

VALENTIA TO NEWFOUNDLAND.

"Thomson to McFarlane: — Where are keys of the glass cases and drawers in the apparatus-room?"

NEWFOUNDLAND TO VALENTIA.

"McFarlane to Thomson: — Don't recollect."

VALENTIA TO NEWFOUNDLAND.

"Saward to De Sauty: — Are American wires broken, or working?"

NEWFOUNDLAND TO VALENTIA.

"Working."

VALENTIA TO NEWFOUNDLAND.

"Field: — I send my warmest congratulations on the success of the Atlantic Telegraph. God be praised! GURNEY."

(This was acknowledged by Newfoundland.)

"North American with Canadian, and the Asia with direct Boston mails, leave Liverpool, and Fulton Southampton, Saturday next. To-day's morning papers have long, interesting reports by Bright. Indian news. — Virago arrived at Liverpool to-day; Bombay dates 19 July. Mutiny being rapidly quelled."

NEWFOUNDLAND TO VALENTIA.

"Sampson, London: — I will attend to your request. Have no doubt I can do what you require. CYRUS W. FIELD."

This was acknowledged by Newfoundland.

August 26.

NEWFOUNDLAND TO VALENTIA.

"Why don't you give 'finis' (signal) when you have done?"

VALENTIA TO NEWFOUNDLAND.

"We have had storm, with thunder. Cable put to earth for one hour twenty-five minutes."

(Professor Thomson was testing from 9 A. M. till 11.30 A. M. On the morning of Thursday, August 26, there was a storm of heavy rain, accompanied by thunder and lightning, in Newfoundland. It commenced at 2.30 A. M., and at 3.05 A. M. the lightning was so intense that the end of the cable was put to earth for protection. At 4.30 A. M. the storm ceased, and at 7.15 A. M. the weather is noted as having been since very fine.)

"Can't read your signals. Send slower, and repeat all."

"Your signals too weak to read."

"Your signals very weak. Have twenty messages for you. Will you take them?"

"Your signals better. Repeat."

VALENTIA TO NEWFOUNDLAND.

"Try only one galvanometer in circuit. We must understand stoppage of Monday night and learn how to manage."

NEWFOUNDLAND TO VALENTIA.

"What do you mean by stoppage of Monday night?"

"Understand. Go on."

VALENTIA TO NEWFOUNDLAND.

"Saward to De Sauty: — T. H. Brooking & Co. authorize an advance on your order by Hepburn to extent of one hundred pounds."

"Thomson to De Sauty: — Your signals were very weak Monday night at 1.12 Greenwich time. None came from 2.44 to 4.06. Then very weak indeed. Improved later. At 8 good. We sent one message eight times, from 2.45 till 5.12. Had no reply. Stoppage again from 2 to 6 in the afternoon. Can you explain why? Tell us each time."

NEWFOUNDLAND TO VALENTIA.

"Understand. New York, 25 August. Samuel Gurney, Esq., London: — Many thanks for message received. Americans wild with joy. Great celebration throughout the land, September 1 and 2.

"C. W. FIELD."

August 27.

NEWFOUNDLAND TO VALENTIA.

"Have you received message to Gurney?"

"Please take message, Thomson."

VALENTIA TO NEWFOUNDLAND.

"No. Must send long press messages. Are you ready?"

NEWFOUNDLAND TO VALENTIA.

"Understand. Signals weak. Send ten words at a time."

VALENTIA TO NEWFOUNDLAND.

"George Saward, Secretary Atlantic Telegraph Company, to Associated Press, 58 Beaver Street, New York: — News for America by Atlantic Cable. Emperor of France returned to Paris Saturday. King of Prussia too ill to visit Queen Victoria. Her Majesty returns to England 31st August. — St. Petersburg, 21st August. *Settlement of Chinese question. Chinese Empire open to trade; Christian religion allowed; foreign diplomatic agents admitted; indemnity to England and France.* — Alexandria, August 9. The Madras arrived at Suez 7th inst. Dates, Bombay 19th, Aden 31st. Gwalior insurgent army broken up. All India becoming tranquil."

This message was commenced at 2.10 A. M. and finished at 11.10 A. M.

VALENTIA TO NEWFOUNDLAND.

"De Sauty: — Till not troubled by stoppage, every day, shall send, and you receive, from 12 to 1, from 2 to 3, from 4 to 5, &c. You send from 1 to 2, from 3 to 4, &c. Never stop during hour. Give reversals when not speaking."

NEWFOUNDLAND TO VALENTIA.

"Is this Greenwich time? If so, give us 1 o'clock."

VALENTIA TO NEWFOUNDLAND.

"Yes; we begin now, and to 11, if you understand."

NEWFOUNDLAND TO VALENTIA.

"Understand."

August 28.

NEWFOUNDLAND TO VALENTIA.

"To the Directors: — Take news first, Saward. Sir William Williams, of Kars, arrived Halifax Tuesday. Enthusiastically received. Immense procession, welcome address, feeling reply. Held levee; large numbers presented. Niagara sailed for Liverpool at one this morning. The Gorgon arrived at Halifax last night. Yellow fever in New Orleans, sixty to seventy deaths per day. Also declared epidemic, Charleston. Great preparations in New York and other places for celebration to be held 1st and 2d Sept. New-Yorkers will make it the greatest gala

day ever known in this country. Hermann sailed for Frazer's River; six hundred passengers. Prince Albert sailed yesterday for Galway. Arabia and Ariel, arrived New York; Anglo-Saxon, Quebec; Canada, Boston. Europa left St. John's this evening. Splended aurora Bay Bulls to-night, extending over eighty-five degrees of the horizon.

"DE SAUTY."

VALENTIA TO NEWFOUNDLAND.

"Understand 'per.' Send faster."

"Repeat 'Sept.' to 'day ever.'"

"Take one from Thomson. Can you read?"

NEWFOUNDLAND TO VALENTIA.

"Understand, 'yes'; understand."

"After 'fifty yards,' repeat."

"We received badly all day Monday; weak signals on after 'fifty yards.'" [Messages referred to some parts of a message which they could not make out in Newfoundland, and which they did not succeed in obtaining.]

"Nothing received."

"Say if you have received Thomson's."

VALENTIA TO NEWFOUNDLAND.

"No; send it."

NEWFOUNDLAND TO VALENTIA.

"Shall repeat message Thomson."

August 29.

VALENTIA TO NEWFOUNDLAND.

"How are my signals?"

(No communications from Newfoundland to-day.)

August 30.

NEWFOUNDLAND TO VALENTIA.

"Can you read?"

VALENTIA TO NEWFOUNDLAND.

"Yes, we can read you. Send news slowly. Saward *asks where Kells is? How are my signals? Persia arrived Saturday.* Receive *on one galvanometer only, fault signals, produced* currents from coil *of your larger galvanometer.*" (None of the words italicized were read in Newfoundland.)

NEWFOUNDLAND TO VALENTIA.

"Can read some of your sending. Take this message: — New York. The Directors Atlantic Telegraph Company, London. Parties pressing upon us messages for Europe. When will line be open for business? Has Mr. Morgan sailed for New York? Early in the morning of September 1, please send me message that I can read at the celebration that day, and another on the 2d, I can read at dinner that evening.

"C. W. FIELD."

August 31.

VALENTIA TO NEWFOUNDLAND.

"Can you read? We have two government messages. Will you take? Reply direct."

NEWFOUNDLAND TO VALENTIA.

"Try, but send."

VALENTIA TO NEWFOUNDLAND.

"The Military Secretary to Commander-in-Chief Horse Guards, London. To General Trollope, Halifax, Nova Scotia: — The sixty-second regiment is not to return to England."

(This message, and that which will be found farther on in regard to the thirty-ninth regiment, saved to the British government the sum of fifty thousands pounds ($250,000), by avoiding the shipment and transportation of troops.)

NEWFOUNDLAND TO VALENTIA.

"This received: The Military Secretary to Commander-in-Chief Horse Guards, London."

"'Trollope,' understand. Go on after 'Scotia.'"

"Is it finished after 'England?'"

VALENTIA TO NEWFOUNDLAND.

"Yes. Now take another. Are you ready?"

NEWFOUNDLAND TO VALENTIA.

"Yes, send."

VALENTIA TO NEWFOUNDLAND.

"The Military Secretary to Commander-in-Chief Horse

Guards, to General Officer commanding, Montreal, Canada: — The thirty-ninth regiment is not to return to England."

NEWFOUNDLAND TO VALENTIA.

"I want you to repeat 'Canada.'"

VALENTIA TO NEWFOUNDLAND.

"Can't read. Try 'Daniels.'"

NEWFOUNDLAND TO VALENTIA.

"Repeat from 'Canada' to 'return.'"

September 1.

VALENTIA TO NEWFOUNDLAND.

"Canada. The thirty-ninth regiment is not to return."

NEWFOUNDLAND TO VALENTIA.

"Understand. Will you take a service?"

VALENTIA TO NEWFOUNDLAND.

"I will try. Slow."

NEWFOUNDLAND TO VALENTIA.

"We have received nothing since you repeated last."

VALENTIA TO NEWFOUNDLAND.

"Can you take message?"

NEWFOUNDLAND TO VALENTIA.

"Yes."

VALENTIA TO NEWFOUNDLAND.

"C. W. Field, New York: — The directors are on their way to Valentia to make arrangements for opening wire to public. They convey through cable to you and your fellow-citizens their hearty congratulations and good wishes, and cordially sympathize in your joyous celebration of the great international work."

NEWFOUNDLAND TO VALENTIA.

"Forty-eight words. Right, right."

(These were the last words received at Valentia.)

VALENTIA TO NEWFOUNDLAND.

"Right (signal understand)."

Some portions of the following message were received in Newfoundland: —

"*C. W. Field, New York, please inform* American *government we are now in position to do best to forward* their government messages to England.

"SAWARD, London."

The words italicized in the message were received in Newfoundland, and they were the last received from Valentia.

A Summary, showing the Number of Messages, and the Words and Letters they contain, sent through the Atlantic Cable from Valentia to Newfoundland.

Day.	Date.	No. of Messages.	No. of Words.	No. of Letters.
Friday,	Aug. 13,	9	7	47
Saturday,	" 14,	10	14	76
Sunday,	" 15,	1	1	4
Monday,	" 16,	12	169	835
Tuesday,	" 17,	4	9	43
Wednesday,	" 18,	—	—	—
Thursday,	" 19,	8	30	125
Friday,	" 20,	22	198	967
Saturday,	" 21,	10	126	626
Sunday,	" 22,	5	38	188
Monday,	" 23,	2	14	70
Tuesday,	" 24,	14	301	1,475
Wednesday,	" 25,	6	99	490
Thursday,	" 26,	4	119	595
Friday,	" 27,	5	166	823
Saturday,	" 28,	4	19	88
Sunday,	" 29,	1	4	15
Monday,	" 30,	1	13	65
Tuesday,	" 31,	8	85	411
Wednesday,	Sept. 1,	3	62	310
Total,	20 days,	129	1,474	7,253

A Summary, showing the Number of Messages, and the Words and Letters they contain, sent through the Atlantic Cable from Newfoundland to Valentia.

Day.	Date.	No. of Messages.	No. of Words.	No. of Letters.
Tuesday,	Aug. 10,	16	54	231
Wednesday,	" 11,	12	41	182
Thursday,	" 12,	5	43	167
Friday,	" 13,	27	221	1,103
Saturday,	" 14,	17	249	1,238
Sunday,	" 15,	8	58	285
Monday,	" 16,	18	129	623
Tuesday,	" 17,	10	268	1,335
Wednesday,	" 18,	2	12	60
Thursday,	" 19,	21	352	1,740
Friday,	" 20,	23	415	2,054
Saturday,	" 21,	17	121	565
Sunday,	" 22,	14	140	700
Monday,	" 23,	4	18	90
Tuesday,	" 24,	12	154	764
Wednesday,	" 25,	14	129	640
Thursday,	" 26,	13	109	546
Friday,	" 27,	18	67	335
Saturday,	" 28,	7	170	850
Sunday,	" 29,	—	—	—
Monday,	" 30,	2	76	375
Tuesday,	" 31,	7	39	187
Wednesday,	Sept. 1,	4	20	98
Total,	23 days,	271	2,885	14,168

The reader is aware of the tenacity with which many people have held to the belief that the Atlantic Telegraph was an impracticable undertaking, and of the controversy which was waged a few months ago, which had for its object the refutation of the statement that the cable was ever successfully worked, or that even a single word was sent from station to station. A reference to the summary of the messages presented above shows that from

the 10th of August to the 18th of September one hundred and twenty-nine messages were sent from Valentia to Newfoundland; while the number sent from Newfoundland to Valentia during the same period was two hundred and seventy-one, making a total of four hundred messages sent both ways. This statement is verified on oath by Henry W. Irvin of the Electric Staff in Newfoundland, and Edward Bull of the Electric Staff at Valentia, Ireland, before Mr. Robert B. Campbell, United States Consul at London.

"For Cyrus W. Field, Esq.: — Correct diary of messages sent through the Atlantic Cable.

"July 4, 1859."

"Cyrus W. Field, Esq.: — I hereby certify this document to be a faithful and complete record of the communications and messages sent and received through the Atlantic telegraph cable during the period of its working, — viz. from August the 10th to September the 1st, inclusive, — extracted from and collated with the diaries kept at the respective stations, at Valentia, Ireland, and Cyrus Station, Bay of Bull's Arm, Newfoundland.

"HENRY W. IRVIN,
Of the Electrical Staff in Newfoundland."

"London, July 7, 1859."

"CONSULATE OF THE UNITED STATES OF AMERICA, LONDON.

"I, Robert B. Campbell, Consul of the United States of America for London and the dependencies thereof, do hereby certify that on this 6th day of July, in the year of our Lord one thousand eight hundred and fifty-nine, before me personally appeared and came Henry W. Irvin, to me known, who signed the following certificate in my presence, and then and there acknowledged the same to be his free act and deed. In testimony whereof, I have herewith set my hand and affixed my seal of office at London, this day and year above mentioned, and in the eighty-third year of the independence of the said United States.

[SEAL.] "ROBERT B. CAMPBELL.

"This is to certify that I was on board the Agamemnon during the laying of the Atlantic cable, and employed on the electrical staff from the time the cable was landed, August 5, 1858, to the 4th of November, 1858, inclusive, and that the annexed is a correct account of messages sent and received through the Atlantic cable from August 10 to September 1, both inclusive.

"EDWARD BULL,
Of the Electrical Staff at Valentia, Ireland."

Here, then, we have four hundred hard, solid facts for the digestion of those who still contend that no message was ever received through the Atlantic Telegraph Cable. Some, however, went still further in their scepticism, asserting that the cable never was laid; and one individual in England became so crazy upon the subject that the police authorities of London were obliged to look after him. The array of facts which we present will do more to satisfy the public mind in regard to the ultimate success of the great work, than anything that has yet been published. Who can doubt for a moment that it will be accomplished, when he learns that all these messages were transmitted through the cable under the most unfavorable circumstances, and despite the defects which it is now known existed in the insulation? And here it may be well, as this is an important feature in the history of the enterprise, to refer to it more at length.

When the cable was in process of manufacture in the factory of Messrs. Glass and Elliott, in Greenwich, near London, it was coiled in four large vats, and there left exposed, day after day, to the heat of a summer sun, which was intensified by the tarred coating of the cable to one hundred and twenty degrees. This went on, day after day, with the knowledge of the engineer and electrician of the company, although the directors had given explicit orders that sheds should be erected over the vats to prevent the possibility of such an occurrence. As might have been foreseen, the gutta-percha was melted, so that the conductor which it was desired to insulate was so twisted by the coils that it was left quite bare in numberless places, thus weakening, and eventually, when the cable was submerged, destroying the insulation. The

injury was partially discovered before the cable was taken out of the factory at Greenwich, and a length of about thirty miles was cut out and condemned. This, however, did not wholly remedy the difficulty, for the defective insulation became frequently and painfully apparent while the cable was being submerged. Still further evidence of its condition was afforded when it came to be cut up for charms and trinkets. Despite of all this, however, it is now proved in the most conclusive manner that the cable not only worked after it was submerged, between Ireland and Newfoundland, but that four hundred messages were sent through it even in its defective condition.

There is one fact particularly deserving of notice, as showing the great importance of the Atlantic Telegraph in a commercial point of view. We refer to the collision of the Europa and Arabia, which was made known under two days after its occurrence off the coast of Newfoundland. But this is not all, for there is another, if possible, still more conclusive on the subject. The British government was enabled, through the transmission of two despatches to Halifax and Montreal, to countermand the sailing of a large body of troops who had previously received orders by mail to proceed to India. The amount which they saved by the telegraph in this way is estimated at two hundred and fifty thousand dollars. Of the commercial importance of the line, however, there can be no doubt, when it is known that, almost immediately after the cable was laid, the company were beset with applications and requests that it should at once be thrown open for the transmission of business messages.

The best guaranty for the permanent success of the enterprise is to be found in the new basis upon which it has been placed. The company have reorganized the electrical and engineering departments, and have got rid of their former chief electrician and engineer, and the useless members of their respective corps. This is the wisest thing they could have done, and the only wonder is that they did not dismiss these gentlemen before; but the company imagined they could get along with them without resorting to so severe a course, — a course which, however severe it might appear, was yet the only one left, and the one

which we now see they have been obliged to adopt. The bungling manner in which the electricians stationed at the opposite ends of the line performed their work, is evident from a perusal of the messages to which we have referred. They appear to have had no regular system, but evidently worked without a settled plan, and as chance favored them. Now, in consideration of all this, the only wonder is that they were ever able to get a single message through the conductor. However, as we have said, they have been discharged, the two departments have been reorganized, and, with the experience which the company have acquired, there is no doubt that their next success will be a permanent one. The revolution which has been effected in the electrical and engineering departments was accomplished during the recent visit of Mr. Field to England. This is just what was wanted to insure the success of the enterprise, and we have no doubt that in the course of another year the Atlantic telegraph will be a fixed fact, so that when the next war breaks out in Europe we shall receive daily despatches in regard to its progress. In conclusion, we may state that preparations are now being made for the manufacture of a new and improved form of cable, the conductor of which will be composed of a strand of seven wires, about double the thickness of the conductor of the cable which now lies stretched along the great telegraph plateau from the two island outposts of the Old and New Worlds. By increasing the thickness of the core, or conductor, greater rapidity in the transmission of messages is secured, besides greater strength in the copper wires of which it is composed. We also learn that two vessels are now in course of construction for the express purpose of laying cables, and that they will be ready long before the time appointed for the setting out of the next expedition. The British government will, we understand, give the services of two of their war steamers as escorts, and furnish as many men as may be required.

The following statement from Mr. F. C. Webb, Chief Electrician of the Atlantic Telegraph Company, dated Valentia, August 10, 1859, is the latest in regard to the condition of the cable. It is addressed to the Chairman and Directors of the Atlantic Telegraph Company.

"GENTLEMEN:—

"According to your request, I have made, from Valentia, a careful examination of the electrical state of the Atlantic cable. I made some tests for comparison on the various pieces of Atlantic cable in Messrs. Glass's premises at Greenwich, during July 31 and August 1.

"I arrived here on the 4th instant, and, assisted by Mr. Collett, made experiments during the 5th, 6th, 8th, and 9th instant.

"I find the lowest resistance shown to be 278 statute miles.

"I find it is possible to increase this resistance up to 589 miles, by sending a copper current for some time from six 12-plate Daniell's batteries.

"By experiments I have made on various kinds of constructed faults, I find that a fault which could be thus oxidized so as to give (by reversal of the current) a difference of resistance equal to the difference obtainable on the cable, viz. 311 miles, must give a *minimum* resistance of about 16 miles.

"When the fault is large, and thus gives little resistance, no great change can be obtained by reversing the battery; and, indeed, it is evident that when the connection between the line and earth is increased beyond a certain extent of surface, no difference in the resistance of the circuit can be obtained by reversing the battery.

"When the fault is very minute, it can be almost perfectly sealed up by a copper current, but the resistance will still be very great, even with a zinc current.

"My experiments show that a fault of about 16 miles, minimum resistance, can be varied with certainty by reversal of the battery to the same degree as the fault in the cable; and that if the fault gives less resistance than 16 miles it cannot be varied to that extent, while, if it gives more resistance, the variation cannot be produced with the same certainty, nor quite to the same degree.

"Taking, therefore, the resistance of the fault and cable beyond the fault to be equal to 15 miles, this would bring the fault to about 263 statute miles from Valentia.

"As I have no information of the return current due to differ-

ent lengths of the Atlantic cable, which might have been observed and tabulated during the paying out of the cable, it is impossible to check the resistance tests accurately by the observed return current.

"Comparing it, however, with the return current on the Cagliari and Malta and Corfu cables, and making, roughly, allowance for the increased size of the gutta-percha in the Atlantic cable, I find it to be about what is due to the supposed distance of the fault.

"I also made experiments on the return current with a wire leading to earth from the cable, and by placing resistances in circuit in this wire I could represent a fault close at hand, and of varying resistance.

"I found that in such an arrangement, when the artificial fault gave a resistance of 300 miles, the return current was only reduced about 22 per cent.

"If the real fault, therefore, was close at hand, the return current of the whole length of perfect cable beyond the fault would be only reduced about 22 per cent also.

"I am of opinion that the observed return current is much less than 78 per cent of the return current due to the whole cable, as it would be if the fault were close at hand and of a resistance of about 300 miles, and that it coincides, as nearly as I can judge, with that due to the length shown by the resistance.

"Again, when the artificial fault was made to represent a resistance of 260 miles, and then increased to 580, the return current only increased about 17 per cent, whereas when the real fault is increased to the same amount of resistance (by sending a copper current for some time) the return current increases about 80 per cent. This shows also that the return current is more influenced by the partial healing of the fault, than it would be if the fault was a small one near at hand, and consequently tends also to confirm the supposition that the fault is distant, and offers, when at its *minimum*, little resistance.

"I am of opinion, therefore, that a serious fault exists about 263 statute miles from Valentia, measured along the cable, and that the cable between that spot and this shore is comparatively perfect.

"No tests from here can now decide whether the cable is mechanically severed, since all attempts to detect the reception of the most intense currents from the opposite shore have long since proved fruitless.

"Still, from the various circumstances attendant on the decline of the insulation, there is every reason to believe that the continuity both of the cable and the conductor is perfect.

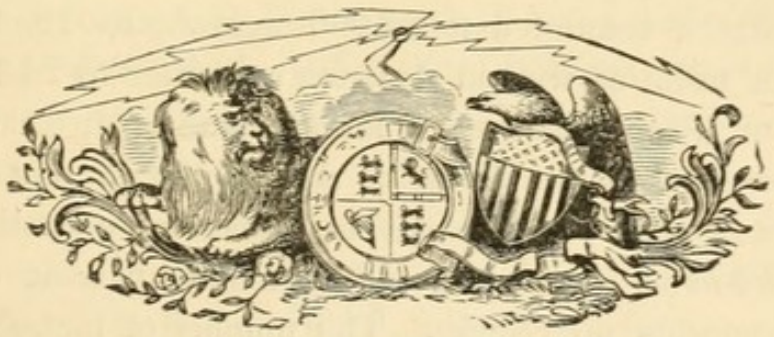
"Whether any other faults exist beyond the one alluded to, it is impossible to ascertain by tests from Valentia.

"The fact that the signals received at Valentia were always better than those received at Newfoundland proves, undoubtedly, that the worst insulation has always been near Valentia; and therefore it seems probable that if the fault which exists on this coast, and which, very likely, forms the principal cause of leakage, could be removed, the insulation would be so far improved as to render the cable again available for signalling, provided the fault which is said (by those who have tested from Newfoundland) to exist in Trinity Bay were also repaired.

"I have the honor to be, Gentlemen,

"Your obedient servant,

"F. C. WEBB."



PART V.

PROGRESS OF THE ELECTRIC TELEGRAPH.

CHAPTER XV.

"Their line is gone out through all the earth, and their words to the end of the world."
PSALM xix. 4.

AMONG the impossibilities enumerated to convince Job of his ignorance and weakness, the Almighty asks, "Canst thou send lightnings, that they may go, and say unto thee, Here we are?"

At the present day, every people in Christendom can respond in the affirmative.

The lines of electric telegraph are increasing so rapidly, that the length in actual use cannot be estimated at any moment with accuracy. At the commencement of 1848, it was stated that the length in operation in this country was about 3,000 miles. At the end of 1850, the lines in operation, or in progress, in the United States, amounted to 22,000 miles. In 1853, the total number of miles of wire in America amounted to 26,375.

It is but fifteen years since the first line of electric telegraph was constructed in this country; and at the present time there are not less than 50,000 miles in successful operation on this continent, having over 1,400 stations, and employing upwards of 10,000 operators and clerks. The number of messages passing over all the lines in this country annually is estimated at upwards of 5,000,000, producing a revenue of $2,000,000; in addition to which, the press pays $200,000 for public despatches.

In Europe there are lines rivalling those in America. The electric wire extends under the English Channel, the German

Ocean, the Black and Red Seas, and the Mediterranean; it passes from crag to crag on the Alps, and runs through Italy, Switzerland, France, Germany, and Russia. India, Australia, Cuba, Mexico, and several of the South American States, have also their lines; and the wires uniting the Pacific and Atlantic States will shortly meet at the passes of the Rocky Mountains.

The electric telegraph, which has made such rapid strides, is yet in its infancy. The effect of its future extension and of new applications cannot be estimated, when, as a means of intercourse at least, its network shall spread through every village, bringing all parts of our republic into the closest and most intimate relations of friendship and interest. In connection with the railroad and steamboat, it has already achieved one important national result. It has made possible, on this continent, a wide-spread, yet closely-linked, empire of States, such as our fathers never imagined. The highest office of the electric telegraph, in the future, is thus to be the promotion of unity, peace, and good-will among men.

In Europe, Great Britain and Ireland have the greatest number of miles of electric telegraph, — namely, 40,000. France has 26,000; Belgium, 1,600; Germany, 35,000; Switzerland, 2,000; Spain and Portugal, 1,200; Italy, 6,600; Turkey and Greece, 500; Russia, 12,000; Denmark and Sweden, 2,000. In Italy, Sardinia has the largest share of lines, having about 1,200 miles; and in Germany, after Austria and Prussia, the largest share belongs to Bavaria, which has 1,050. Saxony has 400 miles; Würtemberg, 195. The distance between stations on lines of Continental telegraph is from ten to twelve miles on the average, and the number of them is about 3,800.

In France the use of the electric telegraph has rapidly increased within the last few years. In 1851, the number of despatches transmitted was 9,014, which produced 76,723 francs. In 1858, there were 463,973 despatches transmitted, producing 3,516,634 francs. During the last four years, that is to say, since all the chief towns in France have been in electric communication with Paris, and consequently with each other, there have been sent by private individuals 1,492,420 despatches, which have

produced 12,528,591 francs. Out of the 97,728 despatches exchanged during the last three months of 1858, 23,728 were with Paris, and 15,409 with the thirty most important towns of France. These 15,409 despatches are divided, as to their object or nature, as follows: — Private and family affairs, 3,102; journals, 523; commerce and manufactures, 6,132; Bourse affairs, 5,253; sundry affairs, 399.

In Great Britain, the rate of charges upon the telegraph lines was formerly very exorbitant, but within a few years a great improvement has taken place. According to the tariff, as last arranged by the Electric Telegraph Company, all messages consisting of not more than twenty words are transmitted to distances not exceeding 50 miles for 25 cents; to distances not exceeding 100 miles, for 62 cents; and to all greater distances, for $1.25. For each additional ten words, or fraction of ten words, proportionate charges are made. In certain exceptional cases the 25-cent charge is extended to much greater distances than 50 miles; and the 62-cent charge to much greater distances than 100 miles. These exceptions include towns of the highest commercial and manufacturing importance, with which a large telegraphic business must always be transacted. Thus, between London and Birmingham (112 miles), the charge is only 25 cents; and between London and Liverpool (210 miles), London and Manchester (180 miles), and London and Carlisle (309 miles), the charge is only 62 cents.

Among the more recent improvements in the transaction of telegraphic business which have been made in England, the following may be mentioned.

Franked message papers, prepaid, are now issued, procurable at any stationer's. These, with the message filled in, can be despatched to the office when and how the sender likes; and the Company intend very quickly to sell electric stamps, similar to our postage-stamps, which may be stuck on to any piece of paper, and frank its contents without any further trouble. Another very important arrangement, for mercantile men, is the sending of remittance messages, by means of which money can be paid in at the central office in London, and, within a few minutes, paid out

at Liverpool or Manchester, or by the same means sent up to town with the like despatch from Liverpool, Manchester, Bristol, Birmingham, Leeds, Glasgow, Edinburgh, Newcastle-on-Tyne, Hull, York, Plymouth, and Exeter. There is a money-order office in the Lothbury establishment to manage this department, which will, no doubt, in all emergencies, speedily supersede the government money-order office, which works through the slower medium of the post-office.

The actual celerity with which correspondence is transmitted between London and parts of Europe more or less remote, may be judged from the fact that the Queen's speech, delivered at the opening of the recent Parliamentary session, was delivered verbatim, and circulated in Paris and in Berlin, before her Majesty had left the House of Lords.

Messages have been sent from the office in London to Hamburg, Vienna, and, on certain occasions, to Lemberg, in Galicia, being a distance of 1,800 miles, and their reception acknowledged by an instantaneous reply.

In Australia, the electric telegraph is in constant use, affording a remunerating revenue, and the amount of business has forced on the government the necessity of additional wires.

Cuba has six hundred miles of wire in operation. Messages can be transmitted only in Spanish, and the closest surveillance is maintained by the government officials over all despatches offered for transmission. From the fact that no less than a dozen errors occurred in a despatch transmitted by a Boston gentleman from Cardenas to Havana, we judge that the telegraphic apparatus, invented by our liberty-loving American, Professor House, rebels at such petty tyranny.

Several hundred miles of electric telegraph have been constructed in Mexico; but the unfortunate condition of the country for the last few years has precluded the possibility of maintaining it in working order, and it has, like everything else in the land of Montezuma, gone to decay.

The English and Dutch governments have come to an understanding upon a system of cables which will unite India and Australia, and eventually be extended to China. The arrange-

ments between the governments are: — That the Indian and Imperial governments shall connect India with Singapore; that the Dutch government shall connect Singapore with the southeast point of Java; that the Australian governments shall connect their continent with Java. The cable for the Singapore-Java section was to have been laid during the month of December, 1859; the Indian Singapore section is to be laid this spring (1860); and the connection with Australia will, it is believed, be completed in the course of next year.

The Red Sea and India Telegraph Company have announced the arrangements under which they are prepared to transmit messages for the public between Alexandria and Aden. Messages for Australia and China will be forwarded by post from Aden. It is considered probable that a direct communication with Alexandria will shortly be established through Constantinople, and then the news from India will reach London in ten or eleven days.

A late European steamer brings a report that two Russian engineers have proceeded to Pekin, China, to make preparations for a telegraphic connection between that place and the Russian territory.

There is reason to believe that arrangements will soon be made at St. Petersburg, through private companies and government subsidies, for completing the line of telegraph from Novgorod to the mouth of the Amoor, and thence across the straits to Russian America. A gentleman writing from Pekin, in August, 1859, states that these two engineers, one of whom is a Russian, and the other a Circassian, had been engaged in laying out the route for a telegraphic line from St. Petersburg to the mouth of the Amoor, from which it would be extended, by the submarine process, to the island of Jesso, which is divided between the Russians and the Japanese. It may even be extended to Hakodadi, on the southern part of the island and in the Japanese territory, a post opened by the late treaties, and already attaining a high degree of commercial importance, especially to Russia and the United States. Think of it, — a telegraph from the Baltic to the Pacific, and through the most mountainous regions, the most dreary des-

erts, the densest forests, and the most uncivilized races of Europe and Asia! The Circassian said he had passed through forests whose great trees and undergrowth were so compact that he could make only three miles' progress a day. He was often obliged literally to cut his way through. The distance from Pekin to Kiakhta, in Siberia, where all commercial business is transacted between the Russians and Chinese, or rather was before the late treaties had been concluded, is one thousand miles, and from this point the Russians expect to extend a branch line to Pekin itself. "Had it been my fortune to be here a few years hence, — less, probably, than half a dozen, — I might have sent you a telegraphic message, which, in *a few minutes*, should tell its tale in your very office-building, instead of waiting an indefinite period for a conveyance to Shanghai, and then travelling about sixty days by sea and by land before reaching its destination. The distance from Pekin to Shanghai is a thousand miles, which are travelled in about thirty-three days, in chairs, the usual mode of conveyance, as wheel-carriages are not used. The Prime Minister told Mr. Ward, at Shanghai, that he would require sixty days to get back to the capital. Mails are regularly carried from the capital to all parts of the empire, or at least to the capital cities of all the provinces. But they are carried on horseback, across rivers and over the worst of roads, and, as I believe, convey only governmental matter, — the Pekin Gazette and imperial edicts from Pekin, and the reports of the provincial officials and all sorts of Mandarins in return. The mail, therefore, does nothing or little for the general enlightenment and interests of the people. When Siberia and China have established lines of telegraph, and magnetic wires unite St. Petersburg and Pekin, the most invincible old fogy will admit the world is making progress, in the material and earthly, if not in the spiritual and heavenly. The ordinary period occupied by the post in travelling from Pekin to St. Petersburg is about sixty days; but, last year, at the conclusion of the Russian treaty at Tien-tsin, by almost superhuman effort it was done in a little short of forty days, horse-flesh heading off steam, and the first news of peace reaching France and England through St. Petersburg, greatly to the mortification of both."

When the telegraphic line is stretched from St. Petersburg to the mouth of the Amoor and to Pekin, and from London, under the Mediterranean, across Egypt, under the Red Sea and the Persian Gulf, and thence across India and Malaya to Singapore and Hong Kong, *a work soon to be completed*, the distance between the East and the West will be fairly and forever annihilated.

In the mean time, a company has already been formed and incorporated in Canada, under the name of the Transmundane Telegraphic Company, which will afford important aid in continuing the proposed line through British America. The plan is, to carry the wires from the mouth of the Amoor across Behring's Strait, to and through Russian and British America. From Victoria a branch will be extended to San Francisco, and another to Canada. The line from San Francisco to Missouri is under way, and Mr. Collins, who is engaged in the Russian and Canadian enterprise, thinks that, by the time it is in operation, he shall have extended his line to San Francisco.

This is unquestionably the most feasible route for telegraphic communication between America and Europe; and, though the longest by several thousand miles, it would afford the most rapid means of communication, owing to the great superiority of aerial over subaqueous lines.

No limit has yet been found to aerial telegraphing; for, by inserting transferrers into the more extended circuits, renewed energy can be attained, and lines of several thousands of miles in length can be worked, if properly insulated, as surely as those of a hundred. The lines between New York and New Orleans are frequently connected together by means of transferrers, and direct communication is had over a distance of more than two thousand miles. Quite recently direct communication was had between Halifax, Nova Scotia, and Beloit, Wisconsin, a distance of over three thousand miles. The operators, situated at this enormous distance from each other, were able to converse as freely and rapidly as if they had been separated but a few rods. No perceptible retardation of the current takes place; on the contrary, the lines so connected work as successfully as when divided into shorter circuits.

This is not the case with subaqueous lines. The employment of submarine, as well as of subterranean conductors, occasions a small retardation in the velocity of the transmitted electricity. This retardation is not due to the length of the path which the electric current has to traverse, since it does not take place with a conductor equally long, insulated in the air. It arises, as Faraday has demonstrated, from a static reaction, which is determined by the introduction of a current into a conductor well insulated, but surrounded outside its insulating coating by a conducting body, such as sea-water or moist ground, or even simply by the metallic envelope of iron wires placed in communication with the ground. When this conductor is presented to one of the poles of a battery, the other pole of which communicates with the ground, it becomes charged with static electricity, like the coating of a Leyden jar, — electricity which is capable of giving rise to a discharge current, even after the voltaic current has ceased to be transmitted.

M. Werner Siemens, of Berlin, observed, in 1850, the following remarkable phenomena: —

"A very remarkable phenomenon is constantly observed on long submarine telegraphic lines. Suppose one extremity, *B*, of the wire be insulated, and the other, *A*, be connected with one pole of a battery of which the other touches the earth: at the instant of communication a brief current is observed in the near parts of the wire, in the same direction as the instantaneous current which would exist if the extremity, *B*, were connected with the earth; on lines of perfect insulation, no trace of this current remains. Suddenly replacing, through the action of a commutator, the battery by an earth-conductor, a second instantaneous current is obtained, of an intensity nearly equal to the first, but in the inverse direction. Finally, breaking the communication of *A* with the battery and also the earth, so as to insulate this extremity, and uniting the end *B*, at the same instant, with the ground, an instantaneous current is observed nearly equal in intensity to the former, and this time in the same direction as the first, i. e. as the continuous current of the battery. This last experiment can only be made on a double subterranean or submarine line, having

the two extremities, *A* and *B*, at the same station. One might at first sight suppose these phenomena to be due to secondary polarities developed in the wire, but many facts oppose such a conclusion. 1. The phenomena are more striking as the wire is better insulated. 2. The currents are much more brief than those due to secondary polarities. 3. Their intensity is proportional to the force of the battery, and independent of the intensity of any derived current that may occur in consequence of imperfect insulation; it follows that the intensity of the instantaneous currents can greatly surpass the maximum intensity which secondary currents in the same circuit could acquire. 4. Finally, the intensity of the instantaneous current is proportional to the length of the wire, whilst an inverse relation ought to occur if the currents were due to secondary polarities.

"The above phenomena are easily comprehended, if we recall the beautiful experiment by which Volta furnished the most striking proof of the identity of galvanism and electricity. He showed that, in communicating one of the ends of his pile with the earth, and the other with the interior of a non-insulated Leyden battery, the battery was charged in an instant of time to a degree proportional to the force of the pile. At the same time an instantaneous current was observed in the conductor between the pile and the battery, which, according to Ritter, had all the properties of an ordinary current. Now it is evident that the subaqueous wire with its insulating covering may be assimilated exactly to an immense Leyden battery. The glass of the jars represents the gutta-percha; the internal coating is the surface of the copper wire; the external surface is the surrounding metallic envelope and water. To form an idea of the capacity of this new kind of battery, we have only to remember that the surface of the wire is equal to fourteen square yards per mile. Making such a wire communicate by one of its ends with a pile, of which the other extremity is in contact with the earth, whilst the other extremity of the wire is insulated, must cause the wire to take a charge of the same character and tension as that of the pole of the pile touched by it. That is what came to pass in the first of the instantaneous currents described. In Volta's experiment, on break-

ing the communication between the pole and the battery, and connecting the two coatings of the latter by a conductor, an ordinary discharge was obtained. To this discharge correspond the two instantaneous currents which are observed in opposite directions at the two extremities of the charged wire, on communicating their extremities with the earth, to the exclusion of the pile. It will be understood, also, that the first instantaneous current, namely, that which is connected with the charge of the wire, ought to be equally produced, though of a lower intensity, even when the other extremity of the wire is in communication with the earth. The instantaneous current then precedes the continuous current, or, if the statement be preferred, is added to it at the first moment. This instantaneous current has an intensity much greater than that of the continuous current; doubtless because, in the act of charging the wire, the electricity, in going to the different points of the wire, passes through paths so much the shorter as the points to be charged are nearer to the pile."

Professor Wheatstone experimented upon the cable intended to unite La Spezia, upon the coast of Piedmont, with the island of Corsica. It was one hundred and ten miles in length, and contained six copper wires one sixteenth of an inch in diameter, individually insulated, and each covered with a coating of gutta-percha one twelfth of an inch in thickness. The cable was coiled in a dry pit in the yard, with its two ends accessible. The ends of the different wires could be united, so as to make of all these wires merely one wire six hundred and sixty miles in length, through which the electric current could circulate in the same direction. This current was itself furnished by an insulated battery formed of one hundred and forty-four Wheatstone's pairs, equal to fifty of Grove's.

In the first series of experiments, it was proved that, if one of the ends of the long wire, whose other end remained insulated, were made to communicate with one of the poles of the battery, the wire became charged with the electricity of that pole, which, so long as it existed, gave rise to a current which was made evident by a galvanometer; but in order to obtain this result, the second pole of the battery must communicate with the ground, or with another long wire similar to the first.

In a second series of experiments, Professor Wheatstone interposed three galvanometers in the middle and at the ends of the circuit, determining in this manner the progress of the current by the order which they followed in their deviation. If the two poles of the battery were connected by the long conductor of six hundred and sixty miles, the precaution having been taken to divide it into two portions of equal length, it was observed, on connecting the two free extremities of these two portions in order to close the circuit, that the galvanometer placed in the middle was the first to be deflected, whilst the galvanometers placed in the vicinity of the poles were not deflected until later.

By a third series of experiments, Wheatstone, with the galvanometer, has shown that a continuous current may be maintained in the circuit of the long wire of an electric cable, of which one of the ends is insulated, whilst the other communicates with one of the poles of a battery whose other pole is connected with the ground. This current is due to the uniform and continual dispersion of the statical electricity with which the wire is charged along its whole length, as would happen to any other conducting body placed in an insulating medium.

It was owing to the retardation from this cause that communication through the Atlantic Cable was so exceedingly slow and difficult, and not, as many suppose, because the cable was defective. It is true that there was a fault in the cable, discovered by Varley before it left Queenstown; but it was not of so serious a character as to offer any substantial obstacle to the passage of the electric current.

The only instrument which could be used successfully in signalling through the Atlantic Cable was one of peculiar construction, by Professor Thompson, called the marine galvanometer. In this instrument momentum and inertia are almost wholly avoided by the use of a needle weighing only one and a half grains, combined with a mirror reflecting a ray of light, which indicates deflections with great accuracy. By these means a gradually increasing or decreasing current is at each instant indicated at its due strength. Thus, when this galvanometer is placed as the receiving instrument at the end of a long subma-

rine cable, the movement of the spot of light, consequent on the completion of a circuit through the battery, cable, and earth, can be so observed as to furnish a curve representing very accurately the arrival of an electric current. Lines representing successive signals at various speeds can also be obtained, and, by means of a metronome, dots, dashes, successive A's, etc., can be sent with nearly perfect regularity by an ordinary Morse key, and the corresponding changes in the current at the receiving end of the cable accurately observed. The strength of the battery employed was found to have no influence on the results; curves given by batteries of different strengths could be made to coincide by simply drawing them to scales proportionate to the strengths of the two currents. It was also found, that the same curve represented the gradual increase of intensity due to the arrival of a current, and the gradual decrease due to the ceasing of that current.

The possible speed of signalling was found to be very nearly proportional to the squares of the lengths spoken through. Thus, a speed which gave fifteen dots per minute in a length of 2,191 nautical miles reproduced all the effects given by a speed of thirty dots in a length of 1,500. At these speeds, with ordinary Morse signals, speaking would be barely possible. In the Red Sea, a speed of from seven to eight words per minute was attained in a length of 750 nautical miles. Mechanical senders, and attention to the proportion of the various contacts, would materially increase the speed at which signals of any kind could be transmitted. The best trained hand cannot equal the accuracy of mechanism, and the slightest irregularity causes the current to rise or fall quite beyond the limits required for distinct signals. No important difference was observed between signals sent by alternate reverse currents and those sent by the more usual method. The amount of oscillation, and the consequent distinctness of signalling, were nearly the same in the two cases. An advantage in the first signals sent is, however, obtained by the use of Messrs. Siemens and Halske's submarine key, by which the cable is put to earth immediately on signalling being interrupted, and the wire thus kept at a potential half-way between the potentials of the poles of two counteracting batteries em-

ployed, and the first signals become legible, which, with the ordinary key, would be employed in charging the wire.

A system of arbitrary characters, similar to those used upon the Morse telegraph, was employed, and the letter to be indicated was determined by the number of oscillations of the needle, as well as by the length of time during which the needle remained in one place. The operator, who watched the reflection of the deflected needle in the mirror, had a key, communicating with a local instrument in the office, in his hand, which he pressed down or raised, as the needle was deflected; and another operator occupied himself in deciphering the characters thus produced upon the paper. As the operator at Trinity Bay had no means of arresting the operations at Valentia, and *vice versa*, and as the fastest rate of speed over the cable could not exceed three words per minute, it will not surprise the reader that the operators were unable to accomplish more during the three weeks that the cable remained in operation. Upon our land lines of the same length, there would have been no difficulty in transmitting in twelve hours the same number of despatches which were sent through the cable.

In Liverpool, £150,000 have already been subscribed to the project of completing or relaying the Atlantic Cable.

A contract has been recently made by the English government for a cable to be laid from Falmouth to Gibraltar, 1,200 miles, which is to be ready in June next. This will be succeeded by one from Gibraltar to Malta and Alexandria, thus giving England an independent line, free from Continental difficulties.

Steamers were to have left Liverpool during the month of December, 1859, with the remainder of the cable to connect Kurrachee with Aden. The cable to connect Alexandria with England is now to be laid through the islands of Rhodes and Scio to Constantinople, and not by way of Candia, as previously intended; it is expected to be laid during the year 1860. Hellaniyah, one of the Kuria-Muria Islands, has been decided on as a station for the Red Sea Telegraph.

The new electric cable between Malta and the opposite coast of Sicily at Alga Grande is safely laid. Two previous attempts

had been made; but, in consequence of the late strong winds, nothing could be done. The shore-end on the Malta side had been laid down and connected with the company's offices before the expedition started; the outer end, about one mile off the Marsamuscetto harbor, into which the cable has been taken, being buoyed ready to complete the communication from shore to shore the moment the cable was submerged. The operation of paying out the cable was completed without the least accident. The mid-portion of the cable is of great strength, being able to sustain a strain of ten or twelve tons without parting, and the shore-ends are of nearly double that strength. The depth of water throughout is within eighty fathoms; so that if any accident should ever occur, it may be remedied without much difficulty.

A great change in the rates to Sicily and the Italian States will result from the completion of this new line, a reduction in some cases of seventy-five per cent being made, — a great boon to the English merchants. Messages in French, English, or Italian will be transmitted, and we must congratulate the company upon their success in inducing the Neapolitan government to make this concession, and upon the exceedingly low tariff proposed.

Mr. De Sauty is the electrician of this company. He will be remembered by the reader as the mysterious operator at Trinity Bay, from whom an occasional vague and exceedingly brief despatch was received in relation to the working of the cable. Nothing really satisfactory could ever be obtained, and, when visited by some officers connected with the United States Coast Survey, he would not permit them to enter the office or examine the apparatus. His name was published in the daily journals with several different varieties of spelling, and for this reason, and in consequence of his extreme reticence, one of them perpetrated the following: —

"Thou operator, silent, glum,
Why wilt thou act so naughty?
Do tell us *what* your name is, — come:
De Santy, or De Sauty?

"Don't think to humbug any more,
Shut up there in your shanty, —
But solve the problem once for all, —
De Sauty, or De Santy?"

Electric telegraphy in the Ottoman Empire has within a few months had a remarkable development. Several lines are already in course of construction. A direct line from Varna to Toultcha, passing by Baltschik. A line from Toultcha to Odessa, passing by Reni and joining the Russian telegraph at Ismail. The subaqueous cable from Toultcha to Reni, on the Danube, is the sixth in the Ottoman Empire. This line, which will place Constantinople in direct communication with Odessa, will not only have the advantage of increasing and accelerating the communications, but will very considerably reduce their cost.

There is also to be a line from Rodosto to Enos and Salonica; and from Salonica to Monastir, Valona, and Scutari in Albania. The line from Salonica to Monastir and Valona will be joined by a submarine cable crossing the Adriatic to Otranto, and carried on to Naples. It will have the effect of placing Southern Italy in communication with Constantinople, and also of reducing the cost of messages. A convention to this effect has been signed by a delegate of the Neapolitan government and the director-general of the telegraphic lines of the Ottoman Empire, touching this line to Naples. The ratification of the two governments will shortly be given to this convention.

A line from Scutari in Albania to Bar-Bournon, and thence to Castellastua, passing round the Montenegrin territory by a submarine cable. This line is already laid, and will begin working immediately on the completion of the Austrian lines to the point where it ends.

A line from Constantinople to Bagdad. Three sections of this are being simultaneously laid down. The first from Constantinople to Ismid, Angora, Yuzgat, and Sivas: the works on this have been already carried to Sabanja, between Ismid and Angora. The second section, from Sivas to Moussoul: the works on this line are in a state of favorable preparation, and the line will be actively gone on with. The third section, from Bagdad to Mous-

soul: for this also the preparations have been made, and the works will begin when the season opens, the materials being all ready along the line. From Bagdad this line will extend to Bassora, to join a submarine cable to be carried thence to British India.

A projected line from Constantinople to Smyrna. For this, two routes are thought of: one, the shortest, but most difficult, would run from Constantinople to the Dardanelles, Adramyti, and Smyrna; the other, the longest, but offering fewest difficulties, would pass from Constantinople by Muhalitch, Berlick-Hissar, and Maneesa, to Smyrna.

A line from Mostar to Bosna-Serai. Mostar is already connected with the Austrian telegraphs at Metcovich.

Other lines have been in the mean time completed and extended, and will soon be opened to the public. Thus, a third and fourth wire are being laid on the line from Constantinople to Rodosto; from the latter point three wires have been carried to Gallipoli and the Dardanelles, two of which are for messages from Gallipoli to the Dardanelles, and the third is to join the submarine cable connecting Constantinople, Candia, Syra, and the Piræus.

The communications between Constantinople and Candia would already have begun but for an accident to the engineer. Those with Syra and the Piræus will begin as soon as the ratification of the convention entered into between the Ottoman and Greek governments on this subject shall have taken place. The laying of the cable between Candia and Alexandria, which has not yet succeeded, will be resumed this spring (1860).

Thus, after the completion of these lines, Constantinople will be in communication with nearly all the chief provinces and towns of the empire, with Africa, and with Europe by five different channels, — by the Principalities, by Odessa, by Servia, by Dalmatia, and by the kingdom of the Two Sicilies. With such a development of the system, it will be imperatively necessary to increase the telegraphic working-staff. Already the number of despatches arriving every day renders the service very difficult, and occasions much confusion and many grievous mistakes.

Nothing is easier than to remedy all this by increasing the number of the *employés*.

It will be observed that one of the lines from Constantinople will be to British India, through Bagdad and Bassora. The very thought of a telegraph office in Bagdad transports one at once to the realms of fancy, to the dreams of childhood, when the marvellous stories of the Arabian Nights were veritable facts, and the adventures of Sinbad were envied or deplored according as he met with good or ill fortune. What a pity it is that Haroun, and Giafar, and the rest of those immortals who in the "golden time" lived, and loved, and hated, and murdered in those renowned cities, can't have a day's return to earth to see something that would have astonished even the magnificent Alamon!

The great distinguishing feature of the telegraphs used in Great Britain is, that they are of the class known as oscillating telegraphs, — that is, telegraphs in which the letters are denoted by the number of motions to the right or left of a needle or indicator. Those of France are of the class called dial telegraphs, in which an index or needle is carried around the face of a dial, around the circumference of which are placed the letters of the alphabet; any particular letter being designated by the brief stopping of the needle. A similar system has been used in Prussia; but, recently, the American, or recording instrument of Professor Morse, has been introduced into this, as well as every other European country; and even in England the national prejudice is gradually giving way, and our American system is being introduced.

In America none but recording instruments have ever been used. Of these we have many kinds, but only five are in operation at present, viz.: — The electro-magnetic timing instrument of Professor Morse; the electro-magnetic step-by-step printing of Mr. House; the electro-magnetic synchronous printing of Mr. Hughes; the electro-chemical rhythmic of Mr. Bain; and the combination-printing, combining the essential parts of the Hughes instrument with portions of the House. The Morse apparatus is, however, most generally used in this country and every other. Out of the two hundred and fifty thousand miles of electric tele-

graph now in operation or in the course of construction in the world, at least two hundred thousand give the preference to it.

Although the Morse apparatus is a recording one, yet for the last six years the operators in this country have discontinued the use of the paper, and confined themselves to reading by the ear, which they do with the greatest facility. By this means a great saving is made in the expense of working the telegraph, and far greater correctness insured; as the ear is found much more reliable in comprehending the clicks of the instrument, than the eye in deciphering the arbitrary alphabet of dots and lines.

The rapidity of the several instruments in use may be given as follows: — Cooke and Wheatstone's needle telegraph of Great Britain, 900 words per hour; Froment's dial telegraph, of France, 1,200; Bréguet's dial telegraph, also French, 1,000; Siemens's dial telegraph, formerly used upon the Prussian lines, 900; Bain's chemical, in use between Liverpool and Manchester, and formerly to a considerable extent in the United States, 1,500; the Morse telegraph, in use all over the world, 1,500; the House printing, used in the United States to a limited extent, and in Cuba, 2,800; Hughes's and the combination instruments, 2,000. The last three systems are American inventions: thus it will be seen that to our country is due the credit of inventing the most rapid and the most universally used telegraphic systems.

But though we surpass all other nations in the value of our electric apparatus, we are far behind many, and indeed most countries, in the construction of our lines. This does not arise from want of knowledge or of means, but from the custom which obtains to a great extent among all classes and professions in this country, of providing something which will answer for a time, instead of securing a permanent success.

> "But to my mind, — though I am native here,
> And to the manner born, — it is a custom
> More honored in the breach than the observance," —

especially in building lines of electric telegraph, where the best are always the cheapest.

When Shakespeare made Puck promise to "put a girdle round about the earth in forty minutes," he undoubtedly supposed he

would thereby accomplish a remarkable feat; but when the great Russo-American line *via* Behring's Strait and the Amoor is completed, and the Atlantic Cable is again in operation, we can put an electric girdle round about the earth before Puck could have time to spread his wings!

In view of what must actually take place at no distant day, — the girdling of the earth by the electric wires, — a singular question arises. If we send a current of electricity east, it will lose twenty-four hours in going round the globe; if we send one west, it will gain twenty-four, or, in other words, will get back to the starting-place twenty-four hours before it sets out. Now, if we send a current half-way round the world, it will get there twelve hours in advance of, or twelve hours behind our time, according as we send it east or west; the question which naturally suggests itself, therefore, is, What is the time at the antipodes? is it *yesterday* or *to-morrow*?

Hark! the warning needles click,
Hither, thither, clear and quick;
Swinging lightly to and fro,
Tidings from afar they show,
While the patient watcher reads
As the rapid movement leads.
He who guides their speaking play
Stands a thousand miles away.
Sing who will of Orphean lyre,
Ours the wonder-working wire!

Eloquent, though all unheard,
Swiftly speeds the secret word,
Light or dark, or foul or fair,
Still a message prompt to bear:
None can read it on the way,
None its unseen transit stay.
Now it comes in sentence brief,
Now it tells of loss and grief,
Now of sorrow, now of mirth,
Now a wedding, now a birth,
Now of cunning, now of crime,
Now of trade in wane or prime,
Now of safe or sunken ships,
Now the murderer outstrips,

Now it warns of failing breath,
Strikes or stays the stroke of death.
Sing who will of Orphean lyre,
Ours the wonder-working wire!

Now what stirring news it brings! —
Plots of emperors and kings;
Or of people grown to strength,
Rising from their knees at length; —
These to win a state, or school;
Those for flight, or stronger rule.
All that nations dare or feel,
All that serves the common weal,
All that tells of government,
On the wondrous impulse sent,
Marks how bold Invention's flight
Makes the widest realms unite.
It can fetters break or bind,
Foster or betray the mind,
Urge to war, incite to peace,
Toil impel, or bid it cease.
Sing who will of Orphean lyre,
Ours the wonder-working wire!

Speak the word, and think the thought,
Quick 't is as with lightning caught,
Over — under — lands or seas,
To the far antipodes.
Now o'er cities thronged with men,
Forest now, or lonely glen;
Now where busy commerce broods,
Now in wildest solitudes;
Now where Christian temples stand,
Now afar in Pagan land;
Here again as soon as gone,
Making all the earth as one.
Moscow speaks at twelve o'clock,
London reads, ere noon, the shock;
Seems it not a feat sublime?
Intellect hath conquered Time!
Sing who will of Orphean lyre,
Ours the wonder-working wire! *

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* Chambers's Papers for the People.

PART VI.

VARIOUS APPLICATIONS OF THE ELECTRIC TELEGRAPH.

CHAPTER XVI.

USE OF THE ELECTRIC TELEGRAPH UPON RAILWAYS.

One of the most useful applications of the electric telegraph is in connection with our railroads. No railroad should be without a telegraph line, so that the precise situation of every train on the road is known at the Superintendent's office, and at all the depots on the line.

On some English railways, the movement of trains is entirely regulated by telegraphic signals. The conditions under which trains or engines are allowed to move are, that every train leaving or passing a station is signalled *out* to the next station, and must not go on till the *out* signal is taken. Its arrival is signalled back to the last station, and no second train is allowed to follow until the first has arrived; for no two trains are permitted to be on the same length of railway between two signal stations at the same time. A train is considered *in* when within the protection of the semaphore-signals of the station, and the telegraph permission for a second train to follow refers only to the open line, as far as the previous train is concerned, and extends only to the distant signals of the station. On approaching the station, the train is subservient to the visible signals.

The Erie Railroad was the first road in this country to adopt the telegraph as an adjunct, and a description of its progress is therefore given. The telegraph line upon the New York and

Erie Railway was originally constructed by that company from Piermont to Dunkirk, the former *termini* of their road, with a single wire, which was devoted exclusively to the business of the road, in transmitting communications to and from officers, *employés*, &c. At this time, and for nearly a year after its construction, it was thought impracticable and unsafe to have recourse to the telegraph for the moving of trains, the advantages which have since been realized from its use, as adapted to railways, not being so apparent as now.

Soon after Mr. Tillotson's appointment to the superintendence of the line, in 1851, it occurred to him that an immense amount of time and money might be saved to the company by making use of the telegraph for expediting the movements of trains, when out of time and held by trains moving in an opposite direction, or by those of a superior class in the same direction.

Upon his recommendation, the Superintendent of the Susquehanna division of the railway was induced to try the experiment, the result of which was that a system was at once adopted by the Superintendents throughout the line, aided by the General Superintendent, Charles Minot, Esq., which has been so far perfected that the engineers and conductors now actually feel safer and more secure while moving under telegraphic orders than when following their printed instructions; although, at the time the system was inaugurated, it was not a little amusing to the operators to witness the alarm manifested by these same men at this innovation upon their old-fogyish views. Indeed, in some instances, so great was their prejudice, that they sacrificed their situations rather than comply with telegraphic orders.

It was about this time that telegraphs upon railways began to be appreciated; for no sooner was it discovered to what uses it was successfully applied upon the Erie road, than all the principal roads throughout the country were supplied with lines; and now a railroad of any length without a telegraph is indeed behind the age.

As an evidence of the regard in which it is held, we quote an extract from the General Superintendent's report to the stockholders, for the year 1855: —

"The use of the telegraph is a most important auxiliary in working the road, as, by the rules in force, trains moving in one direction possess positive rights to run without regard to time, or without reference to any opposing train; and an opposing train upon reaching a point whence, by the time-table, it should be met and passed by a train having the right to the road, is not permitted to leave until the arrival of such train; but by the use of the telegraph, conductors in such cases may be immediately communicated with, and directed to move forward, without the slightest danger of collision.

"Without the telegraph, under such circumstances, they would be obliged to remain stationary, or proceed slowly at the most imminent risk.

"*A single-track railroad may be rendered more safe and efficient by a proper use of the telegraph than a double-track railroad without its aid;* as the double-track can only obviate collisions which occur between trains moving in *opposite* directions, while the telegraph may be used effectually in preventing them either from trains moving in an opposite or the same direction.

"I have no hesitation in asserting that a single-track railroad, having judiciously located turn-outs, equal in the aggregate to one quarter of its entire length, and a well-conducted telegraph, will prove to be a more safe and profitable investment than a much larger sum expended in a *continuous* double-track, operated without a telegraph.

"In moving trains by telegraph, *nothing is left to chance.* Orders are communicated to the conductors and engineers of the opposing trains, and *their answers returned,* giving their understanding of the order, before either is allowed to proceed.

"It would occupy too much space to allude to all the practical purposes to which the telegraph is applied in working the road, and it may suffice to say that without it the business could not be conducted with anything like the same degree of *economy, safety, regularity, or despatch.*"

Since the publication of the report from which the foregoing is an extract, the telegraphic facilities have been very much increased. They have now two wires running the entire length of

the road, both connecting with one general office in New York. In conjunction with the American Telegraph Company, they have recently laid a cable from New York City to Jersey City, which is in successful operation.

Both of the wires are kept almost constantly busy, — most of the time in transmitting messages for the road, although the line is now open to the public, and the revenue derived from paid messages amounts to about $ 15,000 per year. The expense of operating the line is about $ 36,000 per annum.

The length of each wire (upon the main line) is four hundred and sixty-nine miles. Beside this they have the Piermont and Newburg branches, making altogether over one thousand miles of line.

One of their wires is divided into sections to correspond with the division of the road; the business of each division being transacted separately from the others. The other they work in one circuit between New York and Dunkirk, four hundred and sixty-nine miles.

They employ about one hundred operators, seven repairers, twelve messenger-boys, and sixty-eight offices, — seventeen of which are kept open constantly, both day and night.

They use the Morse apparatus; — in the main circuit the Grove battery, and for locals Daniell's improved zinc and copper.

In concluding this description of the use of the telegraph upon one of the best-managed roads in this country, we will say, what strict justice requires, that to Charles Minot, Esq. is due the credit of its conception and completion, in the face of great opposition on the part of other officers of the road, the accomplishment of which has been of inestimable benefit to both the railroad and the public generally.

THE ELECTRIC FIRE-ALARM.

Among the most important uses of the Electric Telegraph is that of the Telegraphic Fire-Alarm, originated by Dr. William F. Channing and Moses G. Farmer, for the city of Boston, in 1852.

From the central station at the City Hall, wires extend to every part of the city. These wires are called signal-circuits, and are five in number: by means of which the existence of a fire is signalized from any part of the surface of the city to the centre. In connection with these circuits are fifty signal-boxes, attached to buildings at convenient distances. They are of cast-iron and cottage-shaped (Fig. 75). On the door of each sig-

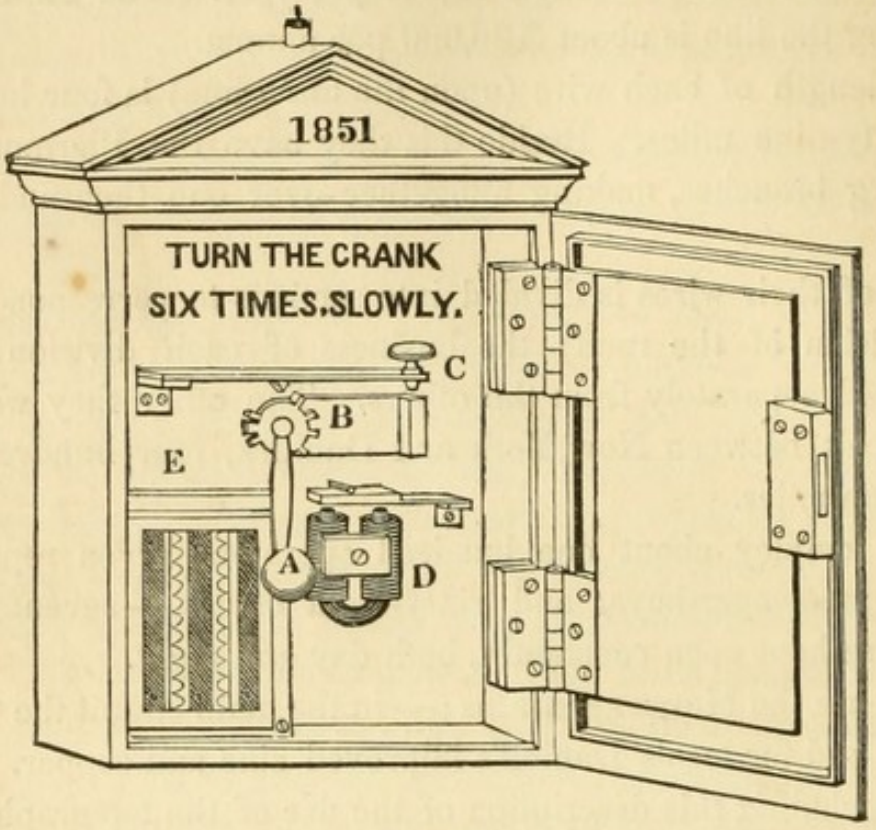


Fig. 75.

nal-box, the number of the fire district, and also the number of the box or station itself, in its district, are marked; and the place in the neighborhood where the key-holder may be found is also prominently notified. On opening the door of the signal-box, a crank is seen. Connected with this crank are the two signal-wires which extend to the central office, and by turning this it communicates to the centre the number of the fire district and of the box, and nothing else. Repeated turns give a repetition of the same signal. By this means a correct signal will be given by turning the crank, however stupid may be the signalizer.

At the central office, alarm-bells are connected with the signal-circuits, and also a register which records the alarm received

from the signal-box. The battery which supplies the signal-circuits is placed at the central station. If a fire occurs near Signal-box or Station 5, in District 3, and the crank of that box is turned, the operator at the central station is instantly notified by the alarm-bell, and reads at once on his register the telegraphic characters which signify District 3, Station 5.

The characters used in the fire telegraph are dots to indicate the district number, and dots and lines for the station number.

The following is the combination: —

Districts.		Stations.	
1	-	1	—
2	- -	2	- —
3	- - -	3	— - -
4	- - - -	4	- — -
5	- - - - -	5	- - —
6	- - - - - -	6	— - - -
		7	- — - -
		8	- - — -
		9	- - - —
		10	— - —

Thus a dot, and a dot and line, would indicate District 1, Station 2; these alternate on the record, and are repeated as often as the crank is turned.

The apparatus used for recording at the central station is a modification of the Morse, and the alphabet for general use is the combination adopted by Bain.

Having described the mode of communicating the alarm to the central office, let us see how the alarm is given from that centre to the public. From the central station extend five circuits of wires, called alarm-circuits, which go to the various fire-bells throughout the city, and which are connected with striking machines similar in character to the striking machinery of a clock, but *liberated by telegraph.* The operator at the central station is enabled, by simply moving the pointer upon the dial of a clock placed in connection with the several alarm circuits, to throw all the striking machines into simultaneous action, and thus give instantaneous public alarm.

The heavy hammers which are used to sound the alarm upon the bells are run by weights, which in several instances are wound up by the force of the water compressed in the mains. By means of the eccentric water-engine, known familiarly under the name of the "water-meter," the power necessary to wield the heavy hammers with the greatest facility is obtained. But how are hammers of one or two hundred pounds' weight to be tripped by telegraph? To effect this readily, Mr. Farmer invented his electro-magnetic escapement, one of the most beautiful and original of recent mechanical applications. In this escapement, the electro-magnet, when it becomes charged by the galvanic influence received from the central station, attracts the little piece of soft iron or armature in front of it, which supports a small lever poised nearly vertically, and weighted with a little ball at its upper end. This lever and ball, when tripped by the withdrawal of the armature, acquires sufficient momentum to strike up the detent of the train of wheels which, in their revolution, raise the hammer, and then allow it to fall. A single blow of the hammer follows each electrical impulse sent from the central station, and the revolution of the train of wheels raises also the falling lever into its place, and catches it again on the armature lever, ready to be disengaged or tripped for another blow.

At the central station, connected with the alarm circuit, is a magneto-electric machine, which furnishes all the power necessary to work the apparatus of the alarm-circuits.

The Cochituate water is used as a motive power to carry the magneto-electric machine. This arrangement saves the expense

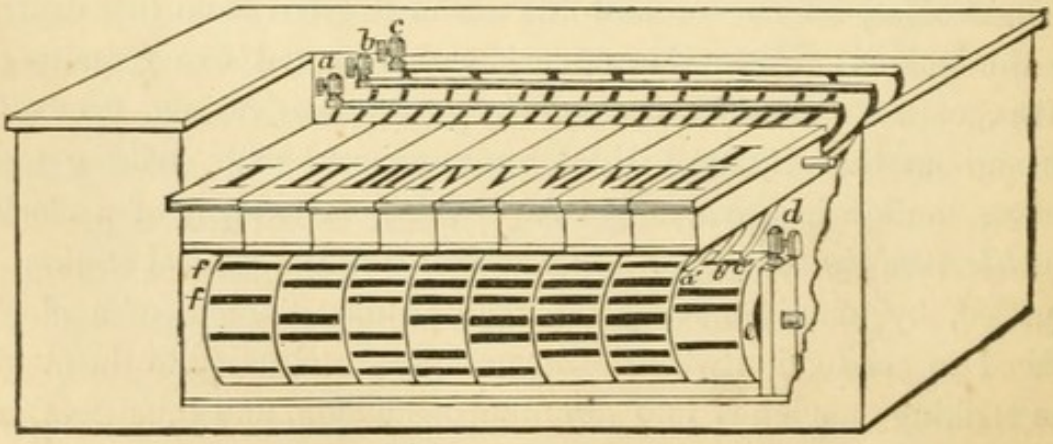


Fig. 76.

and inconvenience of maintaining a large quantity battery to work the alarm-circuits.

An ingenious arrangement of a cylinder (Fig. 76) carried by clock-work, upon the circumference of which are metal plates connected with the several alarm-circuits, enables the operator, by placing the pointer of the clock upon any number upon the dial, to set the machinery in motion, so as to complete the circuit at such intervals as to strike and repeat on the distant alarm-bells the district number represented by that number, with suitable pauses between.

We will suppose the operator at the central station receives the signal of fire from District 3, Station 5. He now places the pointer upon the dial upon the figure 3, and instantly all the alarm-bells in the city begin to strike synchronously the district number 3, and continue to do it, no matter what their number or what the weight of their hammer, so long as that pointer remains upon that number upon the dial.

The operator has also a key before him connected with the signal-circuits, by which he can answer back, and strike a little bell through the action of an electro-magnet armature, enclosed in each signal-box. He has received a signal of fire from District 3, Station 5. While the pointer rests upon number 3 upon the dial, he taps occasionally five times on the keys of the signal-circuits, which we have just described. The little bell in each signal-box, at the corner of every square, strikes five. The fireman listens to the public alarm-bells, and gets from them the number of the district; he runs by the nearest signal-box, and listens a moment to gather the station number from its little signal-bell, and he now knows that the fire is at District 3, Station 5. He directs his own motion and his engine, from the start, to within perhaps one hundred yards of the fire.

No other system has ever attempted to localize a fire more precisely than by the district number; and in some cities, like New York, the districts may be two miles long.

In all previous systems there has been a delay, first, in getting an alarm from the fire to the bells; and, second, in finding the place of the fire in the district after the alarm was given, and

reaching it by the shortest route. By the Boston fire-alarm telegraph, both district and station are publicly notified, — the one by the alarm-bells, the other by the signal-boxes.

Let us now consider the analogy between the municipal organization thus described, and the nervous organization of the individual. A coal of fire falls upon your hand; one of the nervous extremities, or papillæ, the signal-box of the part, sends instantly its own special signal, by means of a nerve of sensation, or signal-wire, to the brain, where the existence and locality of the lesion is at once recognized. An act of intelligence and volition ensues. The watchman of the central station, or brain, does his part. An impulse to motion is sent out over the proper motor nerves, or alarm-wires, and muscles are called into play in a suitable manner to remove the cause of injury, just as the electro-magnetic muscles and iron limbs in the bell-towers are thrown into suitable and related action to the original cause and plan of alarm.

The telegraph, in its common form, communicating intelligence between distant places, performs the function of the sensitive nerves of the human body. In the fire telegraph it is made to act for the first time in its motor function, or to produce effects of power at a distance; and this is also connected with the sensitive function, through a brain or central station, which is the reservoir of electric or nervous power for the whole system. We have thus an excito-motory system, in which the intelligence and volition of the operator at the central station come in to connect sensitive and motor functions, as they would in the case of the individual.

The conditions of municipal organization absolutely compelled the relation of circuits which has been described. The analogy with the laws of individual life was not perceived until after the system was evolved, and it came then as a confirmation of the correspondence of the system to natural law, and of the necessity of the arrangement as a means of order.

In Boston, where the fire-alarm telegraph has been in successful operation for nearly eight years, a star of wires is seen radiating from the top of the City Hall. These are the signal

circuits, connecting into one system fifty signal-boxes scattered over the city, and the alarm circuits connecting twenty-three belfries on church, school, and engine-houses. A few large bells would be preferable to this multiplicity of smaller ones, but this whole number are struck by means of the clock movement in the central station. For the sake of economy in battery power, the cylinder is so arranged as to throw the current from the magneto-electric machine in the four alarm circuits separately, but in rapid succession at each blow. Practically, the bells strike together, or as much so as is desirable. At night, sometimes out of the profoundest stillness, the district number will suddenly strike upon the ear in a chime of perhaps eight or ten bells, their sound coming in one after the other in proportion to their distance from the ear, but always in an invariable succession at each blow. Then the alarm ceases, and the whole city is as suddenly silent.

The operator at the central station is sometimes able to throw the bells on, and tap back to the signal-boxes before the originator of the alarm has ceased to turn his crank in the immediate neighborhood of the fire. As soon as the bells strike, groups of persons will be seen clustering around each signal-box to listen to the tapping of the station number, and it is soon known to the whole fire department exactly where the alarm originated.

The battery employed on the Boston signal circuits is Daniell's (sulphate of copper), which keeps in action several months by the addition each week of a few crystals of the sulphate of copper. Instead of a galvanic battery on the alarm circuits, a large magneto-electric machine has been substituted, similar in principle to those described in the earlier part of this work.

The heaviest hammer in the system at Boston weighs one hundred pounds, and is wielded by the Cochituate water at an expense of only one gallon for each blow, and tripped by telegraph from a distance of two miles. By virtue of the electric current and the pent-up water, this bell, and others associated with it, might be rung in measured strokes from the beginning to the end of the year by the pressure of a finger upon a telegraph-key a hundred or a thousand miles distant. The bells were rung, not long since, from Portland, and the Superintendent of the Fire-Alarm, Mr.

J. B. Stearns, had made arrangements to have them rung by telegraph from London just as the Atlantic cable ceased to work.

All the stations in Boston are provided with lightning-arresters, or ground-conductors for atmospheric or induced electricity. Hence an incidental protection from lightning, commensurate with the extent of the network of wires above, is attained for the city. When these ground-conductors have been temporarily removed from the alarm-bell stations, a flash of lightning has been occasionally followed by a single blow from one or more of the bells. But where the lightning-arresters have been in place, they have proved sufficient, except in rare instances, to direct atmospheric or induced currents from the electro-magnets to the ground. No practical or serious inconvenience has resulted from this source. But it has occasionally been a matter of curiosity and interest to hear the lightning thus tolling the alarm-bell.

The whole number of alarms and the proportion of false alarms have been greatly diminished by the system. Science can make no contribution to civilization without the requisite social conditions. The trust of the fire-telegraph system, in this case, was placed in the hands of the citizens, and it has yielded to them its fruits without abuse. This may deserve, perhaps, to be chronicled as an instance of well-rewarded confidence in the sobriety and capacity for self-government of the American people. The signal-boxes, which are the sensitive extremities of the system, may be protected by various methods, according to social requirements. In Boston, it has been guarded best by putting it in the most public place and exposing it to the fullest light.

The mechanism of the fire telegraph is arranged and disposed for the purpose of preserving the wealth, the fruit of human industry and Nature's bounty, from destruction. It therefore accomplishes an end of human use. But more than this, — it is a higher system of municipal organization than any which has heretofore been proposed or adopted. In it the New World has taken a step in the forms of civilization in advance of the Old.

Arrangements have been made by which uniform time is given to the inhabitants of Boston every day at noon by means of the

fire-alarm telegraph. An exact chronometer is placed in the circuit, which sends an electric current every day, at precisely twelve o'clock, and causes the hammer attached to the bell upon the Old South to strike one blow. This gives the inhabitants of the city an opportunity to regulate their time by a correct standard, and is a great advance upon the London system, which only drops a ball from a pole erected in the Strand, the telegraph wires being connected with the Royal Observatory. It is also much better than the Paris method of firing a cannon, which is touched off by telegraph. In the London plan, the few persons in the vicinity of the Strand only are benefited; and at Paris, the man who is half a mile distant loses several seconds, unless he makes allowance for the speed of sound; but in the Boston plan the whole city can be *tolled* the time to the fraction of a second. The public appreciate the system, and we shall doubtless soon witness the incongruity of people taking time from steeples that have no clocks in them.

The following interesting tables, showing the number of alarms which have occurred each hour, day, week, month, and year since the fire-alarm telegraph was established, in April, 1852, to January 1, 1860, have been computed by J. B. Stearns, Esq., Superintendent of the Boston Telegraphic Fire-Alarm.

Table I. shows the number of alarms in each hour during the twenty-four hours of the day in each year from 1852 to 1860, and the totals for the eight years, together with the number of blows struck upon the bells during the same period.

Table II. shows the number of alarms during each month of each year, and the totals for the eight years.

Table III. shows the number of alarms during each day of the week for each year, and the totals for the past eight years.

TABLE I.

Year.	Forenoon.												A. M.	Afternoon.												P. M.	Total.	No. of Blows.
	1	2	3	4	5	6	7	8	9	10	11	12		1	2	3	4	5	6	7	8	9	10	11	12			
1852*	2	3	6	1	4	0	2	1	3	4	2	4	32	7	2	6	3	4	10	7	6	10	10	9	6	80	112	4,806
1853	5	8	12	6	2	2	6	7	5	6	6	6	71	8	7	10	7	6	9	8	13	17	21	13	7	126	197	8,629
1854	15	8	7	8	6	4	4	2	8	4	3	9	78	9	7	2	7	10	9	10	11	12	9	12	10	108	186	6,575
1855	4	7	8	7	9	1	0	7	5	6	3	5	62	5	4	6	4	2	4	6	11	12	6	11	11	82	144	6,498
1856	14	9	7	7	6	3	1	3	3	6	3	3	65	3	4	10	9	5	5	12	8	15	11	11	10	103	168	8,689
1857	10	14	16	10	1	1	1	5	3	7	5	4	77	7	5	2	4	3	8	4	8	12	18	10	16	97	174	8,022
1858	8	7	8	6	1	2	1	0	7	4	2	5	51	7	7	10	6	4	6	3	9	12	9	11	16	100	151	6,695
1859	6	10	9	10	5	3	3	5	9	4	6	3	73	5	7	8	4	8	4	4	10	12	10	11	16	99	172	6,538
Total,	64	66	73	55	34	16	18	30	43	41	30	39	509	51	43	54	44	42	55	54	76	102	94	88	92	795	1,304	56,452

* Commencing April 28, 1852.

TABLE II. — Months.

Months.	1852.	1853.	1854.	1855.	1856.	1857.	1858.	1859.	Total.
January,		10	15	8	16	15	11	9	84
February,		29	20	13	10	14	10	11	107
March,		12	19	12	19	13	15	13	103
April,	1	21	10	13	29	11	10	11	106
May,	21	25	12	10	12	15	21	12	128
June,	5	25	20	16	9	15	13	11	114
July,	18	10	16	13	16	17	9	20	119
August,	8	11	15	12	10	16	7	23	102
September,	9	12	13	15	14	11	11	10	95
October,	15	17	14	7	9	22	14	21	119
November,	16	11	15	13	9	11	15	11	101
December,	19	14	17	12	15	14	15	20	126
Total,	112	197	186	144	168	174	151	172	1,304

TABLE III. — Days of the Week.

	1852.	1853.	1854.	1855.	1856.	1857.	1858.	1859.	Total.
Sunday,	16	30	27	12	22	20	23	29	179
Monday,	19	26	20	17	20	19	27	33	181
Tuesday,	16	37	31	24	26	31	30	20	215
Wednesday,	16	18	31	26	27	29	16	19	182
Thursday,	19	27	24	18	27	27	15	16	173
Friday,	11	23	26	20	27	24	16	23	170
Saturday,	15	36	27	27	19	24	24	32	204
Total,	112	197	186	144	168	174	151	172	1,304

The diagram (Fig. 77) is intended to exhibit the results of the past eight years' experience with the fire-alarm apparatus, showing in what hours of the day and night fires are most or least likely to occur. The diagram covers the twenty-four hours of the day, and is divided by the dotted lines into the forenoon and afternoon, and also into the portions between six o'clock A. M. and six P. M., and six o'clock P. M. and six o'clock A. M.

The outer, inner, and middle circles represent respectively the maximum, minimum, and medium periods of alarms.

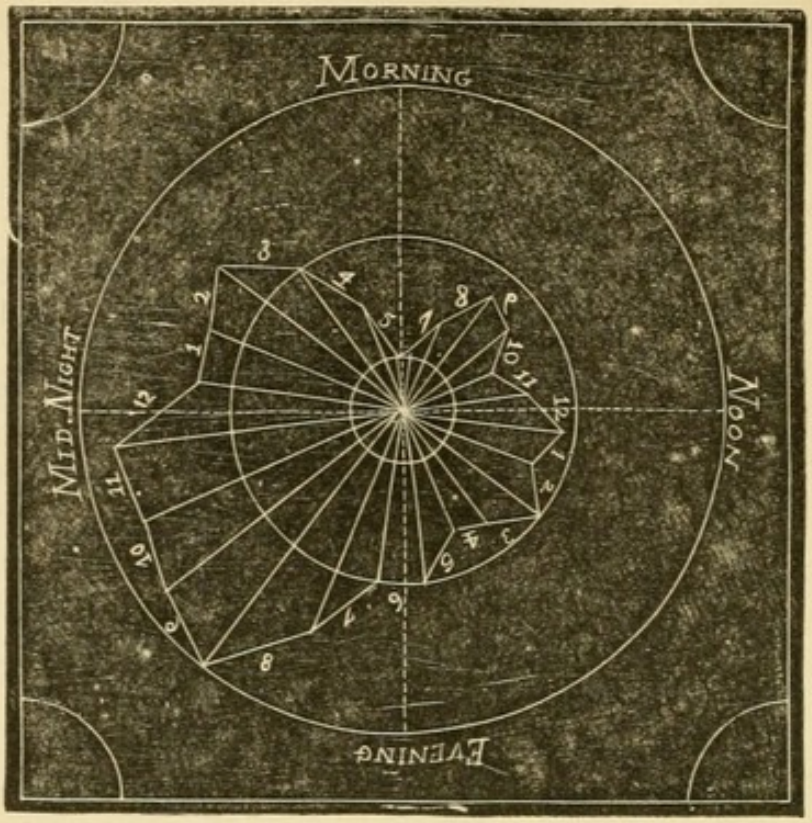


Fig. 77.

Thus it will be seen that the maximum of alarms occurs between eight and nine P. M., the minimum at six o'clock A. M., and the medium at precisely six o'clock P. M.

The larger number of fires occur between six o'clock P. M. and six o'clock A. M.; in fact, the angles in the other twelve hours of the day reach even the medium circle but twice, — between two and three, and five and six, — and do not extend above it in a single instance; while in the former part the angles do not drop below the medium circle until nearly four o'clock A. M.

Of the days of the week, the larger number of alarms occur on Tuesdays, and the next in number on Saturdays. This may be accounted for from the fact that Saturday is baking-day, and Tuesday is generally appropriated to ironing, — both requiring more intense fires than upon other days, excepting, perhaps Monday, washing-day, when there is always plenty of water for subduing any fires which may occur.

EMPLOYMENT OF THE ELECTRIC TELEGRAPH IN SCIENTIFIC AND ASTRONOMICAL OBSERVATIONS.

The various processes and apparatus that we have been describing have been devised with a view especially to the services which the telegraph may render to social relations. However, science, and more particularly astronomy, has found it a valuable auxiliary for certain observations which require simultaneity of operations in very distant places, or an immediate communication between two very distant points. Thus it is that, by means of the electric telegraph, we are able to know at the same instant the state of the atmosphere on several points of the terrestrial globe, — valuable data for meteorology. Thus also are we enabled to transmit the announcement of a hurricane in the direction according to which it is propagating itself, so as to give time to those who run the risk of suffering by it to take the necessary precautions. Many of the steamboat companies are thus saved many thousands of dollars, in this country alone, by the timely notice of approaching storms. But, as we have said, it is astronomy that has especially derived advantage from this instantaneous mode of communication.

Mr. Airy, Director of the Royal Observatory at Greenwich, has devoted his attention continuously, and with the greatest success, to this application of the electric telegraph, seconded by the co-operation of M. Quetelet and M. Leverrier. He has established at Greenwich a complete system of voltaic batteries, always charged and ready to enter into action, each having its special destination, and composed of a greater or less number of pairs according to their destination. From each of these batteries are led copper conductors, covered with gutta-percha, which extend into an apartment, whence, by means of commutators and other suitable apparatus, the current receives the desired direction. Thus, one of the conductors causes an astronomical clock to move; another serves to write down the passage of the stars, by means of dots, traced by a system analogous to Morse's, upon a paper fixed round a cylinder to which a helicoidal motion is imparted, and upon which is traced beforehand a spiral line to

serve as a base line. This instrument was devised by Professor Bond, of Harvard University, and is used for the same purpose in several Observatories in the United States. Another current is used for transmitting, by means of the telegraphic wire, Greenwich mean time to the different telegraphic stations in England, and especially to show the hour of one P. M. in London and at Deal at the very moment of one P. M. at Greenwich, by the dropping of balls placed in elevated situations, visible afar off. There exist also a considerable number of other applications to astronomical wants, of an analogous nature, devised by Mr. Airy. We could not point them all out without exceeding the limits within which we are compelled to confine ourselves; besides, they are based upon the same principles as those which have occupied our attention for so long a time, and differ from them only in certain mechanical details in the construction of the apparatus, which are easy of comprehension. In 1852 the wires were established for the purpose of connecting the Greenwich Observatory with the principal telegraphic offices in London; and through them, first, in 1853, with the Observatories of Cambridge and Edinburgh, and subsequently with those of the Continent, both that of Brussels and that of Paris. We shall not dwell upon the preliminary details relative to the determination of the correction of the clocks, or to the manner of closing the circuits, which must be done by different persons from those charged with observing the signals.

The first important determination to be obtained was that relative to the comparison of the hours of the electric signals, observed at Brussels and at Greenwich, which were not accompanied by observations of the transit of stars. Another point essential to know, but of a purely astronomical nature, was the determination of the elements necessary for calculating the errors of the transit instrument, and the clock errors for the days during which the observations of the difference of longitude were made.

These precautions being taken, two methods were followed for arriving at the determination of this difference. In one, the transits of fundamental stars were employed; it was not necessary that the stars observed should be the same in both observatories. In the second method two lists of stars were prepared, the one

preceding, the other following the signals. Before employing them for correcting the clock, the lists of the stars observed in the two observatories were compared, and all those rejected which had been observed in one observatory only. With regard to clock errors, they were obtained by comparing the transits corrected with the calculated positions of the stars; and these errors, duly reduced to the time of each signal of observation, were applied to the times given by the clock for the signals. The difference of these times for the two observatories gives the apparent difference of longitude; that is to say, the comparison of the sidereal times of the telegraph signals observed at Brussels and at Greenwich. In order to obtain the real difference of longitude, it is necessary to take the mean of the separate results, that are obtained in equal numbers, by making a similar number of Greenwich observations at Brussels, and reciprocally of Brussels observations at Greenwich. In order to eliminate the influence of the time employed by the current for passing over the distance by which the two observatories are separated, the following steps were taken. The signals given by the Greenwich battery to Brussels give the excess of the indication of the Brussels above the Greenwich clock, *increased* by the *time of transmission*. Signals given by the Brussels battery to Greenwich give the excess of the indication of the Brussels clock, *diminished* by the *time of transmission*. By noting the results of the signals given by each station in turn, and letting $+x$ in the one case and $-x$ in the other represent the time of transmission, and by interpolating the equations so as to correct any error in the rate of the clocks, the Astronomer Royal obtained, as the final result for the time employed by the current for traversing the distance by which the two observatories are separated, $0''.109$; — a value which depends upon 2,616 observations. This duration, which, if the velocity were uniform, would lead to a velocity of 2,500 English miles per second, since the telegraphic distance between Greenwich and Brussels is 270 miles, would be very great compared with that obtained by other methods.

But we should observe that from Greenwich to London, and from London to Ostend, the telegraphic line is situated entirely

under ground or under water, which, as we have seen from the experiments in connection with electric cables, occasions a considerable retardation in the rapidity with which electricity is propagated at the first moment when the circuit is closed. It is therefore very probable that the retardation observed is almost entirely due to the part of the line that passes under ground or under the water; and that the retardation from Ostend to Brussels, a route along which the wires are in the air, is insensible in practice.

With regard to the difference of longitude between Greenwich and Brussels, the means of 1,104 signals give the final result of 17′ 28″.9; this is the best that under present circumstances can be obtained for the determination of the element in question; it is, moreover, identically the same, according to the remark of M. Quetelet, as that which is furnished by the observation of the solar eclipse of May 15, 1856.

In 1854, conjointly with M. Leverrier, Mr. Airy likewise determined the difference of longitude between the Greenwich Observatory and that of Paris. The method was the same, and consisted in the employment of telegraphic signals for the comparison of the simultaneous state of the clocks of the two observatories. The signals themselves resulted from the deviation of two magnetized needles placed in the two stations, and set in motion by the action of the same current. The signals were observed by the precaution which the astronomer took of noting the time of the clock at which they appeared; but as it was not possible, in a general way, to calculate upon an accuracy greater than two tenths of a second in the appreciation of the instant at which a signal thus observed appeared, it was necessary, in order to arrive at a high degree of precision, to employ a great number of signals. M. Faye would have preferred that recourse should have been had to the method of coincidences for the comparison of the sidereal clocks of the two observatories. By allowing a series of simultaneous signals to be taken, in each of them, by means of a mean-time pendulum, the epoch could have been observed of the coincidence of these signals with the sidereal pendulum. The relative state of the two pendulums would have been exactly concluded, because the coincidence of the two beats would

have been observed with a precision far superior to that with which a fraction of a second of time is estimated directly.

This method, based upon the coincidence of pendulums, was likewise proposed and put in practice by M. Thaler of the Observatory of Upsal. By furnishing the extremity of the rods of the two pendulums with small steel points, which were plunged into mercury at the moment when the rods were perfectly vertical, M. Thaler closed his circuit, so that the coincidence of the two pendulums, whatever their distance and their difference of rate, might be indicated by the establishment of a current, which it was easy to employ, either by the magnetization of an electro-magnet, or in any other manner, so as to give a signal. The simultaneous states of the clocks at the moment of the coincidence were determined either by the observers themselves or by registers. It is necessary to remark, that the current was interrupted as soon as the pendulum rods, or one of them, ceased to be in a vertical position.

M. Leverrier was led to think that the question would be still more simplified if it were possible completely to do without the determination of the relative state of the pendulum; and this by registering upon the same chronograph the observations made in two stations, as has been done for some years in the United States by Professor Bond of Cambridge. This method could not in principle present any objection, since the registration is made by the intervention of a current that traverses a telegraphic wire, the length of which is a matter of indifference. But, in practice, it presented great difficulties, which have been only gradually surmounted in an apparatus, the construction of which has been intrusted to M. Liais. Upon a band of paper, set in motion by a train of wheels, an iron point traces equidistant divisions, corresponding to the movements of a sidereal pendulum, and by the action itself of this pendulum one or two points permit the observers to mark by dots, by means of the electric current, upon this same paper band, the instants in which the same star passes the various wires of their instruments. The difference of the stations in longitude is hence concluded, as may easily be understood. There are many precautions to be taken in the employ-

ment of this method, which has, however, enabled M. Leverrier to determine, with remarkable accuracy, the difference of longitude between the Observatory of Paris and the Dépôt of War, where a meridian telescope had been established.

TELEGRAPHING THE APPROACH OF STORMS.

The electric telegraph is found of very great importance in meteorological observations, — in forewarning the approach of storms, and in facilitating marine reports from distant points.

It was known in Franklin's time, and, if we mistake not, first published to the world by that eminent philosopher, that northeast storms always come from the southwest. It was doubtless considered in his day a statement of doubtful veracity, and we can imagine many a wiseacre shaking his head and exclaiming, "I don't believe it!" And yet, at the present day, where can a school-boy even be found who does not know that they are shivering with a northeaster in New York several hours before the Bostonians see any indications of foul weather?

Thanks to the promulgation of Espy's theory of storms, the whole matter is now well understood in this country, as well as in Europe.

Among those who have applied this knowledge to practical account in this country we must place in the front rank Mr. Joseph Brooks, the manager of the line of steamers which ply between Boston and Portland. In 1850, Mr. Brooks requested us to employ an agent for him in New York, to make daily observations of the state of the wind and weather, and send them to him, over the wires, every day at three o'clock. If the weather looked bad in the morning, he was to send a despatch at eight o'clock; if a storm came up, to send another about noon; and then at three to give a full statement of its condition, and, as nearly as possible, of its prospects.

With data like these, Mr. Brooks could at once tell at what hour the storm would reach New Haven, Springfield, Boston, and all the points between Boston and Portland. He could tell with absolute certainty whether it would be prudent to send his

boat to Portland, or whether it would be safe for the Portland boat to come to Boston. If the storm had been raging with severity for some hours in New York, he knew it would not be safe for the Portland boat to come out, as she would be sure to encounter it before arriving here; but the case with the Boston boat might be different, for she could reach Portland before the storm could overtake her.

Storms of ordinary velocity will travel about twenty-five miles an hour, but some will sweep along at more than twice this rate of speed, and will cover a space of nearly a thousand miles in length by several hundred in breadth.

When the importance of the matter becomes fully understood, the state of the weather will be telegraphed between every important town upon the seaboard, as regularly as the stocks and markets are at present; and the approach of every large storm will be announced upon our coast by storm signals, put up at government expense. If our government had the wisdom and liberality of the English and French governments, this matter would long ago have been looked after, and it would have established storm signal-stations along the whole coast of Cape Cod, as well as upon other desirable points.

Were such a system in operation, it is impossible to tell the amount of property which might be saved every year. Vessels might have ample time to make safe harbor, which, not knowing of the approach of the storm, pass on their way and are lost.

To show the importance of this matter in Mr. Brooks's case, who has made daily use of the wires for the past nine years; it is enough to say that his steamers have avoided all storms, and his line is the safest and most reliable in the country. So highly does he esteem it, he assures us, that he would rather pay the cost of telegraphing for a whole year, than have one of his boats exposed to a storm, even if she sustained no particular damage.

TELEGRAPH MARINE REPORTS.

Upon the extreme end of Cape Cod, within a few miles of Provincetown, there is an elevated strip of land extending from

Cape Cod Bay to the ocean, called "Highland Light," in the town of Truro. There are no residents there except the light-house keepers and their families. The soil — if it can be called soil — is poor, barely raising a little grass and corn, and the whole aspect of the place is dreary and cheerless; and yet, to the Boston merchant and ship-owner, the place possesses a peculiar charm, for it is from this point that he obtains, often, the first tidings of his expected ship!

Situated upon a point of land quite near the edge of the precipice, and not far from the light-house, its only companion is a small, one-story house, containing but one room. In this room there is a telescope, a book or two of marine signals — Marryatt's, Rogers's, and some others, — and an electric-telegraph instrument. A young man stands at the door, telescope in hand, and every now and then raises it to his eye and sweeps the broad ocean. Presently he observes in the far distance an object, which, to the untutored eye, is scarcely visible; but his long accustomed vision has already made her out to be a ship, and he is now endeavoring to decipher her signals. At last he has them, and he at once goes to his signal-book, makes out her name, where she belongs, who she is owned by, and by whom commanded. Having obtained these facts, he goes up to that faithful servant of man, the telegraph instrument, and calls "Boston." In a moment the operator answers, "Go ahead," and in two minutes the fact is recorded in bold letters upon the General Record Book at the News Room in State Street, that the "——, of Boston, Capt. ——, from Smyrna, passed Highland Light at 10 A. M., bound in, — distant nine miles."

PART VII.

CONSTRUCTION OF TELEGRAPH LINES.

CHAPTER XVII.

POSTS.

THE most important consideration in relation to the subject of electric telegraphy is to have the lines properly constructed; but this, in our country at least, has been the least attended to. We are quite apt to say such a thing will answer the purpose for a while, and rarely in any undertaking look far into the future. It is an American custom to substitute temporary expedients, even when we have the means of producing permanent results.

This common custom and fault of our countrymen has been very generally manifested in the construction of all our telegraph lines. They are usually built in haste, the posts generally set while filled with sap, often without taking off the bark; and the consequence has been, that in a very few years they have rotted off at the surface of the earth, and then been replaced by others in the same manner.

Now, had our telegraph managers consulted any competent authority upon the subject, they would have ascertained that the poles should have been cut at least six months before they were to be used, thoroughly dried, the bark carefully removed, and the bottoms charred for five or six feet. Chestnut poles, five inches in thickness at the top, prepared in this manner, would last at least twenty years.

In France the posts are of pine or fir, from twenty to thirty feet in length, which they inject with sulphate of copper, by the Bouchirn process, to lengthen the time of their preservation. They bark them and fix them in the earth, the smallest to the depth of thirty inches, the tallest to the depth of sixty inches; the buried part is perfectly preserved by the sulphate of copper. Poles prepared in this manner are very durable, but there is considerable expense attending it, and we presume the simple charing would be preferable in this country, where the best poles can be had for about eighty cents apiece. They should be at least five inches in diameter at the top, and about fifteen feet out of the ground, and five feet in. The length of the posts must necessarily vary according to the locality in which they are placed; but if along a line of railway, twelve or fifteen feet is sufficient. Experience has demonstrated that, in this country especially, there are no considerable number of persons who are disposed to molest the apparatus of the telegraph, no matter how much exposed it may be. In the vicinity of Boston the wires are conducted along the railings of the bridges, where they could be easily deranged; but no disposition to interfere with them has ever been manifested.

Aerial lines are greatly superior to subterranean, both on account of the facility with which breaks and other accidents may be detected, and because the apparatus works with much greater speed. There are few systems, in fact, capable of working over long submarine lines, on account of the return current from static induction, and the same is true of subterranean lines, as proved by the experiments in England with the House instruments.

The posts should be firmly set in the ground, to the depth of five feet. They should also be placed in a straight line, or as nearly so as possible, to prevent unnecessary strain; and wherever an angle occurs, a strong pole, capable of sustaining the utmost tension of the line, should be placed. The posts should average thirty to the mile.

Whenever it is found necessary to place more than one wire upon a post, arms or supports should be fastened to the posts,

and the wires carried at least two feet from them. This would give a distance of four feet between the wires, which would lessen the liability of the escape of the electric fluid from one wire to another.

There are many persons connected with telegraphing, who suppose the magnetic influence of a current sent over one wire, and which is manifested upon another, to be due to the phenomena of induction; but this is an error capable of being demonstrated very readily. You have only to place a wire having a current flowing through it in close proximity to one without an electrical current, but whose extremities are joined together, or connected with the earth. By placing a galvanometer within the second circuit, it can very easily be proved that the phenomena of induction are not sufficient to account for the effects produced upon the instruments connected by parallel lines. This influence is due to conduction between the wires, caused by the accumulation of moisture upon the insulators and the posts; and in England, where occasionally as many as twenty or more wires are placed on the same post, the action is most detrimental, and electricity, when intended to be transmitted along one wire only, often finds its way more or less into all the wires, and thus not only lessens the quantity intended to be transmitted to the distant instrument, but disarranges the instruments connected with all these other wires. Owing to this result of imperfect insulation, it has been found impossible for weeks together to telegraph direct even between London and Liverpool.

We experience no difficulty in this country from conduction between the wires (except when in actual contact), saving in wet weather; but upon some routes, the effect during wet weather is very serious. We have known two wires upon the same posts, which worked admirably during dry weather, to be rendered useless by even a half-hour's severe rain, unless one of them were discontinued from all attempts at operation.

To refer to the matter of induction again briefly: it is well known that an induced current flows in the opposite direction to the current inducing it, and therefore, if a positive current were sent west, the negative would return. Such, however, has never

been the case with any of the so-called induced currents upon telegraph lines; upon the chemical lines, only the positive current colors the paper, but during rain-storms, or fogs, the currents of conduction between the lines have always been in the same direction as the primitive currents, and were known, in fact, as "rain crosses," in contradistinction to the actual metallic contacts, commonly called "crosses."

THE WIRE CONDUCTORS.

The wire used for telegraph lines for the past thirteen years has been iron; generally, in this country, of No. 9; but in Europe No. 8 is more commonly used. Iron wire of the same diameter conducts only about one seventh as well as copper, but the cheapness and strength of the former render it far preferable to the latter. Twisted wire has been tried upon some lines in this country, but after a few years' trial was pronounced a failure, and its use abandoned.

The iron wire ought to be galvanized, or, rather, coated with zinc to prevent it from rusting; but few lines in this country have adopted it. As a matter of economy, to say nothing of the greater ease with which the current propagates itself upon it, it should be used. Near the sea, wires not coated rust off in a few years; in fact, we have seen instances where they have completely melted away, in less than two years, under the influence of the action of salt spray.

On the contrary, zinc-coated lines have been used for ten years, and are yet in good preservation. When rain first falls on the zinc covering, an oxide of zinc is formed, and, this oxide being insoluble in water, a second fall of rain cannot dissolve or penetrate it. The zinc covering and the iron wire inside are thus prevented from rusting away.

Where the distance between the supports for the wire is very great, as in the crossing of broad rivers, steel wire is employed instead of iron. The longest stretch of this kind in America is that over the St. Lawrence River near Caughnewaga. The rapids at this point are the most dangerous upon the river, and no navigators, except the native Indians, are capable of crossing them; and even with them, the feat is not considered an easy one.

In the autumn of 1855, Mr. Alphonso Prescott, the Superintendent of the Montreal and New York Printing Telegraph Company, after several weeks of unceasing, severe, and hazardous labor, succeeding in stretching a steel wire across these dangerous rapids, and safely hoisting it upon the masts at either side. Several times, with the aid of his faithful Indian assistants, he nearly accomplished the feat, when the wire would be snapped by the force of the current; but, nothing daunted by repeated failures, he persevered, amid cold and danger, until success crowned his efforts. To those who have passed through the Lachine Rapids upon the St. Lawrence, we need say nothing of the dangers attending it; and to those who have never done so, it would be difficult to convey an adequate idea of their wild character.

In order to accomplish the feat of stretching the line across, it was necessary for the canoes to paddle up the stream some considerable distance, to make up for the loss by the force of the current in crossing. Six of these canoes took part in the operation, the first containing Mr. Prescott, the coil of wire, "Big Bettese," the chief of the Caughnewaga tribe, and one other brave. The slightest accident to the frail canoe was certain death; but Mr. Prescott had full faith in his Indian friends, both as to their wonderful skill in the navigation of these dangerous rapids, and to their sincere friendship for him, and the result proved the propriety of this confidence.

Where iron wires coated with zinc are in the neighborhood of manufacturing towns, where great quantities of coal are daily burned, the sulphurous vapors arising from such fuel, and passing over the oxide of zinc formed on the covering of the wires, convert such oxide of zinc into a sulphate of zinc when the same is covered with moisture. This sulphate of zinc, being soluble in water, is immediately melted by the rain, and drops off with it. The wire is thus denuded of its insoluble covering, and soon melts away. We have had wires reduced from a diameter of an eighth of an inch down to the diameter of a common sewing-needle in less than two years. In such cases it is necessary to protect the wires by a covering of varnish or paint, in order to prevent the contact of these vapors with the wire, or to employ wires entirely encased in bone-rubber.

INSULATION.

One of the most important matters connected with the electric telegraph is the proper insulation of the wires; but this, we are sorry to say, is one of the great defects of all the lines in this country. It does not matter how perfect our apparatus is in other respects; if the insulation is defective, it is a constant source of annoyance, and causes, oftentimes, great loss of business. Much can be done by increasing the power of the batteries, and by distributing them along the line; still the disagreeable fact ought not to be withheld, that in rainy or foggy weather not one of our telegraph lines in this country is reliable, or, if they work at all, it is only from one short station to another, and that with much difficulty. But this is also the case in England, France, Germany, — in a word, in every country where the electric telegraph has been introduced.

Cannot the insulation be improved, and something approaching the *desideratum* long hoped for be obtained? We think it can. Science and experience have been teaching us, ever since the first rod of telegraph wire has been in operation, that we should not rely upon glass as an insulator; and yet it has been almost universally used in this country. Every one has observed that, whenever the weather is wet or foggy, every article of glass is covered with a thin film of water; and of course each insulator on a line of telegraph is so covered with moisture. Certainly some electricity will escape over each glass insulator so covered; in fact, glass becomes a conductor as soon as it is exposed to humidity; it attracts to its surface the aqueous vapors of the atmosphere; they form there a thin film of water, by which the electricity passes away. When we reflect, that, on a line of telegraph 500 miles in length, there are 15,000 such imperfect insulators to conduct the fluid from the wire, we are at no loss to account for the dissipation of all, or nearly all, the galvanism generated by the battery, and the consequent bad working of the line.

The insulators now in use are the glass, unprotected by iron or other covering; glass protected by an iron covering; pine wood

baked and soaked with shellac, and having a piece of glass inserted; glazed porous earthenware, or baked clay; glass upon wooden pins, protected by a wooden shield; white flint; bone-rubber surrounding an iron hook, the rubber having a screw cut upon it which is fastened to a wooden block; and the bone-rubber protected by an iron covering.

The chief and unsurmountable objection to the use of the unprotected glass insulator is its great liability to fracture. So great does this objection practically prove, especially in thinly populated districts, where blows from missiles are most liable to occur, that on lines of one hundred miles in length, insulated with unprotected glass, there are always from five to thirty insulators fractured and useless. Within the past year we have been obliged to replace over one thousand of these unprotected glass insulators upon a line of one hundred and fifty miles in length. It is obvious that during rain-storms the working of a line thus imperfectly insulated must be sadly interrupted. The manufacturers of the glass insulator find it extremely difficult greatly to increase the strength of the material by increasing its thickness, on account of the difficulty experienced in suitably annealing it. A slight scratch will often cause the thicker insulator to fracture and become useless.

The iron-protected insulator (that is, a glass insulator with an iron covering) is practically much superior to unprotected glass, and is the kind at present used upon some lines. Still, it is in several respects highly objectionable. The glass within the iron is extremely liable to fracture from the effects of missiles striking the iron protection. When the glass within is fractured or cracked, capillary attraction ensues during moist states of the atmosphere, and thus is formed an electrical connection between the two metallic surfaces which the glass should insulate. When one of the iron-protected insulators becomes imperfect, it is extremely difficult, in riding by, to find the exact location of the difficulty, and determine which insulator is at fault. The large majority of posts splintered by the effects of lightning during the spring and summer months are upon lines making use of iron-protected insulators. The cause is obvious. The res-

ence of so large a mass of metal serves to attract and accumulate a great quantity of free electricity, which, having no conductor to the earth, except the damp post, and that offering a great resistance to its passage, is shivered in the descent. The iron-protected insulator is necessarily costly, being composed of two materials, and manufactured at places usually quite distant. Double handling, and an extra transportation, augment the expense.

The chief objections to wood, coated or saturated with shellac, are, that the shellac cracks and decomposes upon the surface on exposure to atmospheric influences and during moist weather, and the difficulty of shaping wood into forms most approved for shedding rain, without large expense.

Porous earthenware and baked-clay insulators are principally defective from the fact, that the body is so porous as readily and easily to absorb moisture. Whenever the glazing is broken through by the wire and the spike, a moist communication is at once established, and the insulator is highly imperfect. A similar objection holds against the use of gums, resins, and other non-conducting substances less hard than glass, as the wire would soon wear through and touch the pin upon which the insulator rests; the surface, also, is liable to gradual decomposition on exposure. This system of insulation is extensively used in Great Britain, where they have undergone great expense in providing wooden roofs to shelter them from the rain; but they answer a very indifferent purpose, even when so protected.

In Germany and France they use glass very extensively, as indeed they do in Australia, California, South America, Canada, and other British American Provinces, and in the United States.

The glass with a wooden shield (Fig. 78) is preferable to the iron, and far preferable to the unprotected glass insulator; but it is open to the serious objection, that when a fracture occurs it cannot be discovered except by climbing the pole and making a minute examination (Fig. 79). We have under our charge some two hundred miles of line insulated in this manner, which has been in operation about four years, and has required very little

repair; but it has not proved a good insulator in wet weather, it being difficult sometimes, after a few hours' rain, to work through a circuit of less than a hundred miles.

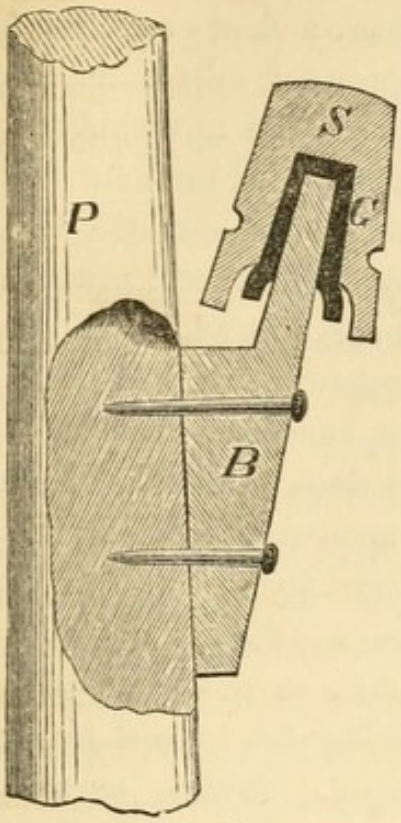


Fig. 78.

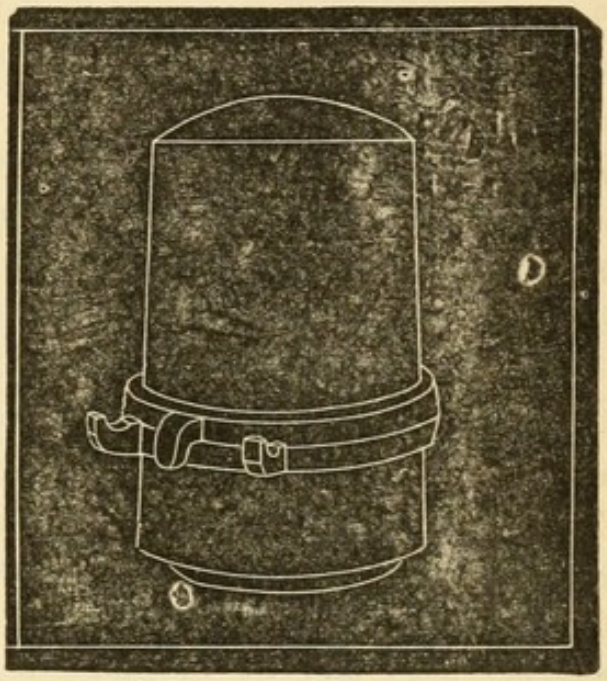


Fig. 79.

The white flint insulator (Fig. 80), invented by Mr. E. B. Elliott, we consider the best in use. The superiority of this insulator consists in its strength, insulating properties, and economy. The claim for invention is twofold: the anti-porous nature of the material — being the result of a continued series of careful experiments, and the improvements in form — tending to give increased strength, and also affording additional protection against the ill effects of atmospheric changes.

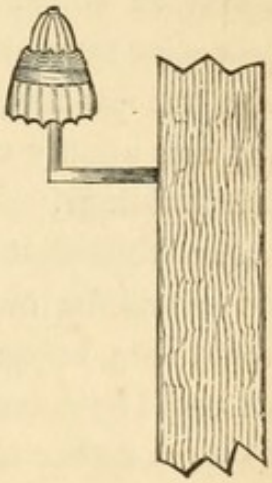


Fig. 80.

Its composition is flint, felspar, and quartz, principally flint. The strength of the heaviest of the insulators in use has been thoroughly tested by pistol-balls, and also by being brought forcibly in contact with the iron-protected

insulators in common use; in the former case merely flattening the bullets upon the convex surface, without fracturing the insulator, and in the latter case breaking not only the glass within the iron, but fracturing the iron protection itself. Its insulating properties equal those of the purest glass, and are superior to those of glass in common use. No deliquescent salts enter into its composition; consequently moisture from the atmosphere is less likely to accumulate upon the surface of this insulator than upon those made of common glass. Its anti-porous qualities have been made the subject of severest tests by scientific and practical telegraphers. The corrugations beneath serve as additional protection against such an accumulation of moisture as would permit a premature escape of the electric current, since the moisture is little likely to collect, at one and the same time, on the ridges and in the depressions. Hence, there is left upon the surface at least one dry and insulating ring, which the electricity cannot pass.

As regards economy, this insulator can be afforded at a lower price than any protected insulator heretofore used, — the prices ranging from ten to fifteen cents each, being determined by the quantity used and by the pattern adopted. Adding to these prices six cents, the cost of an iron spike upon which the insulator is placed, gives from sixteen to twenty-one cents for the total cost of insulator and spike. If wooden pins, costing one cent each, are used, the total cost of insulator and pin will be from eleven to sixteen cents. The cost of iron-protected insulators now in use varies from twenty-five to sixty-two cents. There are, however, but few lines still retaining the iron-protected insulator, and they are mainly confined to use in cities, where the wires cross high buildings.

The white-flint insulator is fractured with very great difficulty, and would be uninjured by missiles as ordinarily thrown; but should one become imperfect, the fact would be at once evident, and could be detected as far as the insulator could be distinguished. It serves rather to protect posts from the injurious effects of lightning (which iron-capped insulators invite), and on this account is peculiarly adapted to the wants of the South and our Western prairies. Its insulating properties depend on no mere glazed

coating. Its shape is perfectly adapted to the attainment of the greatest strength consistent with the affording of due protection from the injurious effects of storms and atmospheric influences. Should fracture occur, it would, in the majority of cases, continue supporting the wire, and be still an insulator. It affords the readiest facilities for prompt repair, an advantage of no small practical importance. It is throughout an insulator, and, like glass, impervious to moisture, under common atmospheric pressures.

This insulator has been used to some extent during the past five years, and experience has demonstrated the correctness of the statements we have made in regard to it; and although it is not a perfect insulator, it approaches nearer the requirements of such than any other which has been tried. Upon some lines, of forty to sixty miles in length, the operators have not experienced any escape during the heaviest storms. But to give them a thorough trial, they ought to be placed upon lines of several hundred miles in length. It is greatly to be hoped, that, in the changes now going on so extensively among the leading telegraph interests in this country, this most important and vital question of insulation may be placed in the hands of some thorough, practical electrician for solution. Our present system of insulation is a positive disgrace to the scientific ability of our American telegraphic engineers. Our principal lines work very well during dry weather, when in fact scarcely any insulation, beyond the dry poles, is needed; but let a shower, even, come up, and all the wires are seriously affected by escape.

It is not an unfrequent occurrence, during the rainy season, for all communication between the important cities of New York and Boston, by the wires, to be suspended, notwithstanding there are no less than eight direct lines extending between the two places. There is no necessity for this whatever; and were the large and most approved pattern of white-flint insulator — set upon a wooden pin — substituted for the defective varieties now in use, we feel assured that the serious difficulty would be surmounted, and that telegraphic intercourse between these points would be placed beyond the reach of rain-storms or fogs.

In using the white-flint insulator, we should strongly recommend the use of wooden brackets for supports, instead of iron.

During the past few years a new material has demanded the attention of our telegraph managers, as a substitute for glass and other insulating substances, viz. bone-rubber. Some ten thousand miles of wire are insulated with this substance at the present time.

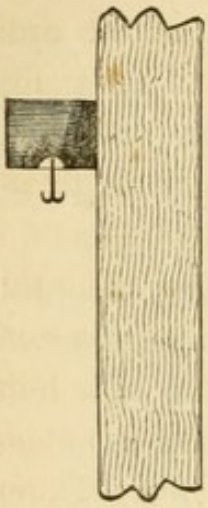


Fig. 81.

The form most generally used is that of a straight shank, terminated with a hook. The shank is of iron, covered with bone-rubber, upon which is cut a screw-thread, which is then screwed into a wooden block (Fig. 81), four inches square; the block is made fast to the posts by means of iron spikes. The wire is held by the hook, which depends from the under side of the block

This insulator has but one substantial fault, and that easily remedied, — want of insulating distance. There is but one inch of insulating distance between the iron hook and the wooden block, and, of course, during a heavy rain-storm this soon becomes covered with moisture, and the current escapes in large quantities. In fact, with a good earth wire in our hands, and applying the tongue to the moist pole, we can taste the escape current within a few inches of the block.

A very large number of these insulators have been used upon the Northern and Eastern lines, and various expedients proposed to remedy the defect. One of them is a rather complicated arrangement, by which a glass cylinder is fastened to the hook, and the line wire tied to the glass. Besides being very easily broken, the glass is so filled and tied about with iron, as to afford scarcely any insulating surface.

We have proposed to remedy the defect of this insulator by simply increasing the insulating surface of the bone-rubber. Instead of having only one inch of insulating distance, let us have twelve. This can be done either by increasing the length of the shank, or by having the shank covered with a shield of bone-rubber. This would make a firm, durable insulator, giving twelve inches of insulating distance, six of which would be beyond the influence of descending moisture.

We cannot speak from positive knowledge, — to be only obtained, as are all scientific facts, by actual experiment, — but we have no doubt that an insulator thus made would enable a wire to work five hundred miles during any weather.

This insulator would be somewhat more costly than the ordinary kind, but not sufficiently so to bar its use from any line where good insulation is required.

A line of fifty miles in length may be worked in ordinary weather without the aid of other insulators than the posts, and it may be worked half that distance even during a storm; but this distance cannot be safely increased. In 1847, a line was constructed between Boston and Portland, — a distance of one hundred and ten miles, — without insulators, the wire being simply attached by iron spikes to the posts; but the experiment did not prove a successful one, the line not being able to work until insulated. The very idea of trying to work a line this distance without insulation showed most unpardonable ignorance on the part of the proprietor, the necessity for such insulation having been demonstrated by Franklin, Watson, and Le Mounier, for high-tension electricity, in 1747 – 50, and by Gauss and Weber, Steinheil, and Wheatstone, in 1833 – 37, for that of low tension, or galvanism.

The use of iron, or other metals, in the construction of telegraphs, except as conductors, should be avoided as much as possible. Many lines have been seriously injured by the improper use of rods of iron, extending between posts situated upon opposite sides of a street, to which were attached insulators, for the purpose of conducting wires out of the branches of trees.

Such rods have been used in many of the cities and villages in Connecticut, where there are great numbers of shade-trees; but it was found that in damp weather they caused great escape from one wire to another, and they were consequently removed.

COST OF CONSTRUCTING AERIAL LINES.

The cost of constructing lines of aerial telegraph depends very much upon the *route*, the peculiarities of the soil, and whether they are upon lines of railway or over turnpikes. We give the

cost of the materials used, and the expense of construction per mile: —

No. 9 iron wire, 7¾ cts. per lb., 320 lbs. per mile,	$ 24.80
30 posts, at 80 cts.,	24.00
30 insulators, at 20 cts.,	6.00
Setting posts per mile,	5.00
Putting up the wire per mile,	2.00
Total cost per mile,	$ 61.80

This is about the cost of construction of a majority of our lines; but if constructed as they should be, they would cost $ 150 per mile.

The cost of posts varies according to the locality. In some places they can be had of good chestnut for forty cents apiece.

We also give the prices of the different kinds of insulators in general use: —

Glass (unprotected), with iron spike,	13 cts.
Glass, with wooden shield and brackets,	25 cts.
White flint, with wooden pin,	18 cts.
Bone-rubber, with block,	20 cts.
Bone-rubber, with iron covering,	62 cts.

Cost of Instruments, Batteries, &c.

Morse register,	$ 30.00
Morse relay magnet,	15.00
Key,	4.00
Local battery,	3.00
Total cost of apparatus for office,	$ 52.00

Now let us see what the cost of a line of telegraph of five hundred miles would be, constructed in the best manner, and fully equipped with all the necessary apparatus for business.

500 miles of line, at $ 150 per mile,	$ 75,000.00
100 cells Grove battery, at $ 1.50,	150.00
50 stations, at $ 52 for apparatus,	2,600.00
	$ 77,750.00

The cost of constructing lines of telegraph in England is much greater than in this country, owing to the more substantial manner in which they are built.

The wire generally used is iron, of about one sixth of an inch in diameter (No. 8 gauge), covered with a layer of zinc, in order to prevent oxidation. The posts are from 15 to 20 feet high, according to circumstances, 6 to 12 inches square at the base, and 4 to 6 inches square at the top; they are painted white, and are tarred at the lower end, where it enters into the ground; their distance varies from 55 to 73⅓ yards.

Independently of the supporting poles, *winding*-posts exist at regular distances, — the mean of which is a quarter of a mile, — intended, as their name indicates, for straining the wires, which but for this, on account of their great length, would form a curve, that would bring them too near the ground. It is essential that the wires should not be in immediate communication with the wood of the poles, which is a conductor, especially when it is moist, because the currents would be diverted, and pass into the neighboring wires, or penetrate into the ground, which would occasion great disturbances. In order to insulate them, supporters are employed of different forms of baked clay, or glazed porcelain, which are fixed upon the wooden poles, and along which the wires are made to pass. Upon the early English lines a wooden arm was fixed by iron bolts against the supporting pole, which is separated from it by discs of earthen-ware; the arm itself carries four or more double cones of earthen-ware, retained by iron clips. The conducting-wires traverse one of these cones, and are thus very well insulated; a double system of wires passes before and behind the pole, which is covered by a small wooden roof. Each winder carries on each side its *strainer*, composed of a drum and axis with wheel and ratchet; the ends of the winder are insulated from the post by earthen-ware discs, and the wires are attached to it on either side; in order to complete the circuit, a secondary wire is soldered to the principal wire, on either side of the post. At each winding-post, only half the wires, in most cases, are interrupted; the other half passes the post, still being insulated from it by means of the double cones of earthen-ware, the axes of

which they traverse. It follows from this arrangement, that, since the poles are a quarter of a mile apart, each wire is half a mile in length.

In France the cost of constructing aerial lines, including the apparatus in the offices, is in general about 500 francs per kilometre, or nearly $ 200 per mile. This includes the injection of the posts with sulphate of copper, and the construction of the lines in the most durable and substantial manner. The first cost of building a line in this manner is about twice as much as the cost of constructing ours, but the durability of these lines is at least ten times as lasting as those of the United States.

We must not omit to notice the changes which have taken place in the construction of lines, as well as in the instruments and batteries, since the first line was built, in 1844. The wire used in constructing that line was copper, covered with cotton and a preparation of asphaltum, it being supposed necessary to insulate the wires from the atmosphere, which is now known to facilitate the passage of the current. The line was composed of two wires, — one for the passage, and the other for the return current, — it not being known at that time by Professor Morse that the earth formed an admirable medium for the return current, although the fact was well known by European electricians many years before, as we have shown, from the experiments of Gauss and Weber, and the subsequent use of the earth as a return conductor by Steinheil of Munich.

Since 1847, iron conducting-wires have been used instead of copper, which, besides being much more expensive, are much more liable to be broken. It was found that No. 16 copper wire — the size used for telegraphic purposes — would not sustain its own weight when extended upon poles two hundred feet apart, but gradually drew to a fine thread, and then of course broke. The lines between Boston and New York, and between New York and Buffalo, were originally constructed with copper wire; but in the autumn of 1846 the copper wires between Boston and New York were taken down, and iron erected in their place; and in the succeeding spring the same change was made upon the New York and Buffalo lines.

Harrison Gray Dyar seems to have demonstrated the practicability of employing iron wires for telegraph lines as early as 1828, but no advantage was taken of this discovery by our countrymen, and it remained for M. Steinheil to bring it into general notice.

Mr. Alfred Vail, in a work upon the electro-magnetic telegraph, published in 1846, showed that two or more lines could be worked from the same battery, but for many years no practical use was made of this very important discovery. Until 1851, all the telegraph lines in the United States and the Canadas used separate batteries for each wire, and I believe Boston is entitled to the credit of demonstrating the practicability of working more than one line from the same battery.

Mr. E. B. Elliott, the manager of the House Printing Telegraph Office, was the first, we believe, to try the experiment upon a line, and we subsequently worked two wires upon the Merchants' Line between New York and Boston, from the Boston terminus, six months before the discovery was generally known. Now there are ten lines working out of the same battery at the American Telegraph Office in this city, — seven of them using the Morse instruments, two using the Combination, and one the House. The electric fluid, leaving the same battery, travels upon its useful errand east, west, north, and south, transmitting despatches to Maine, New Brunswick, Vermont, and New York, and returning by a short cut under ground, making the circuit, whether long or short, as quick as thought. Only one ground wire is used for all the lines, and only one wire is brought from the battery to the operating room, where all the lines are attached. This using one battery for so many lines is a vast saving in the expense of working several wires from the same office. With a battery of fifty Grove's cells, no perceptible change is observed in the circuits, in consequence of a less or greater number of wires being attached to the battery, providing the lines be well insulated.

Two things only seem to be necessary: — 1st. That a large conductor shall be brought from the battery to the operating room, and from the other pole of the battery to the ground. 2d. That

there shall be no earth connection, by which a return can be made, within a distance of fifty miles, unless a rheostat of sufficient resistance be interposed to make the circuit equal to that number of miles.

With a battery of fifty Grove's cells attached to lines well insulated, the number of circuits which may be worked from it without undergoing any change in strength or steadiness has not yet been ascertained, but it is doubtless very great. During heavy storms, however, there arise serious derangements to the circuits from the escape, and the operation of one wire will interrupt that of others. It has been suggested that this difficulty might be avoided by increasing the size of the cells, and thus increasing the quantity of the current, without adding to the intensity. The cause of the change in the steadiness of the currents being due to the close proximity of the escape, and the consequent shortness of the circuits, it is supposed this might be obviated by giving them sufficient quantity to supply such extra demand. The subject is well worthy the attention of our telegraphic managers, and we hope it may receive proper consideration.

The wires which run out of the office in Boston, and which are connected by one conducting-wire of large diameter with the battery of fifty Grove cells, work circuits of the following lengths: — New York, 230 miles; Rutland, Vt., 160 miles; Calais, Me., 300 miles; Springfield, Mass., 100 miles; Portland, Me., 110 miles; Provincetown, 160 miles; Rockport, Cape Ann, 50 miles; New Bedford, 60 miles; Scituate, Mass., (as the line runs,) 50 miles.

By the introduction of a rheostat of very great resistance, an alarum is operated by throwing the main battery current into the earth, without affecting the working of the instruments in the least. This alarum is used for the purpose of calling the attention of the messenger, whose duty it is to carry the despatches from the operator's table to that of the delivery clerk. As may be readily surmised, the arrangement is rather more fanciful than useful, and we only allude to it here, to show how useful the rheostat may prove, in cases where the main battery is used upon a very short circuit.

There has been a great change, since the first introduction of the Morse instrument, in the construction of the electro-magnets; those which were used originally were very large and awkward affairs, weighing thirty or forty pounds, — they are now made so light and compact that they can be carried in the vest pocket.

With the Morse system of telegraphy, an expert operator will send, or receive, fifteen hundred words an hour, — or between 8 A. M. and 8 P. M. he will send and receive three hundred despatches of the ordinary length. These despatches, at the rate of twenty-five cents apiece, would amount to seventy-five dollars, — showing that the business is a profitable one, providing there are not other expenses which are counting up very fast while the operator is using the line in this profitable manner. The truth is, the business is very profitable upon nearly all routes in this country where the lines are even tolerably well managed. Much money has been wasted in expensive lawsuits between rival patentees, and lines working under them have suffered in consequence. Much money has also been foolishly wasted by incompetent *employés*, who have, in consequence of their ignorance of the science of electricity, expended large sums upon useless experiments, especially in regard to insulation. We shall not particularize, but we have now in recollection one line which has undergone over a dozen complete changes in insulation, and has not yet arrived at a system worthy of the name! One of the larger companies employed an ignorant adventurer, who possessed no knowledge of the science of electricity, or of the practice as applied to telegraphy, except what he gained by a few months' experience in one of our American telegraph offices; and yet this man was paid a large salary, and employed for some years in place of a good practical electrician, of whom there are many occupying subordinate positions upon nearly all the lines in this country. One of the most glaring pieces of stupidity, perhaps, which this company had to endure, was the expenditure of some $ 15,000 in the purchase of iron insulators, coated with a thin glazing of porcelain. Of course a couple of weeks' use, exposed to the influence of heavy winds and the strain of the wire, broke the thin coating, and thus utterly destroyed all insulating properties in the so-called insulator.

Heretofore very little attention has been paid to the amount of knowledge which a man possessed of the science of electricity, in his appointment as manager or superintendent of a telegraph line, it seemingly not having occurred to our directors that the electric telegraph is the application to a useful purpose of a *science*, and that at least a limited supply of knowledge upon the subject would be useful. It is greatly to be hoped that hereafter more attention will be paid to this matter, as well as to the constructing of good, substantial lines in the place of the present mere apologies for such.

TELEGRAPH IN ITALY.

The most surprising examples of long lines of wires without intermediate support are presented on the telegraphic line passing north and south through Piedmont, between Turin and Genoa. There, according to a report published in the Piedmontese Gazette, in the course of the line passing through the district intersected by the chain of the Bochetta, the engineer, M. Bonelli, had the boldness to carry the wires from summit to summit across extensive valleys and ravines, at immense heights above the level of the ground. In many cases, the distance between these summits amounted to more than half a mile. In passing through towns, this line is carried underground; emerging from which, it is again stretched through the air from crest to crest of the maritime Apennines; after which it finally sinks into the earth, passing through Genoa under the streets, and terminating in the Ducal palace.

It is stated that the insulation of the wires on this picturesque line has been so perfect, notwithstanding the adverse circumstances of its locality, that although it was constantly at work day and night during the first winter, no failure of transmission or extraordinary delay ever occurred.

Why would it not be well for the American Company to construct a line between the most important points of their vast territory upon the above principle? — using stout posts, say one thousand feet apart, and the best and toughest iron wire of No. 8 gauge. This would avoid all difficulty from imperfect insulation, even in the most stormy weather.

TELEGRAPH IN INDIA.

Dr. O'Shaughnessy, of the East India Company's medical department, in constructing an experimental line through a distance of eighty miles from Calcutta, used, instead of wires, iron rods, — being the only obtainable material. These were fastened together and supported on bamboos.

By experiments thus made, he found that the wires employed in Europe would be quite inadequate to the Indian telegraph, for no sooner were the rods mounted on their bamboo supports in India, than flocks of that largest of all birds, the adjutant, found the rods convenient perches, and groups of monkeys congregated upon them; showing clearly enough that the ordinary wire would be insufficient to bear the strains to which these telegraphic lines would be subjected. It was found, also, that not only must the wire be stronger, but that it must be more elevated, to allow loaded elephants, which march about, regardless of roads or telegraph lines, to pass underneath.

The telegraphic communication thus practically effected is subjected to attacks to which the lines in this country are but little exposed. Storms of lightning destroyed the coils, and hurricanes laid prostrate the posts.

One of the peculiarities of the railway lines in India is the great distance between the posts, which are higher and stronger than those used in other countries. The thick wire is raised on posts an eighth of a mile apart. To obtain the necessary strength to bear the strain, the posts are fixed with screw-piles. To show the strength of the wires thus extended, a rope was, for experiment, hung to the centre of the wire of largest span, and a soldier climbed up it, the weight of his body producing but a slight curvature. The common deflection arising from the weight of a wire of a furlong span does not exceed eighteen inches.

Dr. O'Shaughnessy's plan of underground communication is very economical. The copper wires, coated with gutta-percha, are inlaid in wooden sleepers, well saturated with arsenic to protect them from the white ants, and laid in a trench two feet deep.

An underground system of two wires may thus be laid down for $175 per mile.

The plan adopted for joining the lengths of the thick galvanized wire is to have the two ends turned, so as to link into one another, which are then introduced into a mould, like a bullet-mould, and, an ingot of zinc being cast over them, they form a most substantial joint, and perfect metallic connection.

There are several thousands of miles of line in operation in India at the present time.

REPAIRING TELEGRAPH LINES.

After the proper construction of the line, the next important consideration is the keeping of it in repair. For this purpose, there should be provided a suitable number of repairers, stationed at regular intervals throughout the line, whose duty should consist in repairing the districts allotted to them. These repairers should be under the control of the superintendent solely, and should be held by him accountable for a thoroughly good condition of the posts, wires, insulators, &c. in their districts at all times.

As repairers cannot be stationed at all the offices, nor be always at hand when a break occurs, the operators in the intermediate offices should also be able to repair breaks and other derangements upon the line whenever they occur within their respective sections, and no repairer is present. For this purpose, each office should have on hand at all times a supply of wire and insulators sufficient for any emergency, and should also be provided with plyers, creepers or climbers, and straps and vices. With these simple and inexpensive tools, which would cost only about ten dollars, each office would be fully equipped for any emergency. The repairers, in addition to the tools above mentioned, should be provided with crowbars, shovels, axes, hatchets, and light ladders.

In the large towns, a certain number of repairers, according to the extent of lines in the town and the number radiating from it, should be stationed at the offices, to be ready at all times to repair breaks which may occur in their immediate vicinity. In towns where the wires are attached to the roofs of private and public

buildings, the duties of such repairers are not only of an important, but a responsible character. No legislation has ever been had upon the subject; but there have never been found any real difficulties in the way of constructing and maintaining the wires upon private dwellings, from the fact that almost every person has an interest in the successful operation of the electric telegraph. Still, the importance of employing efficient and gentlemanly persons to visit private dwellings for the purpose of making repairs must be obvious.

In London, Paris, and most other European cities, the wires are laid in tubes under ground. Besides being expensive, this method is objectionable on account of the less satisfactory operation of subterranean as compared with aerial lines; and it is to be hoped that nothing may occur to interrupt the good feeling between the public and the telegraph companies in this country in this particular.

HOW TO LOCATE A BREAK, ETC.

The question is often asked, how operators upon telegraph lines are able to tell where a break, upon a lengthy line, is to be found. This is done by an investigation called *testing*. We have explained that electro-magnetism is produced by an *electric current;* that an electric current is obtained by uniting the two poles of a galvanic battery by means of a *conductor;* and that the earth, from its immense surface, forms not only a good conductor, but the very best conductor in the world, — a conductor, in fact, whose resistance is nothing. Each end of a telegraph line is always connected with the earth, — the earth serving instead of a return wire. The necessity of such a return conductor will be seen at once, by starting from the *positive* pole of a battery in Boston, and running a wire to New York. Now the end of the wire in New York and the *negative* pole in Boston must be united by a *conductor*, else there will be no current. The earth serves as this conductor, by simply running a wire from the negative pole in Boston, and a similar one from the positive pole in New York, to the earth. The following diagram (Fig. 82) will enable the reader to understand the ar-

rangement of the batteries, instruments, wires, and other apparatus upon a long telegraph line.

In this diagram the fluid is represented as flowing from the positive pole in Boston, through the wire to New York, thence through the battery to the earth, thence back to the plate buried in the earth at Boston, thence through the wire connected to the plate, to the negative pole of the battery, thus completing the circuit.

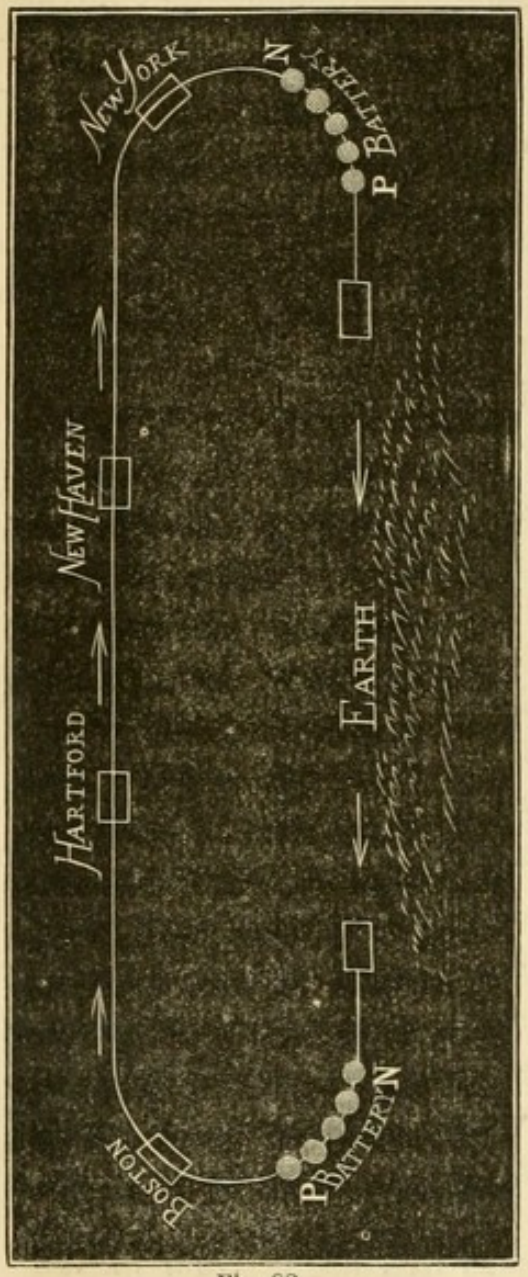


Fig. 82.

We have spoken here of the fluid as if there were but one, while in fact we know there are two, and that the negative fluid flows in the opposite direction to that of the positive, which is represented by the arrows. The theory which generally obtains in regard to the electrical fluid is, that the two kinds, positive and negative, are neutralized by each other at every point throughout the whole extent of the wire conductor, and thus by the act of neutralization create what we term the current. The earth, having a surplus of both kinds, neutralizes the two fluids without loss, presenting, in fact, the same result as if the two ends of the wire were united. To illustrate: — Suppose a wire extending between Boston and New York required twenty Grove's cups to produce a certain influence upon an electro-magnet or a galvanometer, — the termini of the wire connecting with the earth, — the circuit would represent 460 miles, — 230 being a wire conductor, and the earth supplying the remainder. Now,

take the same length of wire, and make the circuit from New York to Hartford and return, and the length of the circuit will be only 230 miles; but it will require precisely the same amount of electro-motive force in the battery, or, in other words, the same number of cups, to produce the same effect upon the galvanometer, or electro-magnet, as in the circuit of twice the length, in which the earth formed a part. But suppose we put the termini of the wire in the earth at Hartford and New York, instead of forming an entire metallic circuit; then we require but half the electro-motive force to produce the same results upon the galvanometer. This shows that the resistance to conduction by the earth is null.

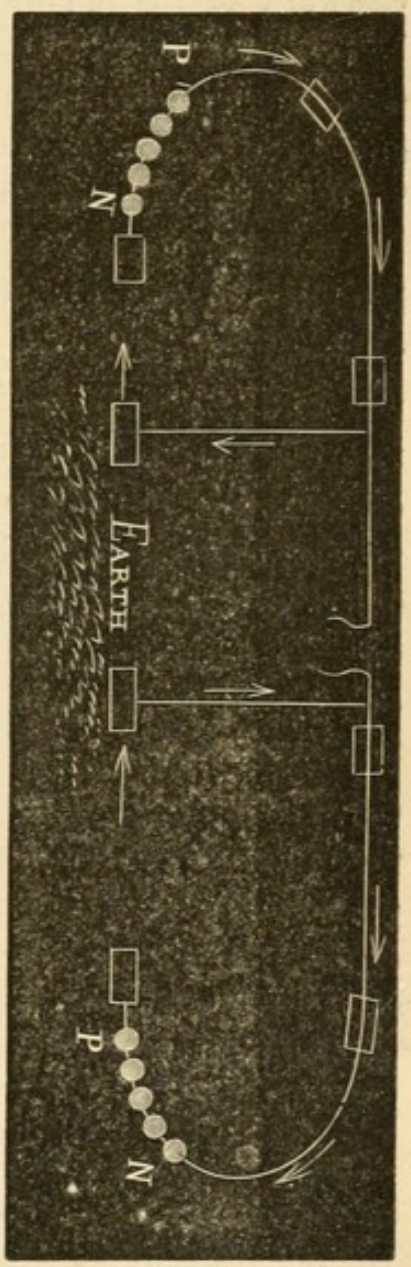


Fig. 83.

As the current in passing through the wire creates magnetism in all the helices which are in the circuit, their armatures are drawn up; but if the line breaks, the current ceases, the armatures are forced back by their springs, and every operator at once becomes cognizant of the fact. Each operator then applies his earth-wire to the line upon each side of his relay magnet, and, if he obtains a current, he knows that the line is whole upon that side; and if he gets none upon the other, he concludes the line is down, and sends out a repairer to put it in order.

We will now suppose the line to be broken between Hartford and New Haven; each operator at his respective station puts on his ground wire, and ascertains at once upon which side of him the break has occurred. Hartford, ascertaining the break to be west, sends his repairer in that direction, with orders to proceed until he finds the break, or meets the

repairer from New Haven; New Haven sends his repairer east, with the same instructions.

The foregoing diagram (Fig. 83), represents the manner in which a circuit is divided into short circuits, when a break has occurred. In the diagram, the line having broken between Hartford and New Haven, Hartford puts on a ground wire westward of his apparatus, and establishes a circuit through his ground with Boston; while New Haven puts on a ground wire eastward of his apparatus, and establishes a circuit with New York.

Breaks are easily found and repaired, but "grounds," "escapes," and "crosses" often require much labor and skill to locate. They require sometimes to be tested for from pole to pole.

The following is the plan most convenient for establishing the location of a ground. We will suppose Boston and New York to be working, but with much difficulty, from the escape of a portion of the electric fluid into the earth. Boston says, "Let us test; please open." New York then lifts his key, and thereby opens the circuit, while Boston breaks and closes his connection with the wire, and finds he gets a strong current while New York is open. This proves that there is a serious "ground" between them. Boston then calls Stamford, the next station, and gets him to open; then Bridgeport, then New Haven. When New Haven opens, he gets no circuit, and thus has located the difficulty between New Haven and Bridgeport. He then notifies them of the fact, and each sends out a repairer, who meet, we will say, at Stratford, half-way, and neither has found any trouble; they then conclude it must be a fault in the cable across the Housatonic, and they accordingly disconnect at both ends of the cable, take the line wire in one hand and the cable in the other, and apply the conducting wire of the cable to the tongue; if there is a leak in the cable, a strong or weak current will be found, according to the size of the leak and the strength of the battery.

A pocket magnet (Fig. 84) is a very convenient instrument for the purpose of testing upon a line, as you can converse with the operators, when necessary, with the greatest ease. We have

never found any difficulty, however, in conversing by means of shocks through the fingers or tongue, without any apparatus.

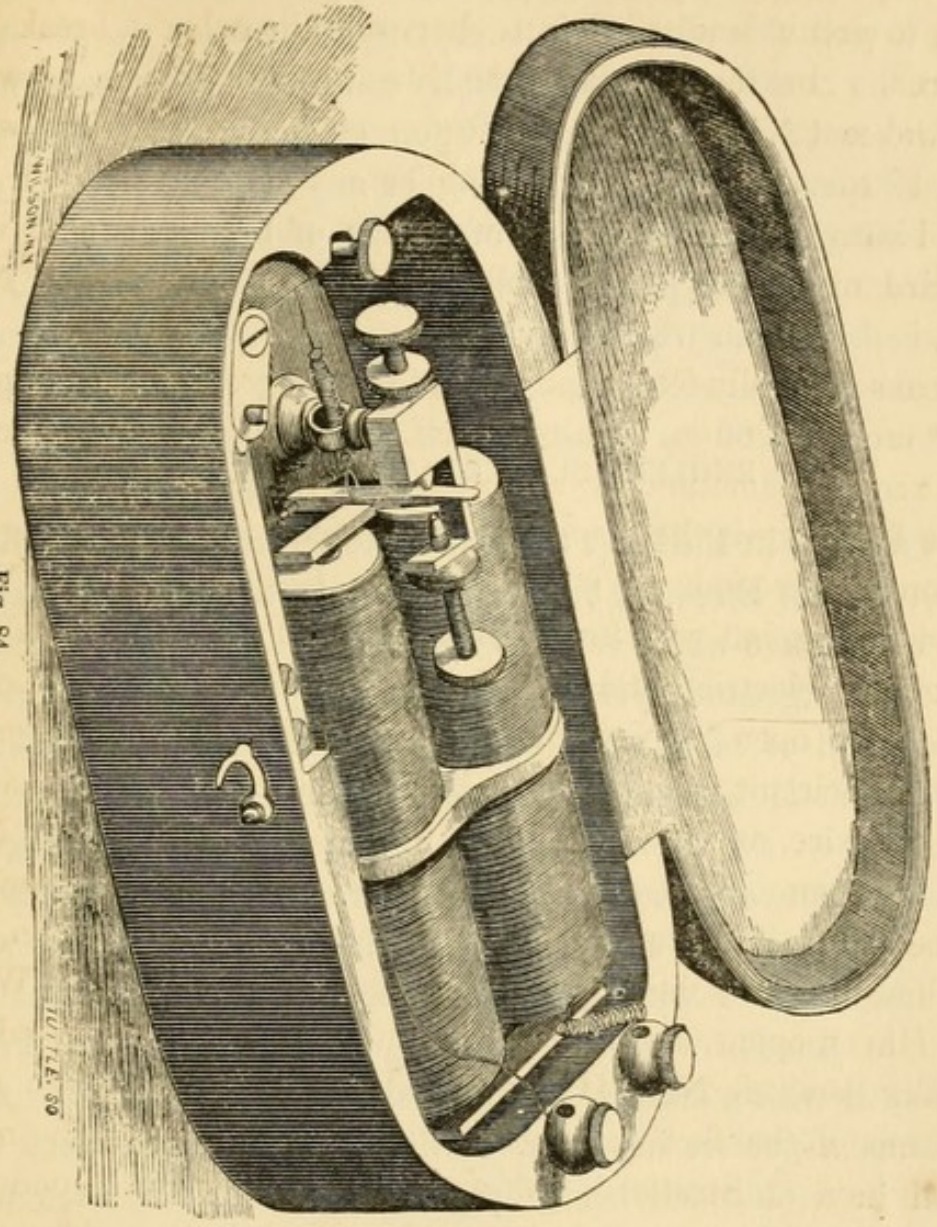


Fig. 84.

Repairing the wire when broken is a very simple affair. If broken between two poles, a piece of wire is joined to the longer part sufficient to reach to the next pole. The repairer then puts on his creepers or spurs and mounts the pole, taking the wire in his hand. When arrived at the top, he draws, with his hand, as much of the slack as he can, and then applies a vice attached to a strap to the wire, and placing the strap around the top of the pole, draws in the remainder of the slack, and joins the wire.

We notice, in a work recently published upon the telegraph, a

drawing representing a man standing between two posts, with a pair of blocks attached to the two ends of the broken wire; the man is pulling away at a rope, the supposition being that he is going to pull the wire some twenty-five feet up in the air, while in fact, he is of course doing all he can to pull it to the ground! The writer of the work in question evidently has had a very limited experience in telegraphing in any capacity, but why he should imagine that by means of a pair of blocks he could pull the wire up into its place, *without anything for the blocks to rest upon,* is more than we can divine.

ENGLISH SUBTERRANEAN LINES.

We alluded in Part IV. (page 172) to the subterranean system in operation in England, but we did not treat the matter so fully as its importance would seem to demand.

The underground system has been adopted in the streets of London, and of most other large towns; upon the English and Irish Magnetic Telegraph Company's lines, to a great extent; and also upon the wires of the European Submarine Telegraph Company, between London and Dover. The methods adopted for the preservation and insulation of these underground wires are various. The wires proceeding from the central telegraph station in London were originally wrapped with cotton thread, and coated with a mixture of tar, resin, and grease. This coating forms a perfect insulator. Nine of these wires were then packed in a half-inch leaden pipe, and four or five such pipes were packed in an iron pipe about three inches in diameter. These iron pipes were then laid under the foot pavements, along the sides of the streets, and were thus conducted to the terminal stations of the various railways, where they were united to the lines of wire supported on posts along the sides of the railways. More recently the wires deposited in the underground pipes are insulated altogether by means of a coating and envelope of gutta-percha.

The Electric Telegraph Company has at present (1860) no less than fifteen miles of this underground piping laid along the

streets of London, containing *three hundred and fifty miles* of gutta-percha-covered conducting-wire.

The wires of the Magnetic Telegraph Company are laid and protected in the following manner. Ten conducting-wires are enveloped in a covering of gutta-percha, so as to be completely separated one from another. Thus prepared, they are deposited in a square creosoted wooden trough, measuring three inches in the side, so that nearly a square inch of its cross-section is allowed for each of the two wires. This trough is deposited on the bottom of a trench cut two feet deep along the side of the common coach-road. A galvanized iron lid, of about an eighth of an inch thick, is then fastened on by clamps or small tenter-hooks, and the trench filled in.

The method of laying the wires in the streets adopted by this company is a little different. In this case iron pipes are laid, but they are split longitudinally. The under halves are laid down in the trench, and the gutta-percha-covered wires being deposited, the upper halves of the pipes are laid on and secured in their places by means of screws through flanges left outside for the purpose.

To deposit the rope of gutta-percha-covered wires in the trough, it is first coiled upon a large drum, which being rolled along slowly and uniformly over the trench, the rope of wires is payed off easily and evenly into its bed.

So well has this method of laying the wires succeeded, that in Liverpool the entire distance along the streets from Tithe Barn Railway station to the Telegraph Company's offices in Exchange Street East was laid in eleven hours; and in Manchester, the line of streets from the Salford Railway station to Ducie Street, Exchange, was laid in twenty-two hours. This was the entire time occupied in opening the trenches, laying down the telegraph wires, refilling the trenches, and relaying the pavement.

One of the objections against the underground system of conducting wires was, that while they offered no certain guaranty against the accidental occurrence of faulty points where their insulation might be rendered imperfect, and where, therefore, the current would escape to the earth, they rendered the detection of

such faulty points extremely difficult. To ascertain their position required a tedious process of trial to be made from one testing post to another, over an indefinite extent of the line.

A remedy for this serious inconvenience, and a ready and certain method of ascertaining the exact place of such points of fault, without leaving the chief or other station at which the agent may happen to be, has been invented and patented by the Messrs. Bright of the Magnetic Telegraph Company.

Instruments called Galvanometers, which we have described in the first part (page 46,) are constructed, by which the relative intensity of electric currents is measured by their effect in deflecting a magnetic needle from its position of rest. The currents which most deflect the needle have the greatest intensity, and currents which equally deflect it have equal intensities.

The intensity of a current diminishes as the length of the conducting-wire — measured from the pole of the battery to the point where it enters the earth — is augmented. Thus, if this length be increased from twenty miles to forty miles, the intensity of the current will be decreased one half.

The intensity of the current is also decreased by decreasing the thickness of the conducting-wire. Thus the intensity, when transmitted on a very thin wire, will be much less than when transmitted on a thick wire of equal length; but the thick wire may be so much longer than the thin, that its length will compensate for its thickness, and the intensity of the current transmitted upon it may be equal to that transmitted on the shorter and thinner wire.

The method of Messrs. Bright is founded upon this property of currents. A fine wire wrapped with silk or cotton, so as to insulate it and prevent the lateral escape of the current, is rolled upon a bobbin like a spool of cotton used for needlework. A considerable length of fine wire is thus comprised in a very small bulk.

The wire on such a bobbin being connected by one end with the wire conducting a current, and by the other end with the earth, will transmit the current with a certain intensity depending on its length, its thickness, and, in fine, on the conducting power of the metal of which it is made.

Now let us suppose that a certain length of the wire of the telegraphic line be taken, which will transmit a current of the same intensity. A galvanometer placed in each current will then be equally deflected. But if the length of the line-wire be less or greater than the exact equivalent length, the galvanometer will be more or less deflected by it than it is by the bobbin-wire, according as its length is less or greater.

It is, therefore, always possible by trial to ascertain the length of line-wire which will give the current the same intensity as that which it has upon any proposed bobbin-wire.

Bobbins may therefore be evidently made carrying greater or less lengths of wire, upon which the current will have the same intensity as it has upon various lengths of line-wire.

Suppose then a series of bobbins provided, which in this sense represent various lengths of line-wire from 100 feet to 300 miles, and let means be provided of placing them in metallic connection in convenient cases. Such an apparatus is that by which the Messrs. Bright detect the points of fault.

Let B (Fig. 85) be the station-battery; G a galvanometer upon the line-wire; F the point of fault at which the current escapes to

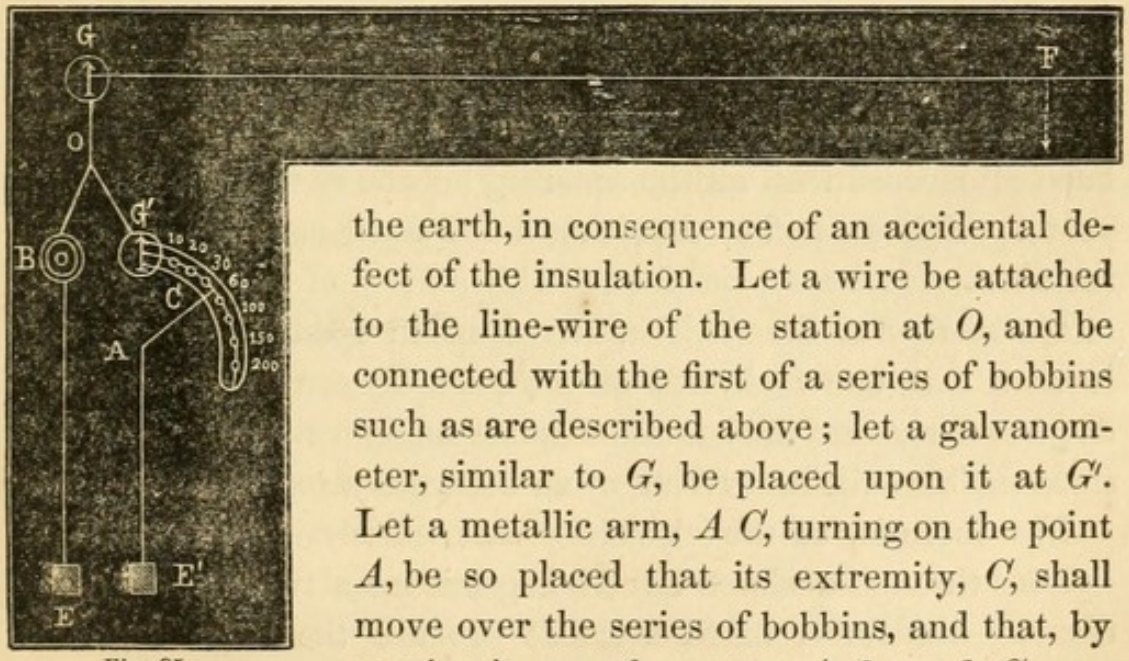


Fig. 85.

the earth, in consequence of an accidental defect of the insulation. Let a wire be attached to the line-wire of the station at O, and be connected with the first of a series of bobbins such as are described above; let a galvanometer, similar to G, be placed upon it at G'. Let a metallic arm, $A\ C$, turning on the point A, be so placed that its extremity, C, shall move over the series of bobbins, and that, by moving it upon the centre, A, the end, C, may be placed in connection with the wire of any bobbin of the series. Let A be connected by a conducting-wire with the earth at E';

the negative pole of the battery, B, being connected with the earth at E.

The apparatus being thus arranged, let us suppose that the wire $A\,C$ is placed in connection with the first bobbin, representing 10 miles of the line-wire, and that the distance, $G\,F$, of the point of fault is 145 miles. In that case, the battery-current will be divided at O between the two wires $O\,G$ and $O\,G'$, but the chief part will flow by the shortest and easiest route, and the galvanometer G' will be very much, and G very little deflected. This will show that F must be very much more than 10 miles from the station. The arm $A\,C$ will then be turned successively from bobbin to bobbin. When directed to the second bobbin, the current on $O\,G'$ will have the same intensity as if it flowed on 20 miles of line-wire; when turned to the third, the same as if it flowed on 30 miles of line-wire; and so on. The needle of G' will therefore continue to be more deflected than that of G, although the difference will be less and less as the number of bobbins brought into the circuit is increased. When the bobbins included represent 140 miles, G' will be a little more, and when they represent 150 miles it will be a little less deflected than G, from which it will be inferred that the point of fault lies between the 140th and 150th mile from the station. A closer approximation may then be made by the introduction of shorter bobbins, and this process may be continued until the place of the fault has been discovered with all the accuracy necessary for practical purposes. This method of detecting faults is the one adopted in the series of experiments instituted with a view of ascertaining the exact locality of the fault in the Atlantic Cable. When there is more than one fault, and only a partial exposure of the conducting-wire, the tests become more complicated, and require considerable skill in arriving at an accurate solution.

The intensity of the electricity that travels in the form of a current through a closed circuit depends upon two circumstances alone, — the force, or forces, that produce the electricity, and which we may call electro-motive forces, and the resistances to conductibility presented by all the circuit taken together. This latter element, which had never previously been taken into ac-

count, was pointed out by De la Rive, in 1825. In an important work, which appeared in 1827, M. Ohm, as a result of purely theoretical speculation, came to the conclusion that the force of the current in a closed circuit is directly proportional to the sum of the electro-motive forces that are in activity in the circuit, and which we will call E, and inversely proportional to the total resistance, or the sum of the resistances of all the parts of the circuit, which we will designate by R; in other words, that the intensity of the current, I, is equal to the sum of the resistances; $I = \frac{E}{R}$.

A law which arises immediately out of the preceding is, that, if we increase or diminish the resistance of any part of a circuit, the total intensity of the current diminishes or increases, all other circumstances remaining the same, in a proportion which is the same as that existing between the resistance added or removed, and the total new resistance of the entire circuit.

If, in the formula $I = \frac{E}{R}$, R becomes $R + r$ or $R - r$, I becomes $\frac{E}{R+r}$ or $\frac{E}{R-r}$. Calling I' the intensity in the former case, and I'' the intensity in the latter, we have

$$I : I' : I'' = \frac{E}{R} : \frac{E}{R+r} : \frac{E}{R-r} = \frac{1}{R} : \frac{1}{R+r} : \frac{1}{R-r};$$

whence we deduce,

$$I - I' : I = r : R + r, \text{ and } I'' - I : I = r : R - r;$$

namely, that the diminution of intensity is to the primitive intensity as the added resistance, r, is to the new total resistance, $R + r$; and the increase, $I'' - I$, is to the primitive intensity as the suppressed resistance, r, is to the new total resistance, $R - r$.

THE TELEGRAPH LINES OF THE UNITED STATES.

The first line of electric telegraph constructed in the United States was between Washington and Baltimore, in May, 1844, over a distance of 40 miles. It was then extended to Philadel-

phia and New York, over a distance of 250 miles. It reached Boston in 1845, and became the great line of the North, from which branched two others; — one, of the length of 1,000 miles, from Philadelphia to Harrisburg, Lancaster, Pittsburg, Columbus, Cincinnati, Louisville, and St. Louis; the other, of the length of 1,300 miles, from New York to Albany, Troy, Utica, Rochester, Buffalo, Erie, Cleveland, Chicago, and Milwaukie.

A fourth line was constructed from Buffalo to Lockport, Queenstown, the Lakes Ontario and Erie, the cataract of Niagara, Toronto, Kingston, Montreal, Quebec, and Halifax, over an extent of 1,395 miles.

Two lines were constructed south; — one from Cleveland to New Orleans, by Cincinnati; the other from Washington to New Orleans, by Fredericksburg, Charleston, Savannah, and Mobile. The first is 1,200 miles long; the second, 1,700 miles.

The line between Washington and Baltimore is the only one constructed under governmental patronage, the remainder having been projected by private enterprise, the patentee being allowed one half the stock for the use of the patent, as his share of the investment. The capital invested in the Morse lines alone up to January 1, 1850, was $ 400,000, exclusive of the patent-right, upon which Mr. Morse up to that time had received some $ 30,000.

At a very early period in the history of the electric telegraph in the United States, a misunderstanding occurred between the Morse patentees and Mr. Henry O'Reilly, a contractor under them, the result of which was that rival lines were constructed throughout the country before the system had been sufficiently developed to be remunerative, even without such competition.

The invention of the letter-printing telegraph by Mr. House, in 1846, and the introduction of the electro-chemical telegraph of Mr. Bain into this country, in 1849, greatly facilitated the construction of competing lines.

The first line operating under the House patent was completed in March, 1849, by the New Jersey Magnetic Telegraph Company (since, the New York and Washington Printing Telegraph Company) from Philadelphia to New York City. They were

incorporated by the Legislature of New Jersey, with a capital stock of $100,000.

The Boston and New York Telegraph Company, using the same patent, was completed in the autumn of the same year, and was followed by one from New York to Buffalo, and subsequently to St. Louis and Chicago.

During the year 1849, which was very prolific in the production of competing lines, the Bain patent was introduced upon lines extending between New York and Boston, New York and Buffalo, and New York and Washington; and in the succeeding year, upon lines extending between Boston and Montreal, and Boston and Portland.

In 1851, there were seven Bain lines in operation in the United States having over 2,000 miles of wire; eight House lines, having about 3,000 miles of wire; and sixty-seven Morse lines, having 20,000 miles of wire.

In the autumn of this year, the Magnetic Telegraph Company, having lines extending between New York and Washington, and the Bain company having lines over the same route were consolidated; and in the succeeding spring the Morse and Bain lines extending between New York and Boston were united under one company. The union of these lines was followed by that of the New York and Buffalo Morse and Bain lines, and subsequently by those of the House company between these points. The lines of the Rhode Island Telegraph Company, extending from Worcester to Providence, Fall River, Taunton, New Bedford, Warren, and Bristol, were sold, March 1, 1853, to the New York and New England Union Telegraph Company (the Morse and Bain united) for $5,000. The cost of these lines, including the patent, was $20,000.

In the autumn of 1853, all the leading telegraph lines in the West, South, and Northwest were united in business interests. Among these are the New Orleans and Ohio line, extending from New Orleans to Pittsburg; the People's line, from New Orleans to Louisville; the Louisville, Cincinnati, and Pittsburg line; the Western line, from Wheeling and Pittsburg to Baltimore and Washington City; and the lines between Buffalo and

Chicago, — all direct parties to the contract securing these arrangements.

The New York and Erie Telegraph line, built by E. Cornell and J. J. Speed, was also united by a lease with the New York and Buffalo Morse company.

In 1853, therefore, out of the large number of competing lines which had been constructed, there remained only the House lines between New York and Washington, and New York and Boston, — all the others having been consolidated with, or sold out to, rival lines.

As a new era in the history of the electric telegraph opened at this period, it is perhaps worth while to look over the scanty data at hand, and ascertain how the lines were paying.

From the Annual Report of the Magnetic Telegraph Company, extending between Washington and New York, for the year ending June, 1852, we find that the number of messages transmitted during the year was 253,857, the receipts upon which amounted to $ 103,232.37.

In 1847, the receipts of this company, which was the first organized in the country, were $ 32,810; in 1848, $ 52,252; in 1849, $ 63,367; in 1850, $ 61,383; in 1851, $ 67,737.

In January, 1852, the Magnetic Telegraph Company became possessed of the wires of the Bain line, by which its facilities were increased and its business augmented beyond what it would have been without such facilities.

In 1848, this company paid six per cent dividend; in 1849, nine per cent; in 1850, two per cent; in 1851, two per cent; in 1852, nine per cent, — upon a capital of $ 370,000.

The Maine Telegraph Company constructed a line extending from Portland to Calais, Maine, 306 miles in length, in 1848, which has proved one of the most profitable lines in the world. From the date of its completion until its lease to the American Company in 1855, it always paid a handsome dividend, generally twenty per cent per annum, and in 1853 the surplus earnings enabled the company to purchase the lines between Portland and Boston, when fifty per cent in stock was divided among the stockholders.

In 1855, the company voted to lease their lines for a term of years to the American Telegraph Company, receiving for rent ten per cent per annum upon the capital stock. The American Telegraph Company also leased the New Brunswick line, extending from Calais, Maine, to Sackville, N. B.; the Northern line, extending between Boston and Burlington, Vt.; the Troy and Canada Junction line, extending between Troy and Montreal; and the Sandy Hook line, extending between New York City and the Highlands. They also purchased, in 1855, the House lines extending beween Boston and New York, with a branch from Springfield, Mass., to Albany, N. Y.

At the commencement of the year 1860, however, they accomplished a movement which has created quite a revolution in telegraphic affairs upon the seaboard routes. This is nothing less than the consolidation of all the lines from Sackville, N. B. to New Orleans; thereby acquiring the exclusive use of all the patents of the various telegraphic apparatus in use.

This company has over 25,000 miles of wire in operation, representing an aggregate capital of $ 1,500,000.

The officers of the American Telegraph Company consist of a President, Treasurer, Secretary, and a board of twelve Directors. The administration of the affairs of the lines is entrusted to an Executive Committee consisting of three members of the Board of Directors. The company employs twelve superintendents, four hundred and fifty operators and clerks, six hundred messengers, and one hundred and fifty repairers.

A most liberal and commendable spirit has been exhibited by this company towards its *employés*, in the payment of remunerative salaries, as well as in providing a *corps* of operators and clerks in each office sufficient for the easy performance of its duties. The company is also liberally expending large sums of money in rebuilding, and thoroughly insulating, its lines, so that in the course of a few months the lines along the Atlantic seaboard will rival in excellence those of any part of the world.

It is understood that the leading telegraph companies of America have entered into an arrangement for mutual protection, the object being to prevent the establishment of rival lines over the

routes occupied by the present companies. By this agreement, each company pledges itself, in case competing lines are constructed over any route already occupied, to share the expense of crushing out such rival line, by putting the tolls upon the route in question at a mere nominal sum, and keeping them so as long as the competing line exists.

There is no question but that one company can do the telegraphic business between any points upon the same route much cheaper and better than two or more. There is a striking analogy between the telegraph and the mail service, and no one will deny that one company can manage the postal service better than two. It is therefore unquestionably for the interest of all who have occasion to use the wires, — and who has not? — that they be managed by a capable, liberal, and high-minded company, — and such, we are confident, the public will find in the American Company.

It is announced in the journals of the day, that a rival line is about to be constructed between Boston and New York; and if the announcement is correct, we may shortly expect cheap telegraphic facilities between these important points.

Without wishing to enter into any discussion as to the necessity of more telegraphic facilities in this country, we feel it our duty to suggest to gentlemen who may feel inclined to invest their money in telegraphic schemes, that they may find them more seductive than remunerative. Few of the stockholders who have contributed the millions of dollars expended in constructing telegraph lines in this country have ever received any return for their investment, and we must acknowledge that the chances in the future are not very promising. There is one institution, however, able to construct lines of telegraph, and to maintain them against any combination which can be brought against it, namely, the Associated Press. This association pays to the various telegraph companies about $ 200,000 per annum, — a sum sufficient to maintain a line of telegraph from Halifax to New Orleans. The public, therefore, need not fear an odious monopoly; for whenever the existing arrangements should lead to such a result, the Press, having the means, will not long delay the application of a remedy.

PART VIII.

ELECTRICAL DISTURBANCES UPON TELEGRAPH LINES.

CHAPTER XVIII.

ATMOSPHERIC ELECTRICITY.

TRANSMISSION upon the electric telegraph lines is not always as regular as could be desired, even when the wires are in good order and well insulated. We shall examine, in this chapter, the different influences which affect the operation of the apparatus.

The electric atmosphere is the most frequent cause which deters or prevents transmission. During storms, we see that the apparatus works irregularly, interrupting the passage of strong currents instantaneously, and often produces upon the apparatus in the offices, between metallic points, bright sparks; the armatures of the electro-magnets are drawn up with great force, and the wires and other metallic substances about the instruments fused. We observe also, but more rarely, currents, which continue for a longer or shorter time, that prevent all working.

The theory of atmospheric electricity explains equally well all these phenomena; — free electricity, which is manifested during thunder-storms, being the cause of the former; and electricity of a lower tension, manifested during a display of the aurora-borealis, causing the latter.

In order to comprehend this matter fully, before going into the details of the effects upon the lines, let us examine the causes and nature of atmospheric electricity.

We must give to Franklin the credit of establishing the proof that the phenomena of lightning, of thunder, and of the effects of lightning are due to electricity. Before him, the identity that exists between these electric phenomena had been greatly suspected. After having produced, for the first time, the electric spark, Doctor Wall immediately compared it to claps of thunder. The analogy was striking, and philosophers endeavored to establish it by approximations more or less ingenious. But all passed away in reasoning, from which nothing could be concluded, because in physics it is experiment alone which must decide. Franklin therefore entertained the bold thought of going to seek for electricity in the very bosom of the clouds. As the question was only to convey a body into the region of thunder, he conceived the idea of employing the kite; and, after some fruitless attempts, he succeeded in drawing from the extremity of the string which held the kite, that was thrust into the midst of the clouds, a bright spark, which was followed by several others.

The air under a perfectly serene sky is constantly positive, but this positive electricity is not uniformly distributed in the atmosphere; it is, it is true, at very nearly the same intensity in a horizontal stratum, but stronger in the upper strata, and stronger still as we rise higher. At the surface of the ground the electricity is null; it does not begin to be sensible in the open country until about a yard and a half above the ground. When there are on the surface of the ground trees, buildings, in a word, elevated bodies, the height at which the air begins to give signs of positive electricity becomes greater. It evidently seems that the air and the earth are charged with contrary electricities, which recombine continually in the lower strata of the atmosphere, either directly or by the intervention of bodies placed upon the surface of the ground.

Observations, with the view of proving the annual variations of the electricity of the air, were made each day about noon, and commenced in August, 1844. The results of each year perfectly accord, and may be summed up in the following manner: — 1st. Atmospheric electricity, considered in a general manner, attains its maximum in January, then decreases progressively

until the month of June, which presents a minimum of intensity; it increases during the following months to the end of the year. 2d. The maximum and the minimum of the year have for their respective values 605° and 47°, so that the electricity in January is thirteen times as energetic as in the month of June.

The difference between the maximum and minimum is much more sensibly felt during serene weather than during cloudy weather. During the different months, the electricity of the air is more powerful when the sky is serene than when it is cloudy, except toward the months of June and July, when the electricity attains a maximum, the value of which is nearly the same, whatever be the state of the sky.

The electric intensity observed during fogs has, at a mean, almost exactly the same value as that observed during snows. This value is very high, and corresponds to the mean maxima observed for the former and the latter months of the year.

A very remarkable fact, which appears from recent observation, is that moisture acts in a manner altogether different in the cold months and in the hot ones; it increases the electricity in the winter months, it diminishes it in the summer months. The fundamental fact is, that humidity acts in two manners, the effects of which tend to oppose each other. On the one hand, it facilitates the escape of the electricity accumulated in the upper regions of the atmosphere to the stratum in which the observation is made; on the other hand, it facilitates the escape into the ground of the electricity which this stratum possesses: thus, on the one hand it increases the intensity of the electric manifestations of the instrument, on the other hand it diminishes them.

According to M. Peltier, the terrestrial globe is completely negative, and inter-planetary space positive; the atmosphere itself has no electricity, and is only in a passive state; so that the effects observed are due to the relative influence of these two great magazines of electricity. With regard to ourselves, without discussing for the present this opinion, we are disposed to assume that the terrestrial globe possesses, at least on its solid part, an excess of negative electricity, and that it is the same with bodies placed at its surface; but it appears to us to follow,

rrom the various observations made, that the atmosphere itself is positively electrized; this positive electricity evidently arises from the same source as the negative of the globe. It is probable that it is essentially in the aqueous vapors with which the atmosphere is always more or less filled that it resides, rather than in the particles of the air itself; but it does not the less exist in the atmosphere.

STORMS, AND ACCOMPANYING ELECTRIC PHENOMENA.

When the sky is not serene, the normal electric state of the atmosphere suffers notable disturbances. The formation of a cloud or of a fog is always accompanied with a change of distribution in the electricity of the stratum of air in which this formation takes place. It is probable that the positive electricities with which each particle of vapor is charged are united in the globule formed by the reunion of several of these particles at the moment when their precipitation takes place. The globules are themselves, as we know, so many small spherical balloons, in which a small pellicle of water serves as an envelope to the interior air; now, it is this stratum of water that possesses all the positive electricity which was distributed among the multitude of particles of vapor which have served towards its formation.

When a storm-cloud, and consequently one powerfully electrized, approaches the earth, it decomposes by induction the natural electricity of all the more or less conductive parts that are at the surface of the ground. Its action may be arrested there, if the wind brings near it another cloud, endowed, naturally or by induction, with an electricity contrary to its own; the explosion then takes place between the two clouds, and the portion of terrestrial surface whose electricity has been decomposed reverts to the natural state. But it may happen, also, that the discharge takes place between the cloud and the ground; in this case it will be the objects that are nearest to the cloud, among those whose natural electricity is susceptible of decomposition, which will serve to transmit this discharge, and which, consequently, will be struck by lightning.

Whatever may be the place where the lightning falls, it tends in preference towards the conducting bodies that are found there, and towards metals. Thus lightning, in falling upon a house, sometimes carries away all the gildings that are found there, without injuring any of the inmates; it may traverse the metal rods and wires of a house without leaving any other trace of its passage than the fusion of the wires, whilst the conducting-rods, being larger, have suffered no alteration; then it may divide, and traverse the barrel of a fowling-piece placed against a wall, which itself remains intact, whilst the stock is broken and the wall pierced where the end of the barrel was resting against it. It suffices that there be masses of iron, clasps, nails, disseminated in walls, in order that the lightning shall direct itself there, sometimes tearing them out, but more frequently producing in the walls themselves damage more or less considerable.

It will thus be seen, that, the clouds which are above the telegraph line being electrized by positive electricity, and the earth to which the wires are connected being electrized by negative electricity, the wires serve as conductors, through which the two electricities are neutralized, and an equilibrium established.

If the wires were large enough to convey to the earth all the electricity which accumulates upon them, and the different parts of the apparatus were also sufficiently large, there could arise from such discharges no serious consequences beyond the temporary interruption of the working of the line; but as the wires of the electro-magnets are very small, and incapable of containing a large amount of electricity, they are always melted, or burned off, whenever a great discharge is permitted to reach them.

Formerly the line wire was connected with the inner wire of the helices, and whenever there was a considerable discharge of atmospheric electricity, the helices exploded, sometimes causing serious effects.

In the summer of 1846, the helices in the telegraph office at New Haven were exploded in this manner, and the pieces were thrown with great violence across the room, and struck the walls, leaving marks which were not effaced for many years. The report of the explosion was distinctly heard an eighth of a mile off.

In the summer of 1851, an atmospheric discharge came into the office upon the Chemical line in Boston, which melted a hole into the brass disc, and drove the iron pen-wire into it, completely fastening it there as firmly as if it had been brazed. The sky at the time was perfectly serene, and the discharge had traversed the line thirty miles, — the thunder-storm being at that distance from the city, and having shattered several poles at the precise time when the discharge occurred in the office. There was no electro-magnet in the circuit in this instance, and therefore there was no particular injury done to any part of the apparatus.

The line wires now connect with the outer wires of the helices, and whenever a discharge occurs, it generally burns off the small copper wire before reaching the inner part of the coils, and they are thus rarely ever seriously injured.

There have been several kinds of lightning-arresters, or *paratonneres*, as the French call them, and they all serve a very good purpose.

One plan is to place two large, flat surfaces of brass together (Fig. 86), with a thin sheet of oiled silk, or gutta-percha, or even

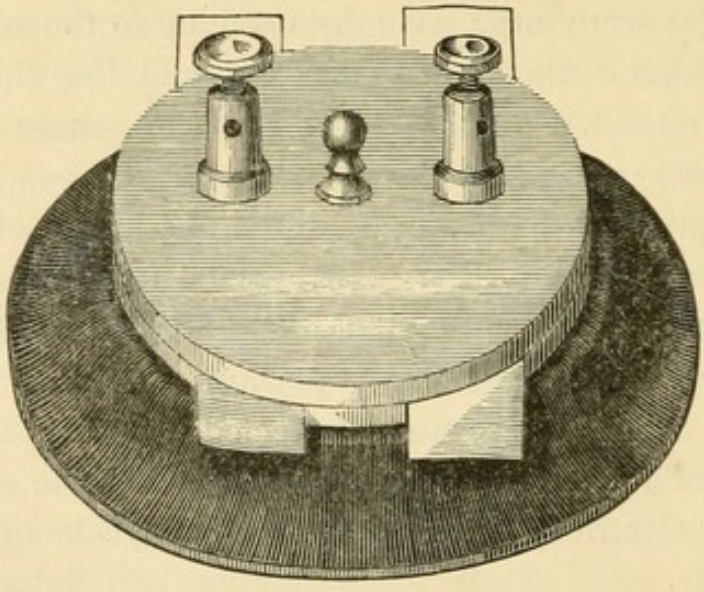


Fig. 86.

paper, between, and to connect one piece of the brass with the line wire and one with the earth. The atmospheric electricity, being of such high tension, prefers to pass through the thin sheet of paper, and thus reach an excellent conductor to the earth, rather than

through the small wire conductor which leads to the apparatus (Fig. 87).

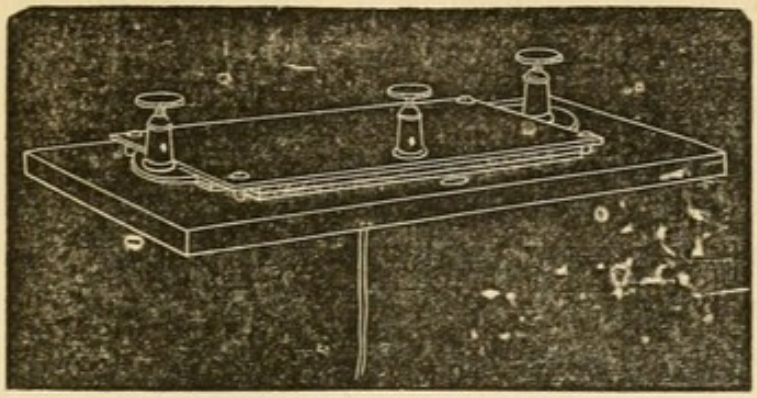


Fig. 87.

Another plan is to line a small wooden box with sheets of tin, which is then filled with iron filings. The sheets of tin are connected with the earth; and the line wire, after being covered with oiled silk, is passed through the iron filings. The atmospheric electricity is attracted by the myriads of fine points presented by the filings, and is thus carried off to the earth. It is hardly necessary to say, that the galvanic electricity is of so low a tension as to require a conductor without solution of contact, and is thus entirely unaffected by the filings or the brass plates, which are not in contact.

Another excellent plan is to wind around a brass cylinder, which is connected with the earth, a dozen feet of silk-covered wire of very small size; the atmospheric electricity would pass the light barrier of the silk and into the earth, while the galvanic currents would not be affected.

We have found a few feet of small wire, intervening between the air-lines and the submarine cables, an effectual remedy against atmospheric injury. Some have used other kinds of lightning-arresters for this purpose. It is rather difficult to keep any kind of apparatus dry in so exposed a situation, and therefore for this purpose we give the preference to the simple coil of silk-covered wire.

Several other inventions have been contrived for protecting telegraphic apparatus from the effects of atmospheric electricity. Among the number, we will mention the following,

which is founded upon the resistance that is presented by alcohol to the passage of the electric current. It consists of a conductor in the form of an arc placed in the interior of a vessel filled with alcohol; in the middle and very near the vertical branches of this conductor, and parallel to these branches, rises a metal rod, which is toothed, as is also the plate itself, which is in the form of an arc; this rod is terminated in a point toward the summit of the arc, but without touching it, and is in communication with the ground by its lower extremity. In order to arrive at the telegraph, the line current is obliged to traverse the plate, which is also well insulated by means of the alcohol, so that the current cannot be diverted; but as soon as atmospheric electricity accumulates in it, it is transmitted by means of the points, or closely approximated teeth, to the interior rod, and thence to the ground.

M. Hipp, having remarked that the induced current due to the action of atmospheric electricity tends to leap, according to its direction, from a point to a plate, and never from a plate to a plate, or from a point to a point, has arranged lightning-conductors upon the Swiss lines so that the discharge always finds means to leap from a point to a plate, whatever be the direction in which it is travelling. With this view, he interposes in the line wire a metal plate, traversed by two metal points, below and very near to which is a second plate communicating with the ground, and furnished also with two points, likewise very near to the former plate.

These latter forms of lightning-conductors, the primitive idea of which belongs to Steinheil, who was the first to think of placing telegraphic apparatus beyond the action of atmospheric electricity, rest upon the principle that this electricity, like that which is developed by frictional electric machines, tends to pass under the form of a spark by the shortest path, even when there is an insulating interval, provided that it be very small; whilst the electric current that is derived from a voltaic battery requires for its transmission a continuous circuit, and will traverse this circuit even were it several hundreds of miles in length, rather than follow a shorter route that might present a slight interruption. This principle, which is a consequence of the difference of

tension that exists between electricity produced according to the former mode, and that which is produced according to the latter, is confirmed by the observation of Steinheil, who found, before he had furnished the telegraphic stations with lightning-conductors, that, when the line wire is found charged with atmospheric electricity, this electricity leaps forth in sparks from one end to the other of the wire of the telegraphic apparatus, instead of following all the contortions of this wire, as does the current which is intended for giving signals. However, this is not always the case, especially when the action of atmospheric electricity upon the line wire is an inductive action, which produces in this wire an instantaneous current, the effect of which is to cause necessarily a disturbance in the indications of the apparatus, but yet without producing in them any damage or serious accidents.

NATURAL CURRENTS.

The electric lines are constantly traversed by feeble currents, independent of the instantaneous or continued currents which are produced by storms; the causes of the former are very diverse, and as yet little understood.

We have found by investigation that the accumulation of electric tension from the atmosphere, which varies each instant of the day, can determine in the wires an electric movement; the differences of temperature at the different points of the line can equally give place to a little electro-motive force; but the most general cause is, without doubt, the development of electricity produced by chemical action, which operates by the contact of bodies placed in the earth to make communication between the batteries and apparatus and the common reservoir.

In order to have a good communication with the sun, we place in a damp vessel a mass of iron sufficiently large: the water which surrounds these electrodes contains always some salts, which produce, with the iron, chemical reactions in sufficient quantities to develop an electric current. These currents are in general very feeble, and without action upon the apparatus in which the electro-magnets are used; but we can observe them by

the aid of sensitive galvanometers. We have had much experience with these currents, and believe they are manifested in certain places periodically, but varying in feeling and intensity.

In volcanic countries they appear to have much greater intensity, and their origin is without doubt different.

Upon submarine lines these currents are extremely remarkable; they acquire at certain times a great degree of energy, and produce upon the needle of the galvanometer singular oscillations. Some attribute them to an electric movement in the sea, the nature and cause of which are unknown. It is principally in the changes of the weather that they are observed. They often interrupt transmission.

Between Calais and Dover these currents are often observed so strong as to deviate the needle of the galvanometer having forty turns of wire, 80°. The needle goes ordinarily from one extreme to the other upon the graduated limb of the galvanometer, and passes by the zero; the duration of each of these oscillations is about a quarter of an hour; they grow more feeble, and cease entirely in two or three hours.

It is only after a great number of experiments that we can determine the true cause of these phenomena; and take from the results facts for the advancement of natural science.

RETURN CURRENTS.

If we send a current of electricity through a submarine telegraphic line between two distant points, and then instantly put the end having the battery in connection with the earth, leaving the battery disconnected, we shall find the armature of the electromagnet will be drawn up, and then fall back through the action of a return current. These currents are of very brief duration, but vary according to the length of the lines; — the more lengthy the line, the greater the length of time during which the return currents continue. The duration of these currents is often so short, that the circuit of the local battery is not closed long enough to make a signal.

CHAPTER XIX.

TERRESTRIAL MAGNETISM.

We have already spoken, in Part I. page 38, of the property that is possessed by magnets, of assuming a determinate direction, under the influence of the terrestrial globe. We will now consider the force which produces that direction, and which is designated under the name of *terrestrial magnetism*. It is one of the modes of manifestation of the natural sources of electricity, since magnetism itself is only a particular form of electricity. The magnetic force of our globe is manifested at its surface by three classes of phenomena; namely, the *declination* of the magnetized needle, its *inclination*, and the *intensity* with which the force acts. The declination is the angle that is formed with the direction of the meridian of the place by the direction of the magnetized needle placed upon a vertical pivot. The inclination is the angle that is formed with the horizon in the magnetic meridian by the direction of a magnetized needle sustained by its centre of gravity, around which it is able to turn freely in a vertical plane. These three elements, declination, inclination, and intensity, vary not only from one place to another, but in the same place, with time. They also manifest irregular and accidental variations, designated under the name of *disturbances*, and the existence of which is connected with the presence of some natural phenomenon, such, in particular, as that of the aurora borealis.

It is well established that the forces which act upon the magnetized needle emanate directly from the terrestrial globe. But what is this magnetism? Where does it reside? What is its form, its distribution, its origin?

Gilbert thought the earth a magnet, and that it has consequently two magnetic poles, tolerably near to its terrestrial poles. Halley, in order to explain all the phenomena of terrestrial mag-

netism, found it necessary to admit the existence of four poles. Hansteen arrived at the same conclusion, and assigned the place to these four poles. It is necessary, under this hypothesis, to admit that the earth is traversed by two magnets, crossing each other in its centre, the axes of which form a certain angle. It is true that there exists in the earth a magnetic oxide of iron, endowed with polarity, and Humboldt has made some curious observations upon the polar magnetism of certain rocks, and even of a mountain; but besides our being unable to admit that the earth contains a quantity of these magnetic rocks sufficient to constitute terrestrial magnetism, we could not comprehend to what would be due the regular distribution which their magnetic polarity would assume. Gauss considers that the whole mass of the globe is magnetic, and that there exist a great number of magnetic centres.

Mr. Barlow, after having demonstrated that neither the presence of a single magnet, nor the arrangement of several magnets in the interior of the globe, could produce the phenomena of terrestrial magnetism, considers that, on the contrary, we may very well account for them by assuming, as Ampère did, *electric currents*, circulating around the terrestrial globe in a direction very nearly from east to west. He has endeavored to confirm this hypothesis by distributing upon the surface of a wooden globe a series of electric currents, arranged so as to produce upon a magnetic needle, not subject to terrestrial influence, and placed in divers positions, the same kind of action that the earth imparts to it in analogous positions (Fig. 88).

De la Rive considers that the forces which produce terrestrial magnetism have their origin in the solidified portion, that is, in the solid crust of the terrestrial globe, which does not prevent the points of application of their resultants being in the interior of the globe, more or less near to its centre; and hence the idea of electric currents circulating in this solid envelope, and forming a solenoid more or less complicated, appears to him most natural. But whence arise these currents, and what is the cause by which their direction is determined? In order to explain atmospheric electricity, a production of electricity is assumed,

resulting from chemical actions which take place in the interior of the terrestrial globe; but we cannot comprehend how this de-

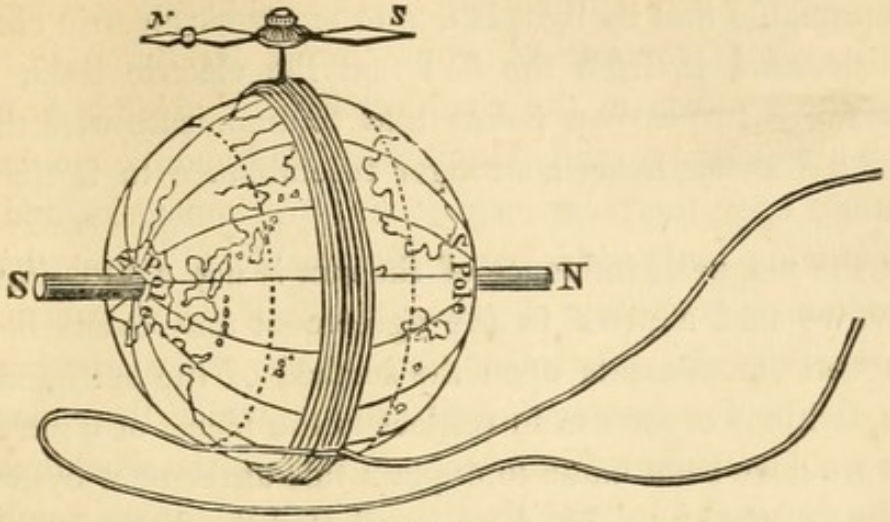


Fig 88.

velopment of electricity should give rise to currents circulating from east to west. This direction must evidently be connected with the movement of rotation of the earth, which takes place from west to east; and consequently it is only in the existence of *induced currents*, arising from a magnetic action exterior to the earth, but susceptible of being exercised upon it, that the confirmation may be found of the hypothesis of Ampère, adopted by Mr. Barlow.

Indeed, the inductive currents are connected, more or less, according to their direction, with the direction of the movement of the induced body; and we know that on causing a body to rotate rapidly on its axis, under the influence of a magnetic pole, we are able to produce in it continuous induced currents. But where would the inducing body be, when the terrestrial sphere is in question? Evidently, it could only be found in the moon or in the sun. The moon plainly exercises an influence over the movements of the magnetized needle; but this influence is very feeble, and nothing enables us to discover traces of magnetism or of dynamic electricity in the moon, the mass of which, besides, is too small in respect to the earth for us to suppose that it can act upon it. It would be much more likely that the earth should act upon the moon.

It is only in the sun that we can find a body exterior to the earth capable of exercising upon it an inductive action. The sun appears to possess powerful electro-dynamic properties, for it is very probable that its light is due to energetic electric currents, which surround it, from the fact that the electric light, which plays between two carbon points that communicate with the two poles of a battery, bears a stronger resemblance to it than any other.

That the magnetic influence of the sun is not a gratuitous hypothesis, we find a proof in the agreement that exists between the magnetic movements upon the surface of the earth, and the various positions of the sun in respect to the places of observation. Endeavors have been made to explain this agreement by an indirect action of the sun. M. Aimé attributed the diurnal variations of the magnetic elements to thermo-electric currents, all emanating from the most heated point, — a point which, changing its place with the sun, must make the turn of the globe in twenty-four hours; so that, in every place on the earth, except upon the parallel in which is the centre of the action, the direction and the force of the currents change throughout the day. But this hypothesis has against it, independently of a general objection, the small probability of the existence of thermo-electric currents upon the surface of the earth, either on account of the imperfect conductibility of this surface, or on account of the enormous proportion of water that it presents, which is not susceptible of thermo-electricity.

Faraday attributes the magnetic variations to the magnetic properties of the oxygen of the atmosphere, — properties which follow, in their degrees of force, the variations of temperature, in such a manner that heating reduces and cooling exalts them.

Father Secchi concludes from all the phases which the variation of declination undergoes, that *the sun acts upon the magnetized needle as if it were itself a large magnet, placed at a great distance from the earth, and having its poles of the same name as those of the earth turned to the same side of the heavens.* But in order to recognize the accuracy of these laws, regard must be had to the inverse action which the needle undergoes on the part of the sun in the twenty-four hours, by the effect of the rotation of the

earth, the front of the needle that faces the sun being different at noon and at midnight, and the earth being interposed at the second epoch.

There are, however, other causes which affect the magnetized needle. M. Arago observed, on February 19, 1822, an extraordinary agitation in the needle of diurnal variations, and there was at the same moment a strong earthquake in Auvergne, at Lyons, and in Switzerland. Mr. Gray likewise observed in Valdivia, on the western coast of South America, a very remarkable disturbance in the magnetized needle at the period of a terrible earthquake which took place in those latitudes in February, 1836. But among all natural phenomena, there is one whose connection with terrestrial magnetism is so well established that we have, in the movement which the magnetized needle suffers, a proof of its presence, namely, the aurora borealis.

THE AURORA BOREALIS.

The aurora borealis, or rather the polar aurora, — for there are auroræ australes as well as auroræ boreales, — has been an object of wonder and admiration from time immemorial.

Pliny and Aristotle record phenomena identical with those which later times have witnessed. The ancients ranked this with other celestial phenomena, as portending great events.

In a Bible imprinted at London in the year 1599, the 22d verse of the 37th chapter of Job reads thus: "The brightness commeth out of the Northe, the praise to God which is terrible." The writer of the Book of Job was very conversant with natural objects, and may have referred to the aurora borealis and the phenomena immediately connected therewith.

In 1560, we are told, it was seen at London in the shape of burning spears, a similitude which would be no less appropriate now than then. Frequent displays are recorded during the fifteen years following that date. During the latter half of the seventeenth century, the phenomena were frequently visible, oftentimes being characterized by remarkable brilliancy. After 1745, the displays suddenly diminished, and were but rarely seen for the next nine

years. The present century has been favored to a remarkable degree. The displays during the years 1835, '36, '37, '46, '48, '51, '52, and '59, have been especially grand.

What is the origin of these remarkable phenomena? The ancients asked the question, and the moderns reply by repeating it. Before proceeding to describe the magnificent auroral displays of August 28th and September 2d, let us examine authorities upon this subject, and see if we cannot arrive at some satisfactory solution of the phenomena. The following is the description given by Humboldt in "Cosmos":—

"An aurora borealis is always preceded by the formation in the horizon of a sort of nebulous veil, which slowly ascends to a height of 4°, 6°, 8°, and even to 10°. It is towards the magnetic meridian of the place that the sky, at first pure, begins to get brownish. Through this obscure segment, the color of which passes from brown to violet, the stars are seen, as through a thick fog. A wider arc, but one of brilliant light, at first white, then yellow, bounds the dark segment. Sometimes the luminous arc appears agitated, for hours together, by a sort of effervescence, and by a continuous change of form, before the rising of the rays and columns of light, which ascend as far as the zenith. The more intense the emission of the polar light, the more vivid are its colors, which, from violet and bluish-white, pass through all the intermediate shades of green and purple-red. Sometimes the columns of light appear to come out of the brilliant arc mingled with blackish rays, resembling a thick smoke; sometimes they rise simultaneously from different points of the horizon, and unite themselves into a sea of flames, the magnificence of which no painting could express; for, at each instant, rapid undulations cause their form and brilliancy to vary. Motion appears to increase the visibility of the phenomena. Around the point in the heaven which corresponds to the direction of the dipping-needle produced, the rays appear to meet and form the boreal corona. It is seldom that the appearance is so complete, and is prolonged to the formation of the corona; but when the latter appears, it always announces the end of the phenomenon. The rays then become more rare, shorter, and less vividly colored. Soon nothing further is seen on the

celestial vault than wide, motionless nebulous spots, pale, or of an ashy color; they have already disappeared, when the traces of the dark segment whence the appearance originated still remain on the horizon."

Dr. P. Moulton, of New Rochelle, N. Y., communicates the following description of a remarkable aurora borealis observed by him: —

"In one of my evening rides, about thirty years ago, I witnessed a remarkable display of the aurora borealis in a cloudless sky while the moon was below the horizon. When I first took notice of the aurora, before it was dark, and while the evening shade was growing darker, I saw a veil in the north, with a fringe of light forming an arc, as described by Humboldt in 'Cosmos,' which obscured the stars beyond it. Rays or columns of light of equal length and breadth were seen moving with great regularity, and at first pretty rapidly, from northeast to northwest. They did not, as usual, shoot up from the edge of the dark veil. Their bases appeared to touch the arc, and as they moved between me and the stars, which were visible beyond these transparent stripes, they appeared to me to form a part of some vast machine, or an immense wheel whose axis might be supposed to be at the point where I was observing them, and connected with them by invisible arms radiating from it. These luminous stripes, for they were not like radii diverging from the centre of a circle, appeared, as I said before, to belong to a vast wheel revolving in the heavens; and at this stage of the exhibition or display the scene would appear, to an untrained and superstitious observer, awful and terrific, though nothing was presented to view but grandeur, order, and beauty.

"These luminous stripes (or rays, if you prefer that term) preserved their parallelism as they ascended from the north; and if we suppose the axis to be inclined more and more to the south, and the stripes of light to continue parallel to the imaginary axis till it became horizontal, they would represent an arch which would span the heavens from east to west.

"I would remark here, that the stripes were longest when I first saw them, extending through a space of 40° in height, and that

they moved from the point where they first seemed to be formed, in the northeast, to the northwest, 90° distant, where a column of light appeared which was motionless, and which appeared to me to be formed by the accumulation of the stripes or rays. The spaces between the rays were wider than they were when I first saw them; but the spaces became narrower, and the rays or columns broader and shorter, as they ascended from the sensible horizon, and their motion, as of a revolving wheel, became gradually slower, till it ceased or was imperceptible.

"An hour after I first noticed the veil and rays, I went into a house to visit a patient, and when I came out, half an hour later, instead of rays I saw luminous clouds, not like cirri, but what might be called strato-nimbi, which were in a regular series, extending from east to west like an arch. I regret having failed to watch the phenomena from first to last, as I am much inclined to believe that these strato-nimbi were the rays transformed. When I last saw them, they retained their relative position in regard to each other and to the imaginary axis, and they were progressing towards the south, as if the southern extremity of the axis dipped below, while the northern rose above, the horizon."

The connection that seems to exist, says De la Rive, between the polar light and the appearance of a certain species of clouds, is confirmed by all observers; all have affirmed that the polar light emitted its most brilliant rays when the high regions of the air contained heaps of cirri, — strata of sufficient tenuity and lightness to cause a corona to arise around the light. Sometimes these clouds are grouped and arranged almost like the rays of an aurora borealis; they then appear to disturb the magnetized needle. Father Secchi has remarked, that magnetic disturbances are manifested at Rome whilst the sky is veiled with clouds that are slightly phosphorescent, which, at night, present the appearance of feeble auroræ boreales.

After a brilliant aurora borealis, we have been able to recognize, on the following morning, trains of clouds, which during the night had appeared as so many luminous rays.

The absolute height of auroræ boreales has been very variously

estimated by different observers. It has long been thought that we might determine it by regarding, from two places widely distant from each other, the same part of the aurora,—the corona, for example. But we have started from a very inaccurate assumption, namely, that the two observers had their eyes directed to the same point at the same time,—whilst it is now well proved that the corona is an effect of perspective, due to the apparent convergence of the parallel rays situated in the magnetic meridian; so that each observer sees his own aurora borealis, as each sees his own rainbow. The aspect of the phenomenon depends also upon the positions of the observers. The seat of the aurora borealis is in the upper regions of the atmosphere; though sometimes it appears to be produced in the less elevated regions where the clouds are formed. This, at least, is what follows from some observations, especially from those of Captain Franklin, who saw an aurora borealis the light of which appeared to him to illuminate the lower surface of a stratum of clouds; whilst some twenty-five miles farther on, Mr. Kendal, who had watched the whole of the night without losing sight of the sky for a single moment, did not perceive any trace of light. Captain Parry saw an aurora borealis display itself against the side of a mountain; and we are assured that a luminous ring has sometimes been perceived upon the very surface of the sea, around the magnetic pole. Lieutenant Hood and Dr. Richardson, being placed at the distance of about forty-five miles from each other, in order to make simultaneous observations, whence they might deduce the parallax of the phenomenon, and consequently its height, were led to the conclusion that the aurora borealis had not a greater elevation than five miles. M. Liais, having had the opportunity of applying a method, which he had devised for measuring the height of auroræ boreales, to an aurora seen at Cherbourg, October 31, 1853, found that the arc of the aurora was about two and a half miles above the ground, at its lower edge.

Various observations made by Professor Olmsted, in conjunction with Professor Twining, of New Haven, led him, on the contrary, to fix the elevation on different occasions at forty-two,

one hundred, and one hundred and sixty miles. He claims that it is rarely less than seventy miles from the earth, and never more than one hundred and sixty. He also claims that its origin is cosmical, — or, in other words, that the earth, in revolving in its orbit, at certain periods passes through a nebulous body, which evolves this strange light in more or less brilliancy, as the body is larger or smaller. To support this theory, he attempted to establish that there were fixed epochs for its display in the highest degree of brilliancy. The length of these periods was from sixty to seventy years, and the next appearance was to be in 1890. The remarkable displays of August 28th and September 2d show the fallacy of his conclusions in this respect.

Mairon and Dalton had also thought that the aurora borealis was a cosmical, and not an atmospheric phenomenon. But M. Biot, who had himself had an opportunity of observing the aurora in the Shetland Isles in 1817, had already been led to recognize it as an atmospheric phenomenon, by the consideration that the arcs and the coronæ of the aurora in no way participate in the apparent motion of the stars from east to west, — a proof that they are drawn along by the rotation of the earth. Hence, almost all observers have arrived at the same conclusions; we will in particular cite MM. Lottin and Bravais, who have observed more than a hundred and forty auroræ boreales. It is therefore now clearly proved that the aurora borealis is not an extra-atmospheric phenomenon. To the proofs drawn from the appearance of the phenomenon itself we may add others deduced from certain effects which accompany it, such as the noise of crepitation, which the dwellers nearest to the pole affirm that they have heard when there is the appearance of an aurora, and the sulphurous odor that accompanies it. Finally, if the phenomena took place beyond our planet and its atmosphere, why should they take place at the polar regions only, as they often do?

J. S. Winn, in a letter to Dr. Franklin, dated Spithead, August 12, 1772, says: "The observation is new, I believe, that the aurora borealis is constantly succeeded by hard southerly or southwest winds, attended with hazy weather and small rain. I think I am warranted from experience in saying *constantly*, for in twenty-

three instances that have occurred since I first made the observation it has invariably obtained; and the knowledge has been of vast service to me, as I have got out of the Channel when other men as alert, and in faster ships, but unapprised of this circumstance, have not only been driven back, but with difficulty escaped shipwreck."

Colonel James Capper, the discoverer of the circular nature of storms, remarks: "As it appears that, on all such occasions, the current of air comes in a direction diametrically opposite to that where the meteor appears, it seems probable that the aurora borealis is caused by the ascent of a considerable quantity of electric fluid in the superior regions of the atmosphere to the north and northeast, where, consequently, it causes a body of air near the earth to ascend, when another current of air will rush from the opposite point to fill up the vacuum, and thus may produce the southerly gales which succeed the aurora borealis."

The bark "Northern Light," arrived at Boston from Africa, was at sea on the night of the great exhibition of the aurora borealis, the 28th of August. The vessel was struck by lightning twice, after which the red flames of the aurora burst upon the astonished vision of the crew. Most of them are confident that they smelt a sulphurous odor all night.

M. de Tessan, who, in the voyage of the "Venus" around the world, had the opportunity of seeing a very beautiful aurora australis, which he describes with much care, also considers that this phenomenon takes place in the atmosphere. The summit of the aurora being in the magnetic meridian, it was elevated 14° above the horizon, and the centre of the arc was on the prolongation of the dipping-needle, the dip being about 68° at the place of the observation. M. de Tessan did not hear the noise arising from the aurora, which he attributes to the circumstance that he was too far distant from the place of the phenomenon; but he reports the observation of a distinguished officer of the French navy, M. Verdier, who, on the night of October 13th, 1819, being in the latitude of Newfoundland, had heard very distinctly a sort of crackling or crepitation, when the vessel he was on board of was in the midst of an aurora borealis.

This was also observed in many localities during the aurora of August 28th, 1859. A New York paper, alluding to the subject, remarks: "Many imagined that they heard rushing sounds, as if Æolus had let loose the winds; others were confident that a sweeping, as if of flames, was distinctly audible." Burns, a good observer, if ever there was one, and not likely to be aware of any theories on the subject, alludes in his "Vision" to a noise accompanying the aurora, as if it were of ordinary occurrence:—

> "The cauld blue North was flashing forth
> Her lights wi' hissing eerie din."

It finds confirmation also in the fact, generally admitted by the inhabitants of the northern regions, that, when the auroræ appear low, a crackling is heard similar to that of the electric spark. The Greenlanders think that the souls of the dead are then striking against each other in the air. M. Ramm, Inspector of Forests in Norway, wrote to M. Hansteen, in 1825, that he had heard the noise, which always coincided with the appearance of the luminous jets, when, being only ten years old, he was crossing a meadow covered with snow and hoar-frost, near which no forests were in existence. Dr. Gisler, who for a long time dwelt in the North of Sweden, remarks that the matter of the auroræ borealis sometimes descends so low that it touches the ground; at the summit of high mountains it produces upon the faces of travellers an effect analogous to that of the wind. Dr. Gisler adds, that he has frequently heard the noise of the aurora, and that it resembles that of a strong wind, or the hissing that certain chemical substances produce in the act of decomposition.

M. Necker, who has described a great number of auroræ which he observed at the end of 1839 and at the commencement of 1840, in the Isle of Skye, never himself heard the noise in question; but he remarks that this noise had been very frequently heard by persons charged with meteorological observations at the lighthouse of Sumburgh Head, at the southern extremity of Shetland. M. Necker is not the only observer who has not heard the noise; neither have MM. Lottier and Bravais, who have observed so great a number of auroræ, ever heard it; and

a great many others are in this case. This may be due to the fact that it is necessary to be very near to the aurora in order to hear the crepitation in question, and also to the fact that it is possible that it does not always take place, at least in a manner sufficiently powerful to be heard.

We have just been pointing out, as concomitant effects of the aurora borealis, a noise of crepitation analogous to that of distant discharges, and a sulphurous odor similar to that which accompanies the fall of lightning. M. Matteucci also observed at Pisa, during the appearance of a brilliant aurora borealis, decided signs of positive electricity in the air; but of all phenomena, those which invariably take place at the same time as the appearance of the aurora borealis are the magnetic effects. Magnetized needles suffer disturbances in their normal direction which cause them to deviate generally to the west first, afterwards to the east. These disturbances vary in intensity, but they never fail to take place, and are manifested even in places in which the aurora borealis is not visible. This coincidence, proved by M. Arago without any exception, during several years of observation, is such, that the learned Frenchman was able, without ever having been mistaken, to detect from the bottom of the cellars of the Observatory of Paris the appearance of an aurora borealis. M. Matteucci had the opportunity of observing this magnetic influence under a new and remarkable form. He saw, during the appearance of the aurora borealis of November 17, 1848, the soft iron armatures employed in the electric telegraph between Florence and Pisa remain attached to their electro-magnets, as if the latter were powerfully magnetized, without, however, the apparatus being in action, and without the currents in the battery being set in action. This singular effect ceases with the aurora, and the telegraph, as well as the batteries, could operate anew, without having suffered any alteration. Mr. Highton also observed in England a very decided action of the aurora borealis, November 17, 1848. The magnetized needle was always driven toward the same side, even with much force. But it is in our own country that the action of the aurora upon the telegraph-wires has been the most remarkable.

Our attention was first called in 1847 to the probability of the aurora's producing an effect upon the wires; but, although having an excellent opportunity to observe such an effect, we were not fortunate enough to do so until the winter of 1850, and then, owing to the feeble displays of the aurora, only to a limited extent. In September, 1851, however, there was a remarkable aurora, which took complete possession of all the telegraph lines in New England, and prevented any business from being transacted during its continuance. The following winter there was another remarkable display, which occurred on the 19th of February, 1852. It was exceedingly brilliant throughout the northern portion of our continent. We extract the following account of its effects upon the wires from our journal of that date. We should premise, that the system of telegraphing used upon the wires, during the observation of February, 1852, was Bain's chemical. No batteries were kept constantly upon the line, as in the Morse and other magnetic systems. The main wire was connected directly with the chemically prepared paper on the disc, so that any atmospheric currents were recorded with the greatest accuracy. Our usual battery current, decomposing the salts in the paper, and uniting with the iron point of the pen-wire, left a light blue mark on the white paper, or, if the current were strong, a dark one, — the color of the mark depending upon the quantity of the current upon the wire.

"Thursday, February 19, 1852.

"Towards evening a heavy blue line appeared upon the paper, which gradually increased in size for the space of half a minute, when a flame of fire succeeded to the blue line, of sufficient intensity to burn through a dozen thicknesses of the moistened paper. The current then subsided as gradually as it had come on, until it entirely ceased, and was then succeeded by a negative current (which bleaches, instead of coloring, the paper). This gradually increased, in the same manner as the positive current, until it also, in turn, produced its flame of fire, and burned through many thicknesses of the prepared paper; it then subsided, again to be followed by the positive current. This state of things continued during the entire evening, and effectually prevented any business being done over the wires."

Never, however, since the establishment of the telegraphic system in this country, have the wires been so greatly affected by the aurora as upon Sunday night, the 28th of August, 1859. Throughout the entire northern portion of the United States and Canada the lines were rendered useless for all business purposes through its action. So strongly was the atmosphere charged with the electric fluid, that lines or circuits of only twelve miles in length were so seriously affected by it as to render operation difficult, and at times impossible.

The effects of this magnetic storm were apparent upon the wires during a considerable portion of Saturday evening, and during the whole of the next day. At six P. M. the line between Boston and New Bedford (sixty miles in length) could be worked only at intervals, although, of course, no signs of the aurora were apparent to the eye at that hour. The same was true of the wires running eastward through the State of Maine, as well as those to the north.

The wire between Boston and Fall River had no battery upon it Sunday, and yet there was an artificial current upon it, which increased and decreased in intensity, producing upon the electro-magnets in the offices the same effect as would be produced by constantly opening and closing the circuit at intervals of half a minute. This current, which came from the aurora, was strong enough to have worked the line, although not sufficiently steady for regular use.

The current from the aurora borealis comes in waves, — light at first, then stronger, until we have frequently a strength of current equal to that produced by a battery of two hundred Grove cups. The waves occupy about fifteen seconds each, ordinarily, but we have known them to last a full minute; though this is rare. As soon as one wave passes, another, of the reverse polarity, always succeeds. We have never known this to fail, and it may be set down as an invariable rule. When the poles of the aurora are in unison with the poles of the current upon the line, its effect is to increase the current; but when they are opposed, the current from the battery is neutralized, — null. These effects were observed at times during Saturday, Saturday

evening, and Sunday, but were very marked during Sunday evening.

It is hardly necessary to add here, that the effect of the aurora borealis, or magnetic storm, is totally unlike that of common or free electricity, with which the atmosphere is charged during a thunder-storm. The electricity evolved during a thunder-storm, as soon as it reaches a conductor, explodes with a spark, and becomes at once dissipated. The other, on the contrary, is of very low tension, remains upon the wires sometimes half a minute, produces magnetism, decomposes chemicals, deflects the needle, and is capable of being used for telegraphic purposes, although, of course, imperfectly.

Mr. O. S. Wood, Superintendent of the Canadian telegraph lines, says: "I never, in my experience of fifteen years in the working of telegraph lines, witnessed anything like the extraordinary effect of the aurora borealis, between Quebec and Father's Point, last night. The line was in most perfect order, and well-skilled operators worked incessantly from eight o'clock last evening till one o'clock this morning, to get over, in even a tolerably intelligible form, about four hundred words of the steamer Indian's report for the press; but at the latter hour, so completely were the wires under the influence of the aurora borealis, that it was found utterly impossible to communicate between the telegraph stations, and the line was closed for the night."

We have seen from the foregoing examples that the aurora borealis produces remarkable effects upon the telegraph lines during its entire manifestation. We have, however, to record yet more wonderful effects of the aurora upon the wires; namely, *the use of the auroral current for transmitting and receiving telegraphic despatches.* This almost incredible feat was accomplished in the forenoon of September 2, between the hours of half past eight and eleven o'clock, on the wires of the American Telegraph Company between Boston and Portland, upon the wires of the Old Colony and Fall River Railroad Company between South Braintree and Fall River, and upon other lines in various parts of the country.

The auroral influence was observed upon all the lines running

out of the office in Boston at the hour of commencing business (eight o'clock, A. M.), and it continued so strong up to half past eight as to prevent any business being done; the ordinary current upon the wires being at times neutralized by the magnetism of the aurora, and at other times so greatly augmented as to render operations impracticable. At this juncture it was suggested that the batteries should be cut off, and the wires simply connected with the earth.

It is proper to remark here, that, the current from the aurora coming in waves of greater or less intensity, there are times, both while the wave is approaching and while it is receding, when the instruments are enabled to work; but the time, varying according to the rapidity of the vibrations of the auroral bands, is only from a quarter of a minute to one minute in duration. Therefore, whatever business is done upon the wires during these displays has to be accomplished in brief intervals of from a quarter to half a minute in duration.

During one of these intervals, the Boston operator said to the one at Portland: "Please cut off your battery, and let us see if we cannot work with the auroral current alone."

The Portland operator replied: "I will do so. Will you do the same?"

"I have already done so," was the answer. "We are working with the aid of the aurora alone. How do you receive my writing?"

"Very well indeed," responds the operator at Portland; "much better than when the batteries were on; the current is steadier and more reliable. Suppose we continue to work so until the aurora subsides?"

"Agreed," replied the Boston operator. "Are you ready for business?"

"Yes; go ahead," was the answer.

The Boston operator, Mr. Milliken, then commenced sending private despatches, which he was able to do much more satisfactorily than when the batteries were on, although, of course, not so well as he could have done with his own batteries without celestial assistance.

The line was worked in this manner more than two hours, when, the aurora having subsided, the batteries were resumed. While this remarkable phenomenon was taking place upon the wires between Boston and Portland, the operator at South Braintree informed us that he was working the wire between that station and Fall River — a distance of about forty miles — with the current from the aurora alone. He continued to do so for some time, the line working comparatively well. Since then we have visited Fall River, and have the following account from the intelligent operator in the railroad office at that place. The office at the station is about half a mile from the regular office in the village. The battery is kept at the latter place, but the operator at the station is provided with a switch, by which he can throw the battery off the line and put the wire in connection with the earth at pleasure. The battery at the other terminus of the line is at Boston; but the operator at South Braintree is furnished with a similar switch, which enables him to dispense with its use at pleasure. There are no intermediate batteries; consequently, if the Fall River operator put his end of the wire in connection with the earth, and the South Braintree operator do the same, the line is without battery, and of course without an electrical current. Such was the state of the line on the 2d of September, 1859, when for more than an hour they held communication over the wire with the aid of the celestial batteries alone.

We extract the following communications, on the influence of the aurora borealis upon the electric telegraph-wires, from the American Journal of Science, for January, 1860: —

Observations made at White River Junction, Vt., communicated by J. H. Norris, *Telegraph Superintendent.*

During the forenoon of September 2d, an unusual current of varying intensity was present most of the time on the wires of the Vermont and Boston telegraph. The polarity of this current appeared to change frequently, sometimes being opposite to, and nearly or quite neutralizing, the battery current when an attempt was made to use the line; at other times much increasing the force of the battery current. The auroral current produced the

same marks upon our chemical paper (we use the Bain or chemical system of telegraph) as those produced by the use of the battery. Signals and messages were transmitted between Boston and Manchester *by the sole use of the auroral current.*

Observations made at Springfield, Mass., by J. E. SELDEN.

On the evening of August 28th, upon the Boston and New York circuit, at one moment there was a very heavy current on the wire, and the next none at all. On the Albany and Springfield circuit, a *flash* passed across from the break-key of the telegraph apparatus to the iron frame, the flame of which was about half the size of an ordinary jet of gas. It was accompanied by a humming sound, similar to a heavy current passing between two metal points almost in contact. The heat was sufficient to cause the smell of scorched wood and paint to be plainly perceptible.

Observations made at New York by J. C. CROSSON, *Telegraph Operator.*

On the evening of August 28th, at $7\frac{1}{2}$ o'clock, I experienced considerable difficulty in working, on account of the variation of current. I could work south by constantly altering the adjustment of my magnets, but the magnetism on the eastern circuit was so nearly destroyed that I could do nothing. About ten o'clock I could see nothing of the aurora in the southern hemisphere, yet the same variations of current were manifest upon the line for an hour afterward. There was during this time a very strong turning current from the east, which resembled a reversed current so much that I disconnected my battery and put on a "ground," but I could not then get magnetism sufficient to work a simple armature. At $12^{h.}\ 30^{m.}$ the current from the east assumed a new feature, producing enough magnetism to work quite well, yet wavering and varying in intensity.

Observations made at Philadelphia, communicated by H. EMMONS THAYER, *Telegraph Superintendent.*

On the evening of August 28th, about 8 o'clock, we lost current on all our four wires running from Philadelphia to New York,

and we had strong circuit, as if from a near ground connection; but there was no interruption on wires running south to Baltimore and Washington. At $9^{h.}$ $10^{m.}$ the wires were relieved to a great extent from the influence of the aurora, giving us our usual working current.

On testing wires at 8 o'clock on the morning of September 2d, I found two of our wires, those running *via* Camden and Amboy to New York, strongly under the influence of an aurora. The effect was different from that of August 28th. There was an intensity of current which *gave a severe shock* when testing, giving a reversed current, neutralizing our batteries, and destroying magnetism. On removing the batteries we had a very strong circuit, giving powerful magnetism, but could not raise New York. On the line running from this city to Pittsburg, the operator, Mr. Steacy, succeeded in transmitting a business message to Pittsburg *wholly on the auroral current.* The current was changeable, suddenly disappearing and returning at intervals of from five to ten minutes. The signals were distinct, and the conversation lasted four or five minutes, the operators exchanging remarks as to the singularity of the phenomenon. At 9 A. M. all the wires were relieved from the effects of the aurora, and worked well as usual.

Observations made at Washington, D. C., by FREDERICK W. ROYCE, *Telegraph Operator.*

On the evening of August 28th I had great difficulty in working the line to Richmond, Va. It seemed as if there was a storm at Richmond. I therefore abandoned that wire, and tried to work the northern wire, but met with the same difficulty. For five or ten minutes I would have no trouble; then the current would change, and become so weak that it could hardly be felt. It would then gradually change to a "ground" so strong that I could not lift the magnet. The aurora disappeared at a little after ten o'clock, after which we had no difficulty. During the auroral display, I was calling Richmond, and had one hand on the iron plate. Happening to lean towards the sounder, which is against the wall, my forehead grazed a ground wire. Immediately I received *a*

very severe electric shock, which stunned me for an instant. An old man who was sitting facing me, and but a few feet distant, said that he saw *a spark of fire* jump from my forehead to the sounder.

Observations made at Pittsburg, Pa., communicated by E. W. Culgan, *Telegraph Manager.*

During the aurora of August 28th, the intensity of the current evolved from it varied very much, being at times no stronger than an ordinary battery, and then, suddenly changing the poles of the magnets, it would sweep through them, charging them to their utmost capacity, and compelling a cessation of work while it continued.

On the morning of September 2d, at my request, the Philadelphia operator detached his battery, mine being already off. We then worked with each other at intervals as long as the auroral current continued, which varied from thirty to ninety seconds. During these working intervals we exchanged messages with much satisfaction, and *we worked more steadily when the batteries were off than when they were attached.*

On the night of August 28th the batteries were attached, and on breaking the circuit there were seen not only sparks (that do not appear in the normal condition of a working line), but at intervals regular *streams of fire*, which, had they been permitted to last more than an instant, would certainly have fused the platinum points of the key, and *the helices became so hot* that the hand could not be kept on them. These effects could not have been produced by the batteries.

This seems almost too wonderful for belief, and yet the proof is incontestable. However, the fact being established that the currents from the aurora borealis do have a direct effect upon the telegraph wires, and that the currents are of both kinds, positive and negative, as we have shown in our remarks upon the aurora of 1852, which sometimes left a dark line upon the prepared paper, and at other times bleached it, — it is a natural consequence that the wires should work better without batteries than

with them, whenever a current from the aurora has sufficient intensity to neutralize the current from the batteries.

We will try to be clear upon this point. It makes no difference in working the Morse, or any other system of *magnetic* telegraph, whether we have the positive or the negative pole to the line; but whichever way we point in commencing, the same direction must be continued with all additional batteries put upon the line. Now if we put a battery upon the line at Boston, of say twenty-five cells, and point the positive pole eastward, and the same number of cells at Portland, pointing the positive pole westward, the current will be null, that is to say, each will neutralize the other. Now the aurora, in presenting its positive pole, we will say, increases the current upon the line beyond the power of the magnet-keeper spring to control it, and thus prevents the line from working, by surfeiting it with the electric current; until, presently, the wave recedes and is followed by a negative current, which neutralizes the battery current, and prevents the line from working for want of power. It is plain, therefore, that, if the batteries be taken off, the positive current of the aurora cannot increase, nor the negative decrease, the working state of the line to the same extent as when the batteries are connected; but that, whichever pole is presented, the magnetism can be made use of by the operator for the ordinary duties of the line.

At Springfield, a gentleman who observed the needle of the compass, during the auroral display of August 28th, noticed that it was deflected first to the west, and then to the east, while the waves of the aurora were in motion. The electrotype plates at the office of the "Republican" at that place were so seriously affected by the aurora, that they could not be printed from during the continuance of the phenomenon.

The aurora borealis of August 28th was surpassingly brilliant, not only in the northern portion of this continent, but also as far south as the equator, — as well as in Cuba, Jamaica, California, and the greater portion of Europe. The London newspapers of the 29th contain glowing descriptions of it. A California journal says: "During the last ten years the aurora borealis was never seen in California except on very rare occasions, and then the

light was very faint or barely visible; but on the 28th ult. it appeared in wonderful splendor, the whole northern part of the sky being of a bright crimson; and the same phenomenon, with equal magnificence, was repeated on the night of the 1st instant."

In Jamaica the aurora borealis was witnessed for the first time, perhaps, since the discovery of this island by Columbus. So rare is the phenomenon in those latitudes, that it was taken for the glare of a fire, and was associated with the recent riots.

Mr. E. B. Elliot of Boston, in an interesting article upon the recent aurora, points out the simultaneous occurrence of the auroral display of February 19th, 1852, with the eruption of Mauna Loa, — the largest volcano in the world, situated on Hawaii (one of the Sandwich Island group), — on the 20th of February; on which occasion the side of the mountain gave way about two thirds of the distance from the base, giving passage to a magnificent stream of lava, five hundred feet deep and seven hundred broad.

Again, on the 17th of December, 1857, between the hours of one and four in the morning, there occurred an aurora of unwonted magnificence. The first steamer arriving from Europe after that date brought the following intelligence, which is taken from one of the journals of the day: "An earthquake took place on the night of the 17th, throughout the whole kingdom of Naples, but its effects were most severe in the towns of Salerno, Potenza, and Nola. At Salerno, the walls of the houses were rent from top to bottom. Numerous villages were half destroyed."

Were these coincidences of extraordinary auroras with extraordinary commotions in the physical condition of our globe merely accidental? or are these phenomena due to a common cause? The latter supposition is not improbable, but the question can be fully settled only by further observations.

Mr. Meriam, "the sage of Brooklyn," as the daily journals denominate him, considers the aurora as the result of earthquakes or volcanic eruptions. He also says: "The auroral light sometimes is composed of threads, like the silken warp of a

web; these sometimes become broken and fall to the earth, and possess exquisite softness and a silvery lustre, and I denominate them the products of the silkery of the skies. *I once obtained a small piece, which I preserved.*"

It is due to Mr. Meriam, as well as to the scientific world, to say, that he stands alone in his convictions with regard to the aurora, both in respect of the cause and the effect of the phenomenon.

Having thus illustrated the effects of the aurora, let us now return to the discussion of its causes.

The intimate and constant connection between the phenomena of the aurora borealis and terrestrial magnetism led Humboldt to class under the head of Magnetic Storms all disturbances in the equilibrium of the earth's magnetic forces. The presence of such storms is indicated by the oscillations of the magnetized needle, the disturbance of the currents upon the telegraph-wires, and the appearance of the aurora, of which these oscillations and disturbances are, as it were, the forerunners, and which itself puts an end to the storm, — as in electric storms the phenomenon of lightning announces that the electrical equilibrium, temporarily disturbed, is now restored.

The atmosphere is constantly charged with positive electricity, — electricity furnished by the vapors that rise from the sea, especially in tropical regions, — and, on the other hand, the earth is negatively electrized. The recomposition or neutralization of the two opposite electricities of the atmosphere and of the terrestrial globe is brought about by means of the moisture with which the lower strata of the air are more or less charged. But it is especially in the polar regions, where the eternal ice that reigns constantly condenses the aqueous vapors under the form of haze, that this recomposition must be brought about; the more so, as the positive vapors are carried thither and accumulated by the tropical current, which, setting out from the equatorial regions, where it occupies the most elevated regions of the atmosphere, descends as it advances towards the higher latitudes, until it comes in contact with the earth in the neighborhood of the

poles. It is there, then, chiefly, that the equilibrium between the positive electricity of the vapors and the negative electricity of the earth must be accomplished by means of a discharge, which, when of sufficient intensity, will be accompanied with light, if, as is almost always the case near the poles, and sometimes in the higher parts of the atmosphere, it take place among those extremely small icy particles which constitute the hazes and the very elevated clouds.

There can be no doubt that the occurrence of the phenomenon is materially dependent on the presence in the atmosphere of these particles of ice, forming a kind of thin haze, which, becoming luminous by the transmission of electricity, must appear simply as an illuminated surface of greater or less extent, and more or less cut up. The phenomenon actually takes place in this manner in the parts of the atmosphere that are the most distant from the earth. We perceive what are termed auroral plates of a purple or reddish-violet color, more or less extended, according as this species of veil, formed by icy particles, extends to a greater or less distance from the poles. The tenuity of this veil is such, that it admits of our seeing the stars through the auroral plates. Of its existence, independently of indirect proofs, we have a direct demonstration in the observation of MM. Bixio and Baral, who, being raised in a balloon to a great height, found themselves, on a sudden, although the sky was entirely serene and the atmosphere cloudless, in the midst of a perfectly transparent veil, formed by a multitude of little icy needles, so fine that they were scarcely visible.

If we place the pole of an electro-magnet over the jets of electric light that are made to converge in extremely rarefied air, we shall see that the electric light, instead of coming out indifferently from all points of the upper surface, as had taken place before the magnetization, comes out from the points of the circumference only of this surface, so as to form around it a continuous luminous ring. This ring possesses a movement of rotation around the magnetized cylinder, sometimes in one direction, sometimes in another, according to the direction of the discharge and of the magnetization. Finally, some more

brilliant jets seem to come out from this luminous circumference without being confounded with the rest of the group. Now the magnetic pole exercises over the luminous haze which we have mentioned as always present during an aurora precisely the same action which the pole of the electro-magnet exercises in the experiment just described; and what takes place on the small scale of the experiment is precisely what takes place on the large scale of the phenomenon of the aurora borealis.

The arc of the aurora borealis is a portion of a luminous ring, the different points of which are sensibly at equal distances from the earth, and which centres upon the boreal magnetic pole, so as to cut at right angles all the magnetic meridians that converge towards this pole. Such a ring, seen by an observer placed at the surface of the earth, evidently presents to him the known arc of the aurora; and its *apparent* summit is always necessarily situated in the magnetic meridian of the place.

The diameter of the luminous ring is greater in proportion as the magnetic pole is more distant from the surface of the earth, since this pole must be situated upon the intersection of the plane of the ring with the axis of the terrestrial globe; if we could determine rigorously the position of the aurora borealis, we should then have the means of knowing exactly that of the pole itself.

Each observer sees the summit of the auroral arc at his magnetic meridian; it is, therefore, only those who are on the same magnetic meridian who see the same summit, and who are able by simultaneous observations to take its height.

If the summit of the arc pass beyond the zenith of the observer, the latter is surrounded by the matter of the aurora borealis. This matter is nothing else than aqueous vapors traversed by the discharges, and which are in general luminous only at a certain height from the ground, either because the air is there more rarefied, or because they are themselves congealed, and more capable, consequently, of liberating their electric light. Then it is, that, from being nearer to the spot where the phenomenon is taking place, the observer hears the crepi-

tation, or whizzing, of which we have spoken, especially if he be in an open country and in a quiet place. But if the arc do not attain to his zenith, he is situated beyond the region in which the meeting of the electric currents takes place ; he sees only an arc a little more elevated to the north or the south, according as he is situated in one hemisphere or the other, and he hears no noise, on account of his too great distance. The crepitation is the result of the action of a powerful magnetic pole upon luminous electric jets in its immediate neighborhood. With regard to the sulphurous odor which some observers have perceived, it arises, as does that which accompanies the fall of lightning, from the conversion into ozone of the oxygen of the air, by the passage of electric discharges.

Gisler says, that on the high mountains of Sweden the traveller is sometimes suddenly enveloped in a very transparent fog, of a whitish-gray color, inclining a little to green, which rises from the ground, and is transformed into an aurora borealis. The cirro-cumulus and the hazes become luminous when they are traversed by sufficiently energetic discharges of electricity, and when the light of day is no longer present to overcome their more feeble light. Dr. Usher describes an aurora borealis seen in the open day, at noon, May 24, 1778.

MM. Cornulier and Verdier are convinced, after carefully studying the subject, that there are almost always auroræ boreales in the high polar latitudes, and that their brilliancy alone is variable. This conviction is in accordance with the very careful observations which have now been made for four years in the northern hemisphere. It appears, as the result of these, that the aurora borealis is visible almost every clear night, but it does not show itself at all the stations at the same time. From October to March there is scarcely a night in which it may not be seen ; but it is in February that it is most brilliant. In 1850 it was observed two hundred and sixty-one nights, and during 1851 two hundred and seven. The proportion of nights in which the aurora is seen is much greater the nearer we are to the magnetic pole.

De la Rive, from whose admirable treatise upon Electricity we

have borrowed our general views, and whose theory we have attempted to illustrate in this chapter, concludes that the aurora borealis is a phenomenon which has its seat in the atmosphere, and consists in the production of a luminous ring of greater or less diameter, having for its centre the magnetic pole. Experiment shows, as we have seen, that, on bringing about in rarefied air the reunion of the two electricities, near the pole of a powerful artificial magnet, a small luminous ring is produced, similar to that which constitutes the aurora borealis, and animated by a similar movement of rotation. The aurora borealis would be due, consequently, to electric discharges taking place in the polar regions between the positive electricity of the atmosphere and the negative electricity of the earth. These electric discharges taking place constantly, but with intensities varying according to the state of the atmosphere, the aurora borealis should be a daily phenomenon, more or less intense, consequently visible at greater or less distances, but only when the nights are clear, — which is perfectly in accordance with observation.

The aurora australis presents precisely the same phenomena as the aurora borealis, and is explained, consequently, in the same manner.

PART IX.

MISCELLANEOUS MATTERS.

CHAPTER XX.

DISCOVERY OF THE INTENSITY MAGNET.

In 1838, Messrs. Morse and Smith, proprietors of the Morse patent, went to Europe to take out letters patent for the apparatus. Mr. Smith relates a curious circumstance in relation to this visit, it being nothing less than a discovery of the intensity magnet in operation at Paris,—a discovery of more value to them than the obtaining of patents from every government in Europe.

It seems that the electro-magnet,—the most vital part of the Morse apparatus,—which they took with them, weighed no less than one hundred and sixty pounds! As this immense affair was carried about in England and France, and guarded with great care, the people everywhere eyed it with suspicion, evidently imagining it to be an infernal machine, destined to create some awful destruction!

Happening one day, while in Paris, to enter a public institution, they saw a coil of the same form as their ponderous helix, but weighing less than a hundredth as much, performing the same operation that their apparatus was designed for. They were of course amazed, and Mr. Smith, turning to Mr. Morse, remarked, "Here is the essence of your magnet distilled, and presented in suitable proportions." Upon examining the construction of the coil, they found it to consist of a vast number of convolutions of very fine copper wire wound with silk,—the wire being, instead of the large size used by Mr. Morse, which

was one sixteenth of an inch, only a hundredth part of an inch in diameter, thus giving the magnet a vast and intense power in a small compass.

This modification of the electro-magnet was at once adopted, and is the form used upon all, or nearly all, the electro-magnetic telegraphs in the world, excepting House's, which uses axial electro-magnetism. The large wire coil in fact, though powerful upon a short circuit, is incapable of producing any effects upon a telegraph line of even half a mile in length.

The development of the motor function of electricity, or the means by which electro-magnetic power can be exerted at a distance, is due to the early experiments of Professor Henry, whose discoveries in electro-magnetism, and especially of the *quantity* and *intensity* of the magnet, in 1830, laid the foundation for all subsequent forms of the electro-magnetic telegraph, and made subsequent steps comparatively easy. From recent investigations, however, it would appear that the French were the first to avail themselves of this important discovery, and put the intensity magnet in practical operation.

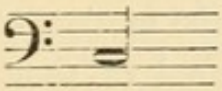
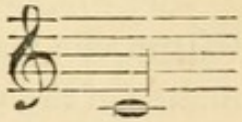
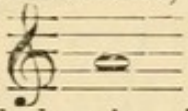
MUSIC BY TELEGRAPH.

It is an amusing fact, that music has actually been transmitted by the Morse telegraph, by means of its rhythm; in fact, it is of very frequent occurrence upon all lines. The following is related by Mr. Jones, who was an ear-witness of the experiment in New York: —

"We were in the Hanover Street office when there was a pause in business operations. Mr. Porter, of the Boston office, asked what tune we would have. We replied, 'Yankee Doodle;' and to our surprise he immediately complied with our request. The instrument commenced drumming the notes of the tune as perfectly and distinctly as a skilful drummer could have made them at the head of a regiment; and many will be astonished to hear that Yankee Doodle can travel by lightning. We then asked for 'Hail Columbia!' when the notes of that national air were distinctly beat off. We then asked for 'Auld Lang Syne,' which was given, and 'Old Dan Tucker,' when Mr. Porter also

sent that tune, and, if possible, in a more perfect manner than the others. So perfectly and distinctly were the sounds of the tunes transmitted, that good instrumental performers could have had no difficulty in keeping time with the instruments at this end of the wires."

That a pianist in Boston should execute a fantasia at New York, Philadelphia, Washington, and New Orleans at the same moment, and with the same spirit, expression, and precision as if the instruments, at these distant places, were under his fingers, is not only within the limits of practicability, but really presents no other difficulty than may arise from the expense of the performances. From what has just been stated, it is clear that the *time* of music has been already transmitted, and the production of the sounds does not offer any more difficulty than the printing of the letters of a despatch.

It is well known that the pitch of any musical note is the consequence of the rate of vibration of the string by which it is produced, and that the more rapid the vibration the higher the note will be in the musical scale, and the slower the vibration the lower it will be. Thus the string of a piano-forte which produces the base note vibrates 132 times in a second; that which produces the note vibrates 66 times in a second; and that which produces the note vibrates 264 times in a second.

On a seven-octave piano-forte, the highest note in the treble is three octaves above  , and the lowest note in the base is four octaves below it. The number of complete vibrations corresponding to the former must be 3,520 per second; and the number of vibrations corresponding to the latter is 27½.

By means of very simple expedients, the current may be interrupted hundreds or even thousands of times in a second, being fully re-established in the intervals. If the pulsations of the current be produced at the rate of a thousand per second, the alternate presence and absence of the magnetic virtue in the soft

iron will equally be produced at the rate of a thousand per second. Nor are these effects in any way modified by the distance of the place of interruption of the current from the magnet. Thus, pulsations of the current may be produced by an operator in Boston, and the simultaneous pulsations of the magnetism may take place in New Orleans, provided only that the two places are connected by a continuous series of conducting-wires.

When it is stated that the vibrations imparted by the pulsations of the current to levers have produced musical notes nearly two octaves higher than the highest note on a seven-octave piano, tuned to concert pitch, it may be conceived in how rapid a manner the transmission and suspension of the electric current, the acquisition and loss of magnetism in the soft-iron rods, and the consequent oscillation of the lever upon which these rods act, take place. The string which produces the highest note, on such a piano, vibrates 3,520 times per second. A string which would produce a note an octave higher would vibrate 7,040 times per second, and one which would produce a note two octaves higher would vibrate 14,080 times per second.

It may, therefore, be stated, that by the marvellously subtile action of the electric current, the motion of a pendulum is produced, by which a single second of time is divided into from twelve to fourteen thousand equal parts.

The adaptation of this power to the production of music upon telegraphic piano-fortes at any distance which may be desired, is a matter of the utmost simplicity, capable of being successfully carried into practice by any one who has the money and taste for the experiment.

CELERITY OF TRANSMISSION.

Although it be true that the signals made at one station are rendered instantaneously apparent at another, no matter how distant, it must not therefore be inferred that the transmission of messages by the telegraph is equally instantaneous. Not only is this not the case, but the celerity with which messages are conveyed between station and station, so as to be rendered practically available for the purposes of intercommunication, differs very

much when one form of telegraphic instrument or one set of operators is compared with another.

The celerity of transmission depends upon a great number of circumstances, the principal of which, in the Morse apparatus, are the skill and dexterity of the transmitting operator, the quickness of ear, practice, activity, and attention of the receiving operator, the distance to which the despatch is transmitted, the insulation of the wires, and the weather.

Different operators have very different powers as to celerity. These powers depend on practice as well as upon natural ability and aptitude, and on manual dexterity. Not only is it necessary to transmit the letters in quick succession, but to do so with such distinctness that they shall be readily interpreted, and with such correctness as to render repetitions unnecessary. In this respect operators having equal practice differ one from another as much as do clerks, some writing rapidly and legibly; some rapidly, but not legibly; some legibly, but not rapidly; and some neither rapidly nor legibly. The relative ability of operators in this respect is partly mental and partly mechanical, depending as much upon quickness of intelligence, attention, and observation as upon manual dexterity and address.

It is a remarkable and very curious circumstance, that, independently of the mere rapidity, clearness, and correctness of transmission, each operator has a manner and character which are so peculiar to himself, that persons receiving his despatch at a distance recognize his personality with as much certainty and facility as they would recognize the handwriting of a correspondent, or the voice and utterance of a friend or acquaintance, whom they might hear speak in an adjacent room. The operators habitually engaged at each of the telegraphic stations, in this way, soon become acquainted with those of all the other stations on the same line, so that a. the commencement of a despatch they immediately know who is transmitting it.

SECRECY OF TELEGRAPHIC COMMUNICATIONS.

Although the electric telegraph has been in successful operation in this country for sixteen years, scarcely an instance is on

record where the secrecy of a despatch has been violated. This is owing mainly to the high sense of honor which every operator feels upon this point, there being no oath of secrecy required, and no laws for the punishment of its violation; but there is another circumstance which, as experience has made manifest, has given security to the public on this point. It appears that the operators who are for many hours laboring at the instrument in the transmission of despatches, word by word, rarely are able to give that kind of attention to the sense and purport of the whole which would be necessary to the clear understanding of it. Their attention is engrossed exclusively in the manipulation necessary to transmit letter after letter, and they have neither time nor attention to spare for the subject of the whole despatch. The case is very analogous to that of compositors in a printing-office, who, as is well known, may go through their work mechanically, without giving the least attention to the subject.

A sort of verbal cipher, or abbreviations, are somewhat extensively used by brokers, mercantile houses, newspaper reporters, and others. This is practised more for the sake of economy than secrecy, although the latter purpose is also attained. The correspondents have a key in which are tabulated a number of single words, each of which expresses a phrase or sentence, such as is of frequent occurrence in such communications. The following example of such a despatch will illustrate the principle. The despatch to be sent consists of sixty-eight words, as follows: —

"Flour market for common and fair brands of Western is lower, with moderate demand for home trade and export; sales, 8,000 bbls. Genessee at $5.12. Wheat, prime in fair demand, market firm, common description dull, with a downward tendency; sales, 4,000 bushels at $1.10. Corn, foreign news unsettled the market; no sales of importance made. The only sale made was 2,500 bushels at 67c."

This despatch, when converted into the verbal cipher, was expressed in nine words, as follows: —

"Bad came aft keen dark ache lain fault adopt."

Cipher is not, however, generally resorted to either for private or public despatches, and is of no practical value except for transmitting stock and market reports.

BREVITY IN DESPATCHES.

The despatches which pass over a telegraph line in the course of a year, if collected together, would present a very curious and interesting volume of correspondence. The price of the transmission of a message depending upon the number of words which it contains, of course renders the construction of it necessarily as brief as possible. Most despatches are contained in less than ten words, (exclusive of address and signature, which are not charged for,) and it is surprising how much matter is often contained in this brief number. Among the best examples of brevity which we have met with, however, are the two following.

A lady in a neighboring city, desirous of ascertaining when her husband would return home, sent him a message making the inquiry; to which he responded, that important business detained him, and that he could not leave for some days.

The lady immediately replied by sending him another despatch in the following laconic manner: —

"At Home, August 12, 1859.

"To F. C. P. — Despatch received. Deuteronomy xxiv. 5.
(Signed,) "KATE."

The gentleman to whom the despatch was addressed, upon referring to the passage in the Scriptures alluded to, obtained the following lengthy and suggestive epistle: —

"When a man hath taken a new wife, he shall not go out to war, *neither shall he be charged with any business:* but he shall be free at home one year, *and shall cheer up his wife which he hath taken.*"

The second example is the reply sent to a person in a distant city, who, having committed some offence against the laws, and run away, was desirous of ascertaining if it would be prudent for him to return. He therefore telegraphed in the following laconic style: —

"New York, July 4, 1859.

"To B. C. M——, Philadelphia.
"Is everything O K? "D. T. M."

To which he obtained the following brief reply: —

"Philadelphia, July 4, 1859.

"To D. T. M——, New York: — Proverbs, chap. xxvii. 12.

"B. C. M."

Upon reference to the passage indicated, the inquiring individual obtained the following valuable advice, which, it is to be presumed, he followed: —

"A prudent man foreseeth the evil, and *hideth himself;* but the simple pass on, and are punished!"

SEEING THE ELEPHANT.

Some years ago there was a joke passing around upon the different telegraph lines, which was played off upon a good many unsuspecting individuals, in the following manner: —

"Boston, April 1st, 1855.

"To L. E. PHANT, *at some Hotel, New Bedford:*

"In leaving this morning, you neglected to take your trunk. What shall be done with it?

"ADAM GOODSELL."

By pronouncing the name of the party addressed quickly, and the signature slowly, a solution of the "sell" is obtained, and you get a view of the elephant at the same time!

READING BY SOUND.

We have mentioned briefly the substitution of reading by sound, instead of by sight, which is a matter of very great importance to the proprietors of telegraph companies, as well as the public. To the former, because it saves expense, and to the latter, because it insures greater safety; and, finally, to both for the same reasons, for the interests of the proprietors and the public are very closely connected.

We shall not pretend to say to whom is entitled the credit of having first discovered the idea of reading by sound; and if we could, it would be a matter of no importance, for no one, with a good idea of time, could be within hearing of a Morse register a day, without being aware of its peculiar adaptedness for this use.

The first time, however, we saw any one read in this manner was in the winter of 1846–7, in New York. The lines were broken, and Mr. O. E. Wood and ourself were sent out to repair them. Mr. Wood carried a small electro-magnet in his hand, and when we reached Harlem Bridge, he disconnected the line-wire, and attached it to one end of the helix-wire; and then, uncoiling a dozen or two feet of iron wire, dropped one end of it in the river, and with the other commenced tapping upon the other extremity of the helix-wire. To our infinite astonishment, we saw the lever fly backward and forward; and presently, when he had stopped writing, he received a reply from the office in New York. He gave us the questions and answers as he received and sent them, and although we have a thousand times since accomplished the same feat, the conversation and the occurrence are still indelibly fixed in our memory.

No trick of legerdemain, performed by the most successful necromancer, has ever been able to excite so much interest in our mind as this.

READING BY SHOCKS.

There is, however, still another mode of receiving intelligence in connection with the Morse lines, besides those already described; namely, by means of the passage of shocks through the system. This, we presume, has often been accomplished by different persons, although we have not been knowing to the fact. Mr. Milliken, of the American Telegraph Office in Boston, assures us that he once read the greater part of a despatch as it was passing over the wires between Boston and Portland, and that he heard the Portland operator respond "O K" (all right) to it, while he was seated upon the draw at Mystic River Bridge, and held the end of a wire in each hand; thus passing the current through his body, and enabling him to read the letters by the duration and number of the shocks which he received.

We have succeeded, upon several occasions, in receiving messages in this manner, when we have been at a distance from an office, and wished to obtain information in regard to the state of the line.

Not long since we had been annoyed upon one of our wires by a very bad earth-current, and, none of the repairers being able to find the difficulty, we instituted a search for it. Finally, upon arriving at Neponset, we opened the circuit at the draw, and inquired of the Boston operator, by touching the ends of the wire together in the proper time, if the earth-current was between us and the Boston office, or beyond. This he could at once tell, by my opening the circuit, — disconnecting the wires; if he got any magnetism when the wires were disconnected, then the earth-current was between us and the office; if he got none, then the trouble was beyond. This was important for us to know. He replied that he did get an earth-current, when we opened the circuit. We asked if it was very strong. "Yes," he replied, "nearly as strong as when you close."

All this, the reader will understand, we received through our system, and interpreted by the duration and number of the shocks.

"There is trouble also upon the New Bedford wire," said he; "I have not had any circuit for nearly half an hour."

We then sent an order for a line repairer to go out at once and repair that line, and then recommenced our investigations into the location of the earth-current, which we shortly afterwards succeeded in finding.

SPIRITUAL INTERRUPTIONS.

We have mentioned in a previous article, that the earth serves as a return wire. The earth, in fact, from its immense conducting surface, constitutes the best conductor, — better than all minerals, for its resistance to the passage of an electric current has been found to be null. It being the same thing, in fact, to put the two ends of the wire into connection with the earth, as to bring them together.

This, as may be imagined, is of vast importance in the economy of working telegraph lines, as one wire in every circuit is thus saved; but there are, sometimes, very provoking consequences resulting from this cause, namely, the loss of current by earth circuits or "escape."

An occurrence of this kind happened upon the line between Boston and Salem some months since, which baffled for weeks the most careful research of experienced repairers.

The earth-current came on at precisely 7 o'clock P. M., and was off at the commencement of business in the morning; therefore there was only from 7 P. M. to 8 A. M. when there was any opportunity for finding it.

Line men were despatched over the road every day with strict injunctions to watch every inch of the wire, but still they reported that nothing could be found. It looked mysterious. Had the spirits anything to do with it? They had never yet troubled the telegraph, but there must be a beginning for all things; was this the beginning? We strongly suspected that it was!

One afternoon we went to Salem ourself, and remained in the office from 6½ to 7 o'clock. We would see if it would come on while we were there. Seven o'clock arrived, no earth-current. One minute past, none; two, none; three, none; we began to feel encouraged, perhaps it had "played out." The train left at 7.15; we hoped to leave in that, with the knowledge that all was right. Seven o'clock, four, no earth-current; seven, five, it is on again!

We were in for it, and we immediately started for a personal solution of the difficulty. Upon walking down the track a few rods we found the "spirit," in the shape of an iron switch-rod, which had been put up about four weeks before, to switch off the Marblehead track at seven o'clock every morning, and *which was switched on at precisely seven o'clock each afternoon.* Upon this occasion the switchman had been five minutes late. He said he noticed when he switched it on that it touched the wires, but he did not know as it would do any damage, as it was only iron!

Thus ended our first assault upon the spirits.

PRACTICAL JOKING BY TELEGRAPH.

Some ten years or more ago there was upon the New York and Washington telegraph line, at the Philadelphia station, an operator named Thayer, who, besides being an adept at the business, was a gentleman of culture and wit, and exceedingly fond of a joke, no matter at whose expense. At the New York ter-

minus of the line there was, upon the contrary, a steady, matter-of-fact sort of man, who was no appreciator of jokes, and never practised them. The President of the line was Hon. B. B. French, for many years Clerk of the House of Representatives at Washington; a wit, poet, and humorist, of course he appreciated humor wherever he came across it.

Thayer took it into his head one day to send a despatch to some fictitious name in New York, for the purpose of enjoying a laugh at the expense of the operator at New York. Accordingly he composed and forwarded the following: —

"Philadelphia, April 1, 1846.

"To Mr. Jones, New York: —

"Send me ten dollars at once, so that I can get my clothes.

(Signed,) "Julia."

"13 words, collect 34 cents."

The operator at New York, not suspecting any joke, asked the Philadelphia operator for the address.

The Philadelphia operator replied, that "the young lady did n't leave any;" and asked him to "look in the directory for it."

The New York operator replied that he "had already done so, but that as there were over fifty Jones's in the directory, he was at a loss to know which one to send it to."

"If that is the case," says Thayer, "you had better send a copy to each of them, and charge 34 cents apiece."

The New York operator did so, and I will give the result of the arrangement in the words of the President, Mr. French, from whom, a few days after this affair, Mr. Thayer received the following letter: —

"New York, April 6, 1846.

"Mr. Thayer: —

"Sir, — A few days since you sent a despatch purporting to come from one Julia, addressed to Mr. Jones, New York. The New York operator informed you that he desired an address, as there were upward of fifty Jones's in the directory, and he was at a loss to know which one of them it was designed for. You replied, that in that case he must send a copy to every one of them, and charge upon each; and the operator at New York, in the in-

nocence of his heart, did so. Some twenty of the Jones's paid for their despatches, but there was one sent to the residence of an elderly merchant by that name, who being away from home when it arrived, it was opened by his wife, and was the occasion of a very unpleasant domestic scene. Mr. Jones has been to see me in relation to the matter, and threatens to sue the company for damages, — taking the thing very much to heart.

"Now, this is all very funny, and a good joke, and I have laughed at it as heartily as anybody; but you had not better try it again, or any of the rest of the operators upon the line, if you value your situations."

ADVANTAGE OF READING BY SOUND.

We chanced to be conversing with the manager of a telegraph office in his counting-room, when an individual entered, and proceeded to the counter where the business was transacted, which was at the farther side of the room, some little distance from where we were standing, and commenced preparing a despatch for the clerk, who stood ready to receive it. The manager, with whom we were conversing, made several apparently careless little taps upon a shelf before him with a pencil, which he held in his hand; the clerk at the other end of the room was also, apparently to us, drumming listlessly with his penholder as he waited on his customer. All this time, while four of us were holding an animated colloquial intercourse, the apparently careless taps of the two telegraphers were intelligible communications exchanged between them.

The following was the dialogue which occurred: —

Manager. "Give your attention for a despatch." (The usual taps for a "call" of an operator from one station to another implying the above.)

Clerk. "All right; go ahead."

Manager. "Don't send that man's messages unless he prepays in cash."

Clerk. "All right; won't credit him a dime."

Manager. "After he pays this one, collect 68 cents for message sent by him yesterday, which he was trusted for."

By this time the clerk had a bank-note which the dilatory customer had produced, upon learning that it was necessary for the message to be prepaid, and from which he blandly made change, deducting the 68 cents.

The communicated sound had in this instance proved of some little service, and was utterly unnoticed save by the two parties interested.

MISTAKES OF THE TELEGRAPH.

Some ten years since, there was a very ludicrous, and at the same time natural blunder, perpetrated upon the line between Boston and New York. A gentleman sent a despatch requesting parties in New York to "forward sample forks by express." When the message was delivered, it read thus: "Forward sample for K. S."

The parties who received it replied by asking what samples K. S. wanted.

Of course the gentleman came to the office and complained that the despatch had been transmitted wrong, and the operator promised to repeat it. Accordingly he telegraphed the New York operator that the despatch should have read, "Forward sample forks." The New York operator, having read it wrong in the first instance, could not decipher it differently now. He replied, that he *did* read it, "Sample for K. S.," and so delivered it.

"But," returned the Boston operator, "I did not say 'for K. S., but f-o-r-k-s!"

"What a stupid that fellow is in Boston," exclaimed the New York operator, in a rage. "He says he did n't say for K. S., but for K. S.!"

The Boston operator tried for an hour to make the New York operator read it "forks," but not succeeding, he wrote the despatch upon a slip of paper, and forwarded it by mail; and it remained a standing joke upon the line for many months afterwards.

Since the paper has been abolished upon the Morse lines, errors like the above rarely occur. The ear is found to be a much more reliable organ for the telegrapher than the eye. We

do not think we should overshoot the mark if we said there is not one error made in reading by sound where there were ten, formerly, in reading from the long strips of paper. One reason is, as we remarked in a previous chapter, that the operator in reading by sound has his eyes at liberty, and can write down his despatch as he reads it by the tick, with all the facility with which an expert reporter can follow, and note down accurately, all the words spoken in debate. The feat seems an extraordinary one, but practice will accomplish wonders.

PERSONS UNQUALIFIED FOR TELEGRAPHY.

There are many persons who seem totally incapable of acquiring a knowledge of the art of telegraphing sufficient for practical use, while others, and especially young persons, will acquire it, even in the short space of a fortnight, sufficiently to transmit and receive despatches with considerable facility.

A ludicrous example of this lack of ability to operate this simple apparatus came to our knowledge quite recently.

A middle-aged man, employed upon one of our railroads as depot-master and telegraph-operator, found great difficulty, after two years' experience, in operating the instrument, and this inability extended to his reading as well as his transmitting despatches. Upon one occasion he rushed out of his office in a great state of excitement, and informed the conductor of a train which had just arrived at his station, that he had just received a despatch stating that the —— train had broken both driving-wheels, and was badly smashed up. No more trains must pass until further orders.

The conductor, who was able to read the telegraphic characters, went to the instrument, and, drawing out the paper, read the following despatch : —

"Ask the conductor of the Boston train to examine carefully the connecting-rods of both driving-wheels, and if not in good condition to await orders."

The conductor, having made the examination in company with the engineer, and found all right, gave the order for the train to move on, to the infinite astonishment of the *soi-disant* operator,

who never was able to find out why the conductor had the temerity to order the train to go on under such grave circumstances.

In the same village where this *reliable* operator is employed there is another telegraph office, where the ordinary telegraphic business is done; and whenever our friend receives a call upon his instrument, he gives the signal to go ahead, and, after receiving the despatch, takes it to the operator at the other office to have it translated for him.

Not long since, he rushed into the office with a strip of the telegraph paper in his hand, and cried out, "I want you to read this for me, quick. I expect there 's some awful accident on the road, the operator rattled away so fast when he sent it."

The operator took the strip, but, to the dismay of the nervous visitor, a large portion of it had been torn off by a dog, who was attracted by its singular appearance as it streamed behind him while he flew along, and the part which remained contained only these words: — "Good morning, Uncle Ben. When are you — " The dog had swallowed the rest!

ARREST OF FUGITIVES FROM JUSTICE.

One of the most important uses of the telegraph is that of controlling the movements of fugitives from justice. Were it not for the wires, a rogue having got one train the start of an officer might travel thousands of miles without the possibility of detection or arrest; but, thanks to this invention, there is no place so unsafe for a rogue as upon a railway, as nine times out of ten an officer would be in waiting at the depot, when the train should arrive, to arrest him.

A dozen years ago, before the use of the telegraph was so common as it is now, we were apprised at New Haven that a man left Hartford in the one o'clock train, intending to take the steamer at the former place for New York, and that he was owing a certain sum of money which it was desirable to obtain before he left. His baggage, consisting of four black trunks, was minutely described, and an officer was in waiting when the train arrived, who at once took charge of it.

When the owner of the baggage came up, the officer pre-

sented him with the claim, and told him he was his prisoner until the amount was paid over.

He was very much surprised and chagrined, but finally, seeing there was no way of avoiding it, and the boat was nearly ready to start, he paid over the money.

"Now," said he, "I want to know how you knew I was on this train."

"O," replied the officer, "I guessed it!"

"Yes; but how did you come to recognize me? You never saw me before," queried the gentleman from Hartford.

"O, I guessed at that, too," said the officer.

"Ah! that may be," suggested the nonplussed individual; "*but how in thunder did you come to guess out my four black trunks so quickly?*"

WEBSTER'S SPEECHES IMPROVED BY THE TELEGRAPH.

Just previous to the Presidential campaign of 1852, it will be remembered, Mr. Webster made a tour through New York State, during which he made a great many patriotic speeches. One of these, made, we believe, at Albany, was particularly good, and abounded in short, pithy Saxon sentences, many of which were in the form of interrogatories. In order that we might do full justice to the speech, we took occasion to punctuate it, as we read it to the copyist, and whenever an interrogatory occurred we said, "question," — meaning, of course, for the copyist to make the sign "?" at the end of the sentence. But what was our surprise and horror the next morning, upon taking up the newspapers, to find them all embellished with the word "question," printed in full at the end of nearly every sentence.

HOW DESPATCHES SHOULD BE WRITTEN.

Telegrams should be written in a concise style, and no superfluous words employed; but they should not be simply skeleton sentences strung together, which it is questionable if your correspondent would understand if transmitted correctly, and which are very liable to contain mistakes, from the greater difficulty of transmitting such despatches correctly.

No despatch, for instance, should be so written as that by the omission of one word a different idea would be conveyed; or, in other words, so that the whole tenor of the despatch centres in one word.

In this country, ten words can always be sent as cheap as one; and yet we frequently find people, from the habit of sending brief despatches, reducing their messages to three or four words, and in this way many errors are made.

While General Taylor was in Mexico, a despatch was received in New York from the South, saying, "General Taylor seen in New Orleans." Much speculation was felt as to the cause of his deserting his post at the seat of war, until the despatch was corrected by the substitution of *son* for *seen*, which in telegraphic characters are nearly identical.

There are many words which, when written in telegraphic characters, resemble others so closely as frequently to lead to curious errors. We have one in mind now to the point.

A gentleman telegraphed for his portrait to be forwarded to him by express; but when the despatch arrived it read thus: —

"Send *post rail* by express."

A NOVEL MEETING.

In accordance with a previous arrangement, the *employés* of the American Telegraph Company's lines between Boston and Calais, Maine, held a meeting by telegraph, after the business of the line was concluded for the day, to take action upon the resignation of Asa F. Woodman, Esq., Superintendent.

Thirty-three offices were represented, scattered over a circuit of seven hundred miles. Speeches were made by Messrs. Palmer and Milliken of Boston, Hayes of Great Falls, Smith of Portland, Bedlow of Bangor, Black of Calais, and others. Each speaker wrote with his key what he had to say, and all the offices upon the line received his remarks at the same moment, thus annihilating space and time, and bringing the different parties, in effect, as near to each other as though they were in the same room, although actually separated by hundreds of miles.

After passing appropriate resolutions, the meeting was ad-

journed in great harmony and kindly feeling, having been in session about an hour.

An account of the above meeting having been published in the newspapers, Punch makes the following humorous suggestions, which are equally applicable to our Congress : —

"Now, why could n't our Parliamentary proceedings be conducted in an equally silent manner? Do you think Cobden would unwind his many miles of Manchester yarns without an audience? Do you fancy Spooner would go on raving for hours when there was not a soul present to hear him rave? And is it likely that Gladstone, even, with all his love of talking, would talk incessantly when all that his eloquence could possibly bring round was a dial? Now an electric Parliament would remedy all the evils that verbiage at present inflicts on the patience of the nation. A member of Parliament would be able to attend to his legislative duties without stirring from his country-seat. The entire business of St. Stephen's might be conducted in a telegraph office. The whole Parliamentary staff, with its numerous bundles of rods and sticks, might be cut down into a Speaker. That worthy functionary would sit in the middle of his office, like a forewoman in a milliner's workshop, watching the numerous needles flying assiduously around him. When the work was done, he would collect the stuff and report the result. The threads of the various arguments would run into his hands, and it would be for him to sort them. His decisions would be final, and justly so, as he would always have the debates at his finger-ends. The Prime Minister or Prince Albert might look in every quarter of an hour to see that the Speaker had not fallen asleep.

"Under our improved plan, one great benefit would unquestionably be gained. There would be no noise! All zoölogical exhibitions would be effectually closed. Your Parliamentary cocks, donkeys, and laughing hyenas would be peremptorily shut up, like their wooden prototypes in a boy's Noah's ark. Really, we see no obstacle in the way of an Electric Parliament. It would, to a great extent, cure the absurd mania for talking, and, moreover, we do not think the speeches there would be half so wire-drawn as they are now. Besides, every little Demosthenes, who at present

is not reported, or else snubbed under the obscure cognomen of the 'Hon. Member,' would have the satisfaction of knowing that his speech had gone to the length, at all events, of *one* line, and, if he were at some distant post, it might run perhaps to the extent of four or five lines, according to the number of wires on the different telegraphs; whilst your Drummonds and your Osbornes, as they indulged in their electric *facetiæ*, might flatter themselves with the belief that they were fairly convulsing the poles with laughter."

HOW CYRUS LAID THE CABLE.

A BALLAD, BY JOHN G. SAXE.

Come, listen all unto my song;
It is no silly fable;
'T is all about the mighty cord
They call the Atlantic Cable.

Bold Cyrus Field he said, says he,
"I have a pretty notion
That I can run a telegraph
Across the Atlantic Ocean."

Then all the people laughed, and said
They 'd like to see him do it;
He might get half-seas-over, but
He never could go through it.

To carry out his foolish plan
He never would be able;
He might as well go hang himself
With his Atlantic Cable!

But Cyrus was a valiant man, —
A fellow of decision, —
And heeded not their mocking words,
Their laughter and derision.

Twice did his bravest efforts fail,
And yet his mind was stable;
He wa' n't the man to break his heart
Because he broke his cable.

"Once more, my gallant boys!" he cried;
Three times! — you know the fable, —
(I 'll make it *thirty*," muttered he,
"But I will lay the cable!")

Once more they tried, — hurrah! hurrah!
What means this great commotion?
The Lord be praised! the cable 's laid
Across the Atlantic Ocean!

Loud ring the bell! — for, flashing through
Six hundred leagues of water,
Old Mother England's benison
Salutes her eldest daughter!

O'er all the land the tidings speed,
And soon in every nation
They 'll hear about the cable with
Profoundest admiration!

Now long live James, and long live Vic,
And long live gallant Cyrus;
And may his courage, faith, and zeal
With emulation fire us;

And may we honor evermore
The manly, bold, and stable,
And tell our sons, to make them brave,
How Cyrus laid the cable!

THE OPERATOR AT TRINITY BAY.

We have alluded elsewhere to the mysterious operator at the Cisatlantic terminus of the cable. The following poem is from the contributions of The Professor at the Breakfast-Table, in the Atlantic Monthly, and tends still further to immortalize this mystical personage.

DE SAUTY. AN ELECTRO-CHEMICAL ECLOGUE.

Professor. *Blue-Nose.*

PROFESSOR.

Tell me, O Provincial! speak, Ceruleo-Nasal!
Lives there one De Sauty extant now among you,
Whispering Boanerges, son of silent thunder,
Holding talk with nations?

Is there a De Sauty ambulant on Tellus,
Bifid-cleft like mortals, dormient in nightcap,
Having sight, smell, hearing, food-receiving feature
Three times daily patent?

Breathes there such a being, O Ceruleo-Nasal?
Or is he a *mythus*, — ancient word for "humbug," —
Such as Livy told about the wolf that wet-nursed
Romulus and Remus?

Was he born of woman, this alleged De Sauty?
Or a living product of galvanic action,
Like the *acarus* bred in Crosse's flint-solution?
Speak, thou Cyano-Rhinal!

BLUE-NOSE.

Many things thou askest, jackknife-bearing stranger,
Much-conjecturing mortal, pork-and-treacle waster!
Pretermit thy whittling, wheel thine ear-flap toward me,
Thou shalt hear them answered.

When the charge galvanic tingled through the cable,
At the polar focus of the wire electric
Suddenly appeared a white-faced man among us, —
Called himself "De Sauty."

As the small opossum held in pouch maternal
Grasps the nutrient organ whence the term *mammalia*,
So the unknown stranger held the wire electric,
Sucking in the current.

When the current strengthened, bloomed the pale-faced stranger, —
Took no drink nor victual, yet grew fat and rosy, —
And from time to time, in sharp articulation,
Said, "*All right!* De Sauty."

From the lonely station passed the utterance, spreading
Through the pines and hemlocks to the groves of steeples,
Till the land was filled with loud reverberations
Of "*All right!* De Sauty."

When the current slackened, drooped the mystic stranger, —
Faded, faded, faded, as the shocks grew weaker, —
Wasted to a shadow, with a hartshorn odor
Of disintegration.

Drops of deliquescence glistened on his forehead,
Whitened round his feet the dust of efflorescence,
Till one Monday morning, when the flow suspended,
There was no De Sauty.

Nothing but a cloud of elements organic,
C. O. H. N. Ferrum, Chor. Flu. Sil. Potassa,
Calc. Sod. Phosph. Mag. Sulphur, Mang. (?)
Alumin. (?) Cuprum, (?)
Such as man is made of.

Born of stream galvanic, with it he had perished!
There is no De Sauty now there is no current!
Give us a new cable, then again we 'll hear him
Cry, "*All right!* De Sauty."

HOUSE-TOP TELEGRAPHS.*

About twelve years ago, when the tavern fashion of supplying beer and sandwiches at a fixed price became very general, the proprietor of a small suburban pothouse reduced the system to an absurdity by announcing that he sold a glass of ale and an electric shock for fourpence. That he really traded in this combination of science and drink is more than doubtful, and his chief object must have been to procure an increase of business by an unusual display of shopkeeping wit. Whatever motive he had to stimulate his humor, the fact should certainly be put upon record that he was a man considerably in advance of his age. He was probably not aware that his philosophy in sport would be made a science in earnest in the space of a few years, any more than many other bold humorists who have been amusing on what they knew nothing about. The period has not yet arrived when the readers of Bishop Wilkins's famous discourse upon aerial navigation will be able to fly to the moon, but the hour is almost at hand when the fanciful announcement of the beer-shop keeper will represent an every-day familiar fact. A glass of ale and an electric shock will shortly be sold for fourpence, and the scientific part of the bargain will be something more useful than a mere fillip to the human nerves. It will be an electric shock that sends a message across

* From Dickens's "All the Year Round."

the house-tops through the web of wires to any one of a hundred and twenty district telegraph stations, that are to be scattered amongst the shopkeepers all over the town.

The industrious spiders have long since formed themselves into a commercial company, called the London District Telegraph Company (limited), and they have silently, but effectively, spun their trading web. One hundred and sixty miles of wire are now fixed along parapets, through trees, over garrets, round chimney-pots, and across roads on the southern side of the river, and the other one hundred and twenty required miles will soon be fixed in the same manner on the northern side. The difficulty decreases as the work goes on, and the sturdiest Englishman is ready to give up the roof of his castle in the interests of science and the public good, when he finds that many hundreds of his neighbors have already led the way.

The out-door mechanical exigencies of this London district telegraph require at least six house-top resting-places in the space of a mile. To get these places at the nominal rental of a shilling a year (with three months' notice for removal) has been the object of the company, professedly that a low tariff of charges may be based upon a moderate outlay of capital on the permanent way. The peculiarity of the company's operations, in appealing rather to the public sentiment of the middle and lower classes, than to their sense of business or desire for gain, has prolonged its out-door negotiations; though not to any great extent. The trial may have been severe, but the British householder, with a few exceptions, has nobly stood the test. He has shown that, if properly applied to and properly treated, he may belong to a nation of shopkeepers, and yet be something more than a mere mercenary citizen.

The first time the proposition to electrify all London was brought before the British householder, it was calculated to inspire considerable alarm. The telegraph, as at present existing, is not a popular institution. Its charges are high; its working is secret and bewildering to the average mind. Its case, as displayed at the railway stations, may look like a mixture of the beer-machine and the eight-day clock; but the curious hieroglyphics and restless

arrows on its dial surface are like the differential calculus framed in a gooseberry tart. The unknown may masquerade in the dress of the known; but the railway porter will still shake his head.

When the sole depositary of the telegraphic secret has gone to dinner, the whole electric system of that particular railway station must stand absolutely still. A certain amount of familiarity will breed contempt; an equal amount of unfamiliarity will breed awe and dread. The British householder has never seen a voltaic battery kill a cow, but he has heard that it is quite capable of such a feat. The telegraph is worked, in most cases, by a powerful voltaic battery, and therefore the British householder, having a general dread of lightning, logically keeps clear of all such machines.

The British householder (number one) took time to consider. The pole that the company wished to raise upon his roof might not be ornamental; might not suit the taste of his wife, who, at that moment, was unwell; might not meet with the approbation of his landlord, who was very fastidious, and very old. If the company would like to communicate with his landlord, that gentleman was to be found in Berkshire, if he had not gone to Switzerland, if he was not up the Rhine. The British householder (number sixty) was only one of a firm, and he could give no definite answer without his partners' consent. The British householder (number sixty-eight) was of a vacillating disposition, and after he had said yes, he took the trouble to run up the street, because he had suddenly decided to say no. The British householder (number seventy) was the second-mate of a trading-vessel, at that time supposed to be running along the South American coast. His wife was not prepared to say whether he had any objection to a flagstaff (although she thought he had not), and she could give no permission to the company until his return. The British householder (number seventy-four) very politely allowed the survey of his roof; and when the most eligible point was fixed upon, he had legal doubts whether he had any power over it, as it was on a party wall. His next-door neighbor, when applied to, was equally scrupulous, and without counsel's opinion it was impossible to get any further. The British householder (number ninety) was in a

mist with regard to the whole scheme. He associated telegraphs of all kinds with large railway stations; and large railway stations with red and white signal-lights. He would sacrifice a good deal for science and the public interest, but to have his parapet glaring all night like a doctor's doorway was more than he could bear to think of. An explanation, accompanied by a display of small pocket-models (one of a standard, as large as a pencil-case, — the other of a bracket, the size of a watch) was necessary to pacify him, and when he found that no lamp was required, he gave his conditional consent. The British householder (number ninety-two) was inclined to be facetious, and he hoped that the company would not do anything to blow him up. The British householder (number ninety-eight) was only too glad to be of service, but unfortunately his house was so old and so crumbling, that not another nail could be driven into it with safety. The British householder (number five hundred and four) was an old lady subject to fits, and she only wondered what next would be proposed to her to hurry her into the grave. The British householder (number six hundred and ten) was another old lady, who worshipped a clean passage, and she merely consented upon condition that the work-people only passed through her house once, to get at the roof, carefully wiping their shoes on the mat in the passage, and once again, to leave the premises, on coming down, carefully wiping their shoes on the mat in the attic. An agreement was made upon this peculiar basis; and the carpenters were kept sixteen hours amongst the chimney-pots; their food being drawn up by a rope from the street. The British householder (number seven hundred and six) was almost rash in his obliging disposition, and he gave the company full permission to take his roof off if they found it in the way. The British householder (number seven hundred and four) might have been induced to give his assistance, had not his wife loudly warned him, from the depths of the shop parlor, to beware. The consent of British householder (number eight hundred and ten) was secured by the display of the pocket-models; but when the workmen arrived with a pole as long as a clothes-prop, he stopped them, on the ground that they were attempting an imposition. He had not allowed for the portable

character of the models; and the pole he expected to see fixed on the house-top was about the size of a toothpick.

Nearly four thousand calls were made upon this errand, to get the consent of some nineteen hundred people; and this only for the hundred and sixty miles of metropolitan wire already raised. The hundred and twenty miles remaining to be surveyed will involve, perhaps, nearly three thousand more visits before the requisite fourteen hundred consents are obtained. The landlords of all house-property are to be consulted, as well as the tenants, which doubles the labor of the company's agents. When the wire is finally fixed over the two hundred and eighty miles, there will have been about seven thousand interviews and negotiations, and nearly three thousand five hundred contracts.

Such is the labor required to spin the thin web that is now shooting across crowded thoroughfares, or creeping under the heavy paving-stones, and joining the hands of chapels, taverns, palaces, police-stations, warehouses, hovels, and shops. Other labor will be required to bring down the mysterious strings, so that every one may be able to move the living puppets, from station to station, from Highgate to Peckham, from Hammersmith to Bow.

Some of these strings (perhaps to the number of ten) will drop into district stations, — offices that will act as centres of particular divisions; others (perhaps to the number of a hundred) will drop into familiar shops and trading-places; amongst the pickle-jars of the oilman, the tarts of the pastry-cook, the sugar-casks of the grocer, the beer-barrels of the publican, the physic-bottles of the dispensing chemist. The post-office, industrious and effective as it is, will find an active rival standing by its side, bidding against it for popularity, coming in to share its message-carrying trade. The elements of nature will be harnessed for hack-work; and four pennyworth of lightning will be as common as a box of pills. The old cab-horse will wonder why he is resting so long on his stony stand; and the two millions and more of busy metropolitan inhabitants may welcome another means of easing their crowded streets. Everybody will find a way of talking over everybody else's head, or under everybody else's feet, or behind everybody else's back. "No door-mat to-night," will be whispered from Brompton to

Hampstead, and no one will be aware of the fact but the two communicants. The Elephant and Castle will despatch the tenderest messages to the Angel at Islington; and as soon as the back of young Emma's mamma is turned at Camberwell, young Edwin will be fully informed at Chelsea. St. Johnswood will suddenly be invited to a roughly got-up, but pleasant, party at Holloway; and Kensington will be told that a private box for the Opera is waiting for it at Bow Street. The doctor at Finsbury will be requested to step up, at once, to Park Lane; and Bayswater will stop the toilet of Clapham by announcing a sudden postponement of a dinner-party. Greenwich will be told by Kensington to prepare a whitebait banquet in three hours; and Rotherhithe will be informed by Camden-town that the child is a boy, and that the mother is doing extraordinarily well. The firemen of Cannon Street will be called to a red-hot task at Blackheath; and when a policeman is missing — as usual — from his beat, a "reserve" can be summoned from the station. The saddest of all messages will also fly across the tidings of hope; for Death will sometimes present himself at the shop-counter to whisper his ghostly dispensations along the wires.

The great centre of all this system is in Lothbury, London, where a graceful school of about sixty young ladies are even now learning the mysteries of the old railway-telegraph signals. Whether they are training their minds and hands in an art that will be wholly set aside, yet remains to be seen; but whatever machines may be used as the central and district stations, it is certain that the sub-district or shop stations will require something exceedingly simple and convenient.

The telegraphs most generally in use, both in this country and on the Continent, require great skill and practice to work; and, in translating their arbitrary signs into ordinary language, it becomes necessary to have specially educated persons to work them. This necessity was, for the first time, obviated by the system of telegraphs invented by Professor Wheatstone in 1840, in which either the letters of the alphabet on a fixed dial were pointed to by a moving hand, or a moving dial presented the letters successively behind a fixed aperture. In these, the transmission of

the message consisted simply in bringing in succession the letters composing it opposite a fixed mark, by means of an apparatus called the transmitter. These instruments were constructed to work, either by the currents generated by induction from a permanent magnet, or by the aid of a voltaic battery; in the former case, the instruments required no preparation to put them, or attention to keep them, in action. Since then, Professor Wheatstone has devoted much time to the improvement of this class of telegraphs; the principal object of which has been to effect their movements with greater steadiness, certainty, and rapidity than hitherto, and by means of magnets of small dimensions. As the instruments are at present constructed, a lady or a child may, after a few minutes' instruction, send or receive a message by them; and, with practice, as many signals may be conveyed per minute as by any telegraphs in present use. Especially applicable to house-top telegraphs, they are more efficient than any others for interchanging messages on railways, in public offices, manufactories, private mansions, docks, mines, &c. Being very portable, and requiring no preparation, they are the best telegraphs for military purposes; and being constructed so as not to be affected by any extraneous movement, they can be used with perfect safety in ships, even on a rough sea, or on railway trains in motion. Professor Wheatstone's new telegraphs have been some time in daily use at the London Docks, and between the Houses of Parliament and the Queen's Printing-office, two miles distant. In form these telegraphs are as portable and familiar as a quart pot or a loaf of bread. A circular box, of the shape and size of a small ship's compass, is placed over a battery of magnets that would go in an ordinary hat-case. The surface of the box presents a dial face, like a clock, round which are arranged the letters of the alphabet, a sign or two, and the ten numerals. Opposite each of the letters—spreading out from the side of the box, like an ornamental fringe round the dial-plate—is a single tongue of brass, resembling a large key of a German flute. By pressing down one of these tongues with your finger (opposite the letter A, for example) you cause a needle, like the long hand of a watch, to point at the same letter on another dial, exactly similar in form,

but smaller in size, placed under the eye of your correspondent at the other end of the wire, — if need be, miles off. The distance of your needle-dial from your battery may be thirty miles, or farther, according to the power of your magnets; but the action of the letter-key upon the letter-needle is instantaneous and infallible. The same operation, accompanied by the same result, will indicate numerals, according to a preconcerted sign, as the figures are placed round the two dials, as far as they will go, in a circle outside the letters. If the battery is portable, the corresponding machinery is much more so, being even smaller than many an ordinary French mantel-shelf clock. The needle-dial is fixed in a small barrel, and fitted up so as to revolve like a microscope, and suit the height of the person observing it. A voltaic battery would be less costly than magnets, but more liable to get out of order in shop-stations. The whole apparatus, as it stands, would not take up half the space required by a post-office desk, or require any more intellect to work it than is required to write or read a letter. An average housemaid could receive and despatch a message, if the shopman had just stepped round the corner, providing she could spell a few words of one, two, or three syllables.

Upon the adoption of some such apparatus as this — most probably upon this particular machine — will depend the success of the London District Telegraph Company. The whole scheme of popular telegraphs runs in a circle. Without simplicity and clearness of machinery there can be no extensive formation of cheap stations; without a number of cheap stations there can be no moderate tariff of charges; without this moderate tariff there can be no general patronage of telegraphs by the great body of the public. Without general patronage, again, there can be no moderate tariff.

Starting, as the company does, in some degree, upon a sentiment, by soliciting the unpaid co-operation of numerous householders and landlords, it will be morally bound to place itself in that position in which it can effect the greatest amount of public good at the lowest possible tariff of charges. The trading instincts of its board of directors will compel them to do this, if

they are not kept in the right path by any higher feeling. It will be fortunate, therefore, for the metropolitan public, that, though the electric shock may not always be required with the glass of ale, both may be included in the fourpence, when absolutely necessary.

THE DOT AND LINE ALPHABET.*

Just in the triumph week of that Great Telegraph which takes its name from the Atlantic Monthly, I read in the September number of that journal the revelations of an observer who was surprised to find that he had the power of reading, as they run, the revelations of the wire. I had the hope that he was about to explain to the public the more general use of this instrument, — which with a stupid fatuity the public has, as yet, failed to grasp. Because its signals have been first applied by means of electro-magnetism, and afterwards by means of the chemical power of electricity, the many-headed people refuses to avail itself, as it might do very easily, of the same signals for the simpler transmission of intelligence, whatever the power employed.

The great invention of Mr. Morse is his register and alphabet. He himself eagerly disclaims any pretension to the original conception of the use of electricity as an errand-boy. Hundreds of people had thought of that, and suggested it; but Morse was the first to give the errand-boy such a written message that he could not lose it on the way, nor mistake it when he arrived. The public, eager to thank Morse as he deserves, thanks him for something he did not invent. For this he probably cares very little. Nor do I care more. But the public does not thank him for what he did originate, — this invaluable and simple alphabet. Now, as I use it myself in every detail of life, and see every hour how the public might use it, if it chose, I am really sorry for this negligence, — both on the score of his fame, and of general convenience.

Please to understand, then, ignorant Reader, that this curious alphabet reduces all the complex machinery of Cadmus and the

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* Written by Rev. Edward E. Hale for the Atlantic Monthly, October, 1858.

rest of the writing-masters to characters as simple as can be made by a dot, a space, and a line, variously combined. Thus, the marks - — designate the letter A. The marks — - - - designate the letter B. All the other letters are designated in as simple a manner.

Now I am stripping myself of one of the private comforts of my life, (but what will one not do for mankind?) when I explain that this simple alphabet need not be confined to electrical signals. *Long* and *short* make it all, — and wherever long and short can be combined, be it in marks, sounds, sneezes, fainting-fits, canes, or children, ideas can be conveyed by this arrangement of the long and short together. Only last night I was talking scandal with Mrs. Wilberforce at a summer party at the Hammersmiths. To my amazement, my wife, who scarcely can play "The Fisher's Hornpipe," interrupted us by asking Mrs. Wilberforce if she could give her the idea of an air in "The Butcher of Turin." Mrs. Wilberforce had never heard that opera, — indeed, had never heard of it. My angel-wife was surprised, — stood thrumming at the piano, — wondered she could not catch this very odd bit of discordant accord at all, — but checked herself in her effort, as soon as I observed that her long notes and short notes, in their tum-tee, tee, — tee-tee, tee-tum tum, meant, "He 's her brother." The conversation on her side turned from "The Butcher of Turin," and I had just time, on the hint thus given me by Mrs. I., to pass a grateful eulogium on the distinguished statesman whom Mrs. Wilberforce, with all a sister's care, had rocked in his baby-cradle, — whom, but for my wife's long and short notes, I should have clumsily abused among the other statesmen of the day.

You will see in an instant, awakening Reader, that it is not the business simply of "operators" in telegraphic dens to know this Morse alphabet, but your business, and that of every man and woman. If our school-committees understood the times, it would be taught, even before phonography or physiology, at school. I believe both these sciences now precede the old English alphabet.

As I write these words, the bell of the South Congregational

strikes dong, dong, dong, —— dong, dong, dong, —— dong, dong, dong. Nobody has unlocked the church-door. The old tin sign, "In case of fire, the key will be found at the opposite house," has long since been taken down, and made into the nose of a waterpot. Yet there is no Goody Two-Shoes locked in. No! But, thanks to Dr. Channing's Fire-Alarm, the bell is informing the South End that there is a fire in District Dong-dong-dong, — that is to say, District No. 3. Before I have explained to you so far, the "Eagle" engine, with a good deal of noise, has passed the house on its way to that fated district. An immense improvement this on the old system, when the engines radiated from their houses in every possible direction, and the fire was extinguished by the few machines whose lines of quest happened to cross each other at the particular place where the child had been building cob-houses out of lucifer-matches in a paper-warehouse. Yes, it is a very great improvement. All those persons, like you and me, who have no property in District Dong-dong-dong, can now sit at home at ease, — and little need we think upon the mud above the knees of those who have property in that district and are running to look after it. But for them the improvement only brings misery. You arrive wet, hot or cold, or both, at the large District No. 3, to find that the lucifer-matches were half a mile from your store, — and that your own private watchman, even, had not been waked by the working of the distant engines. Wet property-holder, as you walk home, consider this. When you are next in the Common Council, vote an appropriation for applying Morse's alphabet of long and short to the bells. Then they can be made to sound intelligibly. Dāung dĭng dĭng, — dĭng, — dĭng dāung, — dāung dāung dāung dāung, and so on, will tell you, as you wake in the night, that it is Mr. B.'s store which is on fire, and not yours, or that it is yours, and not his. This is not only a convenience to you and a relief to your wife and family, who will thus be spared your excursions to unavailable and unsatisfactory fires, and your somewhat irritated return, — it will be a great relief to the Fire Department. How placid the operations of a fire where none attend except on business! The various engines arrive, but

no throng of distant citizens, men and boys, fearful of the destruction of their all. They have all roused on their pillows to learn that it is No. 530 Pearl Street which is in flames. All but the owner of No. 530 Pearl Street have dropped back to sleep. He alone has rapidly repaired to the scene. That is he, who stands in the uncrowded street with the Chief Engineer, on the deck of No. 18, as she plays away. His property destroyed, the engines retire, — he mentions the amount of his insurance to those persons who represent the daily press, they all retire to their homes, — and the whole is finished as simply, almost, as was his private entry in his day-book the afternoon before.

This is what might be, if the magnetic alarm only struck *long* and *short*, and we had all learned Morse's alphabet. Indeed, there is nothing the bells could not tell, if you would only give them time enough. We have only one chime, for musical purposes, in the town. But, without attempting tunes, only give the bells the Morse alphabet, and every bell in Boston might chant in monotone the words of "Hail Columbia" at length, every Fourth of July. Indeed, if Mr. Barnard should report any day that a discouraged 'prentice-boy had left town for his country home, all the bells could instantly be set to work to speak articulately, in language regarding which the dullest imagination need not be at loss,

"Turn again, Higginbottom,
Lord Mayor of Boston!"

I have suggested the propriety of introducing this alphabet into the primary schools. I need not say I have taught it to my own children, — and I have been gratified to see how rapidly it made head against the more complex alphabet in the grammar schools. Of course it does; an alphabet of two characters matched against one of twenty-six, — or of forty-odd, as the very odd one of the phonotypists employs! On the Franklin-medal-day I went to the Johnson School examination. One of the committee asked a nice girl, what was the capital of Brazil. The child looked tired and pale, and, for an instant, hesitated. But, before she had time to commi herself, all answering was rendered impossible by an awful turn of whooping-cough which one

of my own sons was seized with, — who had gone to the examination with me. Hawm, hem hem; — hem hem hem; — hem, hem; — hawm, hem hem; — hem hem hem; — hem, hem, — barked the poor child, who was at the opposite extreme of the school-room. The spectators and the committee looked to see him fall dead with a broken blood-vessel. I confess that I felt no alarm, after I observed that some of his gasps were long and some very *staccato;* nor did pretty little Mabel Warren. She recovered her color, — and, as soon as silence was in the least restored, answered, "*Rio* is the capital of Brazil," — as modestly and properly as if she had been taught it in her cradle. They are nothing but children, any of them, — but that afternoon, after they had done all the singing the city needed for its annual entertainment of the singers, I saw Bob and Mabel start for a long expedition into West Roxbury, — and when he came back, I know it was a long featherfew, from her prize school-bouquet, that he pressed in his Greene's "Analysis," with a short frond of maiden's hair.

I hope nobody will write a letter to "The Atlantic," to say that these are very trifling uses. The communication of useful information is never trifling. It is as important to save a nice child from mortification on examination-day, as it is to tell Mr. Fremont that he is not elected President. If, however, the reader is distressed because these illustrations do not seem to his more benighted observation to belong to the big bow-wow strain of human life, let him consider the arrangement which ought to have been made years since, for lee shores, railroad collisions, and that curious class of maritime accidents where one steamer runs into another under the impression that she is a lighthouse. Imagine the Morse alphabet applied to a steam-whistle, which is often heard five miles. It needs only *long* and *short* again. "*Stop Comet,*" for instance, when you send it down the railroad line, by the wire, is expressed thus: —

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Very good message, if Comet happens to be at the telegraph station when it comes! But what if Comet has gone by? Much

good will your trumpery message do then! If, however, you have the wit to sound your long and short on an engine-whistle, thus: — Scre scre, scre; screeeee; scre scre; scre scre scre scre; scre scre — scre, scre scre, screeeee screeeee; scre; screeeee; — why, then the whole neighborhood, for five miles round, will know that Comet must stop, if only they understand spoken language, — and, among others, the engineman of Comet will understand it; and Comet will not run into that wreck of worlds which gives the order, — with his nucleus of hot iron and his tail of five hundred tons of coal. So, of the signals which fog-bells can give, attached to lighthouses. How excellent to have them proclaim through the darkness, "I am Wall!" Or of signals for steamship-engineers. When our friends were on board the "Arabia" the other day, and she and the "Europa" pitched into each other, — as if, on that happy week, all the continents were to kiss and join hands all round, — how great the relief to the passengers on each, if, through every night of their passage, collision had been prevented by this simple expedient! One boat would have screamed, "Europa, Europa, Europa," from night to morning, — and the other, "Arabia, Arabia, Arabia," — and neither would have been mistaken, as one unfortunately was, for a lighthouse. Any passenger who has ever had a stateroom next the whistle will testify to the sense of secure comfort this nightly chorus would give him.

The long and short of it is, that whoever can mark distinctions of time can use this alphabet of long-and-short, however he may mark them. It is, therefore, within the compass of all intelligent beings, except those who are no longer conscious of the passage of time, having exchanged its limitations for the wider sweep of eternity. The illimitable range of this alphabet, however, is not half disclosed when this has been said. Most articulate language addresses itself to one sense, or at most to two, sight and sound. I see, as I write, that the particular illustrations I have given are all of them confined to signals seen or signals heard. But the dot-and-line alphabet, in the few years of its history, has already shown that it is not restricted to these two senses, but makes itself intelligible to all. Its message, of course, is heard as well

as read. Any good operator understands the sounds of its ticks upon the flowing strip of paper, as well as when he sees it. As he lies in his cot at midnight, he will expound the passing message without striking a light to see it. But this is only what may be said of any written language. You can read this article to your wife, or she can read it, as she prefers; that is, she chooses whether it shall address her eye or her ear. But the long-and-short alphabet of Morse and his imitators despises such narrow range. It addresses whichever of the five senses the listener chooses.

This fact is illustrated by a curious set of anecdotes — never yet put in print, I think — of that critical despatch which in one night announced General Taylor's death to this whole land. Most of the readers of these lines probably read that despatch in the morning's paper. The compositors and editors had read it. To all of them it was a despatch to the eye. But half the operators at the stations *heard* it ticked out, by the register stroke, and knew it before they wrote it down for the press. To them it was a despatch to the ear. My good friend Langenzunge had not that resource. He had just been promised, by the General himself, (under whom he served at Palo Alto,) the office of Superintendent of the Rocky-Mountain Lines. He was returning from Washington over the Baltimore and Ohio Railroad, on a freight-train, when he heard of the President's danger. Langenzunge loved Old Rough and Ready, — and he felt badly about his own office, too. But his extempore train chose to stop at a forsaken shanty-village on the Potomac, for four mortal hours, at midnight. What does he do but walk down the line into the darkness, climb a telegraph-post, cut a wire, and apply the two ends to his tongue, to *taste*, at the fatal moment, the words, "Died at half past ten." Poor Langenzunge! he hardly had nerve to solder the wire again. Cogs told me that they had just fitted up the Naguadavick stations with Bain's chemical revolving disc. This disc is charged with a salt of potash, which, when the electric spark passes through it, is changed to Prussian-blue. Your despatch is noiselessly written in dark-blue dots and lines. Just as the disc started on that fatal despatch, and Cogs bent over it to

read, his spirit-lamp blew up, — as the dear things will. They were beside themselves in the lonely, dark office; but, while the men were fumbling for matches, which would not go, Cogs's sister, Nydia, a sweet blind girl, who had learned Bain's alphabet from Dr. Howe at South Boston, bent over the chemical paper, and *smelt* out the prussiate of potash, as it formed itself in lines and dots to tell the sad story. Almost anybody used to reading the blind books can read the embossed Morse messages with the finger, — and so this message was read at all the midnight way-stations where no night-work is expected, and where the companies do not supply fluid or oil. Within my narrow circle of acquaintance, therefore, there were these simultaneous instances, where the same message was seen, heard, smelled, tasted, and felt. So universal is the dot and line alphabet, — for Bain's is on the same principle as Morse's.

The reader sees, therefore, first, that the dot and line alphabet can be employed by any being who has command of any long and short symbols, — be they long and short notches, such as Robinson Crusoe kept his accounts with, or long and short waves of electricity, such as these which Valentia is sending across to the Newfoundland Bay, so prophetically and appropriately named "The Bay of Bulls." Also, I hope the reader sees that the alphabet can be understood by any intelligent being who has any one of the five senses left him, — by all rational men, that is, excepting the few eyeless deaf persons who have lost both taste and smell in some complete paralysis. The use of Morse's telegraph is by no means confined to the small clique who possess or who understand electrical batteries. It is not only the torpedo or the *Gymnotus electricus* that can send us messages from the ocean. Whales in the sea can telegraph as well as senators on land, if they will only note the difference between long spoutings and short ones. And they can listen, too. If they will only note the difference between long and short, the eel of Ocean's bottom may feel on his slippery skin the smooth messages of our Presidents, and the cat-fish, in his darkness, look fearless on the secrets of a Queen. Any beast, bird, fish, or insect, which can discriminate between long and short, may use the telegraphic

alphabet, if he have sense enough. Any creature, which can hear, smell, taste, feel, or see, may take note of its signals, if he can understand them. A tired listener at church, by properly varying his long yawns and his short ones, may express his opinion of the sermon to the opposite gallery before the sermon is done. A dumb tobacconist may trade with his customers in an alphabet of short-sixes and long-nines. A beleaguered Sebastopol may explain its wants to the relieving army beyond the line of the Chernaya, by the lispings of its short Paixhans and its long twenty-fours.

THE TELEGRAPH.*

Thou lonely Bay of Trinity,
Ye bosky shores untrod,
Lean, breathless, to the white-lipped sea
And hear the voice of God!

From world to world His couriers fly,
Thought-winged and shod with fire;
The angel of His stormy sky
Rides down the sunken wire.

What saith the herald of the Lord?—
"The world's long strife is done!
Close wedded by that mystic cord,
Her continents are one.

"And one in heart, as one in blood,
Shall all her peoples be;
The hands of human brotherhood
Shall clasp beneath the sea.

"Through Orient seas, o'er Afric's plain,
And Asian mountains borne,
The vigor of the Northern brain
Shall nerve the world outworn.

"From clime to clime, from shore to shore,
Shall thrill the magic thread;
The new Prometheus steals once more
The fire that wakes the dead.

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* From the Atlantic Monthly, October, 1858.

"Earth gray with age shall hear the strain
Which o'er her childhood rolled;
For her the morning stars again
Shall sing their song of old.

"For, lo! the fall of Ocean's wall,
Space mocked, and Time outrun! —
And round the world, the thought of all
Is as the thought of one!"

O, reverently and thankfully
The mighty wonder own!
The deaf can hear, the blind may see,
The work is God's alone.

Throb on, strong pulse of thunder! beat
From answering beach to beach!
Fuse nations in thy kindly heat,
And melt the chains of each!

Wild terror of the sky above,
Glide tamed and dumb below!
Bear gently, Ocean's carrier-dove,
Thy errands to and fro!

Weave on, swift shuttle of the Lord,
Beneath the deep so far,
The bridal robe of Earth's accord,
The funeral shroud of war!

The poles unite, the zones agree,
The tongues of striving cease;
As on the Sea of Galilee,
The Christ is whispering, "Peace!

NEW YORK AND BOSTON TELEGRAPH LINES.

The following copy of a report made by Mr. Francis O. J. Smith to the stockholders of the New York and Boston Magnetic Telegraph Association, dated New York, October 28, 1846, presents an interesting *résumé* of the condition of the lines between these important points at that date.

"Gentlemen, — The line between this city and Boston, since I have had charge of it, has been disabled more than half the period, on an average, from causes wholly beyond the power of vigilance,

conducted upon any ordinary means and expense, to avoid; namely, the insufficiency of the wire at the points exposed to the violence and action of the winds, to breaks and crossings.

On sections between Harlem and Bridgeport, the crossings have been most frequent, and in fact constant. This has arisen from the slackness of the wires, as originally put up, under a conviction expressed by the President to the workmen in charge of the work of putting up, and derived from alterations made in the suspension of the wires on the Southern line, that this mode would relieve the wires from breaks. To a considerable extent it has proved so, as fewer breaks have been experienced on that section than on corresponding distances of other sections. But, while breaks have thus been avoided, crossings have been multiplied.

"Along the entire line in the State of Connecticut, and a portion of Massachusetts, the wires are exposed to a much more raking sweep of the winds from the seaboard than on other stations. Hence, during every storm, many more breaks have occurred there than elsewhere. During the late great storm, about *one hundred and seventy breaks* were reported in the distance of about thirty miles, between New Haven and Hartford, while on one hundred miles, from Boston to Springfield, only a half-dozen breaks occurred. At Washington Bridge, the topmast of the mast was broken, although sustained by iron guys; and at Bridgeport the mast was entirely broken up and overthrown. A new topmast is being refitted at the former place, and at both places temporary connections of the wires have been arranged. Twelve hundred feet of the wires, at Connecticut River, were swept off with the overthrown bridge of the Railroad Company, and wires substituted temporarily on the stone piers remaining. Such are the outlines of the late damage to the line. But since these have been repaired, many breaks have occurred, evidently from the tension produced in the wire during the storm, and many more may be anticipated. And it is most manifest that, from the exposed condition of the line along the seaboard, a much more numerous and expensive inspection force will be needed beyond the original supposition, in order to keep the line in any good condition for work, and to have repairs made promptly,

and especially to make the second wire available against crossings. In fact, I am persuaded that, with the present size of wires, and without a much wider separation of them, no confidence can be entertained in the practicability of keeping the two wires apart for independent operations for any considerable distance, or any considerable length of time. And, considering the two causes of interruption of the line that will and must be perpetually occurring with the present wires, viz. breaks and crossings, I do not hesitate to report it as a matter of positive interest and economy for the Company to authorize a sale to be made of at least one line of the present (copper) wire on the best terms practicable, and the substitution of an iron wire of at least 250 to 330 pounds to the mile, either galvanized with zinc, or prepared with some cheaper if less enduring preventive of oxidation, and without any avoidable delay.

"The wire of one line may be sold at from 18 to 20 cents per pound, and for nearly enough, probably, to purchase the requisite iron wire. The expense requiring immediate outlay would be that of taking down and transporting to market the copper wire, and the transporting and putting up of the iron wire. A part of the needful force for putting up, as well as taking down, we have in our inspectors already employed along the line. If means cannot be obtained otherwise to meet this necessary outlay, provided your board shall sanction it, I will endeavor to accomplish it with my own private means and credit, and add it to the existing indebtedness of the Company to me. With two wires of suitable diameter and strength, we should not only have a line at all times far more reliable in respect to integrity, but also one not more than half as expensive of inspection as the present lines. And until this be accomplished, I do not candidly believe the line can be made either creditable or profitable to any party. With this accomplished, I feel confident its reputation and productiveness will answer every reasonable expectation of the stockholders and the public.

"Experience has demonstrated, that, when the line is in a reliable condition, the average receipts of each through wire would not be less than seventy dollars per day, with business enough

for two through wires, while a way wire would probably pay its own expenses, and those of inspecting the entire line.

"With these facts before you, I respectfully request your action and advice in the premises, as you may deem for the interest of all parties concerned."

The following summary of a report from Mr. Smith to the stockholders, dated New York, September 5, 1848, shows the condition of the lines two years later. Many of the grave difficulties enumerated by Mr. Smith in this report will cause a smile at the present time, when similar ones are so easily surmounted.

"Recurring to the financial considerations of the line, the operations of the past year will be found, on analysis, well calculated to encourage steady perseverance, and afford the assurance of an ultimate recompense for the capital that is employed; and this, notwithstanding the line has been in the mean time subjected to the most frequent and perplexing interruptions, and consequently to very large losses of revenue.

"The principal of these interruptions and losses have arisen from the constant and continuous changes which have been prosecuted by the Western Railroad Company, in the removal of old and construction of new depots and storehouses, and for laying a second track along the entire line of the road, from Worcester to Springfield, a distance of sixty miles; and also on a section of the Harlem Railroad by the latter company, for a distance of about seven miles, with reference to accommodating, on a new track, the New Haven Railroad Company, whose road is in the process of construction.

"This latter enterprise has, moreover, most seriously affected the line, by a removal to a new site of the draw of the Washington Bridge on the Housatonic River, thereby rendering an expensive mast, erected at that point by the Association, of no use for the purpose of its erection, and subjecting the line, in addition thereto, to several interruptions daily at the new draw, as also to large additional expenses of inspection, as well as heavy losses. I have arranged for the construction of a tower at this point, to remedy for ever, as I trust, the recurrence of a like disaster there to the line. The cost is estimated at $350.

"Along the distances specified on the Western Railroad, and on the Harlem Road, a very large portion of the original posts of the line have been displaced and reset with far more expense than would have been requisite to build an entirely new line of like length. At several points on the Worcester Railroad, also, removals of posts have been required by the various improvements that have been in progress there; and I have been formally requested to have all the posts of this forty miles of line changed to either one or the other side of the road, so as to allow of no crossing of the road by the wires of the line.

"From these combined causes, to avoid which no effort could be availing, the line, during the past year, has been interrupted, on an average, one day in every six, causing an average difference in the financial condition of the line of full $100 for each day of interruption, or an aggregate loss exceeding $5,000.....

"During the past winter, one section of the line between Worcester and Boston suffered most seriously and expensively from the extraordinary accumulation of frozen snow on the wires. The snow, in this instance, depressed them between the posts with a weight estimated to be equal to five hundred pounds on each wire. And where this occurred at curves of the road and of the line, the wires were brought within striking reach of the engines and cars, and the result of the conflict was a dangerous exposure of the latter to accident and injury, and a total prostration of the wires of the line for long distances in advance and in the rear of the point of contact. The loss of revenue, and the simultaneous progress of ordinary expenses with the cost of repairs in the midst of winter snows and an icy atmosphere, were, in this single instance of interruption, not short of one thousand dollars to the Association.....

"This seemingly endless catalogue of accidents and hinderances incident to the conjunction of telegraph lines with a railroad, and especially in this climate, with each under a distinctive administration, and of which an impatient public takes but little count in their strictures on telegraph lines, and the great losses consequent therefrom, illustrated to the Directors of this line the great error involved in the preference hitherto given to railroads over public

or country roads for the site of telegraphs, and induced their advice and resolution to authorize and hasten as much as possible the absolute removal of their line, at least one wire of it, from the Western Railroad, as also from the Harlem Road. This was seen to involve a new expenditure of a large amount, and of course equal to the construction of that extent of new line; and causing, moreover, a postponement of an immediate dividend in money to the stockholders, which otherwise might be made.

"But looking more to the permanent and prospective interests of the Association, and aiming at no speculative ends in the imparting of a fictitious value to the stock of the line, by paying out its revenues in dividends, rather than in an essential and most important improvement, which the welfare and continuous success of the line demanded, the work was decided on, and has now been nearly accomplished, and this with No. 9 iron wire, and such improvements in the size of the posts (there being none less than six inches in diameter at the top end), and in their increased number (thirty-five to the mile), and in the form, strength, and durability of the insulators, and in the avoidance of curves and angles in the direction given to the wires, whenever practicable, as to secure a telegraph structure that is unequalled in these particulars by any other yet constructed in the United States.....

"The aggregate of receipts of the line from the first of August, 1847, to the first of August, 1848, is $34,835.14; the aggregate of expenditures, $36,034.14. Of this expenditure,

There has been appropriated in extinguishment of debts due at the commencement of the last year, .	$7,216.54
Salaries of officers, operators, inspectors, messengers,	14,917.78
Rents, ...	981.25
Office fixtures, ...	609.46
Battery, ...	967.92
Tools and registers, ...	283.67
Collections for, and payments to, other lines, . .	3,090.78
Lights, fuel, porterage, printing, stationery, freight, &c.,	2,596.06
Repairs, and towards new line (the former item amounts to about $1,000, leaving $4,371.69 towards the latter), ...	5,371.69
Total, ...	$36,035.15

"The sums of indebtedness, existing at the commencement of the year just terminated, and since paid out of its revenues, amount to $7,216.54. This sum added to the sum of $4,371.69, expended towards the construction of the new section of line, make an aggregate of $11,588.23, equal to the apportionment of a dividend of nine per cent on the whole capital of the Association paid in, and exclusive of keeping the line in repair and paying its ordinary expenses. If the losses by interruptions were superadded, the net earnings of the line would have been equal to a dividend of fifteen per cent to the stockholders. . . . . .

"The legislative act of Connecticut, passed May, 1848, is not in its history altogether creditable to either the sense of justice or sagacity of the legislators of that State. At the same time, in its provisions there is nothing seriously objectionable, if our Association be desirous of invoking the protection of statute law, additional to that which the laws of Congress and the common law everywhere throw around our patented privileges and the capital employed under them.

"Connecticut had, at a previous session, passed a penal law for the protection of our line against wilful injury, and granted also a charter of incorporation for our Association. Both of these acts are now repealed by this late act, and without any previous notice to parties known to be specially interested therein.

"The charter, however, was never accepted, and we never had occasion to put the penal law into requisition. For the same moral sense of mankind that recoils at the thought of villany which would poison the sources of our public fountains, or purposely impregnate an atmosphere which all must inhale with the invisible agents of fatal diseases, seems everywhere in our land to have characterized the feelings of the people of all classes towards the telegraph, and to come up to its protection and preservation, regardless of what the law either requires, or legislators may designedly omit to forbid and punish.

"In view of this pleasing and praiseworthy consideration, founded in the deep and honorable regards of the people of Connecticut, no less than of those of other States of our happy confederacy, for all agents honorably engaged in the diffusion of

public and private intelligence, I may remark, that, whatever may have been the motive of the summary proceedings in question of the late Connecticut Legislature, its force will probably be spent without harm to the interests of this Association, though none of the proffered boons of that law be accepted by us. . . . . .

"The grant of a charter by the Massachusetts Legislature is still open to the acceptance of this Association. There would be some advantages incident to its adoption, while it might expose the administration of the telegraph to unwelcome interference in new legislation, if once subjected to the jurisdiction of the State Legislature. It is not doubted that a Legislature so distinguished for its guardianship of worthy enterprise as that of Massachusetts has hitherto been, would in the end accord ample justice to the wants of the telegraph; but the interests, and affairs, and conducting of the business of the telegraph are so unique, and to many minds so mystical, as to expose them to most hasty and unmerited censures, and groundless prejudice, which nothing but time and that patient investigation which is seldom accorded by fault-finders can rebut. I am inclined, however, to the opinion, that our interests will always be safe under the protective policy of Massachusetts legislation and jurisprudence. . . . . .

"No person who has not been in the immediate charge of a telegraph can at all appreciate the multiplicity and endless succession of cares and perplexities incident to such a position; and the indisposition of the public and of the newspaper press to tolerate any failure, however unavoidable, in the working of the telegraph, renders the business exceedingly irksome, thankless, and disagreeable. . . . . .

"A claim has arisen against the Association, out of ordinary occurrence. At Bridgeport, where a man's house was injured by lightning, in the immediate vicinity of the line of telegraph, he conceived the calamity attributable to its influence. On careful investigation, in conjunction with Mr. Pettingall, the resident Director at Bridgeport, it satisfactorily appeared that the agency of the line was exactly opposite to that supposed by the injured party; namely, to the extent of the capacity of the wires as an

electric conductor, it had alleviated and carried off the atmospheric charge from the point of its explosion in the vicinity of the injured house. This being understood, I have not heard of any renewal of the claim."

From 1845 to the autumn of 1849, the above line was the only one extending between Boston and New York, and consequently it had the monopoly of the business; but in the latter year two competing lines, the House and the Bain, were constructed between these points, and the business was divided between the three, until July, 1852, when the Bain and the Morse (or magnetic) lines were united, under the title of "The New York and New England Union Telegraph Company."

The following statement exhibits the receipts of the Union Company's lines from July, 1852, to July, 1859, inclusive.

Receipts for the year ending July, 1853, . .	$ 82,214.16
" " " " " 1854, . .	79,683.73
" " " " " 1855, . .	101,307.98
" " " " " 1856, . .	102,151.78
" " " " " 1857, . .	103,134.06
" " " " " 1858, . .	98,097.73
" " " " " 1859, . .	96,136.06
Total for seven years, ...	$ 662,725.50

During the past seven years there has existed a competing line, using the House and Hughes printing instruments, between the points reached by the above, which has transmitted the entire press reports and a large amount of private despatches, probably as great as that transmitted by the Union Company.

The receipts of the printing lines could not have fallen short, and probably considerably exceeded, those of the above Company; but placing them at the same amounts, we have as the total receipts for despatches transmitted over all the lines between Boston and New York, for the past seven years, $ 1,325,451 !

The increase in the receipts for the year 1853 over 1848, an interval of five years, would, according to the above figures, be *about five hundred per cent.*

Total receipts of the House and Union lines for 1853,	$164,428.32
Total receipts of the Magnetic line, 1848, . .	34,835.14
Increase in 1853, ...	$129,593.18

Mr. F. O. J. Smith, who has always held a controlling interest in the Union Company, and possessed valuable rights in the Morse patent, has recently sold out his entire interest to the American Telegraph Company, for $300,000.

RESISTANCES OF MORSE, PHELPS, AND HOUSE COILS.

We are indebted to Mr. E. B. Elliott for the following statement of some interesting experiments conducted by Mr. Moses G. Farmer and himself.

From carefully conducted experiments it appeared that the resistance of the coils of "Phelps's call" is equal to 16.3 miles of No. 9 iron wire. The resistance of the coil of the House printing instrument was from 72 to 90 miles. That of the Morse "relay," as ordinarily made by Messrs. Palmer and Hall, varied from 8 to 16 miles.

The "call" alluded to is used in connection with the printing instrument to reduce resistance. The wire is finer and the call smaller than the Morse relay, as usually made at the establishment of D. Davis, Jr. (Palmer and Hall, successors).

The House coil alluded to above was a large helix of the House printing instrument, made by Mr. J. B. Richards of New York. The resistance of this helix, therefore, according to the above carefully conducted experiments, was from four to six times that of the "Phelps call," and from six to eight times the resistance of the receiving magnet of Palmer and Hall's make.

MAGNETOMETER.

The magnetometer represented in Fig. 89 is designed to measure the magnetizing power of galvanic currents. It consists of a vertical electro-magnet, of the U form, with an armature above it, attached to the short arm of a balanced lever. The long arm of the lever is graduated decimally, to measure, by means of weights of from 100 to 10,000 grains, the force re-

quired to detach the armature from the electro-magnet when connected with the battery whose power is to be determined.

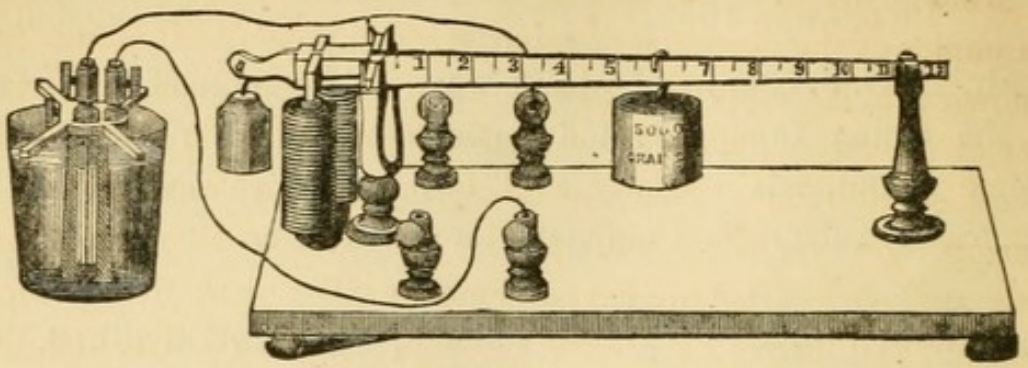

Fig. 89.

The lever is supported on an axis with knife-edge bearings. The armature may also be suspended on knife-edges attached to the beam. On the under surface of the armature is brazed a thin plate of brass, to prevent its adhesion to the poles. A difference of magnetizing power of 10 grains can be estimated in a series extending from 100 to more than 100,000 grains, or the limit of saturation of the magnet. Two sets of screw-cups will be seen on the board; one of these is connected with a short coil round the magnet, the other with a long coil. By making this long coil of fine wire, the instrument compares currents differing in their intensity. Two batteries are first estimated as to quantity, by their magnetizing power through the short coil. Their relative intensity is then shown compared with their quantity, by their magnetizing power through the long coil, their intensity being in mathematical proportion to the conducting-power of the wire for each, and therefore to the amount of electricity which passes. In comparing the power of different batteries, — a matter of some practical importance, — this instrument gives a rapid and uniform result.

Instead of using a long coil of wire, surrounding the magnet, in estimating intensity, the current may be passed through a detached coil of fine wire, and through the short coil of the instrument, which would give a similar result.

THE TELEGRAPH AS A DETECTIVE AGENT.

Among the general uses of the telegraph to the public, many examples of the detection of crime are mentioned. It is generally known that the notorious Tawell, after the commission of the murder of Sherwood, started for London from Slough, by the Great Western Railway. Notice of the crime, and a description of his person, however, flew with the speed of light along the wires, and arrived at Paddington so much earlier than the murderer himself, that upon his arrival he was recognized, tracked from place to place, finally apprehended, tried, convicted, and executed.

One night, at ten o'clock, the chief cashier of the Bank of England received a notice from Liverpool, by electric telegraph, to stop certain notes. The next morning the descriptions were placed upon a card and given to the proper officer, to watch that no person exchanged them for gold. Within ten minutes they were presented at the counter by an apparent foreigner, who pretended not to speak a word of English. A clerk in the office who spoke German interrogated him, when he declared that he had received them on the exchange at Antwerp, six weeks before. Upon reference to the books, however, it appeared that the notes had only been issued from the bank about fourteen days, and therefore he was detected at once as the utterer of a falsehood. The terrible Forrester was sent for, who forthwith locked him up, and the notes were detained. A letter was at once written to Liverpool, and the real owner of the notes came up to town on Monday morning. He stated that he was about to sail for America, and that whilst at a hotel he had exhibited the notes. The person in custody advised him to stow the valuables in his portmanteau, as Liverpool was a very dangerous place for a man to walk about with so much money in his pocket. The owner of the property had no sooner left the house than his adviser broke open the portmanteau and stole the property. The thief was taken to the Mansion House, and could not make any defence. The sessions were then going on at the Old Bailey. Though no one who attends that court can doubt that impartial justice and leniency are administered to the prisoners, yet there is no one

who does not marvel at the truly railway speed with which the trials are conducted. By a little after ten, the next morning, — such was the speed, — not only was a true bill found, but the trial by petty jury was concluded, and the thief sentenced to expiate his offence by ten years' transportation.

The following is extracted from the telegraph book preserved at the Paddington station: —

"Paddington, 10.20 A. M. — Mail train just started. It contains three thieves, named Sparrow, Burrell, and Spurgeon, in the first compartment of the fourth first-class carriage."

"Slough, 10.48 A. M. — Mail train arrived. *The officers have cautioned the three thieves.*"

"Paddington, 10.50 A. M. — Special train just left. It contained two thieves: one named Oliver Martin, who is dressed in black, *crape on his hat;* the other named Fiddler Dick, in black trousers and light blouse. Both in the third compartment of the first second-class carriage."

"Slough, 11.16 A. M. — "Special train arrived. Officers have taken the two thieves into custody, a lady having lost her bag, containing a purse with two sovereigns and some silver in it; one of the sovereigns was sworn to by the lady as having been her property. It was found in Fiddler Dick's watch-fob."

It appears that, on the arrival of the train, a policeman opened the door of the third compartment of the first second-class carriage, and asked the passengers if they had missed anything. A search in pockets and bags accordingly ensued, until one lady called out that her purse was gone. "Fiddler Dick, you are wanted!" was the immediate demand of the police-officer beckoning to the culprit, who came out of the carriage thunderstruck at the discovery, and gave himself up, together with the booty, with the air of a completely beaten man. The effect of the capture so cleverly brought about is thus spoken of in the telegraph book: —

"Slough, 11.51 A. M. — Several of the suspected persons who came by the various down-trains are lurking about Slough, uttering bitter invectives against the telegraph. Not one of those cautioned has ventured to the Montem."

Ever after this the light-fingered gentry avoided the railway and the *too* intelligent companion that ran beside, and betook themselves again to the road, — a retrograde step, to which on all great occasions they continue to adhere.

THE ASSOCIATED PRESS OF THE UNITED STATES.

The telegraphic news reports of the American press have, by their remarkable accuracy, and the enormous amount of matter daily presented in them, excited the surprise of the press of all other countries. A single issue of many of our metropolitan journals often contains three or four columns of telegraphic news, which, at the usual rates of tolls, would amount to at least $ 500, — a sum quite beyond the ability of even the leading London newspapers to pay daily. By what arrangement, therefore, is the press from Maine to Texas supplied with every important event which transpires in any part of our vast country within a few minutes of its actual occurrence? Some ten years since the leading journals in New York associated themselves together for the purpose of collecting, and sharing the expense of telegraphing, the most important items of news from all parts of the world. A general agent was appointed to superintend the practical operations of the system to be introduced, whose head-quarters are in New York. Other agents are located in all the principal cities of the United States and British America, and in some of the European cities. Subsequently to the formation of the New York association, nearly all the daily newspapers in the United States became associated with it. Everything of interest occurring in any part of this country is telegraphed at once to the general office in New York, copies being dropped at all intermediate points on the route, and the other parts of the country being supplied from the central office.

The annual expense of the press reports for the United States is about $ 200,000, of which the New York press pays about one half, and the remainder is divided among the different members of the association in other sections of the country, — the larger cities paying the bulk of the expense, while the country papers are only taxed some $ 30 or $ 40 per month each.

The larger share of the press reports comes over the wires during the night, — commencing about 6 o'clock P. M. and concluding generally about 1 o'clock A. M., but not unfrequently continuing as late as 4 o'clock, and sometimes all night. We have sometimes been occupied in sending press news when the sun descended below the horizon and when it arose the next morning, having continued at our post during the entire night. During the sessions of Congress the reports are the fullest, and towards the period of adjournment the wires are occupied until a late hour every night in transmitting their doings.

One of the earliest feats, after the extension of the telegraph lines west to Cincinnati, was brought about by the agency of the New York Herald, before any regular association of the press was formed in New York.

It became known that Mr. Clay would deliver a speech in Lexington, Ky., on the Mexican war, which was then (1847) exciting much public attention. From Lexington to Cincinnati was eighty miles, over which an express had to be run. Horses were placed at every ten miles by the Cincinnati agent. An expert rider was engaged, and a short-hand reporter or two stationed in Lexington. When they had prepared his speech it was then dark. The expressman, on receiving it, proceeded with it for Cincinnati. The night was dark and rainy, yet he accomplished the trip in eight hours, over a rough, hilly country road. The whole speech was received at the Herald office at an early hour the next morning, although the wires were interrupted for a short time in the night near Pittsburg, in consequence of the limb of a tree having fallen across them. An enterprising operator in the Pittsburg office, finding communication suspended, procured a horse, and rode along the line amidst the darkness and the rain, found the place and the cause of the break, which he repaired; then returned to the office, and finished sending the speech. The expense of forwarding the speech by express and telegraph amounted to about $ 500.

By the rules of the Associated Press, no journal can receive an exclusive despatch from any other points than Washington and Albany. The propriety of this arrangement is obvious, for

if each member of the press were allowed to receive exclusive telegraphic despatches, there would be a constant rivalry to see which would outstrip the other; the result of which would lead to the breaking up of the association.

RAPIDITY OF THE COMBINATION INSTRUMENT.

On Monday, March 12th, 1860, there were transmitted over one wire, from Boston to New York, 204 private messages, containing 7,456 words, and 600 words of press news; and from New York to Boston, over the same wire, 253 messages, containing 8,957 words; making a total of 17,013 words. The time occupied in transmitting this large number of words was nine hours. The length of the circuit operated is 260 miles, and the weather was rainy during the day. The despatches were all printed in plain Roman letters by the Combination instrument, and accurately punctuated.

Messrs. Grace and Edwards were the operators at the Boston and New York termini of the line.

WORKING SEVERAL TELEGRAPH LINES FROM ONE BATTERY.

Mr. E. B. Elliott, of Boston, read before the American Academy of Arts and Sciences the following interesting paper upon the above subject, Tuesday evening, March 27, 1860: —

"Regarding the supplying, at an extreme station, *several telegraphic wires from one battery;* and the influence which the breaking of a portion of the wires so connected will produce upon the strength of current in those remaining closed.

"Proposition: — If the number of independent telegraph wires, of equal resistances, leading from and supplied by *one battery*, be reduced from x to y, the current strength on each of the remaining y wires will be $\frac{q+x}{q+y}$ times the current strength before existing on each of the x wires; and the increase of current will be $\frac{x-y}{q+y}$ times that current strength.

"In the above proposition,

$q = \frac{R}{r}$ $= \begin{cases} \text{resistance of one of the telegraph wires and helices.} \\ \text{resistance of the battery.} \end{cases}$

"Demonstration: — The resistance of conductors is inversely as their conducting powers. Hence, multiplying the number of conductors divides the resistance. But since the current of the battery is supposed to be distributed *equally* among the whole number of conductors, the current strength on each conductor may be obtained by dividing the total current strength by the number of conductors.

"Applying Ohm's formula, if, with a given battery, the current strength made manifest in a single telegraph wire of average length and section, with helices of average number and resistance, be represented by

$\frac{E}{r+R}$ $= \begin{cases} \text{electro-motive force of the battery,} \\ \text{the sum of the resistances,} \end{cases}$

the current strength on x such wires will be $\frac{E}{r+\frac{R}{x}}$, and the current strength on each of the x wires will be $\frac{E}{xr+R}$.

"But

$$R = q\ r;$$

therefore,

S, the current strength on each of the x wires, is to
S', the current strength on each of the y wires,

as $$\frac{E}{xr+R} : \frac{E}{yr+R} :: 1 : \frac{q+x}{q+y}.$$

Hence

$$S' = \frac{q+x}{q+y} \cdot S, \quad \text{and} \quad S' - S = \frac{x-y}{q+y} \cdot S;$$

which represents the increase of current on each of the remaining y wires.

"A comparison and discussion of carefully conducted experiments of Dr. Müller, of Germany, and Mr. Moses G. Farmer, of Salem, give about 500 as the value of q, the ratio of the resistance of one of the conductors to the battery, in case that the

battery is one of fifty pairs of Grove, in which the exciting fluid is the nitric acid of commerce, and the conductor is of No. 9 iron wire of the best quality used in the United States for telegraphic purposes, 240 miles in length, with from eight to ten Morse relays of average resistance.

"If we assume the value of q to be 500, that is, if the conductors and battery are such that the average resistance of the conductors outside the battery is 500 times the resistance of the battery, the formula will become

$$S' - S = \frac{x - y}{500 + y}.$$

"According to this demonstration, it appears that any number of wires, from one to fifty, of resistances equal to the above, may be supplied from the same battery without appreciable variation in the current. Suppose ten wires to lead from the same battery, and the circuit upon nine of them be opened at once, the increase of strength upon the remaining wire will be but one fifty-sixth. Suppose, as an extreme case, fifty wires lead from the same battery, and the circuit be opened upon forty-nine of them at the same instant, the augmentation upon the remaining wire would be but about one tenth of the current strength previously existing upon such wire.

"Should the resistance of any one of the conductors be but one half that of the average resistance above assumed, such conductor must be considered as two conductors; if but one third, as three conductors; and so on, for other cases.

"Should one of the conductors be imperfectly insulated, so that the amount of current that escapes to the ground before reaching the other extreme of such conductor be equal to the amount that traverses the entire circuit, such conductor should be considered, in applying the above formula, as two conductors; if the escape current is double the through current, the conductor so affected should be treated as equivalent to three conductors; and so with other cases."

PART X.

EARLY DISCOVERIES IN ELECTRO-DYNAMICS.

CHAPTER XXI.

SOEMMERING'S TELEGRAPH.

Mr. S. T. Soemmering, of Munich, first applied galvanism to telegraphing; in 1809 he constructed an apparatus, which, by decomposing water, enabled him to give signals. At the station where the news was to arrive were arranged thirty-five small glass test-tubes, filled with water, and reversed in a reservoir also containing that fluid. Into each of these test-tubes projected, through the bottom of the reservoir, the gilt end of one of thirty-five wires, that came from the transmitting station. Each wire at the terminus of the line was connected to its own distinct brass plate or cylinder. These plates were arranged in a row, and perforated at one extremity: by introducing two conical metallic pins connected with the poles of a voltaic battery into these perforations, a circuit was established. Each glass tube was marked with one of the twenty-five letters of the German alphabet, and ten numerals, and the plate connected with it by wire at the other station was stamped with the same. The circuit being established, the water in two of the tubes was decomposed, the gaseous constituents of which, rising, gave two signs, whose succession was determined by considering the letter over the evolved hydrogen at first. Decomposition of water gives twice the volume of hydrogen that it does of oxygen, and thus no mistake could well be made in distinguishing them. The conducting wires well insu-

lated, after passing some distance from the apparatus, were wound into a rope to go on to their destination.

Soemmering connected with his instrument a curiously constructed alarm, to call the attention of the operator. It consisted of a two-armed lever, the longer arm having the shape of a spoon, while the shorter supported a rolling brass ball. The arrangement was easily moved, and it was necessary to poise it after each telegraphic operation. The hollow end of the long arm stood over the end of one of the wire points, and at the commencement of an operation received the hydrogen that was evolved at this point. After half a minute, sufficient gas was evolved to carry upward in its ascent the long arm of the lever, depress the shorter one, and by this depression permit the ball to fall through a tube on a lever connected with an alarm-stop, set it loose, and thus put the alarm in active operation. Though very ingenious, the expense of so many wires, and their insulation, precluded the use of this instrument on a large scale; likewise, the necessity of constant attention on the part of the attendant to watch the evolution of gas in two of the thirty-five tubes, was a strong objection to it.

ROBERT SMITH'S ELECTRO-CHEMICAL TELEGRAPH.

Mr. R. Smith, Lecturer on Chemistry, Blackford, Scotland, invented, in 1840, an electro-chemical telegraph, the following description of which represents it in its improved form: —

In the annexed woodcut (Fig. 90) *A* represents the indicating portion of the telegraphic apparatus; *a* is a leaden cylinder fixed upon a spindle, which is supported, so as to revolve freely, by two standards attached to the bottom plate of the apparatus; *b b* is a piece of calico in the form of a ribbon, coiled upon the roller *c*, placed in the trough *d*, its contrary extremity being attached to the second roller *e*, revolving loosely in standards attached to the opposite end of the bottom plate; *B* is the communicator, or that portion of the apparatus through which any given signal is communicated to the indicator *A*; *f* is a block of wood having a brass plate, *g*, attached to it; *h* is a slip of wood hinged to the block, and slightly raised above the surface of the

brass plate *g*, by means of a spring placed beneath it. The brass plate *g* is connected by the wire *k* with the positive end of the voltaic battery, *C*, the negative end of which is connected with the wire *l*, which passes along to the indicator, *A*, where it is attached to the leaden cylinder, *a*. The other wire, *m*, is attached to the finger-board, *h*, through which it passes, projecting slightly on the lower surface, its contrary end being attached to the impress wire, *n*, which is supported loosely by a cross-beam on the top of the centre standards of the indicator, its lower end resting upon the calico ribbon on the leaden cylinder beneath.

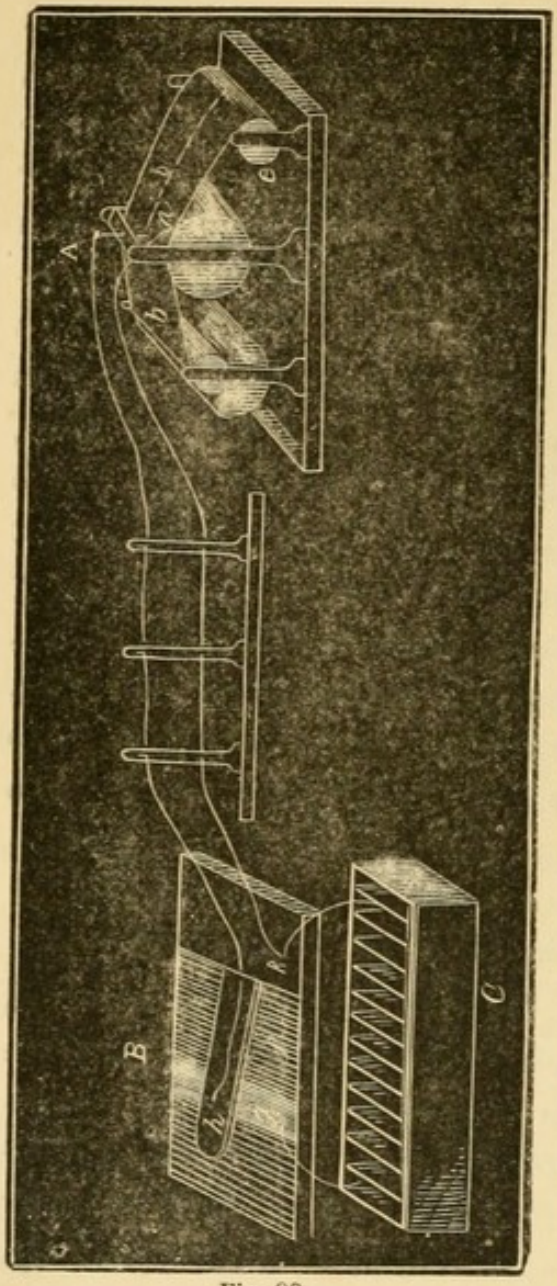

Fig. 90.

To put this apparatus in action, the cells of the battery, *C*, are filled with water, and the trough *d* with a solution of ferrocyanate of potash, to which have been added a few drops of nitric acid. The roller *e*, to which the indicator-cloth is attached, is next put in motion by clock-work, and thus the cloth, wet with the solution contained in the trough *d*, is made to pass uniformly over the leaden cylinder *a*, below the point of the impress wire.

The apparatus is now ready for signalling, which is done by pressing down the finger-board, *h*, so as to bring the end of the wire *n* in contact with the brass plate *f*, thus completing the electric circuit. The impress wire *n* now becomes the positive electrode, and the cylinder *a* the negative one, and a blue mark

is printed upon the cloth, by the electric fluid decomposing the ferrocyanate of potash, thus forming cyanate of iron. If the circuit is formed and broken rapidly, a succession of dots will be printed upon the cloth; if formed and broken at long intervals, the result will be a series of marks. In this manner, long and short spaces and corresponding lines will be formed, according to the duration of the opening or closing of the circuit, and the speed with which the cloth is caused to pass beneath the metallic pen. An arrangement of these various marks thus forms the telegraphic alphabet, from which sentences may be composed, embracing any information which it may be necessary to transmit. For instance, a single dot may stand for A, two for B, three for C, and a dot and line for D, &c.

Experiment has proved that the electric energy from the intensity battery, in producing the electro-chemical effects, *increases* instead of diminishing in regard to distance. Faraday ascertained that the *quantity* of electricity required to decompose a single drop of water is equal to that of a powerful flash of lightning, while from the largest single circuit ever constructed not the slightest chemical effect can be exhibited. On the other hand, a small single circle, composed of only a few square inches of copper and zinc, will temporarily magnetize a large bar of iron, while a powerful voltaic trough will not magnetize a lady's sewing-needle. Throughout the whole of the practical details of the electro-magnetic apparatus, far greater care in workmanship is required than in the voltaic one. Thus, the whole of the joinings of the conducting-wires require to be in perfect metallic contact, and carefully isolated, whilst the electro-chemical communications may be transmitted through the medium of a wire fence.

This instrument is the basis of the Bain telegraph, previously described, and which operated so successfully in this country from 1849 to 1853.

AMPÈRE'S TELEGRAPH.

When Oersted's splendid discovery was announced, and it was seen that feeble electric currents would produce a variety of

magnetic actions, electrical telegraphing received a new impulse, and numerous forms of telegraphic apparatus were proposed.

In 1820, Ampère was led to devise the first telegraph employing the deflection of the magnetic needle by the agency of the galvanic fluid, which, however, it appears that he did not carry out practically. His plan was to have as many magnetic needles as there are letters of the alphabet, which might be put in action by the passage of currents through metallic conductors, made to communicate successively with the battery by means of keys, which could be pressed down at pleasure, and might give place to a telegraphic correspondence that would surmount all distance, and be as prompt as written speech to transmit thought.

Peter Barlow, in 1825, suggested that an instantaneous telegraph might be established by means of conducting-wires and compasses.

In 1828, Victor Triboaillet de Saint Amand proposed to establish a subterranean telegraph between Paris and Brussels, using a voltaic battery and an electroscope, destined to render sensible the slightest galvanic influence. He did not devise any system of signals to represent an alphabet, but left to each one to adopt at pleasure the number of motions to express the words or letters which he might need.

Fechner, of Leipsic, in 1829, proposed to insulate twenty-four wires between Dresden and Leipsic, and, by means of the same number of galvanometers, and signals agreed upon beforehand, to hold telegraphic communications.

Doctor Ritchie, in a lecture at the Royal Institution, London, in 1830, endeavored to illustrate the suggestion of Ampère, and exhibited a model of a telegraph constructed after his description.

In 1832, Baron Schilling, of Cronstadt, a Russian Counsellor of State, devised a needle telegraph, consisting of a number of platinum wires, insulated, and united in a cord of silk, which put in action by a key thirty-six magnetic needles, each of which was placed vertically in the centre of a multiplier. He was the first who adapted to this kind of apparatus an ingenious mechanism for sounding an alarm, which, when the needle turned at the beginning of the correspondence, was set in play by the fall of a little ball of lead.

Counsellor Gauss and Professor Weber, two of the most illustrious philosophers of Germany, to whom the science of magnetism is deeply indebted, entered nobly into the lists in establishing, by means of electricity, telegraphic communication between the Astronomical Observatory, Physical Cabinet, and Magnetic Observatory at Göttingen, the first notice of which was published in 1834. It consisted of a double line of wire carried over the houses and steeples of Göttingen. It was constructed chiefly for the purpose of making investigations of the laws of the force of galvanic currents on a large scale, under different circumstances. The circuit employed in 1833 was about nine thousand feet, and in 1834 fifteen thousand, — three miles. The form of the wire employed was mostly copper, of the size known in commerce as No. 3, of which a length of one metre weighs eight grammes; the wire of the multiplier in the Magnetic Observatory was of silvered copper, No. 14, of 2.6 metres to the gramme. They first employed galvanic electricity by using small-sized plates, and found that the action was much increased by adding to their number. They repeated and perfected their first form of telegraph by applying the phenomenon of magnetic induction discovered by Professor Faraday. The diverse movements or the slow oscillations of magnetic bars, caused by the passage of the currents, and observed by the aid of a glass, furnished to Gauss and Weber all the signals which they wished in corresponding; but the number of signals which they could transmit was few, and the time occupied by each considerable.

The main apparatus was a magneto-electric machine, and to this Counsellor Gauss adapted a peculiar arrangement, by which the direction of the current can be reversed by a single pressure of the finger.

Professor Weber had a delicate apparatus for setting off an alarm of a clock, placed at the side of the magnet in the physical cabinet, by means of the current conducted from the observatory.

STEINHEIL'S TELEGRAPH.

This telegraph (Fig. 91) was in operation previous to July, 1837, and, according to Professor Morse, had been adopted by the

Bavarian government, and was in actual operation during his visit to Europe in 1838. According to the same authority, it was the only European telegraph that professed to write the intelligence.

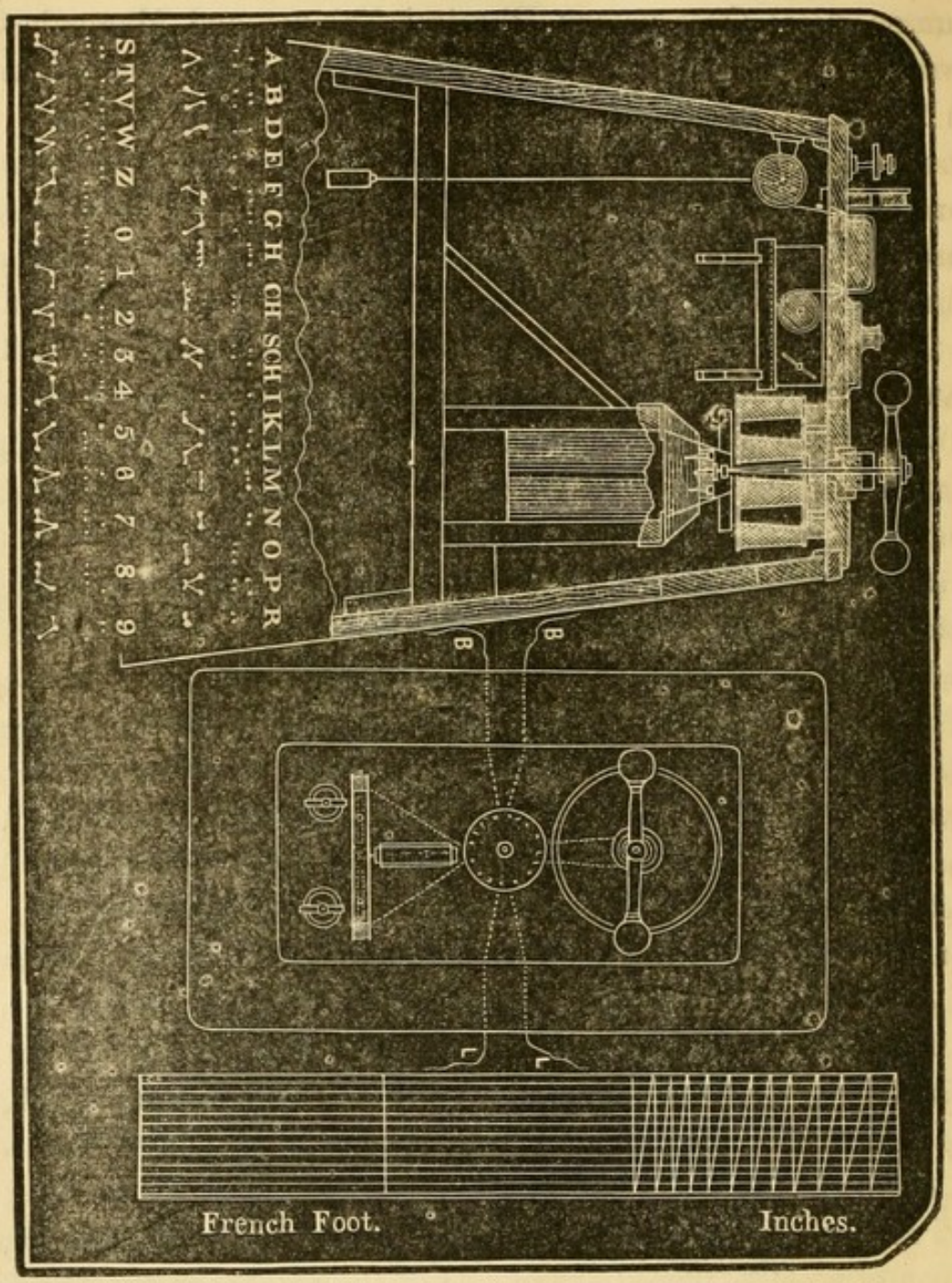

Fig. 91.

This is the first telegraph on record in which the earth was employed for half the circuit, — a most useful application of knowledge, gained at great labor, and not patented, but published freely to the world.

Steinheil's alphabet is one of great beauty and simplicity, and

his entire apparatus displays the man of science, learning, and refinement. In connection with his instrument, he employed a series of musical bells, producing sounds which, striking upon a cultivated ear, conveyed a telegraphic language in imitation of the human voice. But he did not confine himself to the production of evanescent sound; he also employed an alphabet of dots, similar in principle to that subsequently adopted by Mr. Morse. This was recorded permanently upon an endless band of paper. This form of telegraph is a combination of the successive fundamental discoveries of Professors Oersted and Faraday, with the multiplier of Schweigger.

As an inductor, or exciter, Steinheil employed a rotating apparatus similar to the magneto-electric machine described on page 49. The multipliers of which his inductor was composed consisted of a vast number of turns of fine insulated copper wire, made necessary in order that the resistance offered by the thicker wire completing the circuit, even should it be many times as long, might be but little increased. Of the galvanic influence excited, only a small portion was employed, and that when at its maximum of energy. By this means the duration was very short, causing merely a momentary deflection of the little magnetic bars employed for giving the signals. In order to heighten the action of these indicators, they were surrounded by powerful multipliers. Small detached magnets were so placed near these indicators, that they were brought back to their original position when the induced current ceased; or, in other words, as soon as the deflection took place. He was thus enabled to repeat signals in very rapid succession. The same indicator could with ease make five deflections in a second, succeeding each other as fast as the sounds of a repeater when striking. Hence, if bells are placed at the proper striking distance from these indicators, they will ring at every deflection produced; and, as it is quite immaterial at what part of the wire completing the circuit the multiplier containing the indicator is inserted, we have it in our power to produce the sign excited by induction at any part of the course the wire takes. Should it be desired that the indicator, instead of producing sounds, should write, it is merely required to place at

one end of the little magnetic bar a small vessel filled with ink and terminating in a capillary tube. This tube, instead of striking on a bell, thus makes a black spot upon some flat surface held in front of it. If to compose writing, the surface upon which they are written is kept moving on in front of the indicator with a uniform velocity, brought about by an endless band of paper which is rolled off one cylinder on to another by clock-work. As far as the employment of this telegraph is concerned, it may be fairly said to perform all that can be reasonably required of it. The excitation of the current is produced by half a turn of the indicator, and is equally available at all times. The sounds of the bells close to the person making the signals, and which, being produced at the other station too, are also audible there, become by practice intelligible as a language. Should they, however, be misunderstood, the communication presents itself simultaneously written down.

"Ampère required more than sixty wires, whereas thirty or so were sufficient for Soemmering. Wheatsone and Cooke reduced their number to five; Gauss, and, probably in imitation of him, Schilling, as likewise Morse, made use of but a single wire running to the distant station and back. One might imagine that this part of the arrangement could not be further simplified; such, however, is by no means the case. We have found that even the half of this length of wire may be dispensed with, and that with certain precautions its place is supplied by the ground itself. We know, in theory, that the conducting powers of the ground and of water are very small compared with that of the metals, especially copper. It seems, however, to have been previously overlooked, that we have it within our reach to make a perfectly good conductor out of water or any other of the so-called semi-conductors. All that is required is, that the surface that its section presents should be as much greater than that of the metal, as its conducting power is less. In that case, the resistance offered by the semi-conductors will equal that of the perfect conductor; and as we can make conductors of the ground of any size we please, simply by adapting to the ends of the wires plates presenting a sufficient surface of contact, it is evident that we can diminish the

resistance offered by the ground or by water to any extent we like. We can, indeed, so reduce this resistance as to make it quite insensible when compared with that offered by the metallic circuit, so that not only is half the wire spared, but even the resistance that such a circuit would present is diminished by one half. This fact, the importance of which in the erection of galvanic telegraphs speaks for itself, furnishes an additional feature in which galvanism resembles electricity. The experiments of Winckler, at Leipsic, had already shown that, with frictional electricity, the ground may replace a portion of the discharging wire.

"The inquiry into the laws of dispersion, according to which the ground, whose mass is unlimited, is acted upon by the passage of the galvanic current, appears to be a subject replete with interest. The galvanic excitation cannot be confined to the portions of earth situated between the two ends of the wire; on the contrary, it cannot but extend itself indefinitely, and it became, therefore, now only dependent on the law that caused the excitation of the ground, and the distance of the exciting terminations of the wire, whether it was necessary or not to have any metallic communication at all for carrying on telegraphic intercourse.

"I can here only state, in a general way, that I have succeeded in deducing this law experimentally from the phenomena it presents; and that the result of the investigation is, that the excitation diminishes rapidly, as the distance between the terminal wires increases.

"An apparatus can be constructed in which the inductor, having no metallic connection with the multiplier, by nothing more than the excitation transmitted through the ground, will produce galvanic currents in that multiplier sufficient to cause a visible deflection of the bar. This is a hitherto unobserved fact, and may be classed among the most extraordinary phenomena that science has revealed to us. It holds good, however, for small distances. It must be left to the future to decide whether we shall ever succeed in telegraphing at great distances without any metallic communication at all. My experiments prove that such a thing is possible up to distances of fifty feet. For distant stations we can only conceive it feasible by augmenting the power of the

galvanic induction, or by appropriate multipliers constructed for the purpose, or, finally, by increasing the surface of contact presented by the ends of the multiplier. At all events, the phenomenon merits our best attention, and its influence will not perhaps be altogether overlooked in the theoretic views we may form with regard to galvanism itself."

ALEXANDER'S ELECTRIC TELEGRAPH.

A model to illustrate the nature and operation of this telegraph was exhibited at a meeting of the Society of Arts in Edinburgh, in October, 1837.

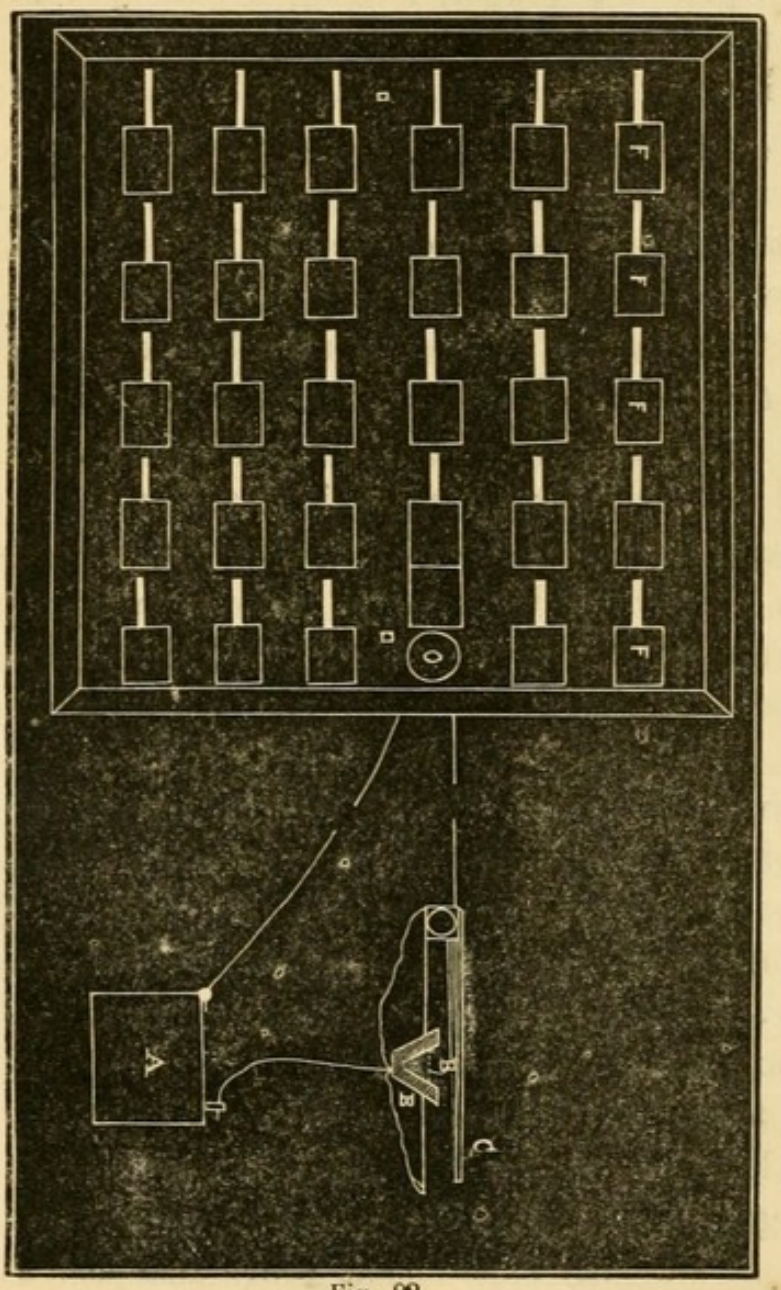

Fig. 92.

The model consists of a wooden chest, five feet in length and three in width, three feet deep at one end, and one foot at the other. Thirty copper wires extend from end to end of the chest, and are kept apart from each other. At one end they are fastened to a horizontal line of wooden keys, precisely similar to those of a piano-forte; at the other, they terminate closely to thirty small apertures, equally distributed, in six rows of five each, over a screen

of three feet square, which forms the end of the chest. Under these apertures, on the outside, are painted in black paint, upon a white ground, the twenty-six letters of the alphabet, with the necessary points, the colon, semicolon, and full point, and an asterisk to denote the termination of a word. The letters occupy spaces about an inch square. The wooden keys at the other end have also the letters of the alphabet painted on them in the usual order. The wires serve merely for communication, and we will now describe the apparatus by which they work. This consists of a pair of plates, zinc and copper, forming a battery placed under the keys; and thirty steel magnets, about four inches long, placed behind the letters painted on the screen. The magnets move horizontally on axes, and are poised within a flat ring of copper wire, formed of the ends of the communicating-wires. On their north ends they carry small, square bits of black paper, which project in front of the screen, and serve as opercula or covers to conceal the letters. When any wire is put in communication with the battery at the south end, the galvanic influence is instantly transmitted to the north end; and, in accordance with a well-known law discovered by Oersted, the magnet at the end of that wire instantly turns round to the right or left, bearing with it the operculum of black paper, and unveiling a letter. When the key A, for instance, is pressed down with the finger at the south end, the wire attached to it is immediately put in communication with the battery; and the same instant the letter A at the north end is unveiled by the magnet turning to the right, and withdrawing the operculum. When the finger is removed from the key, it springs back to its place, the communication with the battery ceases, the magnet resumes its position, and the letter is again covered.

The principle of Alexander's telegraph is represented in the accompanying illustration (Fig. 92). *A* is a voltaic battery; *B*, a trough filled with mercury; *C*, a key to be pressed down by the finger of the operator. *E* is the end of a conducting-wire, which dips into the mercury when the key is depressed, and completes the electric circuit; *D D* is the distant dial upon which the signals are to be shown; *F F* are screens, thirty in number, each

being fixed to a needle, corresponding to the finger-keys before described. When no electricity is passing, these screws remain stationary over the several letters, &c., and conceal them from view; but when a current is made to flow by the depression of a key, the corresponding needle in the distant instrument is deflected, carrying the screen with it, and uncovering the letter, which becomes exposed to view, as at *O*.

VAIL'S PRINTING TELEGRAPH.

The printing telegraph of Alfred Vail was proposed in September, 1837. It consists of a type-wheel, having on its surface the twenty-six letters of the alphabet. On the side of the wheel are twenty-six holes. The type-wheel is moved circularly by means of a spring that the electro-magnetic key causes to advance at each interruption and return of the current. The paper advances under the type-wheel by means of an independent clock-movement.

The precision of the operation depends on the exact correspondence of the machinery, situated at the two extremities of the telegraphic line. It is necessary that the type-wheel present the same letter at both stations, and that the clock move at the same rate. But this system has never been put in execution, and the inventor considers it inferior to the Morse, which he partly devised.

STURGEON'S ELECTRO-MAGNETIC TELEGRAPH.

In the Annals of Electricity for 1840 are published a description and drawing of an electro-magnetic telegraph, proposed by William Sturgeon, of London, a philosopher who, by his numerous experiments and researches into the subject of electricity and magnetism, has conferred signal benefits upon mankind.

The arrangement of Sturgeon's apparatus is seen in Figs. 93 and 94, the former being a side view, and the latter an end view of it; *m* in both figures represents the magnet; *i*, the cross-piece; *a b*, the lever; and *f*, the fulcrum. The cards at the longer ex-

tremities of the six levers are numbered 1, 2, 3, 4, 5, 6, which, individually, and by a series of simple combinations, form all the signals required. When the levers are in the position shown in Figs. 93 and 94, the magnet is out of action, in consequence of the battery circuit being interrupted. If, now, the battery circuit were to be closed, the magnet *m* would immediately be brought into action, and its attractive force would bring down the cross-piece *i*; which, being attached to the shorter arm of the lever, would raise the longer arm, with its card and sign, into the position of the upper dotted circle, where it becomes visible through a circular opening in the face of the instrument, as at 5 in Fig. 95. When that particular sign has appeared the required time to be observed, that circuit is opened, the magnet *m* loses its power, and the longer arm of the lever preponderates and falls down to its first position, and the card with its sign disappears.

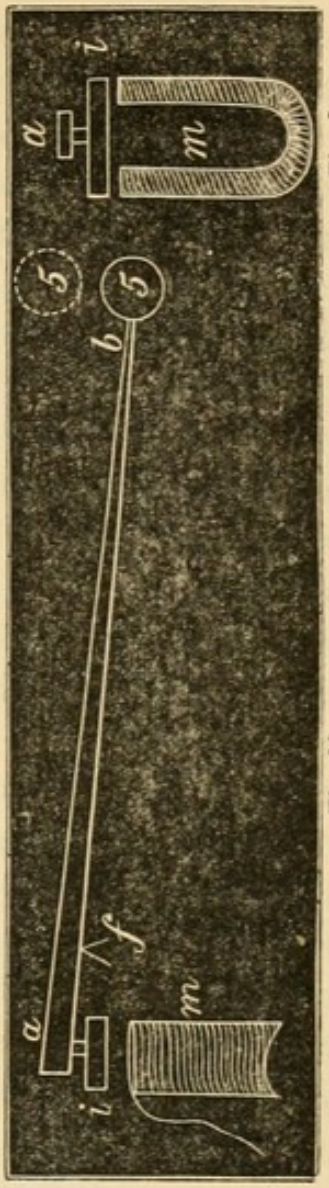

Fig. 94.

Fig 93.

The face or dial of the telegraph is represented by Fig. 95, which may be either of painted wood or metal, silvered in the manner of clock-faces or barometer-scales. On the upper part of the

Fig. 95.

1 = *a*	12 = *h*	23 = *n*	34 = *r*	45 = *u*	56 = *x*
2 = *b*	13 = *i*	24 = *o*	35 = *s*	46 = *v*	
3 = *d*	14 = *k*	25 = *p*	36 = *t*		
4 = *e*	15 = *l*	26 = *q*			
5 = *f*	16 = *m*				
6 = *g*					

dial there are six circular openings, for the occasional appearance of the cards with their figures, which are attached to the longer arms of the six levers (Fig. 93). Below the circular openings in the dial-plate are arranged the signals which are to represent all the alphabetical letters that are necessary for the spelling of words. The signals are thus continually before the eyes of the operator, and are too simple to miss being understood. These levers, with their magnets, &c. (Figs. 93 and 94), are placed behind the dial, in a suitable case, and in such a manner that the figures on the cards may appear at the circular openings whenever their levers move upward by the attractions of their respective magnets at the other or shorter arms, and disappear below those circular openings when the magnets are out of action.

At the battery station, the six insulated wires are to be attached to six ivory keys, with springs, like piano-keys, by the downward motion of which the wires are connected with the battery. On the top of the keys are painted the figures from 1 to 6, so that when one finger is placed on key 2 and another on key 5, the magnets 2 and 5 at the other station are brought into play, and, by attracting their respective pieces of iron, the figures 25 make their appearance on the dial, as seen in Fig. 95, and the letter *p* is understood. By these means the letters of the alphabet are represented without the possibility of error.

MORSE'S MAGNETIC TELEGRAPH.

In order to solve the problem as to what credit is due to others than Professor Morse, in the discovery of the principles, and the invention of the apparatus, embodied in the American or Morse system of telegraph, let us analyze carefully each part, and, so far as we are able, give the names of the discoverers or inventors, with the dates when their inventions or discoveries were patented or made public.

Morse's complete telegraph apparatus, consists of, —

1. An insulated metallic conductor.
2. Use of the earth for the return current.
3. Constant galvanic battery.

4. An electric current.
5. An electro-magnet and armature.
6. Key, or circuit breaker and closer.
7. Clock-work for moving an endless band of paper.
8. Lever and steel point or pen for marking.
9. Alphabet of dots and lines.
10. Local circuit for obtaining increase of power.
11. Adaptation of the sounds produced in making dots and lines to audible telegraphy.

1. *An Insulated Metallic Conductor.* — Doctor Watson, in 1747, in the presence of many scientific persons, transmitted the electric spark through 2,800 feet of wire and 8,000 feet of water, thus employing in his experiments the use of the *earth-circuit.* Afterwards, on the 14th of August, 1747, Doctor Watson conducted an experiment on a much larger scale at Shooter's Hill. The wire was insulated by baked wood, and was 10,600 feet, or nearly two miles, long.

In 1816, Francis Ronalds insulated eight miles of wire for electric telegraph experiments, at Hammersmith, England.

In 1828, Harrison Gray Dyar erected a telegraph line at the race-course upon Long Island, using *iron wire, glass insulators, and wooden posts.*

In 1833, Gauss and Weber constructed a telegraph line at Göttingen, between the Observatory and the *Cabinet de Physiques*, a distance of a mile and a quarter. The wires were run over the tops of the houses, as at present in most American towns.

2. *Use of the Earth for the Return Current.* — In 1837, Professor Steinheil operated a telegraph line, twelve miles in length, between Munich and Bogenhausen in Germany, using iron wire conductors, *and the earth for a return current.* This discovery was published in 1837, in German, and translated into English by Julian Guggsworth, November 24th, 1838; and yet Professor Morse seems not to have been aware of it until some six years afterward, as we find him using an entire metallic circuit upon the line constructed by him between Baltimore and Washington in 1844.

3. *Constant Galvanic Battery.* — The constant galvanic battery was invented by Professor Daniell of London in 1836.

4. The electric current was discovered by Volta in 1800.

5. *An Electro-magnet and Armature.* — Electro-magnetism was discovered by Oersted in 1819. Professor Schweigger of Halle, in 1820, invented the galvanometer, or electro-magnetic multiplier, — the basis of all the needle telegraphs. M. Arago, at the suggestion of M. Ampère, made a galvanic conductor in the form of a helix, or coil, into the axis of which he placed a needle. This helix was simply a spiral coil of wire, the extremities of it being connected to the opposite poles of a battery, thus permitting it to make a part of an electrical circuit. By this arrangement, the current is almost at right angles to the needle, and as each coil adds its effect to that of the others, the entire action of the spiral helix is extremely powerful. In this way a needle can be completely magnetized in an instant, and this is the method now principally employed by artisans in the manufacture of compass-needles.

Mr. William Sturgeon, a native of London, in 1825, discovered that, when wires of soft iron were placed within the coil of a conducting-wire, they were rendered intensely magnetic.

Professor Henry, Secretary of the Smithsonian Institution at Washington, greatly extended the knowledge upon this subject during the period from 1828 to 1831, and to him is due the credit of constructing the present form of horseshoe electro-magnet used upon the Morse and various other systems of magnetic telegraph. Cooke and Wheatstone used this form of the electro-magnet in their telegraph, patented June 12, 1837.

Its use was suggested to Professor Morse by Dr. Charles T. Jackson of Boston, on a voyage from Havre to New York, in the packet-ship Sully, in 1832, together with its application to electric telegraphy. The following is Dr. Jackson's account of the suggestions made to Professor Morse, in a deposition sworn to at Boston, May 21, 1850.

"While on the voyage, one day at table I introduced the subject of electricity and electro-magnetism, describing an experiment by Pouillet of sending electricity a great many times

around the Academy of the Sorbonne, without any perceptible loss of time. There being some expressions of incredulity, I endeavored to enforce the fact by alluding to Franklin's experiment of transmitting an electric spark to a great distance, using a wire and water as conductors. Mr. Morse asked in which of Franklin's works it was contained, and said he had never read it. I stated I believed it was in his Autobiography. After some discussion upon the point, one of the passengers said, 'It would be well if we could send news in this rapid manner.' This was a casual remark, in allusion to our earnest desire to hear from home, as there was some apprehension of a war with France. Mr. Morse said, 'Why can't we?' I immediately replied, 'We can; there is no difficulty about it;' — and then proceeded to explain various methods by which I conceived that intelligence might be transmitted by electricity and electro-magnetism. First, I proposed to count the sparks in a disjoined wire circuit, counting the sparks in time, — that is, counting or noting the sparks, and the intervals between the sparks. Second, by producing colored marks upon prepared paper, the paper being saturated with an easily decomposable neutral salt, and stained with turmeric, or some other easily stained neutral colors. Third, by saturating the paper with a solution of acetate of lead, or carbonate of lead, the paper being moistened while the electric current was passed through it, or over its surface, between points of platina wire. Fourth, *I proposed to make use of the electro-magnet*, which is formed by coiling copper wire, insulated by being wound with silk, around soft iron, bent in the form of the letter U, the iron being rendered temporarily magnetic by the passage of the galvanic current through the copper wire, a keeper or armature of soft iron being placed across the poles, and attracted firmly against them during the time the galvanic current is passing. I proposed to connect with this keeper the short arm of a lever-beam, and to fix a point of steel in the long arm of the lever, so that, when the keeper was drawn to the electro-magnet, the point should perforate holes in the paper. The paper was to be drawn from one reel to another by clock-work machinery, so that in intervals of space these holes might be punctured, and telegraphic indications be produced thereby.

"When I mentioned the subject of electro-magnetism, in the presence of Mr. Morse, during this conversation, he asked me the meaning of the term, saying, 'Electro-magnetism! How does that differ from other magnetism?' I explained it to him, making drawings of electro-magnets and a galvanic battery for that purpose.

"We discussed the subject for some time, and during this conversation I spoke of having an electro-magnet on board, and two galvanic batteries, which were stowed away between decks. I made drawings — rough sketches, as I do not profess to be a draftsman — of the electro-magnet, which I gave to Mr. Morse, who copied them into his note-book in an artistic manner, asking of me explanations as he made the drawings.

"Within a few days after my first conversation above mentioned, I think the third day after, I had a conversation with Mr. Morse as to the practicability of devising a system of signs which could be readily interpreted. I proposed an arrangement of punctured points or dots, to represent the ten numerals. Mr. Morse proposed to reduce it to five numerals and a zero, saying that all numbers could be represented thereby. Mr. Morse took a dictionary and numbered the words, and then tried a system of dots against it. We assigned to each word, selected for that purpose, a separate number, and the numbers were indicated by dots and spaces. We took our respective places at opposite sides of a table. He would send me despatches written in numerals, which I would examine by the aid of a marked dictionary which I held in my hand, and I found no great difficulty in reading them; and then we would change, he taking the dictionary and I sending the words. Mr. Morse took the principal part in arranging the system of signs, and deserves the greatest credit for it. Mr. Morse made notes of the system of signs, so far as we had completed it, in his note-book, either fully or partially. We had absolutely concluded on no complete system before the termination of the voyage.

"I saw Mr. Morse's note-book, in which he made his plans and observations, from his first entries in it in regard to the telegraph, until the end of the voyage. He would often bring

it and show me the notes and plans in it, but I never had it in my possession. I saw nothing in it which I had not explained and given him rough drafts of, except the system of signs, which was the result of our joint action, as before stated.

"We gave the name of Electro-Magnetic Telegraph to the instrument proposed and explained as above, and this was the name by which it was known and called in our conversations.

"After our arrival in New York, he brought to me, in New York, a plate of copper and a plate of zinc, each about two inches square, connected by a strip of copper more than a foot in length, and about half an inch in width, and asked me if that would do for an elementary battery. I told him no; that it would make no battery at all; that the plates must be near each other, and not connected, for an elementary battery, which he proposed to make. His producing a contrivance like that showed he was not acquainted with the subject of galvanism, not even knowing how to construct a galvanic battery, which is essential to produce the electric current. I explained to him how it could be made. In a few days after my arrival at New York, I returned to Boston. Afterwards I went to Philadelphia to attend the medical lectures; and in the spring of 1833 I commenced the practice of my profession in Boston. Soon after, my circumstances became embarrassed through the loss of my property from the failure of my agent, and I was obliged to devote myself assiduously and almost exclusively to the support of myself and of my family, having been married in February, 1834, so that I gave little attention, comparatively, to the Magnetic Telegraph.

"In the spring of 1833, soon after my return from Philadelphia, an article was shown to me in the New York Railroad Journal, wherein an account was given of a caveat filed at our Patent-Office for a Magnetic Telegraph, by an Englishman. This instrument resembling, in some of its details, that which I had described to Mr. Morse, I wrote to him, requesting him to ascertain who this Englishman was, and if he had got possession of our plan. I think Mr. Morse replied to this letter, but I cannot

say positively, as many of my letters were destroyed by a fire in my house, in 1845.

"Subsequently Mr. Morse visited me in Boston, and told me he found this Englishman boarded at Bunker's hotel, where Captain Pell boarded, and that he had probably heard Captain Pell talk about it at table.

"During this visit Mr. Morse requested me to put an experimental line of telegraph between Boston and Cambridge, for the purpose of testing its practicability. I declined, on account of the embarrassed state of my affairs, the expense being more than I could afford. I told him that the batteries would be very expensive, — that several would be required in order to maintain a steady current, no constant battery having been invented at that time. At the time these conversations took place, and for some years afterwards, I was aware that the Electro-Magnetic Telegraph could not be rendered commercially valuable for want of a sustaining battery, or one that would keep up a steady and uniform current of electricity, no such battery being at that time known. Professor Daniell of London invented the first constant or sustaining battery about 1836, and Grove's platinum constant battery, which is still better, was not invented until a year or more after that of Daniell. These or similar batteries are essential to the economic use of the Electro-Magnetic Telegraph, so as to make it available for commercial purposes, although the practicability of such a telegraph could be and was demonstrated by aid of batteries previously in use."

6. *Key, or Circuit Breaker and Closer.* — The signal-key, or circuit breaker and closer, was one of the earliest and most obvious contrivances in connection with the electro-magnetic telegraph. Ampère described the use of the key in 1820.

7. *Clock-work for moving an Endless Band of Paper.* — The graphic register described and used by Mr. Morse is a common and well-known instrument, used for registering evanescent signs.

In the *Mémoires de l'Académie des Sciences* of Paris, for the year 1734, an anemometer, or wind measure, is described and

represented by M. D'Ons en Bray. In this instrument a cylinder five inches long is mounted on a vertical axis, connected with a vane above. This cylinder has thirty-two metallic points arranged spirally upon it, corresponding to the thirty-two points of the compass. A fillet of paper five inches broad passes over a second cylinder, on an axis parallel to the first, and sufficiently near to it for the metallic point on the first presented to it to make the fillet on the second. *The paper is carried by cylinders moved by clock-work.* When the vane turns, the cylinder brings a particular metallic point in forcible contact with the paper, acting by a principle equivalent to the lever.

In the London Philosophical Transactions for 1831, p. 209, a graphic register of tides and winds is described by Henry R. Palmer. In this *a cylinder revolves by clock-work carrying a fillet of paper; a metallic pen-point* is moved over this cylinder in the direction of its axis by a rack and pinion, moved by a tide-float. The *track of the pen-point on the paper records* the change in the tide.

The connection of the graphic register with the electric telegraph was made and published by Steinheil, in Germany, before the date of the caveat of Mr. Morse, of October, 1837. In the paper of Steinheil, included in the Memoirs of the French Academy of Sciences, of the 10th of September, 1838, and published in the *Comptes Rendus* of 1838, he described the results of the practical operation of his graphic telegraph, for more than a year, between Munich and Bogenhausen, and the 19th of July, 1837, is referred to by him as an historical date, on or before which his telegraph was in actual operation and public use. In an article by Steinheil, translated in Sturgeon's Annals of Electricity for March and April, 1839, the use of posts for insulation, of what is technically called the ground circuit, and of iron, instead of copper, wires for conductors, — facts or inventions of great importance to the practical operation of the telegraph, — is fully described. We consider Steinheil, together with Gauss and Weber, who erected their telegraph at Göttingen, in 1833–34, as the scientific explorers for the electric telegraph, to whom the most important part of its practical application is undoubtedly

due. The telegraph of Steinheil registers serial dots, or, more strictly, short lines, by a point brought into contact with a moving fillet of paper by the action of a lever, operated by the deflection of a magnetic bar or bars in a coil of wire.

8. *Lever and Steel Point or Pen.* — Silliman's Journal of Science, Vol. XIX., 1831, contains an illustration and description of Professor Henry's powerful electro-magnetic weigher, — with *armature and lever*, — the lever sustaining two thousand pounds.

Cooke and Wheatstone, in their patent of June 12, 1836, describe the use of the lever in connection with the armature of an electro-magnet. This is prior to the filing of Morse's caveat, and three years before he obtained his first patent in this country.

The steel point is fully described by M. D'Ons en Bray, in connection with the anemometer, in 1734; and in the graphic register of Henry R. Palmer, in 1831.

9. *Alphabet of Dots and Lines.* — The alphabet of dots and lines is the same in principle as that adopted by Steinheil, in 1836, and in the earlier descriptions of the Morse apparatus the combination by the use of several pens is very similar to those of Steinheil.

The same system was also used by Harrison Gray Dyar, in 1828, in his telegraph upon Long Island.

10. *Local Circuit for obtaining Increase of Power.* — The local circuit was used by Cooke and Wheatstone, and patented in connection with their system of telegraphing, June 12, 1837. In order that the telegraph might be practically used, it was essential that some simple means should be employed to call the attention of the operator when a message was about to be sent, as the movement of the needles made no sound. To overcome the difficulty presented by the very small amount of power which would be transmitted to a long distance, and which was not sufficient to make an electro-magnet of any power, and thus discharge an alarum, they placed a second battery at the distant station, having wires connected with a powerful electro-magnet attached to an alarum, or arranged so as to strike a bell as soon as the battery was brought into operation. But as the circuit was broken,

the battery, though charged with acid, and therefore ready to act, could not exert its magnetizing power on the electro-magnet unless the circuit was completed. The current of electricity from the distant station whence the intelligence was to be transmitted, though not powerful enough to make an electro-magnet, was abundantly powerful enough to complete the circuit of the second battery, thus waiting to be called into action. This was effected by a small piece of copper wire attached to a cross-piece, fastened to a delicately suspended vertical galvanometer; when the latter was deflected by even a feeble electric current, the copper wire, by having its ends plunged into two cups of mercury, completed the circuit of the secondary battery, causing the electro-magnet to attract its keeper, and thus let off the alarum to ring the bell.

In a deposition by Professor Henry, of the Smithsonian Institution, made in Washington in 1850, he says: —

"In February, 1837, I went to Europe, and early in April of that year, Professor Wheatstone of London, in the course of a visit to him at King's College, London, with Professor Bache, now of the United States Coast Survey, explained to us his plan of an electro-magnetic telegraph, and among other things exhibited to us his method of bringing into action a second galvanic circuit. This consisted in closing the second circuit by the deflection of a magnetic needle, so placed that the two ends of the wire of the open circuit, projecting upwards, would be united by the contact of the ends of the needle, when deflected. The second circuit was opened by interrupting the current in the first circuit, the needle resuming its original position, due to the directive force of the magnetism of the earth (Fig. 96). I informed him that I had devised another method of producing effects somewhat similar. This consisted in opening the circuit of my large quantity magnet at Princeton, when loaded with several hundred pounds, by attracting upwards a small piece of movable wire by means of a small intensity magnet, connected with a long wire circuit and an intensity battery. When the current of the large battery was thus broken by an action from a distance, the weight would fall, and great mechanical effects would be produced, — such as the

ringing of church-bells at the distance of many miles, an illustration which I had previously given to my class. My impression is strong, that I had explained this precise process to my class before I went to Europe; but on this point I cannot speak positively. I am, however, certain of having mentioned, in course of my lectures, every year previously at Princeton, the project of

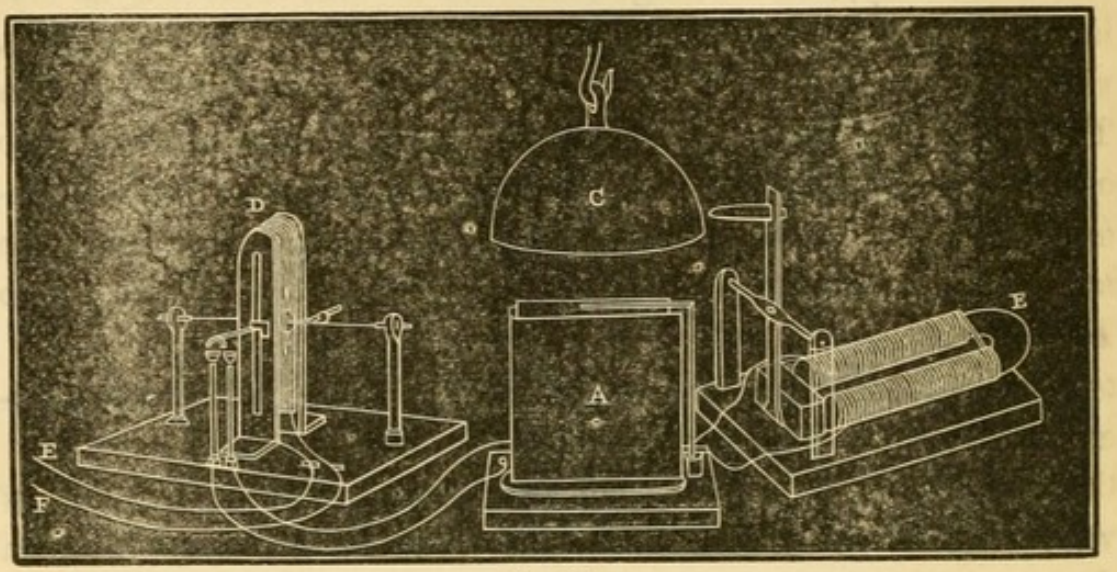

Fig. 96.

ringing bells at a distance by the use of the electro-magnet, and of having frequently illustrated the principle to my class, by causing, in some cases, a thousand pounds to fall a few inches on the floor, by merely lifting a piece of wire from two cups of mercury, closing the circuit.

"The object of Professor Wheatstone, as I understood it, in bringing into action a second circuit, was to provide a remedy for the diminution of force in a long circuit. My object, in the process I have described, was to bring into operation a large quantity magnet, connected with a quantity battery in a local circuit, by means of a small intensity magnet and an intensity battery at a distance.

"The only other scientific facts of importance to the practical operation of the telegraph, not already mentioned, are the construction of the constant battery, in 1836, or about that time, by Professor Daniell of King's College, London, and the *discovery, in* 1837, *of Steinheil, in Germany, of using the earth as a portion of the galvanic circuit.* I believe that I was the first to repeat the

experiments of Daniell and Steinheil in this country. I stretched a wire from my study to my laboratory, through a distance in the air of several hundred yards, and used the earth as a return conductor, with a very minute battery, the negative element of which was a common pin, such as is used in dress, and the positive element the point of a zinc wire immersed in a single drop of acid. With this arrangement, a needle was deflected in my laboratory before my class. I afterwards transmitted currents in various directions through the College grounds at Princeton. The exact date of these experiments I am unable to give, without reference to my notes. *They were previous, however, to the unsuccessful attempt of Mr. Morse to transmit currents of electricity through wires buried in the earth, between Washington and Baltimore, and before he attempted to use the earth as a part of the circuit.* Previous to this time, and after the above-mentioned experiment, Mr. Morse visited me at Princeton, to consult me on the arrangements of his conductors. During this visit, we conversed freely on the subject of insulation and conduction of wires. *I urged him to put his wires on poles*, and stated to him my experiments and their results.

"I heard nothing of the secondary circuit as a part of Mr. Morse's plan until after his return from Europe, whither he went in 1838. It was not until after this that Mr. Morse used the earth as a part of the circuit, in accordance with the discovery of Steinheil.

"I am not aware that Mr. Morse has ever made a single original discovery in electricity, magnetism, or electro-magnetism, applicable to the invention of the telegraph. I have always considered his merit to consist in combining and applying the discoveries of others in the invention of a particular instrument and process for telegraphic purposes. I have no means of determining how far this invention is original with himself, or how much is due to those associated with him.

"Shortly after my return from Europe, in the autumn of 1837, I learned that Mr. Morse was about to petition Congress for assistance in constructing the electro-magnetic telegraph. Some of my friends in Princeton, knowing what I had done in developing

the principles of the telegraph, urged me to make the representation to Congress, which I had expressed some thoughts of doing, namely, that the principles of the electro-magnetic telegraph belong to the science of the world, and that any appropriation which might be made by Congress should be as a premium for the best plan, and the means of testing the same, which the ingenuity of the country might offer.

"Shortly after this, I visited New York, and there accidentally made the personal acquaintance of Mr. Morse. He appeared to be an unassuming and prepossessing gentlemen, with very little knowledge of the general principles of electricity, magnetism, or electro-magnetism. He made no claims, in conversation with me, to any scientific discoveries, or to anything beyond his particular machine and process of applying known principles to telegraphic purposes. He explained to me his plan of a telegraph, with which he had recently made a successful experiment. I thought this plan better than any with which I had been made acquainted in Europe. I became interested in him, and, instead of interfering with his application to Congress, I gave him a certificate, in the form of a letter, stating my confidence in the practicability of the electro-magnetic telegraph, and my belief that the form proposed by himself was the best that had been published.

"In 1837, Professor Gale and Dr. Fisher were the scientific assistants of Mr. Morse in preparing the telegraph. Mr. Vail was also employed. I had been intimately acquainted with Professor Gale for many years. He had been a pupil in chemistry of my friend Dr. Torrey, and had studied my papers on electro-magnetism, and, as he informed me, had applied them in the arrangement of the apparatus for the construction of Morse's telegraph.

"About the beginning of 1848, Mr. Walker, Astronomical Assistant of the Coast Survey, in a report on the application of the telegraph to the determination of differences of longitude, alluded to my researches. A copy of this was sent to Mr. Morse, which led to an interview between Mr. Walker, Professor Gale, Mr. Morse, and myself. At this meeting, which took place at my

office in Washington, Mr. Morse stated that he had not known, until reading my paper, in January, 1847, that I had, two years before his conception in 1832, settled the point of the practicability of the telegraph, and shown how mechanical effects could be produced at a distance, both in the deflection of a needle and in the action of an electro-magnet; that he did not know at the time of his experiments, in 1837, that there had been any doubt of the action of a current at a distance, and that, in the confidence of the persuasion that the effect could be produced, he had devised the proper apparatus by which his telegraph was put in operation. Professor Gale, being then referred to, stated that Mr. Morse had forgotten the precise state of the case; that Mr. Morse, previous to his (Dr. Gale's) connection with him, had not succeeded in producing effects at a distance; that when he was first called in, he found Mr. Morse attempting to make an electro-magnet act through a circuit of a few yards of copper wire, suspended around the room, in the University of New York, and that he could not succeed in producing the desired effect, even in this short circuit; that he (Dr. Gale) asked him if he had studied Professor Henry's paper on the subject, and that the answer was, 'No'; that he then informed Mr. Morse that he would find the principles necessary to success explained in that paper; that instead of a battery of a single element, he should employ one of a number of pairs, and that instead of the magnet with a short wire, he should use one with a long coil. Doctor Gale further stated, that his apparatus was in the same building, and, having apparatus of the kind he had mentioned, he procured them, and that with these the action was produced through a circuit of half a mile. To this statement Mr. Morse made no reply."

Edward Davy's telegraph was patented July 4, 1838. The receiving instrument, or commutator, used by Davy, is in principle the same with that of Cooke and Wheatstone. It is a horizontal galvanometer, upon the magnetic bar or needle of which, at right angles, is placed a metallic cross-piece, one extremity of which comes in contact with a wire or conductor when the needle is deflected, and the other extremity of which is bent down so as to

dip constantly into a cup of mercury. When this cross-piece comes in contact with the conductor, it completes the circuit of a local battery by effecting a connection between the conductor and the cup of mercury. This receiving instrument is employed to *bring into action a local circuit*, first, for the purpose of registering marks by means of galvanic decomposition. The registering apparatus is composed essentially as follows. The fabric used for receiving the marks is calico or cotton cloth, a strip of which passes between two cylinders. One of the cylinders is of metal, connected with the negative pole of the battery. The other cylinder is of wood, having upon it six rings of platina, the thin edges of which press the cotton against the first, or metallic cylinder. These rings, when brought into use, are connected with the positive pole of the battery. The current from the rings to the metallic cylinder passes necessarily through the chemically-prepared cotton cloth at the point of contact. The result is the production of a mark whenever the current is made to communicate with one of the rings. The marks made by the different rings have different signification.

The local circuit is employed, in the second place, to regulate the motion of the clock-work carrying the cloth, by means of a U electro-magnet, armature, and lever, which at each motion withdraws the stop from a fly-wheel for the space of a semi-revolution, during which a single sign is made upon the calico. The stop is thus removed from the fly-wheel by the first impulse of the current, allowing the clock-work to move always in proportion to the number of signs transmitted.

The receiving instrument is employed, in the third place, to effect the relay of long circuits, — an exhausted current from a distance opening a new and fresh telegraph circuit in advance.

The principle of the local circuit is employed, in the fourth place, by means of a peculiar mechanism, consisting in part of two U electro-magnets, with a reciprocating armature to direct the long circuit to either of two branches of the telegraph line, the receiving instrument being placed at the juncture of the two branches, and being operated upon from a distant station.

Mr. Morse patented the relay for long circuits, June 20, 1840,

— two years after Davy's patent for the same in England; and for a short, or local circuit, April 11, 1846, — just nine years after Messrs. Cooke and Wheatstone's patent for the same in England, and nine years after Professor Henry's discovery in this country.

Mr. Morse composed a description of his invention, and exhibited the instrument in operation to the French Academy of Science at their session of the 10th of September, 1838, and it was published in the weekly journal of the Academy, called the *Comptes Rendus*, a few days after. That description, however, *did not include the office, or local circuit, or receiving magnet*, the utility of which, Mr. Morse says in his patent of 1846, was at that time unknown.

11. *Adaptation of the Sounds produced in making Dots and Lines to Audible Telegraphy.* — Reading by sound, so far as the Morse telegraph is concerned, was purely an afterthought, taken up by the operators of their own accord. It was found desirable to have a means of calling the attention of the operator by audible signals, and it was designed at first to have an alarum, consisting of a bell, to be rung by clock-work, similar to that of Cooke and Wheatstone, and the first instruments were so constructed; but it was soon ascertained that the click of the armature was sufficient, and the bell dispensed with. We have explained elsewhere the inauguration of the system of reading by sound, and its great results: the credit of introducing, as well as the discovery, as far as telegraphing goes, is due entirely to the American operators. It was discovered by them, and adopted by them, notwithstanding great opposition on the part of the managers of the lines.

Soemmering, in 1809, rung a bell by electricity, in connection with his decomposing telegraph. Ronalds, in 1816, fired a pistol by the spark. Franklin set spirits on fire across the Schuylkill, by means of an insulated wire and the electric spark; and Gauss and Weber produced sounds by means of magnetic needles, in connection with their telegraph, in 1834.

But one of the most curious instances in proof of the correctness of the adage that there is "nothing new under the sun," is found in a little book in the possession of Dr. Wm. F. Channing,

called, "The Mural Diagraph, or the Art of Conversing through a Wall, by James Swaim," published at Philadelphia, in 1829. This book describes an alphabet of what may be called audible dots and lines, intended for communicating through a wall. This alphabet is also written in dots and lines, and a vocabulary is given at the end of the book, consisting of words referred to by numbers. The combination of dots and lines in a conversation given in pages eleven and twelve resemble obviously the system used by Mr. Morse, as represented in example first, attached to his patent. When applied to its use, *the dots of the Mural alphabet are represented by knocks on the wall, and the lines by scratches;* some hard substance being used to produce the sounds.

Lines of variable length are the simple geometric expression of force. The dot is the simplest geometric representation of a momentary or short exertion of the force employed, which in this case is electricity. The line is the simplest geometric expression of a longer exertion of the same force, and the space is only the interval between the exertions of force, by which succession and number of signs become possible.

Duration and number, thus applied to the electric current, appear to be the essential conditions of electric telegraph signalizing, and to involve, as the geometric expression, lines and intervals of variable length. We are thus conducted at once, as soon as such linear signs are transmitted by an act of intelligence, the representative of alphabetical letters, to the old geometric alphabet of dots and lines, which has been already described.

The use of the graphic register in connection with the electric telegraph appears, therefore, to indicate nothing more than the simplest geometric record of the electric force, as modulated in accordance with the principles of duration and succession. The registration of the natural expression of force seems to be hardly separable from the principle of registration itself. The linear representation of force is also the very function and purpose of the graphic register.

WOODBURY'S DECISION UPON MORSE'S CLAIMS.

The following is an abstract of the decision of Hon. Levi Woodbury, Judge of the United States Supreme Court, upon the prayer for injunction by the Morse patentees against the House Telegraph Company in 1850.

The public mind, among the scientific and machinists, had become so excited on the topic of the electric telegraph, four years previously to 1832, the period of the voyage in the Sully, that numerous attempts were made in 1828 to carry out into more practical use, and to perfect, what had been before indicated so often and so distinctly, as to the use of electricity and electro-magnetism for the purpose of telegraphing. Jacob Green wrote on it. Travoilot proposed to act by a wire from Paris to Brussels, and Sturgeon actually constructed, at Woolwich, an apparatus with a horse-shoe magnet, and the end of a wire coiled round it, communicating with the opposite poles of a galvanic machine, and thus supporting a weight, or bar, of nine pounds.

It is believed that Professor Henry had discovered and described as early as this, and shown at Albany, in 1829, how to increase the power at little expense; and Fechner suggested that galvanism could thus be applied to telegraph from Leipsic to Dresden.

But the most surprising discovery on this subject about this period was by Harrison Gray Dyar, another enterprising American. In 1827 or 1828, he is proved, by Cornwell, to have constructed a telegraph at Long Island, at the race-course, by wires on poles, and using glass insulators. Doctor Bell fortifies this statement, having seen some of his wires, and understood its operation to be by a spark sent from one end to the other, which made a mark on paper, prepared by some chemical salts.

Dyar's own deposition, taken since this cause was argued, and to be substituted for a letter from him to Dr. Bell, which was then objected to by the plaintiff, and ruled out, now verifies the truth of the letter, and goes into several details as to the condition of his invention, when abandoned, in 1830, from fears of prosecution by some of his agents.

He used common electricity, and not electro-magnetism, and

but one wire, which operated by a spark, which, after going through paper chemically prepared, so as to leave a red mark on it, passed into the ground, without a return circuit. The difference of time between the sparks served, by means of an arbitrary alphabet, to signify different letters, and the paper was to be moved by the hand while the telegraph operated, though machinery was contemplated to be introduced for that purpose. This device of an alphabet by spaces of time between sparks evinced remarkable ingenuity, and differs in some degree from Morse's, though very near it in principle.

In 1830, Booth, in Dublin, explained fully how electro-magnetism could be used to telegraph at a distance, and cause marks to be made by the fall of the armature from the horse-shoe magnet when the circuit was broken.

But Barlow had failed in England from want of more power; and following out the new idea of increasing the power of the magnet by closer coils of wire and otherwise, and when the want of greater power to operate farther and quicker, and at less expense, seemed the chief desideratum, Moll, in 1830, succeeded in making a magnet which would sustain 75 pounds, and, soon after, one that sustained 150 pounds, and Professor Henry, in 1831, completed one that could sustain a ton (Fig. 97). During this last year, also, Faraday had matured fully the horse-shoe magnet, and caused, under Saxton, at a distance, a strong circular motion, and brought magnetic electricity almost to maturity.

While all these clearly preceded what took place in the Sully, and remove very much all novelty in some of the ideas then suggested, yet it is certain that there yet remained to be constructed, on these or other principles, some practical machine for popular and commercial use, which would communicate to a distance by electro-magnetism, and record quickly and cheaply what was thus communicated.

From that time forward, Morse is entitled to the high credit of making attempts to do this, however imperfectly informed he may then have been of what had already been accomplished towards it; and he has the still higher credit, among the experimenters from that time to 1837, of having then succeeded in per-

fecting what he describes at that time in his caveat and specification. Laboring on the same subject, and before 1838, Stur-

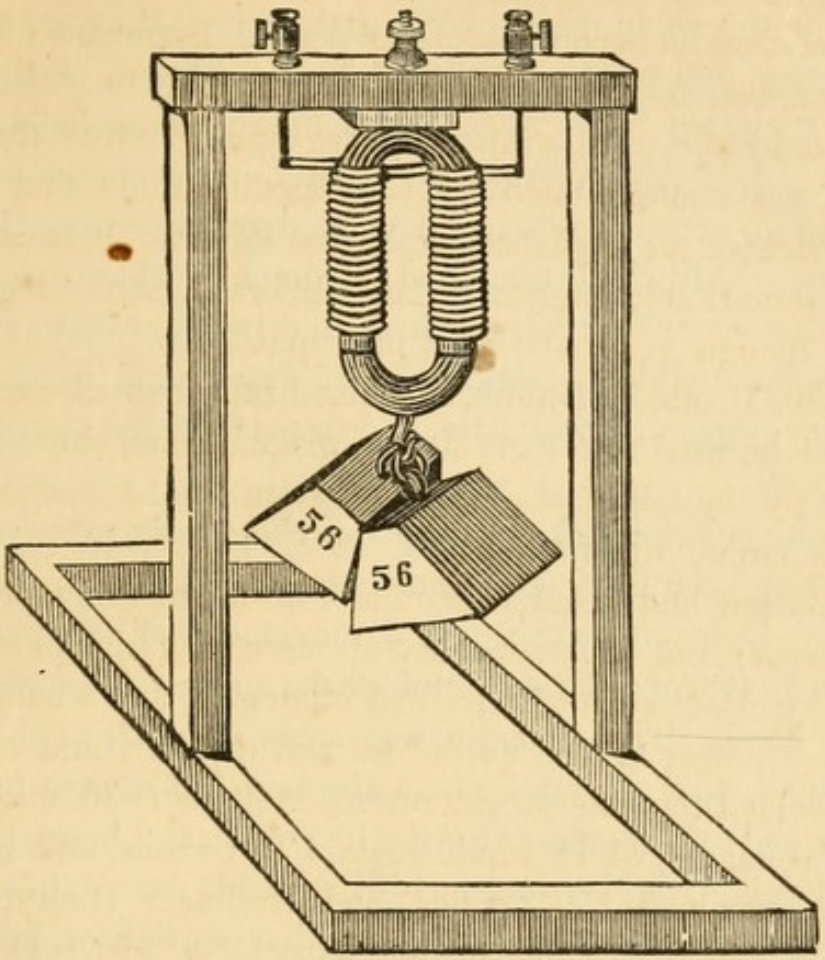

Fig. 97.

geon, in 1832, had formed a rotary electro-magnetic machine, which gave motion to working models of machinery so as to pump water, saw wood, and draw weights. He had batteries of zinc, and electric currents from them, and magnets with attraction and repulsion. And Baron de Schilling, the same year or the next, constructed an electric telegraph at St. Petersburg, which had thirty-six magnetic needles, and sounded alarms, and made signals by the deflection of the needle, which indicated letters by numbers.

In 1833, Dr. Sculther, at Zurich, caused a pendulum motion between two horse-shoe magnets, and Ritchie, with various others, showed how increased power could be cheaply created and used at a distance. And Professor Henry made experiments for

this object with success, and explained that the fall of the weight or armature would ring bells, &c.

Gauss and Weber constructed the first magnetic telegraph at Göttingen the same year, carrying the wires above ground and over houses, and making signs for letters. Some of their wires are still standing. And in 1834 Jacobi made one similar in some respects. And Mr. Gurly, at Dublin, made another, and in 1836 Taquin and Eutychaussen carried another over the streets of Vienna. All which remained to complete what was desirable in a tracing or writing telegraph at a distance, was to make dots or marks intelligible or significant of letters and words, so as to be read or translated with ease, and to perform the operation with useful speed.

To make colored dots, by means of chemically prepared paper, had already been discovered, but not an alphabet in connection, unless by Dyar in 1828; nor a movement of the paper on a roller, so as to make the dots and marks successive, unless by him with the hand. The struggle was such, in 1837, to finish what was wanted, that Morse became alarmed lest others might first complete and obtain patents for the invention, and hence proceeded more actively with his; and in 1837 filed his caveat, in the month of October. In the same year, whether earlier or later is not known, Alexander formed an electric telegraph, by which, through signals somewhat like Morse's, he communicated and spelled out at a distance the word *Victoria*. There is also evidence that this was done earlier, using a key-board, and letters on each key, like House's. Davenport, too, in Vermont, announced another, and obtained a patent in 1838. Cooke and Wheatstone took out a patent for theirs in June, 1837, making the deflection of the needle point to letters on a board.

Steinheil, that year, had at the Royal Observatory an electro-magnetic telegraph, half a mile long, on poles. This made dots and short marks on paper, and *preceded Morse's caveat*, according to Dr. Channing's evidence and that of Hibbard (being before July 19, 1837), and also that of Gould.

It used the ground as a part of the circuit, which use had been before discovered, but to which Morse does not appear to describe a claim, till his first renewal in 1848.

Nor did Morse use poles or posts at first, in 1844, when constructing a telegraph between Baltimore and Washington. Though they were used by Steinheil before 1839, and by Dyar, even in 1828; and were suggested to Morse, as early as 1830, by Professor Henry; yet Morse thinks he himself invented them. After all this, there still was wanting a more perfect succession of marks to be made or recorded, which were letters themselves, or signs of letters, intelligible by an alphabet and power obtained and applied so as to do it quick enough for purposes of business. This deficiency was at length supplied.

Among about *sixty-two competitors to the discovery of the electric telegraph* up to 1838, Morse alone, in 1837, seemed to have reached the most perfect result desirable for public and practical use. This may not have been accomplished so wholly by the invention of much that was entirely new, as by "improvements," to use the language of his patent, on what had already been done on the same subject, *improvements* ingenious, useful, and valuable. By the needle, or lever instead, not only deflected by the magnet, but provided with a pen to write, or, in other words, a pin at the end to make a dot or stroke when thus deflected as the circuit was held longer closed or broken, with machinery to keep the paper moving in the mean time, and so as to inscribe the dots and lines separately, and more especially with an alphabet, invented and matured, assigning letters and figures to these dots and lines according to their number and combination, he accomplished the great desideratum. Thus the fortunate idea was at last formed and announced, which enabled the dead machine to move and speak intelligibly, at any distance, with lightning speed.

It will be seen that, amidst all these efforts at telegraphic communication by means of electricity and electro-magnetism, more or less successful from 1745 to 1838, none had attained fully to what Morse accomplished.

Some had succeeded in sending information by signals, even beyond the decomposition of water and the declivity of the needle. They had made persons at a distance recognize the sign used, and thus obtain intelligence. They had also made marks at a

distance. But in no way does it appear that they have sent information at a distance, and at the same moment, by the same machine, traced down and recorded it permanently and intelligibly and quickly. This triumph was reserved to Morse's inflexible perseverance in experiments, and close observation; and chiefly after arming the end of the needle or lever with a pin, by use of a roller with appropriate machinery to move his paper, so as to trace successive dots and marks, and by a stenographic alphabet to explain the marks made on the paper, and, by more power through his combined circuits, to effect all at a greater distance, and with greater despatch. Afterwards by the improvements in batteries by Daniell and Grove, in 1843, he was enabled, without these local circuits, to increase the power of the electro-magnet, so as to accomplish this at any distance, and with a speed and economy which rendered the invention applicable to general use. Before 1843, Hare's battery was used, and was too feeble, and before that, Cruikshank's. The want of this increased power had rendered former attempts at times abortive for practical purposes; and its being recently supplied by the science of Faraday and Henry tended more speedily, by Daniell and Grove's battery, founded on them, to remove the greatest obstacle to success.

Others had before, and about the same time, as has been noticed already, made marks on paper, at a distance, by the deflection of the needle, and by sparks, and attached special meanings to them, and the spaces between them. But the evidence is strong that Morse's, if not the very first, in these respects, was the most perfect and available for practical use, and the improvements by others in batteries came very opportunely to aid in its power for distant operations, beyond what even the local circuits had done. His special advance beyond others, except some new combination, looks as if chiefly mechanical, but still it sufficed to promote the desired object.

DYAR'S ELECTRIC TELEGRAPH.

The following description of Mr. Harrison Gray Dyar's electric telegraph is extracted from a letter written by Mr. Dyar

to Dr. Luther V. Bell of Charlestown, Mass., dated Paris, 1849: —

"I invented a plan of a telegraph, which should be independent of day or night or weather, which should extend from town to town, or city to city, without any intermediary agency, by means of an insulated wire in the air, suspended on poles, and through which wire I intended to send strokes of electricity in such a manner as that the diverse distances of time separating the divers sparks should represent the different letters of the alphabet, and stops between the words, &c., &c. This absolute or this relative difference of time between the several sparks, I intended to take off from an electric machine by a little mechanical contrivance regulated by a pendulum, and the sparks were intended to be recorded upon a moving or revolving sheet of moistened litmus-paper, which, by the formation of nitric acid by the spark in the air, in its passage through the paper, would leave a red spot for each spark on this blue test-paper. These so produced red spots, by their relative interspaces separating them severally from each other, being taken as an equivalent for the letters of the alphabet, &c., &c., or for other signs intended to be transmitted, whereby a correspondence could be kept up through one wire, of any length, either in one direction, or back and forwards, simultaneously or successively, at pleasure. In addition to this use of electricity, I considered that I had, if wanted, an auxiliary resource in the power of sending impulses along the same wire, properly suspended, somewhat like the action of a common bell-wire in a house. Now you will perceive that this plan is like the plan known as Morse's telegraph, with the exception that his plan is inferior to mine, inasmuch as he and others now make use of the electro-magnetic action, in place of the simple spark, which requires that they should, in order to get dots or marks upon paper, make use of mechanical motions, which require time to move, whereas my dots were produced by chemical action of the spark itself, and would be from that cause transmitted and recorded with any required velocity, only preserving the relative distances between the sparks, which is a decided superiority over the use of motions got by the electro-magnetic

motive action. Perhaps Mr. Morse was not sufficiently familiar with electricity to know of this faculty. My idea is, that Mr. Morse, when returning to America, as you mentioned, got, by the conversation with Mr. Jackson, some notion about carrying electricity along a wire, which enabled him to understand the nature and mode of operation of my wire telegraph, which he must have heard his brother-in-law speak of as a wire reaching from city to city. I may do his science and inventiveness injustice, but you know the intimacy between Charles and myself, and the presence and relation between him and Mr. Morse. I believe that Mr. Morse is not known to be an inventor or a man of science, and for such reasons not likely to originate such a project.

"In reference to what I did to carry out my invention, I associated myself with a Mr. Brown, of Providence, who gave me certain sums of money to become associated with me in the invention. We employed a Mr. Connel, of New York, to aid in getting capital wanted to carry the wires to Philadelphia; this we considered as accomplished; but, before beginning upon the long wire, it was decided that we should try some miles of it on Long Island. Accordingly, I obtained some fine card wire, intending to run it several times around the race-course on the Island. We put up this wire, that is, Mr. Brown and myself, at different lengths, in curves and straight lines, by suspending it from stake to stake, and tree to tree, until we concluded that our experiments justified our undertaking to carry it from New York to Philadelphia. At this moment our agent, Mr. Connel, brought a suit or summons against me for $ 20,000, for agencies and services, which I found was done to extort a concession of a share of the whole project. I appeared before Judge Irving, who, on hearing my statement, dismissed the suit as groundless. A few days after this, Joseph F. White, who knew about our plan of a new telegraph by wire hung up in the air, and who was our patent agent, (intending to take out a patent when we could no longer keep it a secret,) came to Mr. Brown and myself, and stated that Mr. Connel had obtained a writ against us, under a charge of conspiracy for carrying on secret communication from city to city, and advising us to leave New York until he could

settle the affair for us. As you may suppose, this happening just after the notorious bank-conspiracy trials, we were frightened beyond measure, and the same night slipped off to Providence, where I remained some time, and did not return to New York for many months, and then with much fear of a suit. This is the circumstance which put an end, killing effectually all desire to engage further on such a dangerous enterprise. I think that on my return to New York I advised with Charles Walker, who thought that, however groundless such a charge might be, it might give me infinite trouble to stand a suit. From all this the very name of Electric Telegraph has always given me pain whenever I have heard it spoken of, until I received your last letter, stimulating me to come out with my claims; and even now I cannot overcome the painful association of ideas which the name excites.

"I observe in a New York paper, that a Mr. O'Reilly has offered a reward of $300 for the best essay on the progress of Electric Science, with reference to the electric telegraph, to be presented before next May. I suppose this is done by him with a view to discover grounds of invalidating Mr. Morse's patent. If you think it best to write to him, pray do so, or to Mr. Morse; for if he had an account of my telegraph through Mr. Walker, and will state the same, I should not wish to injure his patent, which could be no gain to me. In fact, after the lapse of so many years, it might require my presence in America to get sufficient evidence to invalidate his patent. Although the love of fame is too feeble to stimulate me to take any pains to establish my just claims to this invention, yet it gives me much pleasure to see an old friend interest himself thus in my behalf."

The following testimony was given by Dr. Bell, in the suit for an injunction above referred to.

"I was very intimately acquainted with Harrison Gray Dyar, from about 1828, till the period of his leaving this country, in the spring of 1831, as near as I can remember. He resided in the city of New York; his age was a little more than my own. In my judgment he was a man of the highest inventive skill and scientific attainments; he was engaged in various mechanical in-

ventions. He went to Europe in pursuit of certain pecuniary advantages from some of his mechanical inventions, in which he has, I believe, been eminently successful. I saw him in Paris, in March, 1845; I have heard from him in various ways since; he visited me here, within two years; he now resides in Paris.

"I was engaged with Harrison Gray Dyar for many months in 1828, and often conversed upon the subject of his having invented an electric telegraph, and I recollect seeing in his apartment a quantity of *iron wire* which had been procured by him for the purpose of erecting a telegraph.

"I recollect his speaking of his having placed a quantity of this wire at an elevation around the race-course at Long Island (at the old Union Course), to a length which satisfied him that there were no practical difficulties in carrying it from New York to Philadelphia, which he stated to me had been his intention. I recollect suggesting doubts to him whether the wire would bear the necessary straightening up between the posts, and his reply, that the trial on Long Island had proved to him that there was no difficulty in this course. My understanding, thus derived from his conversation, was, that the electric spark was to be sent from one end of this wire to the other, and that the spark was expected to remove or to leave its mark upon some chemically prepared paper."

This concludes our extracts from authorities upon the matter of previous inventions and discoveries made in electro-dynamics at the time Mr. Morse filed his first caveat in 1837. We do not deem it necessary to offer any opinions in the matter, as the reader, having all the facts before him, is fully as well qualified as ourself to form a correct judgment as to the extent of Mr. Morse's inventions. We have felt it to be our duty, however, in compiling this, to bring forward all the proofs of originality or otherwise which we have been able to obtain, in order that each discoverer or invention might have the due share of credit.

The letter of Mr. Dyar, upon which the most implicit confidence was placed by the late Hon. Levi Woodbury, contains matter of great interest. It seems difficult for us to believe, that, thirty years ago, a man of the greatest scientific ability was

obliged to flee from the great metropolis of our country, from the fear of prosecution for inventing and operating an electric telegraph. And yet such unquestionably was the case!

As we have seen, the telegraph of Mr. Dyar could not have proved a success, owing to the use of frictional electricity, even had he been unmolested in his operations, and no electric telegraph was practically possible until the discovery of the constant battery by Professor Daniell in 1837; but it only needed this discovery to render it one of the best of recording telegraphs. In less than ten years from the period of Mr. Dyar's unsuccessful *début* in New York, the electric telegraph was hailed as the most wonderful discovery of modern science, and its introduction as a means of communication, as one of the greatest blessings of the age.

How wonderful that an all-wise Providence should so order it, that the inventions and improvements of the age should exactly keep pace with the march of the human mind!

The electric telegraph would have been of no comparative value a hundred years ago, even if, having been invented then, it had been allowed to work; but it has been a natural consequence of the inventions in steam, — following closely upon the introduction of the steamboat and railroad. Within the past ten years it has taken such a hold upon the common affairs of the world, as to be looked upon as a necessity, and rivals in importance even the mail itself.

PART XI.

CHAPTER XXII.

GALVANISM.

In the first part of this work we devoted some pages to the consideration of the subject of Galvanism. We shall now present the matter at greater length, with a view of illustrating the various theories which have obtained in regard to it, and to show what kinds of batteries are best adapted for all kinds and lengths of telegraphic circuits. The following is mainly an abstract of Dr. Müller's paper, translated from the German for the Smithsonian Institution.

Brief Sketch of the Theories.

Volta found that when a slip of zinc and one of copper were soldered end to end, the one exhibited signs of positive, and the other of negative electricity. He therefore concluded that the electricity was due to the contact of the two metals, and that the acid of the circuit only performed the office of a conductor. This view was at first generally adopted, but, as the phenomena came to be more minutely studied, it was found insufficient to explain them, and Wollaston, Davy, and others adopted the hypothesis that the electricity was due to the chemical action of the acid on one of the metals. It has been shown that a galvanic current can be produced by the action of two liquids without metallic contact, and therefore the theory of contact requires to be so modified as to extend the idea of contact to that of the liquids as well as the solids of the galvanic combination. On the other hand, it has never been fully proved that the contact of two metals does not in itself produce a disturbance of the electrical equilibrium, though this effect does not appear sufficient to account for the great amount of electricity evolved in the action of the battery. The two theories, properly modified, approximate each other, and each, perhaps, involves elements of truth.

The hypothesis, that the development of electricity is only the consequence of chemical action, — that without chemical decomposition of the electrolyte, no electricity can appear in the circuit, — is that against which the attacks of the advocates of the contact theory were directed; and it is, indeed, opposed to a great number of facts. The chemical theory, in this form, ignores completely the fundamental experiment of Volta; it does not explain how the tension of electricity of the open pile increases with the number of plates. But what is most inconsistent with the maintenance of this theory is the circumstance that a number of galvanic circuits can be constructed, in which, when open, not a trace of chemical decomposition takes place, but which nevertheless give rise to currents when they are closed.

Schönbein, in a memoir *On the Cause of the Hydro-Electric Current*, has referred to several such circuits. A solution of perfectly neutral sulphate of zinc does not attack zinc; yet a combination of zinc and copper in this solution produces a current.

Another weighty objection to the form of the chemical theory, which attributes the formation of the current to a preceding chemical attack upon one of the metals of the circuit, is that the electro-motive force of a circuit is not at all proportional to the violence of the attack. If the copper of a Daniell's battery be placed in a solution of sulphate of copper, the electro-motive force of the apparatus is almost wholly unchanged, whether the zinc is placed in water, dilute sulphuric acid, or in a neutral solution of sulphate of zinc. This has been proved by Svanberg, among others, by accurate measurements. If the current had its origin in chemical action, the electro-motive force should be far greater upon application of dilute acid, than of water and sulphate of zinc.

It is a fact that the current of the water battery cannot circulate without decomposition of the liquid. The decomposition appears essentially connected with the passage of the electricity through the liquid, and the contact theory has fully acknowledged the important part which chemical decomposition in the cells plays in the formation of the current. A dispute as to whether decomposition is the cause of the electrical current, or whether the chemical decomposition in the battery is preceded by a state of electric tension, the source of which we need not at present ask, is the same as though there should be a controversy as to whether the motion of a water-wheel is owing to the fall of water or the weight of water. The weight occasions the fall, and the fall the revolution of the wheel, just as the electric tension occasions chemical decomposition, in consequence of which the current

circulates. Even Faraday, who is prominent in maintaining chemical decomposition as the source of the electrical current, concedes that decomposition is preceded by a state of tension of the liquid; for he says, in the case where he applies his theory of induction to electrolytic decomposition: —

"The theory assumes that the particles of the dielectric (now an electrolyte) are, in the first instance, brought, by ordinary inductive action, into a polarized state, and raised to a certain degree of tension or intensity, before discharge commences; the inductive state being, in fact, a *necessary preliminary* to discharge. By taking advantage of these circumstances, which bear upon the point, it is not difficult to increase the tension indicative of this state of induction, and so make the state itself more evident. Thus, if distilled water be employed, and a long, narrow portion of it placed between the electrodes of a powerful voltaic battery, we have at once indications of the intensity which can be sustained at these electrodes, ... for sparks may be obtained, gold-leaves diverged, and Leyden jars charged."

Thus Faraday concedes that a polarized state precedes decomposition of the electrolyte in the separate cells of the battery; consequently it precedes the formation of the current. The difference between Faraday's theory of the pile, and the contact theory, is not to be found in the fact of deriving the circulation of the current from chemical decomposition in the cells. The contact theory supposes that in the water-battery the formation of the current is the consequence of chemical decomposition in the cells. It also supposes that this decomposition must be preceded by a state of tension; and it is only in reference to the cause of this tension, which is nothing else than the electro-motive force, that there can be any difference of opinion.

Schönbein has attempted so to modify the propositions of the two theories as to bring them more in harmony. The following are the principal features of his theory, extracted from his own paper: —

"Whatever may be the cause or force by which elementary substances are enabled to unite together into an apparently homogeneous body, and to continue in their new combination, this much is certain: that a change must always take place in their condition if a third element is brought into contact with one of the substances, which exercises a perceptible chemical attractive force upon the other components of the compound. To illustrate our idea, let us select water as an example. Oxygen and hydrogen are held together in this compound with a given force; or, to express the same thing in other words, the chemical attractive forces of the elements of water are in a state of

equilibrium. An oxidable substance, as zinc, being now brought into contact with water, it will have a chemical attraction, of a certain intensity, for the oxygen of the water. But, in consequence of this attraction, the chemical relation which subsisted between the oxygen and hydrogen before the presence of the zinc must be changed, or the state of the original chemical equilibrium of these elements is modified in a certain degree, or destroyed; or, in other words, under the circumstances mentioned, the oxygen in each particle of water will be attracted in two opposite directions, — towards the zinc in contact with the molecule of water, and also towards the particle of hydrogen contained in this molecule.

"Now, since the least mechanical molecular change taking place in a body disturbs its electrical equilibrium, or its particles become electrically polarized, the above-described change, caused by the zinc, in the original chemical affinity of the oxygen for the hydrogen of the water, is followed by the electrical polarization of the substances in contact with each other. The particle of zinc nearest the water becomes positive; the oxygen side of the molecule of water touching the zinc is negatively polarized; the hydrogen side of the same particle positively. It is self-evident that the particle of water in contact with the zinc will exert an inductive action on its adjoining molecules, the latter upon the next particles, and so on, until all the molecules of water connected together are in the state of electrical opposition or polarization. Since an inductive action traverses the particles of water from the place where the zinc and water are in immediate contact, all the contiguous particles of zinc become polarized, and in such a manner that the side of each particle turned from the water indicates negative polarity, and the side towards the water positive polarity. By placing in this polarized water a good conductor, or a substance easily electrified which is indifferent towards the oxygen of the water, such as platinum, the sides of the particles of this substance in immediate contact with the water become negatively electrified, and the sides of the same particles turned away from the water positively, in consequence of an inductive action, which is exerted by the polarized water upon the platinum.

"All the other particles of the platinum are similarly affected, that is, the side of each molecule turned from the water has positive polarity; that of each molecule turned towards the water, negative.

"The following diagram gives a clear representation of the electrical condition in which the particles of zinc, water, and platinum are found.

"It is very evident that this condition of all the particles of the substance in question will last as long as the cause producing the polarization exists; that is, as long as the chemical attraction of the zinc for the oxygen of the water continues. But if the contact of the zinc and water be broken, the opposite electrical conditions in which the hydrogen and oxygen of each molecule of water exist are neutralized, which is necessarily followed by a like change in the particles of platinum.

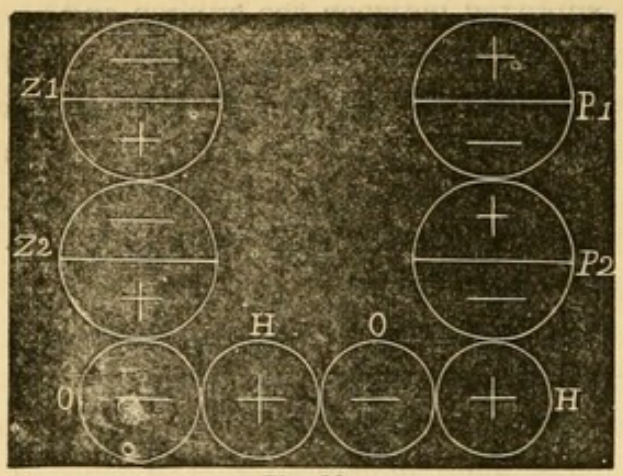

Fig. 98.

"Now, by placing the particle Z of the arrangement in contact with P, the negative side of the former will be in connection with the positive side of the latter, and the opposite states of the two particles will mutually neutralize each other. But at the same moment in which the equilibrium takes place in these particles, it takes place between each two contiguous particles throughout the whole circuit; consequently, between the positive side of a particle of zinc in contact with the water and the negative oxygen particle of a molecule of water in contact with the zinc. Likewise, the electro-negative state of a particle of platinum is in equilibrium with the positive state of the oxygen particle of the water molecule with which it is in contact.

"The electrical equilibrium which now takes place between each metallic particle and each component of a molecule of water is not possible without a decomposition of the latter, and this very act of equilibrium must be considered as the true and ultimate cause of the electrical decomposition of water.

"Evidently, according to this view, the actual combination of the oxygen with the zinc of the battery is regarded as only a secondary action of the current, or the act of electrical equilibrium, and not as the cause or source of the current itself. The chemical combination of the molecules of oxygen and zinc being completed, and a substance being in the water which can remove the oxide of zinc from its place of formation, a new particle of zinc will come in contact with a molecule of water, and the latter, with all the particles of oxygen lying between the zinc and platinum, will be electrically polarized anew. By keeping the circuit closed, a neutralization of the electrical oppo-

sition will take place between each two contiguous particles of the voltaic battery, and the decomposition of new molecules of water follows; and thus proceeds polarizing and depolarizing, circulation and electrolysis, until the necessary conditions cease to be fulfilled.

"Suppose now that water is placed between two metals which manifest an exactly equal attraction for oxygen; it is evident that it will be drawn with equal force, under these circumstances, in opposite directions; hence, the effects upon the particles of water by the metals must be mutually destroyed, the components of these molecules will not be polarized, and in closing such a circuit neither circulation nor electrolytic action can take place.

"But if the water be placed between two metals, one of which has greater affinity for oxygen than the other, the chemical equilibrium existing between the components of each molecule of water will be destroyed, and in proportion to the differences of oxidability of the metals used.

"Since the destruction of the chemical equilibrium between the components of the particles of water also involves the destruction of electrical equilibrium, and the latter is as much more considerable as the former is greater, it follows that the degree of electrical polarization of the molecules of water between metals must be proportional to the difference of oxidability of the said metals; or, to express the same thing differently, the magnitude of the electrical tension which the parts of an open circuit have for each other is measured by the magnitude of the difference which exists between the degrees of oxidability of the metals composing the circuit.

"Now, if the oxidability of a metal is actually related to its voltaic action, as stated, it is very evident that the place which a metallic body has in the tension series of the contactists denotes the degree which belongs to the same metal in the scale of oxidability of metallic bodies. Comparing the tension series of the metals obtained by water and the galvanoscope with the scale of oxidability of the same bodies determined by ordinary chemical methods, it is impossible not to see the great accordance between the two series.

"Now, since we have a number of electrolytes in which other metalloids than oxygen, such as the haloids, sulphur, and selenium, play the part of anions in their combination with hydrogen, it follows from what has been said, that the electrical tension series of metals determined with different electrolytes cannot accord with each other perfectly. This want of accordance has been placed beyond doubt by various experiments, and the number of cases is not very small in

which the same two metals manifest a different voltaic relation for each other when they are placed in different electrolytic liquids; so that the same metal which in one liquid is positive towards the second metal, manifests the opposite in another liquid.

"The case of a reversal of voltaic action which the same two metals exhibit in two different liquids must, in accordance with the above statements, always appear when the chemical relation of these metals to the anions of the electrolytes used is not the same; that is, when the affinity of one and the same metal for the two anions of the electrolyte does not exceed the affinity of the other metal for the same anions, or shows the opposite relations.

"Experience above all teaches that in general the proportions of affinity which exist between the metals and oxygen are similar to those which take place between those bodies and the haloids, sulphur, selenium, &c.; hence the voltaic relations which the metals manifest in electrolytic liquids not containing oxygen, accord so frequently with those which are observed in the same bodies in water.

"Let us now consider those batteries which consist of one metal and two electrolytic liquids.

"The most interesting example is that composed of water, muriatic acid, and gold.

"This battery yields a current which passes from the gold to the acid, and from this to the water. This current is very weak, and, by reason of the rapid positive polarization of the gold immersed in the water, it soon ceases to have a measurable strength. The origin of this current depends upon the simple fact, that the gold possesses a greater chemical affinity for the chlorine of the muriatic acid than for the oxygen of the water.

"It is easily inferred from the preceding explanation, that all voltaic arrangements consisting of two different electrolytes and a metal must form circuits, in case the metal used has a greater chemical affinity for the anion of one of the electrolytic bodies than for the anion of the other. It is likewise evident that the force of the current thus produced must be proportional to the difference of the two affinities.

"It need hardly be mentioned, that other than metallic bodies can also be placed at either end of a continuous series of electrolytic molecules to polarize them. According to the chemical relation which such bodies manifest for the anion or cation of an electrolyte, its molecules will be polarized in the latter or the former direction.

"If, for instance, chlorine be brought in contact with one of the ends of a series of particles of water, the chemical equilibrium of this molecule

will be destroyed, and its hydrogen side will be directed towards the chlorine. If the end of a platinum wire be placed in contact with the chlorine, and the other end of the same wire in contact with any particle of water of the same series, a current must arise, passing from this end of the platinum wire through the water to the chlorine, while the latter combines chemically with the hydrogen of the water.

"On the contrary, a non-metallic substance being placed at the end of a continuous series of molecules of water, having a chemical attraction for the anion of this series, polarization of the particles of water will occur, and it will be opposite to that which chlorine occasions in the case mentioned above.

"Such a substance, for instance, is sulphurous acid, which tends to unite with the oxygen of the water. This tendency is sufficient to polarize the particles of water, and under favorable circumstances to set the current in motion.

"By placing at one end of a series of molecules of water a body which has a chemical affinity for the anions, and at the other end a substance having affinity for the cations of the molecules, it is evident that this series will be under a double polarizing influence, and the electro-motive forces coming into play will mutually increase each other. A series of such electrolytic molecules, having, for instance, chlorine at one of its ends, and sulphurous acid at the other, if closed by a conductor forming a voltaic circuit, must generate a current stronger than that which appears in the cases where chlorine alone or sulphurous acid alone is used, other things being the same.

"It is hardly necessary to remark, that my hydrogen and platinum battery, as well as Grove's new gas pile, are voltaic arrangements, which, although presenting some peculiarities, belong to the class of combinations described above."

Schönbein finally describes the so-called *hyper-oxide battery*. By immersing in water a clean platinum plate, and one furnished with a covering of hyper-oxide of lead, a current will arise as soon as the two metal plates are put in metallic connection; and the positive current will pass from the clean platinum plate, through the liquid, to the other, covered with the hyper-oxide of lead.

The formation of the current, as well as its direction, is easily explained.

It is well known that half of the oxygen in the hyper-oxide exhibits a great tendency to separate and combine with oxidable bodies. Schönbein has, moreover, shown that this second portion of oxygen in the same hyper-oxide has a greater affinity for oxidable substances

than even uncombined or free oxygen; hence the hyper-oxide will polarize the particles of water in such a manner that the hydrogen sides turn towards the hyper-oxide. Other hyper-oxides act in like manner.

If we compare Schönbein's theory with the contact theory, we must understand that they both run parallel, — that the phenomena of the open and closed battery can be explained equally well by both; for Schönbein only removes the place of excitation of electricity from the point of contact of the metals to the point of contact between metal and liquid. But Schönbein's theory has a decided advantage in this, — that it can determine beforehand, in all voltaic combinations, the direction of the current, from the chemical relations of the substance forming the battery, while the contact theory is wanting in such a principle.

That the same metals give a current first in one direction, and then in another, according as one or another liquid is placed between them, is perfectly explicable, according to the modified contact theory, from the different electro-motive relations of the liquids to the metals. Schönbein's theory not only allows the possibility of a reversal of the current by changing the liquids, but it also tells us in what cases, and why, the current is reversed.

Thus Schönbein's theory always determines *a priori*, from the chemical nature of the substances which form the battery, the direction of the current, no matter whether the battery is formed of two metals and a liquid, or of two liquids and a metal; while, on the contrary, the contact theory in many cases is so much at fault, that it is unable to determine beforehand the direction of the current from a general principle, and in such cases an experiment is required to find its direction.

From these considerations, one would suppose that there could be no doubt as to which of the two theories should prevail; whether Schönbein's chemical theory, or the modified contact theory. Yet we cannot decide unconditionally for Schönbein's theory, because it entirely ignores a well-established fact, the *fundamental experiment* of Volta, and is unable to give an explanation of it.

That electricity is generated by different metals coming in contact with each other, is a fact well established by experiments purposely instituted in various forms, and which cannot be ignored nor set aside by such interpretations of the experiments as the opponents of the contact theory have contrived.

The name *contact electricity* is exceedingly unfit, and may have con-

tributed not a little to the confusion of the discussion in question; properly speaking, all electricity, wherever and however it may appear, is contact electricity; for, in generating electricity, two different kinds of bodies are necessarily, under all circumstances, brought into contact; — in electrical machines, glass and amalgam; in the voltaic pile, two metals and a liquid; in the thermo pile, different metallic rods. Wherever heterogeneous substances are brought into contact, a development of electricity takes place; but generally a state of electrical equilibrium soon ensues. For a continuous excitation of electricity this state of equilibrium must be continuously destroyed; this is done in frictional electricity by removing the contact of the closely-touching places of the heterogeneous substances, — in the hydro-battery, by the decomposition of the electrolytes; in the thermo pile, the circulation of electrical equilibrium is produced by the disturbance of thermal equilibrium.

Determination of the Constant Voltaic Battery.

Unit of Force of Current. — Every conductor of electricity, however good, opposes some resistance to its propagation, and many researches have been made to determine the laws of the transfer through conducting media. The following facts have been established by experiment: —

1. Galvanic electricity tends to diffuse itself through the whole capacity of a conductor, and consequently the resistance to conduction will be in proportion inversely to the transverse section of a conductor.

2. All parts of a closed circuit, including the battery itself, are traversed at the same time by the same quantity of electricity, whatever be the diversity of their nature.

It follows from the second law, that the absolute intensity of the electricity that passes in a closed circuit depends upon two circumstances: — first, on the force which develops the electricity, and which is called the electro-motive force; and secondly, on the resistance to conduction presented by the whole circuit taken together. Ohm was the first to give a precise statement of these laws, and with mathematical precision to deduce from them consequences which have become of great importance in establishing the theory of the battery, as well as in the application of electricity to the arts.

If we designate by S the value of the current, or its power to produce effects, and by E the electro-motive force of a single element,

whether this be due to contact or chemical action, or both, and by R the resistance in the battery, then the relations may be expressed by the equation $S = \frac{E}{R}$.

In the foregoing equation, we have supposed that the battery consists of a single element, and that the metals are joined by so short and thick a conductor that it offers no appreciable resistance. If, however, the battery consist of n number of elements, joined as before, then the electro-motive power will be n times greater, and also the resistance will be increased in the same ratio, and therefore we shall have $S = \frac{n\,E}{n\,R}$.

If now we introduce an additional resistance in the conductor which joins the poles, and represent this by r, then the expression becomes $S = \frac{n\,E}{n\,R + r}$.

This is the fundamental equation of Ohm, from which all the relations of galvanic combinations can be derived.

To determine the resistance of a battery, the force of its current, of course, must be measured, if different resistances are inserted successively in the circuit. The resistance of the inserted piece of wire must be first brought to the adopted unit. The simplest way of doing this would be to use only copper wire of one millimetre in diameter, and of different lengths; for a piece 10, 15, 20, &c. metres long, of this normal wire, the resistance would be 10, 15, 20, &c. But, since it is difficult to obtain wires having exactly this diameter, it must be measured accurately, and the computation made how long a copper wire one millimetre in diameter should be which makes the same resistance. In computing the actual resistance of the battery, this reduced length of wire is used.

This section of our normal wire has a surface of 0.785 square millimetre. Since, with equal resistance, the length of the wire increases in proportion to its section, it is evident that a copper wire l metres long, with a radius r, and section $\pi\,r^2$, excites the same resistance as a normal wire of the length $L = \frac{l\,0.785}{\pi\,r^2}$, in which L is the reduced length of the wire. A wire, for instance, having a diameter 0.74 millimetre, a section of 0.43 square millimetre, and a length of 6 metres, will exert the same resistance as a copper wire $\frac{6 \times 0.785}{0.43} = 10.95$ metres long, and 1 millimetre in diameter; thus 10.95 is the reduced length of the wire used in the experiment.

From this inserted copper wire many pieces of different lengths may be attained, 5, 10, 20, &c. metres long, for similar experiments, and ready at all times. Instead of longer copper wires, short pieces of wire of badly conducting metals, as platinum, iron, or German silver, are best; their resistance reduced to the normal wire must be determined by experiment. Wires to about 10 metres long can be wound suitably into coils, and fixed in wooden cylinders from 2 to 3 inches in diameter, and corresponding lengths. Longer wires are covered with silk, and wound on wooden rollers, and used thus. On these cylinders or rollers the length of the wire reduced to the normal wire can be written, so that there will be no further necessity for a reduction of the inserted wire.

It is very evident that for insertions wire of different lengths can be applied advantageously to a rheostat.

Denote by E the electro-motive force of the galvanic battery, by R the essential resistance to conduction; then we have, according to Ohm's law, the force of the current, $s = \frac{E}{R}$, with perfect metallic closing, — that is, with such closing that its resistance to conduction, compared with that of the elements, may be disregarded. Introducing the reduced length of wire, l, the force will be only $s = \frac{E}{R+l}$. We have here s and s' given by observation; l is also known, and from these two equations E can be eliminated, and the value of R computed.

The following tables give a series of observations instituted for determining the resistance to conduction of different batteries. In the last vertical column are the computed values of the electro-motive force, which shall be spoken of later.

BUNSEN'S BATTERY.

Number.	Insertion in Metres.	Deflection.	Tangent of Deflection.	Force of Current.	R	E
1	0	57°	1.54	107.8	7.44	802
	7.2	38	0.781	54.67		
2	0	57	1.54	107.8	7.72	832
	29.2	17.8	0.321	22.47		
3	0	57	1.54	107.8	7.74	834
	49	11.8	0.21	14.7		
					Mean,	823

GROVE'S BATTERY.

Number.	Insertion in Metres.	Deflection.	Tangent of Deflection.	Force of Current.	R	E
1	0	30.8°	0.596	41.7	19.4	809
	7.2	23.5	0.435	30.4		
2	0	30.8	0.596	41.7	20.4	851
	29.2	13.7	0.245	17.1		
3	0	30.8	0.596	41.7	19.8	828
	49	9.7	0.171	12		
					Mean,	829

DANIELL'S BATTERY.

Number.	Insertion in Metres.	Deflection.	Tangent of Deflection.	Force of Current.	R	E
1	0	32°	0.625	43.75	11.1	486
	68.7	5.45	0.101	7.07		
2	0	16.8	0.302	21.14	21.5	454
	7.2	12.75	0.266	15.82		
					Mean,	470

SMEE'S ELEMENT.

Number.	Insertion in Metres.	Deflection.	Tangent of Deflection.	Force of Current.	R	E
1	0	26°	0.488	34.16	5.3	181
	7.2	12.25	0.217	15.19		
2	0	26	0.488	34.16	7	239
	29.02	5.25	0.092	15.19		
					Mean,	210

WOLLASTON'S ELEMENT.

Number.	Insertion in Metres.	Deflection.	Tangent of Deflection.	Force of Current.	R	E
1	0	23.6°	0.437	30.58	6.3	193
	7.2	11.6	0.205	14.17		
2	0	23.6	0.437	30.58	7.3	223
	29.2	5	0.087	6.12		
					Mean,	208

We must append a few remarks on the separate experiments whose data are given in the tables.

The numbers under the head "Insertion" indicate the *reduced length* of the inserted wire.

The sulphuric acid used in the first experiment with the Bunsen battery was diluted with about ten times its quantity of water; in the second and third, the acid was diluted still more. The nitric acid had a specific gravity of 1.18.

In Daniell's battery the red-clay cells were used; in the first experiment, the zinc was placed in a mixture of one part sulphuric acid to ten parts water; in the last experiment, acid which had been already used, and still more diluted, was applied.

The resistance of the element depends upon the nature of the liquid and the size of the pair of plates; hence, to be able to compare the conducting capacity of different galvanic combinations properly, the resistance must be reduced to the same sized pair of plates, and thus the surface of the latter, with which the experiment is made, must be known.

To compare the electro-motive forces of different batteries, the following process is, therefore, to be adopted. In the conducting circuit of the battery, besides the galvanometer, the rheostat is inserted with so much wire as to produce a deflection of the needle of 45°; the resistance is then increased by turning the rheostat until the deflection of the needle is only 40°; the number of turns is thus a measure of the electro-motive force of the battery.

Suppose, for example, the current of a Daniell's element be passed through the rheostat and the galvanometer, and so much wire has been inserted as to produce the deflection of 45°. To reduce the deflection from 45° to 40°, suppose thirty turns of the rheostat must be added. Now insert a Grove's element into the same circuit, and so regulate the entire resistance that the needle stands again at 45°. To bring it down to 40°, the resistance must be increased by (say) fifty turns of the rheostat; then the electro-motive force of Daniell's battery is to that of Grove's as 30 to 50. This is evidently the simplest process for determining the ratio of the electro-motive forces of different batteries.

Wheatstone used a multiplier as a rheometer, and on that account had to insert a considerable resistance to make the current of the hydro-electric elements weak enough. Under these circumstances, of course, only a rheostat with a thin wire can be used.

Although this method was originally designed for a multiplier, it may be also used with any other rheometer, as the torsion galvanom-

eter, tangent compass, &c. But with these instruments, which admit of stronger currents, the current employed, of course, need not be very weak, and therefore a rheostat with a thicker wire can be used.

This method of Wheatstone gives us the values of electro-motive force, measured by the length of wires required to effect the retrogression of the needle; hence these numbers are dependent on the individuality of the galvanometer and the rheostat.

As examples of his method, Wheatstone adduces the following measurements. Three small Daniell's batteries of unequal size were in succession brought into the circuit. To revert the needle from 45° to 40°, the following number of turns of the rheostat was necessary: —

Copper cylinder $1\frac{1}{2}$ inches high, 2 inches in diameter, 30 turns.
" " $3\frac{1}{2}$ " " $2\frac{1}{2}$ " " " 30 "
" " 6 " " $3\frac{1}{2}$ " " " 30 "

Thus the electro-motive force, according to the theory, is independent of the size of the pair of plates.

When batteries of 1, 2, 3, 4, and 5 equal elements were used as electro-motors in succession, the following results were obtained: —

1 element required 30 turns. 4 elements required 120 turns.
2 " " 61 " 5 " " 150 "
3 " " 91 "

Thus the electro-motive force of the battery is, as theory indicates, proportional to the number of pairs of plates.

We have determined by this method the electro-motive force of a Daniell's, a Grove's, and a Bunsen's element, using for this purpose the tangent compass, and a rheostat with thick wire. For bringing the needle back from 15° to 10°, we found as follows: —

With Daniell's element, 9 turns.
" Grove's " 13 "
" Bunsen's " 13.6 "

After these determinations, it is easy to reduce the number of turns necessary to revert the needle from 15° to 10° to the unit of electro-motive force described above. We have 15.1 turns, equivalent to 823 of electro-motive force; hence, one turn is equivalent to 54.51 of electro-motive force. Thus the values determined by revolution of the rheostat expressed in our unit are as follows: —

For Daniell's battery, 490.
" Grove's " 709.
" Bunsen's " 741.

Comparison of Different Voltaic Combinations. — In the last paragraph we have seen how the constants of a voltaic combination can be determined and expressed in comparable values. None of the statements of the effects of batteries, as they are ordinarily presented for comparison, are satisfactory. The want of accurate numerical determinations occasions great uncertainty in regard to the advantages and disadvantages of different galvanic combinations. If such uncertainty exists in the accounts of men of science, it is not at all surprising to find communications in technical journals which betray entire ignorance of the principles here discussed.

Let us now examine the most important of the galvanic combinations somewhat more closely.

Wollaston's Battery.

The Simple Zinc and Copper Battery. — The simple zinc and copper battery is not constant, because the electro-motive force is considerably modified by the polarization of the copper plate, which takes place in consequence of the current. Poggendorff found the electro-motive force of the zinc and copper battery in dilute sulphuric acid, before being modified by polarization, to be equal to 13.8, while the electro-motive force of Grove's battery is equal to 22.9.

Assuming the electro-motive force of Grove's battery to be 830, referred to the chemical unit, the unmodified electro-motive force of the zinc and copper battery would be 500 of the same unit. But according to our experiments, when the current commences, the electro-motive force of the zinc and copper combination is only 208; thus, by polarization, the force is very soon reduced to two fifths of its original value, and this is also the reason that immediately after immersion the current is exceedingly strong, but very rapidly decreases. The polarization having once reached its maximum, the current remains tolerably constant, — at least, so much so as to admit of accurate measurement.

The reason why batteries with one liquid are not constant, is to be sought in the polarization of the negative plate; and this is obviated as much as possible in the so-called constant battery. Yet the strength of the current of the constant battery gradually decreases by leaving it closed for a long time, because the liquid gradually changes, — the dilute sulphuric acid becoming converted, by degrees, into a solution of sulphate of zinc. A corresponding change in the nature of the liquid takes place in all batteries, without exception, and it is only to be avoided by renewing the liquid from time to time. An arrangement

might be so made that the heavy solution of sulphate of zinc would flow off slowly from the lower part of the vessel, and the fresh acid flow in above at the same rate.

A circumstance which acts quite injuriously in all batteries without porous partitions is, that, in consequence of the current, the sulphate of zinc solution is decomposed, and metallic zinc deposited on the negative plate, whence, during a protracted action of the battery, its electro-motive force must decrease more and more.

The constancy of the battery current depends essentially upon its strength. Feeble currents, like those obtained by using very dilute acid, and with great resistance included in the circuit, remain constant for some time; while by using stronger acid and less resistance the strength of the current must necessarily decrease far more rapidly. Hence, if it be desired to compare different batteries with reference to their constancy, equal resistance and like acid must be used. Neglect of these conditions may have been the occasion of numerous errors in regard to the constancy of single batteries.

Batteries composed of zinc and copper plates buried in the moist ground are said to be very constant. Such batteries, however, yield very weak currents, because the resistance to conduction between the plates is very great. Thus it is evident that the current of this battery will remain constant longer than when the plates were immersed in acid.

Smee's Battery.

This battery was greatly praised in many quarters: it was represented to produce very strong currents, and to be far more constant than other batteries with one liquid. No measurements in support of this opinion were made, and I have not found it anywhere confirmed.

The copper of Wollaston's battery is substituted in Smee's by platinum, or silver covered by a rough surface of platinum. This coating of platinum is produced by immersing the perfectly clean plate in a solution of chloride of platinum and potassium in contact with the negative pole of a rather weak battery, the positive pole of which dips at the same time into the solution. The platinum deposits on the plate at the negative pole. If the positive pole be also a plate of platinum, it will be attacked by the chlorine, and the solution will be kept saturated.

The two surfaces of Smee's platinized plate are placed at about one line distance from the zinc plates. The width of the zinc plates is to be only about three quarters that of the platinized plate. What

is to be expected to be gained by this, we cannot see. It is not the case in the Smee element with which we experimented, the negative plate of which was platinized silver.

This battery is far less constant than Wollaston's, and the variations of the needle were far greater.

Assuming as a mean for the insertion 0, the deflection 26°, for the copper wire 12°.25, and for the brass wire 5°.5, the electro-motive force of Smee's element is 212, which is scarcely greater than that of Wollaston's, which we have seen is 208. With equal surfaces, the resistances of the two elements are tolerably equal. From these experiments, it does not appear that Smee's battery deserves any preference over Wollaston's. It is yet to be determined whether platinized platinum gives better results than platinized silver.

The Zinc and Copper Battery with Two Liquids. — When the copper of a zinc and copper battery is placed in a concentrated solution of sulphate of copper, and this in dilute sulphuric acid, the two liquids being separated by a porous partition, the injurious effects of polarization are in a great measure removed, the electro-motive force becomes greater than in the ordinary zinc and copper battery, and the strength of the current is constant.

The electro-motive force of Daniell's battery is, $E = 470$. From Svanberg's experiments it appears that it changes but little with the nature of the liquid. The copper being constantly immersed in a concentrated solution of sulphate of copper, and the zinc immersed in various liquids successively, the following values, expressed in an arbitrary unit, were obtained for the electro-motive force: —

For concentrated solution of sulphate of zinc, . .	15.6
For the same, much diluted, ...	15.9
For concentrated solution of sulphate of copper, . .	16.6
For the same, much diluted, ...	16.2
For slightly acidified water, ...	16.5
For more strongly acidified water, ...	16.7

Daniell's battery is, perhaps, the most constant of all, which is due partly to the acid being used up less rapidly; since the acid, set free by the decomposition of the sulphate of copper, passes, in part at least, through the porous cell to the liquid in which the zinc is immersed.

The best kind of battery to be employed depends entirely upon the nature of the work to be performed by its power. If it has only to move a magnetic needle surrounded by a coil of wire, the simplest arrangement of battery is required, such as one composed of cells con-

taining plates of copper and zinc immersed in a solution of sulphuric acid or of the sulphate of alumina. If, on the other hand, the current is required to perform powerful mechanical effects at a distant station, galvanic batteries of a stronger power are necessary, — such, for instance, as Daniell's or Grove's batteries.

Grove's Battery.

According to our measurements, given in this chapter, — which, however, for Grove's battery, have no claim to great accuracy, — the electro-motive force of this battery is, in chemical measures, 829.

Other observers have determined its force, not in an absolute measure, but compared with that of Daniell's battery. Making the electro-motive force of the latter equal to 1, we have for Grove's as follows: —

By Jacobi, ...	1.666
By Buff, ...	1.712
By Poggendorff, ...	1.668
" "	1.565
Mean, ...	1.653

Assuming the force of Daniell's battery in chemical measure, according to my determination, equal to 470, we should have, in the same measure, that of Grove's, equal to

$$470 \times 1.653 = 777;$$

while I found the value of the electro-motive force of this battery to be 829, or about $6\frac{1}{2}$ per cent greater.

The observers above named made no comparison of the resistance of Grove's battery with that of Daniell's. Such a comparison, however, can hold good only for an individual battery, since it changes with the nature of the earthen cells, and is dependent upon the degree of concentration of the liquid.

In using Grove's battery for telegraphic purposes, it often happens that the nitric acid penetrates through the earthen cells, and attacks the zinc so powerfully that it has to be newly amalgamated every day. Crystals of Glauber salts cast into the dilute sulphuric acid are said to remedy this evil. The explanation of this may probably be, that the Glauber salts are decomposed, and nitrate of soda is formed, the free nitric acid then disappearing.

Bunsen's Battery.

As a mean of all our experiments, the electro-motive force of the zinc and carbon battery was found to have, in chemical measure, the value 824.

The force of Daniell's battery being made equal to 1, that of the zinc and carbon battery was found by Buff to be 1.712; by Poggendorff, 1.548.

The electro-motive force of the zinc and carbon battery, and that of Grove's, are so nearly equal, that in practical use the little difference may be disregarded.

According to Poggendorff, the electro-motive force of Bunsen's battery remains almost the same, if for the nitric acid is substituted a solution of bichromate of potash; indeed, with the liquid it is somewhat greater, the proportion being 1,580 to 1,548.

Zinc and Iron Battery.

It has been proposed by many to use iron instead of platinum or copper in the construction of galvanic batteries. Roberts made a zinc and iron battery in the following manner. A cast-iron vessel 10 inches high and 3.9 inches in diameter served for holding a mixture of one part concentrated sulphuric acid and three parts of strong nitric acid; in this liquid an earthen cell filled with dilute sulphuric acid was placed, which cell also served for the reception of the zinc cylinder 9.9 inches high and 3.3 inches wide. Five such elements yielded forty cubic inches of detonating gas in a volta-metre placed in the circuit. This is certainly quite a considerable effect.

Callan constructed a zinc and iron battery of a form similar to that which Grove had originally given to his zinc and platinum battery, viz. rectangular, smooth earthen cells, $4\frac{1}{2}$ inches long and $4\frac{1}{2}$ high. A turkey-cock was instantly killed by the stroke of such a battery, composed of 620 elements; and on examination the craw was found burst.

Poggendorff found for the electro-motive force of different combinations the following values:—

Zinc and platinum, . . .	100
Zinc and iron, ...	78.6
Zinc and steel, ...	87.0
Zinc and cast-iron, ...	89.6

The zinc being in dilute sulphuric acid, and the platinum, iron, &c. in concentrated nitric acid. The resistances are tolerably equal in all these combinations.

The Iron and Iron Battery.

That, instead of the platinum in Grove's battery, iron can be successfully substituted, is owing, no doubt, to the fact that iron immersed in concentrated nitric acid becomes passive, and in this state acts like a strong electro-negative metal. From this Wöhler and Weber inferred that iron placed in concentrated nitric acid might act towards iron in dilute sulphuric acid as platinum does towards zinc. Their expectation was entirely confirmed on trial, and they constructed a very powerful battery in this manner.

They found it advantageous to use ordinary tin-plate iron for the metal immersed in the dilute sulphuric acid.

The most convenient form of the iron battery is perhaps that of a cast-iron vessel which receives the nitric acid and the earthen cell, in which the dilute sulphuric acid is placed with the active iron.

Callan describes a new voltaic combination, of which Poggendorff gave an account. For the platinum of Grove's battery is here substituted platinized lead, which is immersed in a mixture of four parts of concentrated sulphuric acid, two parts of nitric acid, and two parts of a saturated solution of nitrate of potash. The zinc is in dilute sulphuric acid, separated of course from the other liquids by an earthen cell.

Poggendorff found the electro-motive force of this combination was equal to that of Grove's; and that the current from it for many hours indicated the same constancy as that of a zinc and platinum battery. But, on the other hand, he found that the addition of saltpetre to the nitric acid is no improvement, but the addition of concentrated sulphuric acid has the advantage of protecting the lead from the action of nitric acid, which the pulverulent coating of platina cannot do, and allows, besides, the use of dilute nitric acid.

Considered strictly, this combination is a zinc and platinum battery, since the lead serves properly only as a support for the thin film of platinum; therefore zinc and platinum are the terminations of the metallic circuit immersed in the liquid.

The most convenient Combination of a given Number of Voltaic Elements for obtaining the Greatest Effect with a given Closing Circuit.

Theoretically, this subject has long since been settled, but the investigations are mostly conducted by the aid of the higher calculus, and the whole is presented in such a form that the practical use of the prop-

osition is indicated, rather than fully exhibited; on this account, a somewhat more detailed exposition may here be in place.

Generally, the question is stated thus: How should a given metallic surface, which is to be used in constructing voltaic elements, be arranged, (that is, how many elements, and how large should they be,) in order that a maximum effect shall be obtained with a given closing circuit?

This form of the question does not correspond exactly with practical cases. We are not required, generally, to construct the voltaic battery for a given closing circuit; but the question is, how to combine a disposable number of galvanic elements to obtain a maximum effect.

A maximum strength of current may be obtained from a given number of elements, if they be so arranged that the resistance in the battery is equal to the resistance in the closing arc.

We will first explain this proposition, then prove it. A given number of elements can be combined in the most varied manner. For instance, 24 elements can be arranged in 8 different ways:—

1. As a battery of 28 single elements.
2. " " 12 double elements.
3. " " 8 treble elements.
4. " " 6 four-fold elements.
5. " " 4 six-fold elements.
6. " " 3 eight-fold elements.
7. " " 2 twelve-fold elements.
8. " " 1 twenty-four-fold element.

Which one of these combinations should be selected in a given case, depends upon the resistance to conduction of the circuit. That combination must be taken, the resistance of which is nearest to that of the given circuit. Denoting by 1 the resistance of an element, the resistance of the

1st	combination	is	24.
2d	"	"	6.
3d	"	"	2.666
4th	"	"	1.5
5th	"	"	0.666
6th	"	"	0.375
7th	"	"	0.166
8th	"	"	0.046

Considering the different combinations of 24 elements, as repre-

sented in the above table, it is easily seen that, if the pile be shortened, it becomes broad in the same proportion; that is, if fewer elements be placed one after the other, we can, by using the same number of elements, place more of them beside each other in the same proportion.

Commencing with the second combination, we have here 12 double elements. If we reduce the length of the pile by one half, or to 6, we can double the width of each element. We shall then have 6 four-fold elements.

Making the pile three times shorter, three times as many single elements can be united in one; from 12 double elements we obtain 4 of six-fold. In short, if the pile be made a times shorter, we can unite a times as many single elements in one.

If the number of elements combined, one after another, to form a pile, is a times less, the electro-motive force thus becomes a times less; if the battery had now been made only a times shorter, without increasing its width, the resistance would have been a times less; but if each element of those in a pile consists of a times as many single elements as before, the resistance becomes a^2 times less than before.

Thus the resistance of six quadruple elements (combination No. 4) is four times less than for twelve double elements (combination No. 2); for four six-fold elements (combination No. 5), nine times less than for twelve double, &c.

From this exposition, the proof in question is easily derived. For any combination of a number of elements, let the electro-motive force be E, and the battery resistance l. This battery being closed by a conducting circuit, whose resistance is also l, we have, according to Ohm's law, the strength of the current: —

$$(1) \qquad S = \frac{E}{l + l} = \frac{E}{2\,l}.$$

The pile being now made a times shorter, but the single elements a times wider, the electro-motive force will be a times less, or $\frac{E}{a}$; but the resistance of the battery will be $\frac{l}{a^2}$, and the force of the current, for the same connecting arc, will be

$$(2) \qquad S' = \frac{\frac{E}{a}}{\frac{l}{a^2} + l} = \frac{E}{\left(a + \frac{1}{a}\right)}.$$

But the sum $a + \frac{1}{a}$ is, under all circumstances, greater than 2*, which

in an integral or fractional quantity we may substitute for a; thus the value of the fraction (2) is, under all circumstances, less than that of (1). Since (1) denotes the value of the strength of the current for cases in which the resistance in the electrometer is equal to the resistance of the closing arc, and (2) the value of the strength of the current for cases in which the number of single elements is combined in any other manner, the proposition in question is therefore proved.

The application of this proposition may be shown by an example. If, in magnetizing an electro-magnet, the current of 24 zinc and carbon elements be used, the resistance of one element, with weak acid, is 15.05. But resistance of the coils of the electro-magnet has been found *equal to that of* 13.54 *metres of normal wire*, and therefore the resistance of the connecting arc is 0.9 of that of a single element. A glance at the table upon page 453 shows us that we must select the fifth combination as the most suitable; because its resistance, 0.65, is nearer to that of the closing arc than that of the other combinations. Make, for sake of brevity, the electro-motive force of the element equal to 1, and the resistance also 1; then, if we apply successively all of the eight combinations to the electro-magnet above mentioned, the following values will be obtained for the strength of the current: —

1 $$\frac{24}{24 + 0.9} = 0.963.$$

2 $$\frac{12}{6 + 0.9} = 1.74.$$

3 $$\frac{8}{2.666 + 0.9} = 2.24.$$

4 $$\frac{6}{1.5 + 0.9} = 2.5.$$

5 $$\frac{4}{0.666 + 0.9} = 2.54.$$

6 $$\frac{3}{0.375 + 0.9} = 336.$$

7 $$\frac{2}{0.166 + 0.9} = 1.85.$$

8 $$\frac{1}{0.042 + 0.9} = 1.61.$$

It is observed here, that with the combination 5, the coils of the electro-magnet remaining unchanged, the magnetism of the soft iron will be greater than with any of the other combinations. Combination 4 approaches 5 very closely in its effects; thus the exact maximum should be looked for between 4 and 5.

If a given number of elements be so combined that they will yield in a given circuit a maximum strength of current, an increase of the number of elements will increase the strength of the current, in the most favorable cases, only in proportion to the square root of the number of elements; then 4, 9, or 16 times as many elements must be used to obtain 2, 3, or 4-fold effects.

We shall endeavor to prove this, in a special case. Let the resistance of the closing arc be r, equal to the resistance of one element, the electro-motive force of which is denoted by E, then the strength of the current is

$$S = \frac{E}{r + r} = \frac{E}{2\,r}.$$

Now let us double the force of the current by increasing the number of elements. To obtain a maximum effect from the new combination, the resistance in the battery must continue as great as the resistance of the closing arc; therefore, the resistance of the new combination must not be greater than that of a single element; hence, we shall obtain double the force of the current, if, with unchanged resistance, we double the electro-motive force. This is done by placing one element after another; but we must take two double elements, if their resistance is to be as great as that of a single element.

The most suitable arrangement of the closing arc for obtaining a maximum effect with a given electro-motor. — In some cases the electro-motor is given, and the question is, how the coils of wire must be selected to obtain a maximum effect; from the same quantity of copper, are many coils of a thin and long wire to be made, or fewer coils with short and thick wires? In the case of multipliers, the quantity of copper wire to be used is limited by the space which can be conveniently filled by the coils; in that of the electro-magnets, the quantity of copper wire is limited by the amount of money to be expended in its construction.

Suppose the resistance of a copper wire of a given length and thickness, making n coils, to be equal to l, or the resistance of the electro-motor; then the force of the currents is,

$$S = \frac{E}{l + l} = \frac{E}{2\,l};$$

and this acting in n coils on the magnetic needles in soft iron, we can represent its effects by

$$M = n \frac{E}{2\,l}.$$

If we make the wire m times as long, the mass remaining the same, its section will be m times less, and then the resistance m^2 times greater; hence the force of the current is now

$$S' = \frac{E}{l + m^2\,l} = \frac{E}{l\,(+\,m^2)};$$

but of this length of wire, m times as many coils can be made as before; thus, the magnetic effect is now

$$M' = m \,.\, n \,.\, \frac{E}{l\,(m^2+1)} = n\,\frac{E}{l\left(m+\frac{1}{m}\right)}.$$

But the value of M, as just proved, is always greater than the value of M'. *Hence, with a given mass of wire, a maximum of magnetic effect is obtained by giving to the wire such a thickness and length that the resistance in the coils is equal to that of the elements.*

Comparison of the Effects of different Batteries in given Cases. — The strength of the current for any given case can be computed from the constants of different batteries. If the resistance of the closing arc is l, for a zinc and carbon battery with a mean surface of one square decimetre, and using Stohrer cells with dilute sulphuric acid, the strength of current is

$$S = \frac{824}{12 + l}.$$

For a Daniell's element, of the same size, with sulphuric acid of the same degree of dilution, the force of the current would be

$$\frac{470}{12 \times 1.8 + l} = \frac{470}{21.6 + 1}.$$

If l is very small, compared with the resistance of the elements, the strength of their currents will be to each other as $\frac{824}{12}$ to $\frac{470}{21.6}$, or as 68.6 to 21.8; hence the current of the zinc and carbon battery is more than three times as strong as the other. When the current is well closed, a zinc and carbon element will effect as much as a Daniell's element of three times as great a mean surface.

When the resistance is very great, the ratio is different; then the strength of the current is proportional to the electro-motive force, or

as 470 to 824. In this case, by increasing the surface of the zinc and copper element, but little would be gained. Two Daniell's elements would have to be united, to obtain the same effect as with one zinc and carbon element.

The effect of a zinc and carbon battery can be attained in all cases with a Daniell's battery, by giving to single elements of the latter a threefold surface, and using twice as many of them as would be required of zinc and carbon elements.

What has been said of the zinc and carbon battery holds good for Grove's battery, since the constants are nearly the same in both.

We present the description of a few instruments, which have been used for measuring, in the course of the previous experiments.

Rheostats. — To accomplish a gradual change of the resistance in the closing circuit of an electro-motor within the desired limit, without being obliged to open the circuit, several instruments have been proposed, chiefly by Jacobi and Wheatstone. Jacobi called his instrument an *agometer*. An instrument of this kind is very costly, and therefore will not be generally employed, especially since Wheatstone's instruments, constructed for the same object, besides answering the purpose equally well, are far simpler and more convenient in manipulation. Wheatstone's rheostat with thick wire is to be used when the resistance of the closing conductor is not very great. But when the entire resistance in the battery is very considerable, a great length of this thick wire would have to be wound or unwound to produce a sensible change in the strength of the current; consequently, in such cases a rheostat with a thin wire must be used, and which, of course, must have a different construction.

Wheatstone's rheostat with a thin wire has a cylinder of dry wood about six inches long and one and a half in diameter, and a cylinder of brass having the same dimensions. The axes of the two cylinders are parallel. A screw-thread is cut in the wooden cylinder, and at its end there is a brass ring, to which the end of a long and very fine wire is fastened. This is so wound upon the wooden cylinder as to fill all the screw-threads, and its other extremity is then fastened to the opposite end of the brass cylinder. By means of a crank, which is turned to the right, the wire is unwound from the wooden cylinder, and wound upon the brass one; on the other hand, by turning to the left, the reverse takes place. Since the coils are insulated on the wooden cylinder, and kept apart by the screw-thread, the current traverses the wire throughout its whole length on this cylinder; but on the brass cylinder, where the coils are not insulated, the current passes at once

from the point where the wire touches the cylinder to the spring. The resisting part of the length of the wire is therefore the variable portion which may happen to be on the wooden cylinder. There are forty screw-threads of the wooden cylinder to an inch. The wire is of brass, and 0.01 of an inch in diameter.

For counting the number of coils unwound, a scale is placed between the two cylinders, and the fraction of a turn is estimated by an index fastened on the axis of one of the cylinders, and which points to the divisions of a graduated circle.

Differential Measurer of Resistance. — For determining the resistance of metallic wires, Wheatstone has given a very simple process. The rheostat is inserted in the conducting arc of a constant element with the galvanometer and the wire whose resistance is to be determined, and the whole resistance is so regulated that the needle can come to rest at any desired point, *a*, of the graduated circle. Now, removing the wire from the circuit, the needle will indicate a greater deflection ; and to bring it back to the point *a*, a definite number of turns of the rheostat must be added to the existing resistance. We find, in this manner, how great the resistance of the wire in question is, expressed in turns of the rheostat.

By this method, nearly equally accurate results are obtained, whether a multiplier, the much less sensitive tangent compass, or any other galvanometer be used. The reason is as follows: — To produce in a tangent compass a deflection of, say 45°, the entire resistance of the closing conductor must not be very great. Suppose R is the entire resistance of the whole battery, and an increase or decrease, r, of this resistance produces such a change in the strength of the current that the deflection of the needle is varied by 1°. Now, by using a multiplier, which is about 150 times more sensitive than the tangent compass, the entire resistance of the battery must be about $150\,R$ to cause a deflection of the needle of 45°. To produce a like change in the strength of the current as that above mentioned, the resistance must now be increased or decreased by $150\,r$. But, since the multiplier is 150 times more sensitive than the tangent compass, the 150th part of this change of resistance, or r, will suffice to advance or bring back the position of the needle by 1° ; thus the same change of resistance, r, produces in both instruments nearly equal changes of deflection.

EXPLANATION OF VARIOUS TECHNICAL TERMS.

The terms *quantity*, *intensity*, *electro-motive force*, and *electric tension*, as applied in the science of electricity, are not easily comprehended by the student, and, in fact, are not always used by writers upon the subject with absolute consistency. De la Rive, for instance, uses the term *intensity* as synonymous with *strength of current*, as indeed do Müller, Lardner, and many others; while Faraday uses the term as equivalent to *electro-motive force*, — or, in other words, as proportionate to the *number of cells in a battery*, irrespective of the size of the plates. We will quote the definitions of various writers entitled to credit upon this subject.

Faraday says: "The action in each cell is not to increase the *quantity* set in motion in any one cell, but to aid in urging forward that quantity, the passing of which is consistent with the oxidation of its own zinc; and in this way it exalts that peculiar property of the current which we endeavor to express by the term *intensity*, without increasing the *quantity* beyond that which is proportionate to the quantity of zinc oxidized in any single cell of the series. . . . . The deflecting power of one pair of plates in a battery being equal to the deflecting power of the whole, provided the wires used be sufficiently large to carry the current of the single pair freely."

Francis Watkins says: "The amount of the angle of deviation of the magnetic needle caused by the action of an electric current, is proportionate to the *quantity*, and not to the *intensity*, possessed by the current."

Professor Daniell says: "*Intensity* does not at all depend upon the size of the plates, but is proportionate to the number of alternations. A battery constructed of pieces of copper tube three eighths of an inch in diameter and two and a half inches long, with a piece of zinc wire one eighth of an inch in diameter soldered to each, and turned down into the axis of the next, without metallic contact, and consisting of a series of 1024, will be quite equal to a battery of the same number of plates four inches square."

From Bird's Natural Philosophy: "It is necessary to make a distinction between the *quantity* and *intensity* of the electric current; the former having, *cæteris paribus*, a relation to the size of the plates, and the latter to the number of alternations."

From Noad's Manual of Electricity: "In order to increase the *intensity* of the electrical current, with a view to the exhibition of its chemical and physiological effects, we increase the *number* of the

plates; an arrangement of this sort is called the compound voltaic circle. It was the invention of Volta, and is hence called the voltaic pile. Now the *quantity* of electricity obtained from the voltaic pile is no greater than that from a single pair of plates; it is its *intensity* alone that is increased; — an important fact, which has received much elucidation from the important labors of Faraday."

From Harris's Rudimentary Electricity: "The term *tension*, in its general acceptation, applies to the case of reactive or resisting force, however derived, — whether to the reactive force of an elastic fluid, such as air heaving out under compression, or to the reactive force of a strained or twisted wire, as in the instance of a stretched musical string, or a wire employed in a balance of torsion. In either instance, there is a force set up in these bodies, by which they tend to recover their normal state; and the amount of this force is virtually the tension or degree of suffering to which they are exposed. If we conceive, therefore, for an instant, according to the French theory, that electricity is a certain force exerted by an elastic fluid, capable of compression, then, like any other elastic fluid, such as steam or air, it would exhibit a certain amount of tension or reactive power; and this would be as the density, or the number of particles confined in a given space: such would be the signification of the term *electrical tension* taken in this sense.

"But the term may be also, and equally well, applied to the condition of polarized molecules of a dielectric interposed between two limiting conductors. In this case it expresses the reactive force of the particles constrained to assume a new condition in their electric relations, and the amount of suffering they endure in their forced deviation from their normal state. The higher the compressive and separated powers are exalted, the greater will be the degree of tension which they endure. In a similar way, the lateral or transverse force of dilation upon the representative line of induction is a kind of lateral tension or stretching of these forces, tending to throw the particles asunder, all of which may be conceived to increase up to the limit of the power of endurance; all this is fairly expressed by the general term *tension*, and which term thus becomes representative, either of the particular condition of the electrical agency itself, or of the reactive state of the molecules of a dielectric when charged by induction.

"Now the term *intensity*, although of the same class, is still of a somewhat different character from *tension;* it rather applies to *degree* or *amount of resistance;* it would be no superfluity of language to speak, for example, of the *intensity* of the tension, as indicative of its

greater or less amount in degree; just as we say, the *intensity* of the heat of the sun, the intensity of light, &c. In its application, however, to ordinary electrical phenomena, it has a proper and marked position assigned to it, being peculiarly expressive of the activity shown by an electroscope or electrometer, as indicating the attractive force of a charge upon external bodies. Thus the charge communicated to a jar or battery may be taken in terms of the quadrant electrometer, or any other indicator, in which sense we speak of the jar being charged to a given *intensity;* but what renders this term particularly necessary and distinctive, is the fact that this activity or intensity is as the *square* of the *quantity* of electricity accumulated; whereas the *tension* or force in the dielectric particles actually constituting the charge itself between the limiting conducting surface, is as the quantity only, as is also the *tension* of the electrical agency itself when restrained to a given space. In the case of charged glass, or other dielectric, the electrometer indicates the activity of the uncompensated electricity, or the free action, as it were, of the charged surface. This is one thing, but the *tension* or degree of power in the molecules of the intervening dielectric, tending to break down the induction by a species of mechanical violence, as in the case of a fracture of a charged jar, is another; and hence the two terms *tension* and *intensity* are, under these limitations, fairly and distinctly separable.

From Smee's Electric Metallurgy: "A galvanic battery exhibits two important properties, quantity and intensity. Quantity depends directly upon the size of the negative metal, or strength of the solution, while intensity depends upon much more hidden causes. Quantity requires but one cell. To obtain intensity, we must have recourse to a number of galvanic batteries, arranged as a series; that is, the zinc of one battery connected with the copper of the next, and this in regular continuation, leaving the extreme zinc and silver free. In this way a hundred batteries may be conjoined, but no more quantity obtained; for only the same amount of electricity passes as when one cell is used. Now, however, this same amount can pass through a much greater resistance; for it would seem as if, at every alternation of the battery, the electric fluid obtained a push to overcome any obstacle afforded to its passage, and this push is called its intensity.

"To the beginner these two properties are very difficult to understand; but perhaps a rough idea may be formed of them by comparing quantity to the piston imparting motion to a railway train, which moves readily with one engine on a level road; let the train meet an obstacle, as an inclined plane or a hill, two, three, or one hundred

engines may be required to move this same train over, and yet the piston which turns the wheels of the carriage would move no more times than if one engine had been employed.

"There is no advantage, but even a loss, in using a battery with an intensity more than sufficient to overcome a resistance, whether produced by a fluid to be decomposed, or by any other means; for if ten cells arranged as a compound battery be sufficient to overcome the obstacle, the effect of sixty cells, arranged as six tens, would be six times as much as if a single ten were used, because they would then form a battery of six times the size, but of the same intensity, as before; but if the whole were used as one compound series, the resulting decomposition would be considerably less than six times the quantity, and to use a battery with advantage this fact must be borne in mind. If, again, the surfaces be increased before sufficient intensity be obtained, in like manner it will not add a proportionate amount of power.

"A compound galvanic battery, or one of many cells, has the same quantity of electricity passing in each cell, and therefore the same quantity of zinc dissolved. On this account, the fewer the cells that can be employed to overcome the obstacle, the greater will be the economy. It is obvious, therefore, that, as soon as, by increasing the series, sufficient intensity has been obtained to overcome partially the resistance, quantity should be sought by increasing the surface; for when one cell, as a single series, requires one pound of zinc to do a given amount of work, when that same work is done more quickly by twelve cells, twelve pounds are dissolved, — one pound in each cell; and of whatever size the cells may be, still the result will be the same, for no more zinc will be dissolved."

De la Rive says: "The absolute *intensity* of the electricity that travels in the form of a current through a closed circuit, depends upon two circumstances alone, — the force or forces that produce the electricity, and which we may call electro-motive forces, and the resistances to conductibility presented by all the circuits taken together. In an important work which appeared in 1827, M. Ohm, as a result of purely theoretical speculation, came to the conclusion that the *force of the current* in a closed circuit is directly proportional to the sum of the electro-motive forces that are in activity in the circuit, and inversely proportional to the total resistance, or the sum of the resistances of all the parts of the circuit; in other words, that the *intensity* of the current is equal to the sum of the electro-motive forces divided by the sum of the resistances."

PART XII.

PROGRESS AND IMPROVEMENTS IN TELEGRAPHY.

CHAPTER XXIII.

THE PROGRESS OF THE ELECTRIC TELEGRAPH.

In the spring of 1860 an article was published in the Atlantic Monthly with the above title, giving an account of the extension of the telegraph up to that time. Its progress since has been very great in every quarter of the globe. Upon this continent the electric wire extends from the Gulf of St. Lawrence to the Gulf of Mexico, and from the Atlantic to the Pacific Ocean, connecting upwards of six thousand cities and villages; while upon the Eastern Continent unbroken telegraphic communication exists from London to all parts of Europe, — to Tripoli and Algiers, in Africa, — Cairo, in Egypt, — Teheran, in Persia, — Jerusalem, in Syria, — Bagdad and Nineveh, in Asiatic Turkey, — Bombay, Calcutta, and other important cities, in India, — Irkoutsk, the capital of Eastern Siberia, — and to Kiakhta, on the borders of China.

But however rapid the extension of the telegraph has been in the past, it is destined to show still greater advancement in the future. Neither the American nor the European system has yet attained to its ultimate development. Transient wars now delay the establishment of lines in San Juan, Panama, Quito, Lima, Valparaiso, Buenos Ayres, Montevideo, Rio Janeiro, Surinam, Caraccas, and Mexico, and the incorporating of them, with all their local ramifications, into one American telegraph system. The Atlantic cable, although its recent attempted submergence has proved a failure, will yet be successfully laid; while the equally important enterprise of establishing overland telegraphic communication with Europe *via* the Pacific coast and the Amoor River is now being vigorously pushed forward towards its successful completion.

The latter project, which is being carried out by the Western Union Extension Telegraph Company, with a capital of ten million dollars, embraces the construction of a line of telegraph from New Westminster, British Columbia, the northern terminus of the California State Telegraph Company, through British Columbia and Russian America to Cape Prince of Wales, and thence across Behring's Strait to East Cape; or, if found more practicable, from Cape Romanzoff to St. Lawrence Island, thence to Cape Tchuktchi, and thence by an inland route around the Sea of Okhotsk to the mouth of the Amoor River. At this point it is to be joined by the line now being constructed by the Russian Government to connect with Irkoutsk, where a line of telegraph begins, which stretches through Tomsk and Omsk, in Western Siberia, Katharinburg, on the Asiatic-European frontier, Perm, Kasan, Nijni-Novogorod, and Moscow, to St. Petersburg.

This line, which was projected by Perry McDonough Collins, Esq., United States Commercial Agent for the Amoor River, with its extension by the Russian Government to Irkoutsk, is the link now wanted to supply direct and unbroken telegraphic communication from Cape Race, in Newfoundland, on the eastern coast of America, across the Western Continent, the Pacific Ocean, and the Eastern Continent, to Cape Clear, in Ireland, the westernmost projection of Europe; and when a submarine cable shall be successfully laid between Cape Clear and Cape Race, will complete a telegraphic circuit around the earth between the parallels of forty-two and sixty-five degrees of north latitude.

The chief difficulties to be anticipated in Mr. Collins's enterprise are the extent of the territory to be traversed, its wild and rugged surface formation, and the uncivilized character of its inhabitants.

The distance to be traversed through British America is six hundred miles; through Russian America, nineteen hundred miles; the length of the submarine cable across Behring's Strait, four hundred miles; and the distance from East Cape, by an inland passage around the Sea of Okhotsk, and through the settlements of Okhotsk, Ayan, and Shanter's Bay, which are well-known stations of the whale-fishery, to the mouth of the Amoor River, is about twenty-five hundred miles. The entire length of the line would thus be about five thousand four hundred miles.

That portion of the route which lies through British Columbia is chiefly mountainous, but divided into three ranges, whose courses are from north to south, while intervening valleys invite the introduction of telegraphs and roads. The Pacific coast of Russian America is

mainly level. The portion of Siberia which lies between East Cape and the head of the Sea of Okhotsk is, for a large extent, a steppe or plain, with gentle elevations occasionally rising into mountainous ridges. At the head of the Sea of Okhotsk a range of mountains must be crossed; and the region lying between that range and the mouth of the Amoor River is of the same character as that before mentioned, which extends from the same range northward to East Cape. The electric telegraph has already been carried over steppes, in both continents, similar to those above described; and the Pacific Telegraph line, in crossing the Sierra Nevada, rises to an elevation greater than that which is to be surmounted on this line.

Suitable timber for setting up the line can be found on those portions of the route lying within British Columbia and the Russian dominions on each continent, with the exception of an unwooded steppe five hundred miles wide on each side of Behring's Strait. Here the needful timber can be brought near to the line, either by sea or from the forest-covered shores of navigable rivers.

The temperature of the region through which the northern part of the line would pass is very low; but the winter is less severe than between the same parallels of latitude on the Atlantic coast. The telegraphic line which connects St. Petersburg with Archangel, on the White Sea, and that also which passes around the Gulf of Bothnia and connects St. Petersburg with Tornea, are maintained in operation without difficulty, although they cross as high parallels of latitude as those which lie in the way of this overland line to Europe. The waters of Behring's Strait are about one hundred and eighty feet deep, and they are frozen through one half of the year; but the congealed mass, when broken, generally takes the form of anchor ice, and not that of iceberg. Thus climate seems to offer no serious obstacle to the enterprise; while it is worthy of consideration that in high latitudes timber is far less perishable than in low, and less insulating material is required in cold regions than in more genial climates.

Indian tribes are found along the American part of the route, but they have been so well subjected to the influences of society and government, through the operations of the fur-trade, that no serious resistance from them is apprehended. The inhabitants of Asiatic Russia, who dwell inland, are nomadic Tartars, affecting much independence, but they are, nevertheless, not savages, like the American natives. After centuries of internal war, they have now settled into a state of semi-civilization, in which they are accustomed to barter with whalers, with exploring parties, and with the Government agents

of Russia, and they are hospitably inclined by that intercourse. Thus it is seen that there are no insuperable obstacles, either physical or social, in the way of this projected line of intercontinental telegraph.

From New Westminster, the capital of British Columbia, situated on Frazer River, about fifteen miles from its mouth, and the terminus of the California State Telegraph, the line of the Collins Overland Telegraph has already been commenced. A letter from Mr. F. L. Pope, Assistant-Engineer of the Overland Company, dated June 13th, 1865, states that the work on this portion of the line is proceeding with great energy. Scarcely two months had elapsed since active operations were commenced; and yet during that time nearly three hundred miles of poles had been cut and prepared for use, a large number had been set, and the remainder had been already distributed along the line. The poles are nearly all of cedar, and of good size, and will form one of the most durable lines on the American continent. When the extremely mountainous and difficult nature of the country along the Frazer River is taken into consideration, the rapidity with which this large amount of work has been done is extraordinary. It seems quite probable that the line will be finished the present season from New Westminster to Quesnell River, the terminus of the wagon-road to the mines.

The Colonial Government are now engaged in cutting a road from New Westminster to Yale, a distance of about ninety miles, along which the wire will be carried. There has heretofore been no communication between these points except by water. The river is bordered on both sides by high mountains and dense forests of heavy timber, with an almost impenetrable undergrowth. Notwithstanding these difficulties, Mr. Conway, one of the telegraph engineers, made an exploration of the entire route, during the latter part of last winter, on snow-shoes, being at one time three days in the woods without food or blankets.

From Yale to the Quesnell River, a distance of some three hundred miles, the line will follow the wagon-road, which has been built at an enormous expense by the Colonial Government, as a means of communication with the gold-mining regions of Carriboo. It will be a matter of considerable difficulty to set up a line of telegraph over that portion of this road which passes through the great cañon, as in many places the road has a perpendicular wall of rock upon one side and a perpendicular precipice on the other, and in one place is carried around the face of a cliff in this manner, at an elevation of some two thousand feet, directly over the river, being in some places blasted out of the solid rock, and in others supported by a sort of staging.

Two exploring parties have been despatched from San Francisco: one to examine the route through Eastern Siberia, between Behring's Strait and the Amoor; and the other to follow the proposed route up the Frazer River in British Columbia, and thence along the valley supposed to exist between the Rocky Mountains and the Coast Range, to the head-waters of Pelly River, following down the valley of this river and the Yerkin, into which it empties, to a point near the mouth of the latter, or in the neighborhood of Behring's Strait.

The Pacific Telegraph Line, which will form an important link in the overland line to Europe, was projected in 1859, when the measure was first brought to the attention of Congress. A bill in aid of the project was passed after some opposition, and proposals for the construction of the line were invited by Secretary Cobb. Mr. Hiram Sibley, President of the Western Union Telegraph Company, who was really the originator of the whole enterprise, submitted to the directors of the Company the question of authorizing him to send in proposals; but so formidable did the undertaking appear, that the proposition was carried only by a single vote.

After long and tedious delays on the part of Secretary Cobb, the contract for building the line was awarded, on the 20th of September, 1860, to Mr. Sibley, on behalf of the Western Union Telegraph Company. The Company at once assumed the contract, and furnished all the money required for the line east of Salt Lake.

Mr. J. H. Wade, of Cleveland, one of the officers of the Company, now visited California to confer with parties familiar with the various routes, to determine where and how to build the line, and to arrange with the telegraph companies in the Pacific States to extend their lines eastward and form a business connection. The California Company agreed to assume the construction of the line to Salt Lake City, and, if possible, to have it completed to that point as soon as the line from the eastward reached there. The route selected was *via* Forts Kearney, Laramie, and Bridger, crossing the Rocky Mountains at the South Pass, and thence to Salt Lake City; and from this point, *via* Forts Crittenden and Churchill, across the Sierra Nevada Mountains to Placerville and San Francisco. Mr. Edward Creighton, who had already surveyed the proposed route, and was convinced of the feasibility of maintaining a line over it, was appointed superintendent of construction.

The Company was organized April 17th, 1862, after which time nearly all the wire, insulators, and other material had to be manufactured before the construction of the line could be proceeded with.

The reader can judge of the extent of the preparations required for setting up two thousand miles of telegraph through a wilderness inhabited only by Indians and wild beasts, and a part of which was a desert. The materials and tools were taken to Omaha, Nebraska, at which point everything necessary for the enterprise was gathered in readiness to start westward.

Of the force employed on the Pacific side we have no knowledge; but for the line from Omaha to Salt Lake City, Mr. Creighton had four hundred men, fitted out for a hard campaign, with a rifle and navy-revolver for each man, and with the necessary provisions, including one hundred head of cattle for beef, to be driven with the train and killed as needed. For the transportation of the material and the supplies for this army of workmen, five hundred oxen and mules and over one hundred wagons were purchased by the Company; and these not proving sufficient, other transportation was hired, making the total number of beasts of burden seven hundred oxen and one hundred pair of mules.

The first pole was set up on the 4th of July, 1862, and the line was completed to Salt Lake on the 18th of October following, — the California party reaching the same point six days later. The work proceeded at the rate of about ten miles per day.

The whole line is upon poles, — it being thought best to cross the rivers in this manner rather than by means of submarine cables. The country is for the most part bare of wood; the longest distance, however, that timber had to be drawn in one stretch was two hundred and forty miles. The poles are of large size, and stand eighty to the mile, more than half of red cedar, the remainder mostly pine. On the highest mountains, where the snow accumulates to a great depth during the winter, they are of extra size, and sufficiently tall to keep the wires above the deepest snow; they are also placed close enough together to prevent the wire being broken by an accumulation of snow and sleet.

The wire used in this line is No. 9 iron, zinc-coated, weighing three hundred and fifty pounds to the mile, and the total weight used between Omaha and San Francisco amounts to seven hundred thousand pounds. The insulators are of glass, protected by a wooden shield, of the pattern known as the Wade insulator.

The line is worked by Morse instruments, usually direct from Chicago to Salt Lake, Hicks's self-acting repeaters being kept in the circuit at Omaha and Fort Laramie. At Salt Lake the messages are rewritten, and thence sent direct to San Francisco. The stations average about one for each fifty miles, and the whole length of the line

is inspected twice a week by persons employed for the purpose. The cost of construction was about two hundred and fifty dollars per mile.

No trouble was experienced from Indian depredations until the last winter. Up to that time the line had worked almost uninterruptedly. Even during the Indian difficulties of the previous summer and autumn, which compelled the suspension of the overland mail, the telegraph was not in any manner molested by the savages. This was supposed to be owing in a great measure to the influence of superstitious fear among them in regard to the wire, which they supposed to be under the especial care of the Great Spirit; but it was probably largely due also to the many kind offices done them by the telegraph-operators, who frequently ascertained where the buffalo were in force, and informed their red-skinned neighbors, who were thus enabled to find their favorite game. The charm is now, however, unfortunately, dispelled; and the savages take every opportunity to break and carry off the wire and destroy the poles. Government is despatching a large force of cavalry to punish the marauders and protect the line, which it is to be hoped may prove effectual.

It has already been mentioned that the Russian Government has undertaken to extend the main eastern and western line from Irkoutsk to the mouth of the Amoor River. This extension is now rapidly progressing. But this is only a single and not very prominent part of the work which the Emperor of Russia has begun. His design embraces nothing less than the following stupendous works, viz.: —

A line, with the necessary submarine cables, from the mouth of the Amoor River, across the Straits of Tartary, over the island of Sakhalien, across the Straits of La Pérouse, over the island of Jesso, through Hakodadi, and across the Straits of Sangar, to Jeddo, the capital of Japan.

A line from the confluence of the Usuri with the Amoor, seven hundred miles above the mouth of the latter, thence southward, on the bank of the Usuri, to Lake Kingka, and thence to the port of Vladi Vastok, on the coast of Tartary, opposite the port of Hakodadi, on the eastern coast of the Japanese Sea. Vladi Vastok is selected by the Emperor for his naval station on the Pacific coast.

A line from Irkoutsk, the capital of Eastern Siberia, through Kiakhta, now the entrepôt of European and Chinese overland commerce, through the vast territory of the Mongols, to the gate in the Chinese wall at Yahol, and thence to Pekin, the capital of the Chinese Empire.*

* The Chinese Government has been informed by the Russian Ambassador that the Russian portion of this line to Pekin will be completed by the first of January, 1868.

A line from a station on the main continental line at Omsk, near the southern boundary of Asiatic Russia, passing through Mongolia, and entering China at Hirck, sometimes called Illy, thence crossing Turkistan, Bokhara, and Balk, to Cabool, in Afghanistan, thence to capital places in the Punjaub, where it will meet the telegraphic system of India, and thus become a medium of communication between London and the colonial dependencies of Great Britain, Holland, Spain, and Portugal, on the shores and islands of the great Indian Ocean.

A line from Kasan, on the main central Russian line, through Georgia and Circassia, along the western shore of the Caspian Sea, to Teheran, the capital of Persia, thence to the Tigris, at Bagdad, thence descending along the banks of that river to the head of the Persian Gulf, there to be connected with the Oriental telegraph system of India.

The line from Irkoutsk to Pekin American citizens residing in China are now soliciting, with good prospect of success, permission from the Chinese Government to extend through the Empire, with the needful branches, connecting the principal ports along the Pacific coast, opposite California. A company to carry out this project has been organized under the laws of the State of New York. The wires of this company are first to be put up from Canton to Macao and Hong Kong, a distance of 140 miles, — Canton having a population of 1,000,000, Hong Kong of 40,000, and the trade of both cities world-famous. Lying 245 miles north is Amoy, with 250,000 inhabitants; and 120 miles farther in the same direction is Foochow, a city with a population of 600,000, and within 70 miles of the black-tea districts, with large commerce and with numerous manufactures of great value. Beyond it 250 miles is Ningpo, with 300,000 inhabitants, and thriving manufactures of silks. Eighty miles north is Shanghai, a city of not less than 200,000 inhabitants, and possessing a larger inland or native trade than any other in China. Yet between these great marts there is no telegraphic communication whatever, — nor, indeed, is there a line in any part of the whole Chinese Empire. The Company proposes, therefore, to connect these great commercial cities, and, having done that, to carry on its line to Nankin, with its 400,000 inhabitants, and thence to Pekin, which has a population of 2,000,000, and is the capital of an empire spread over an area of 5,000,000 square miles, and containing more than 420,000,000 souls, who pay to the Government an annual revenue of $120,000,000. It may well be understood that, for Government purposes alone, a line of telegraph thus

extending between the chief cities of China will prove of incalculable value, alike in its use, and in its profits to those who erect it and receive its income. The enterprise is a great one, but its reward will be great. Its successful accomplishment seems to be well assured; and New York may expect presently to claim the honor of first giving to the oldest of existing empires the beneficent invention which the newest of nations created, and at the same time of taking the final step for the completion of the one great line which is to put all the countries of the earth in instant communication.

A line from Calcutta to Canton is already undertaken by an English company, with due authority from the British Government.

In Australia there are now in operation twelve thousand miles of telegraph-wire. This Australian system, which is at present so purely local and isolated, is nevertheless expected to be brought into combination, by alternating submarine and island wires, with the Chinese and Russian line above described.

The statistics of the telegraph-lines in Great Britain show not only an increase in the number of lines, but a great augmentation in the amount of business transacted. In 1861 there were 11,528 miles of line open for public use; in 1862, 12,711 miles; and in 1863, 13,892 miles, comprising 65,012 miles of wire. Last year the number of stations was augmented in like proportion; and facilities were offered for the transmission of telegraphic despatches at no fewer than 1,755 stations, containing 6,196 instruments, through which about 3,400,000 telegrams were sent. In addition to the lines on British soil, the Submarine Telegraph Company has cables stretching to Calais, Boulogne, Dieppe, Jersey, Ostend, Hanover, and Denmark, with which the other lines are more or less in connection, covering 887 miles with 2,683 miles of wire. This company has upwards of 3,000 stations on the Continent. The messages sent by it to and from foreign countries were, in 1861, 230,000; in 1862, 310,595; and in 1863, 345,784.

France possesses a system comprising 71,034 miles of wire and 1,301 stations, which transmit about 1,500,000 private despatches annually, and nearly 175,000 official ones. Russia has 36,663 miles of wire; Austria, 22,230; Italy, 20,120; Prussia, 24,149; Spain, 17,743; Belgium, 3,773; Switzerland, 3,720; Turkey, 6,571; Persia, 2,500; Greece, 3,000; India, 10,994, and 136 stations; Australia, 12,000; South Australia, 2,000; the United States, 120,000; the British Provinces in America, 20,000; — making a total of upwards of 440,000 miles of aerial wire in operation in all parts of the world.

TABLE I.

Submarine Telegraph Cables which are now in Successful Working Order.

No.	Date when laid.	From	To	Number of conducting wires.	Length of cable in statute miles.	Length of insulated wire in statute miles.	Maximum depth of water in fathoms.	Weight in tons per statute mile.	Length of time the cables have worked.
									Years.
1	1851	Dover	Calais	4	27	108	30	6.00	14
2	1852	Keyhaven	Hurst Castle	4	3	12	. .	. .	13
3	1853	Denmark across the	Belt	3	18	54	15	4.00	12
4	1853	Dover	Ostend	6	80½	483	30	5.75	12
5	1853	Frith of Forth		4	5	20	. .	7.00	12
6	1853	England	Holland	1	120	120	30	1.75	12
7	1853	Portpatrick	Donaghadee	6	25	150	160	6.00	12
8	1854	Portpatrick	Whitehead	6	27	162	150	6.00	11
9	1854	Sweden	Denmark	3	12	36	14	6.00	11
10	1854	Italy	Corsica	6	110	660	325	8.00	11
11	1854	Corsica	Sardinia	6	10	60	20	8.00	11
12	1855	Egypt		4	10	40	. .	6.00	10
13	1855	Italy	Sicily	1	5	5	27	6.00	10
14	1856	Prince Edw. Island	Cape Breton	1	12	12	14	2.50	9
15	1857	Norway across Fiords		1	49	49	300	2.75	8
16	1857	Across mouth of Dan	ube	1	3	3	. .	1.75	8
17	1857	Ceylon	India	1	60	60	45	2.75	8
18	1858	Italy	Sicily	1	8	8	60	5.25	7
19	1858	England	Holland	4	140	560	30	9.75	7
20	1858	England	Hanover	2	280	560	30	3.00	7
21	1858	Norway across Fiords		1	16	16	300	2.75	7
22	1858	Dardanelles	Scio	1	115	115	200	1.00	7
23	1858	Scio	Syra	1	85	85	200	1.00	7
24	1859	Alexandria		4	2	8	. .	5.25	6
25	1859	England	Denmark	3	360	1,104	30	4.00	6
26	1859	Scio	Smyrna	1	40	40	40	1.00	6
27	1859	Syra	Athens	1	105	105	150	1.00	6
28	1859	Sweden	Gottland	1	64	64	80	2.50	6
29	1859	Folkestone	Boulogne	6	24	144	32	9.50	6
30	1859	Across rivers in India		1	10	10	. .	4.50	6
31	1859	Otranto	Avlona	1	50	50	400	1.00	6
32	1859	Malta	Sicily	1	60	60	79	3.25	6
33	1859	Jersey	Pirou in France	1	21	21	15	3.75	6
34	1859	South Australia	Tasmania	1	140	140	60	2.00	6
35	1860	France	Algiers	1	520	520	1,585	1.14	5
36	1860	Denmark	(Great Belt)	6	14	84	18	8.00	5
37	1860	Denmark	(Great Belt)	3	14	42	18	6.00	5
38	1860	In Arracan		1	116	116	50	1.00	5
39	1860	Barcelona	Port Mahon	1	198	198	1,400	1.25	5
40	1860	Minorca	Majorca	2	35	70	250	2.00	5
41	1860	Iviza	Majorca	2	74	148	500	2.00	5
42	1860	San Antonio	Iviza	2	76	152	450	2.00	5
43	1861	Corfu	Otranto	1	90	90	1,000	2.75	4
44	1861	Norway across Fiords		1	16	16	300	2.75	4
45	1861	Toulon	Corsica	1	195	195	1,550	1.14	4
46	1861	Malta	Alexandria	1	1,535	1,535	420	1.85	4
47	1861	Beachy Head	Dieppe	6	80	320	30	8.00	4
48	1862	Abermawr	Grenore	4	63	252	58	5.25	3
49	1862	England	Holland	4	130	520	30	9.00	3
50	1862	Across rivers in Ire	land	1	2	2	. .	. .	3
51	1862	Frith of Forth		4	6	24	7	. .	3
52	1862	Fortress Monroe	Cherrystone	1	23	23	. .	. .	3
53	1862	Fortress Monroe	Newport News	1	3	3	. .	. .	3
54	1863	Sardinia	Sicily	1	243	243	1,200	. .	2
55	1864	Gwadur (Persian [Gulf.)	Fao	1	1,450	1,450	. .	. .	1
					6,979½	11,127			

Table II.

Submarine Telegraph Cables which have been successful for some Time, but are not now working.

No.	Date when laid.	From	To	Number of conducting wires.	Length of cable in statute miles.	Length of insulated wire in statute miles.	Maximum depth of water in fathoms.	Weight in tons per statute mile.	Length of time the cables have worked.
1	1850	Dover	Calais	1	25	25	30	. .	1 day.
2	1853	England (3 Cables)	Holland	1	360	360	30	2.00	5 yrs.
3	1854	Holyhead	Howth	1	75	75	70	2.00	5 "
4	. .	Nantucket	Cape Cod	1	25	25	16	. .	. .
5	1855	Varna	Balaklava	1	355	355	300	0.10	9 mos.
6	1855	Balaklava	Eupatoria	1	1	1	. .	. .	9 "
7	1856	Martha's Vineyard	Cape Cod	1	5	5	15	. .	2 wks.
8	1856	Newfoundland	Cape Breton	1	85	85	360	2.50	9 yrs.
9	1857	Sardinia	Bona	4	150	600	1,500	. .	3 "
10	1857	Varna	Constantinople	1	170	170	. .	0.75	5 "
11	1857	Cape Cod	Naushon	1	1	. .	. .	. .	2 "
12	1857	Martha's Vineyard	Nantucket	1	30	30	16	. .	4 "
13	1857	Sardinia	Corfu	1	700	700	1,000	0.90	1 yr.
14	1858	England	Channel Islands	1	102	102	60	2.50	3 yrs.
15	1858	Ireland (Atlantic)	Newfoundland	1	2,500	2,500	2,400	1.00	23 ds.
16	1859	Singapore [India)	Batavia	1	630	630	20	0.04	2 yrs.
17	1859	Suez (Red Sea and	Kurrachee	1	3,500	3,500	1,910	0.94	6 mos.
18	1859	Spain	Africa (Ceuta)	1	25	25	. .	1.00	1 yr.
19	1859	England	Isle of Man	1	36	36	30	2.50	3 yrs.
20	1859	South Australia	Tasmania	1	100	100	60	2.00	1 yr.
21	1859	Liverpool	Holyhead	2	25	50	14	3.10	1 "
22	1859	Syra	Candia	1	150	150	. .	0.89	3 yrs.
23	1860	Across the Mersey	. . .	1	3	3	. .	. .	1 yr.
					9,053	9,527			

Table III.

Submarine Telegraph Cables which are Total Failures.

No.	Date when laid.	From	To	Number of conducting wires.	Length of cable in statute miles.	Length of insulated wire in statute miles.	Maximum depth of water in fathoms.	Weight in tons per statute mile.
1	1852	Holyhead	Howth	1	75	75	70	0.45
2	1852	Portpatrick	Donaghadee	2	17	34	160	. .
3	1852	Portpatrick	Donaghadee	5	15	75	160	4.80
4	1854	Holyhead	Howth	1	65	65	70	2.00
5	1855	Sardinia	Africa	6	50	300	800	8.00
6	1855	Cape Ray	Cape North	3	30	90	360	. .
7	1855	Sardinia	Africa	3	160	480	1,500	3.70
8	1857	Ireland (lost in laying)	Newfoundland	1	300	300	2,400	. .
9	1859	Candia	Alexandria	1	150	150	1,600	0.89
10	1865	Ireland	Newfoundland	1	1,300	1,300	2,400	1.75

The accompanying tables give the details of the principal cables hitherto laid by all makers. They are divided into three heads : 1st, Those which have been wholly successful, and are now working (September, 1865) ; 2d, Those which were partially successful, having worked for a time ; 3d, Those which wholly failed, or never worked after their submergence.

In addition to the list in Table I., there have been laid across American rivers, since 1854, 95 lines, in lengths of from 120 feet to two miles, and comprising from 120 feet to 6 miles of insulated wire each, — making an aggregate of 250 miles of subaqueous wire in operation on this continent, and a total of 6,979 miles of cable, and 11,127 miles of submarine wire in operation in all parts of the world.

It will be seen from the list of failures, that the great extension and success of submarine cables has been attained through many great failures, — among the most prominent being the old and new Atlantic, the Red Sea and India, (which was laid in five sections, that worked from six to nine months each, but was never in working order from end to end,) the Singapore and Batavia, and Sardinia and Corfu. None of these cables, with the exception of the new Atlantic, were tested under water after manufacture, and every one of them was covered with a sheathing of light iron wire, weighing in the aggregate only about fifteen hundred pounds per mile.

These two peculiarities are sufficient to account for every failure which has occurred, with the exception of the new Atlantic. No electrical test will show the presence of flaws in the insulating cover of a wire, unless water, or some other conductor, enters the flaws and establishes an electrical connection between the outside and inside of the cable. All cables now manufactured are tested under water before being laid.

Communication between the Ottoman capital and Western Europe passes through Vienna. From this city to Constantinople there are two distinct lines, — one passing by Semlin and Belgrade to Adrianople, the other by Toultcha, Kustendji, and Varna. There is a third line to Adrianople by Bucharest ; and by the opening of the submarine line between Avlona and Otranto, in Italy, the Turkish telegraph service will be in direct communication with the West, without going through Servia or the Moldo-Wallachian Principalities.

Communication between Constantinople and India is maintained over the following route : — To Ismid, 55 miles ; thence to Mudurli, 104 miles ; thence to Angora, 111 miles ; thence to Guzgat, 113 miles ;

thence to Sivas, 140 miles; Kharpoot, 178 miles; Diarbekir, 77 miles; Mardeen, 61 miles; Djezireh, 104 miles; Mosul, (Nineveh,) 91 miles; Kerkook, 114 miles; Bagdad, 189 miles. From Bagdad to Fao, at the mouth of the Shat-el-Arab, on the Persian Gulf, is 400 miles. From Fao to Kurrachee the submarine cable stretches along the bottom of the Persian Gulf for 1,450 miles; and thence are 500 miles of aerial line across a portion of British India to Bombay.

The accounts of the successful opening of this line tell of the astonishment of the savage Beloochees and Arabs along the Mekran coast at the marvel of a blue spark flashing for the Sahib to the Indus and back again in less time than it takes to smoke a hookah. At Gwadur, no sooner was the cable landed than the people of the surrounding country flocked down to hear and talk of the Feringhee witchcraft. Chiefs of the Beloochees, Muscatees, and Heratees, with their retainers, trod upon each other's toes in their eagerness to see it work. Gwadur has given up the idea that Mahomet taught everything that could be known, and now sits upon the carpet of astonishment and chews the betel-nut of meditation.

The establishment of the electric telegraph in India presented some curious as well as difficult problems. In the first place, it was discovered that the air of India is in a state of constant electrical perturbation of the strongest kind, so that the instruments there mounted went into a high fever and refused to work. Along the north and south lines a current of electricity was constantly passing, which threw the needles out of gear and baffled the signallers. Moreover, the tremendous thunder-storms ran up and down the wires and melted the conductors; the monsoon winds tore the teak-posts out of the sodden ground; the elephants and buffaloes trampled the fallen lines into kinks and tangles; the Delta aborigines carried off the timber supports for fuel, and the wires or iron rods upon them to make bracelets and to supply the Hindoo smitheries; the cotton- and rice-boats kedging up and down the river, dragged the subaqueous wires to the surface. In addition to these graver difficulties were many of an amusing character. Wild pigs and tigers scratched their skins against the posts in the jungle, and porcupines and bandicoots burrowed them out of the ground. Kites, fishing-eagles, and hooded-crows came in hundreds and perched upon the line to see what on earth it could mean, and sometimes after a thunder-storm, when the wires were wet, were found dead by dozens, the victims of their curiosity. Monkeys climbed the posts and ran along the lines, chattering, and dropping an interfering tail from one wire to another, which tended to confound

the conversations of Calcutta. Parrots, with the same contempt for electrical insulation, fastened upon one string by the beak and another by the leg; and in one village the complacent natives hung their fishing-lines to dry upon them.

In 1856 there were four thousand miles of telegraph-wire stretched over India: some upon bamboo posts, which bent to the storms and thus defied them; some, as in the Madras Presidency, upon monoliths of granite, — these, during the Mutiny, proving worth ten times their cost.

Whilst the telegraph has been thus rapidly encircling the globe with its iron threads, great improvement has been made in the apparatus for transmitting the electrical signals over them. Instruments called translators, or repeaters, have been devised, by which aerial lines may be operated, without repetition, over distances of many thousands of miles. Through the use of this valuable invention upon the California line, operators in New York and San Francisco are able to converse as readily and rapidly as those situated at the extremities of a line only a hundred miles in length.

The enormous increase in the amount of matter to be transmitted over the wires has stimulated the inventive genius of our own country and Europe to produce an apparatus by which the capacity of a wire may be greatly increased. Mr. M. G. Farmer, of Boston, Mr. J. G. Smith, of Portland, Maine, Dr. Gintl, of Germany, and one or two other persons, have solved the problem of the simultaneous transmission of messages over a single wire in opposite directions. But while their apparatus, with the proper arrangement of batteries, will unquestionably permit the accomplishment of this apparent paradox, the natural disturbances upon a wire of any considerable length, together with the inequalities of the current caused by escape in wet weather, have precluded its practical use.

In this country, General Lefferts of New York, and in Europe, Professor Bonelli, have devoted much time and expense to the perfection of apparatus for securing greater rapidity of transmission over the aerial lines.

General Lefferts owns several patents covering inventions of great ingenuity and value, which are now being perfected and will shortly be brought into operation. The apparatus consists of an instrument, operated by keys similar to those of a piano-forte, for punching characters, composed of dots and lines, upon a narrow strip of paper. The paper, when thus prepared, is passed rapidly through an instrument

attached to a telegraph-wire, at the other end of which is a similar instrument which runs in unison. The first instrument is provided with a flexible metallic comb, which presses through the perforations in the paper, and thus closes the circuit at each dot and line, while the second instrument is provided with a metallic stylus, or pointer, which rests upon a fillet of paper prepared with chemicals, and produces, whenever the circuit is closed, dots and lines of a dark-blue color upon the prepared paper. When the paper is prepared by the perforating apparatus, it can be run through the instrument at any rate of speed that is desirable, and it is estimated that with this apparatus one wire may easily perform as much work in a day as ten can under the ordinary arrangement.

In Professor Bonelli's system the despatch is set up in printing-type, and placed on a little carriage, which is made to pass beneath a comb with five teeth, which are in communication with five aerial wires of the line, at the extremity of which these same wires are joined to the five teeth of a second comb, under which passes a chemically prepared paper, carried along on a little carriage similar to the one at the other end on which the printing-type is placed. If under this arrangement the electric circuit of a battery composed of a sufficient number of elements, and distributed in a certain order, be completed, then, at the same time that the first comb is passing over the printing-type at the one end, the second comb at the other end will trace the despatch on the prepared paper in beautiful Roman letters, and with so great a rapidity that it may be expected that five hundred messages of twenty words each will be transmitted hourly.

On Wednesday, April 19th, the day of Mr. Lincoln's funeral, eighty-five thousand words of reports were transmitted between Washington and New York, between the hours of 7 P. M. and 1 A. M., being at the rate of over fourteen thousand words per hour. Nine wires were employed for the purpose. Thirteen thousand six hundred words were transmitted by the House printing instruments on a single wire after half past seven o'clock.

A telegraphic message was recently received in London from India in eight hours and a half. This message was forwarded by the Indo-European Telegraph Company, *via* Kurrachee and the Persian Gulf, crossing one half of Asia and the whole of Europe.

During the late Rebellion in this country the telegraph was extensively employed both by the Government and the Insurgents. In the course of the past year, there have been in the service of the Government thirty field-trains, distributed as follows : — In the Army of the

Potomac, five; in the Department of the Cumberland, five; in the Department of the Gulf, three; in the Department of North Carolina and Virginia, three; in the Department of the South, two; in the Department of the Tennessee, six; in the Department of the Ohio, two; at the Signal Camp of Instruction, Georgetown, D. C., three; at the United States Military Academy, West Point, New York, one. Of these trains, some were equipped with five, and others with ten miles of insulated wire. There were carried in the trains lances for setting up the wire, when necessary, — reels, portable by hand, carrying wire made purposely flexible for this particular use, — and various minor appliances, which experience has proved useful. A military organization was directed for each train.

In duty of this kind, the construction of the trains, the equipment to be carried by them, and the military organization to be provided for their use, to enable them to be most rapidly and anywhere brought into action, are the subjects for study; the particular instrument to be equipped is a secondary consideration. The soldiers drilled to the duty of construction acquire in a short time a remarkable skill in the rapid extension of these lines. As was anticipated, they have proved valuable auxiliaries to the services of the corps, and have sometimes rendered them available when they would have been otherwise useless. The greatest distance at which the instruments are reported to have worked is twenty miles. The average distances at which they are used are from five to eight miles. The average speed of the most rapid construction is reported to be at the rate of a slow walk.

At the first Battle of Fredericksburg field-trains were for the first time in the history of the war used on the battle-field, under the fire of the enemy's batteries. The movements to be made on the day of that battle were of the first magnitude. The movements of the retreat were perilous to the whole army. The trains in use contributed something to the success of those movements.

Many incidents are recorded of operators accompanying raiding parties into the enemy's territory and tapping the telegraph-lines, sometimes obtaining valuable information. One is related by the "Selma Rebel." The operator at that place was called to his instrument by some one up the Tennessee and Alabama Road, who desired information as to the number of the forces and supplies at Coosa Bridge. After getting all the information he could, regarding the location and strength of the Rebel forces, he informed the Selma operator that he was attached to the expedition under General Wilson, and that, at that particular time, he was stationed with his instruments

up a tree near Monticello, in the hardest rain he ever saw! Permission being given, he sent a despatch to a young lady in Mobile, and another to a telegraph-operator in the Rebel lines, telling him he loved him as much as before the war. After some other conversation, the Yankee operator clambered down from the tree, mounted his horse, and rode away.

CHAPTER XXIV.

THE TELEGRAPHIC REPEATER.

THE electro-magnetic telegraph of Professor Morse, which was first put in operation between the cities of Baltimore and Washington, in 1844, was the same in principle as that employed at the present day, consisting of a key and relay magnet, in connection with a registering instrument, and a local battery at each station. Professor Morse had, in previous experiments, endeavored to work the registering instrument directly, by means of the circuit of the main line; but the strength of the electric current was found to be so greatly reduced by the resistance encountered in passing through conductors of great length, that sufficient magnetic power could not be produced to work the registering apparatus. He then substituted the arrangement of the local circuit above referred to, which is one of the most valuable parts of his invention in use at the present day.

Two or three years after the value and utility of this great invention had been demonstrated by the brilliant success of the experimental line between Baltimore and Washington, the wires were rapidly extended in every direction throughout the United States. It was soon discovered, however, that it was impracticable to operate the lines in circuits of very great length. A distance of from three to five hundred miles, in good weather, was as great a length of line as could be successfully worked, under the conditions of insulation that prevailed at that day, and but one or two lines were so well constructed as to admit of this. If it was desired to transmit communications to a greater distance, it became necessary to divide the line into two or more distinct circuits at intermediate points, and, of course, at every repeating station that was introduced, it was necessary to employ two additional operators for each wire. This not only increased the working expenses, but greatly increased the liability of errors occurring in the transmission of messages between the terminal stations of the line. Numerous experiments were then made in order to remedy this difficulty, resulting in the invention from time to time of various combinations, each accomplishing the desired result more or less perfectly, until at the present day it is not an uncommon feat for operators to converse

by telegraph with the utmost facility between points situated three thousand miles apart. The instruments now used for the above purpose are constructed upon many different principles, but are all classed under the general term in this country of repeaters, and in Europe of translators.

The repeater is an apparatus for the purpose of duplicating from one electric circuit to another the breaks and completions received from the transmitting station, for the purpose of renewing the power lost by the escape of the electric fluid into the earth through imperfect insulation.

The earliest device for this purpose was perhaps suggested by the arrangement of circuits described in Professor Morse's first patent, but abandoned by him upon the invention of the relay magnet and local circuit. In this plan, Morse proposed to divide the line into a number of circuits, each about twenty miles in length, and provided with an independent battery for each circuit. The electro-magnet at the extremity of the first circuit was so arranged as to complete the second circuit, by causing a forked wire to descend into two mercury cups. The second circuit of twenty miles was then charged, which in like manner actuated the third, and so on to an indefinite extent. This plan would work only in one direction; consequently a duplicate series of wires, batteries, and electro-magnets were necessary in order to telegraph in the opposite direction. By substituting metallic points for the mercury cups, and placing an electro-magnet at each end of the two adjoining circuits, and arranging the circuits of each wire so that it is opened and closed by the magnet of the other, a combination was formed capable of working in either direction. But it will at once be seen that in this plan the second circuit could not respond without a transfer of the switch or button at the central station, by a person employed for the purpose. When the second operator responded, the operator at the principal station, by means of his switch, changed the repeating magnet from the first to the second circuit, and *vice versa*. This apparatus constitutes the button repeater. It is frequently modified by using the levers of the sounders instead of the main magnets to open and close the other circuit. We are unable to state where or by whom the button repeater was first used. Mr. Charles S. Bulkley had one in operation at Columbus, Georgia, as early as 1847. A similar device was constructed by Ezra Cornell, of Ithaca, New York, and was known as the "Cornell Switch," but, we believe, subsequent to the date of Bulkley's invention above mentioned. It is quite probable that the same invention may have been

made by several different persons without the knowledge of each other, as something of this kind could hardly have failed to suggest itself to almost any ingenious person who was endeavoring to find means of overcoming the difficulty of working lines in long circuits, or of obviating the difficulties experienced by the loss of insulation during heavy rain-storms.

BULKLEY'S AUTOMATIC REPEATER.

THIS apparatus (Fig. 99) was invented in 1848 by Mr. Charles S. Bulkley, and immediately introduced upon the lines between New York and New Orleans, where its operation was highly successful.

The instrument in the diagram is represented in its normal position when the line is not in action. The circuit of the western line enters from the left hand, passing through the coils of the relay M, thence through the breaking points attached to one end of the armature a' of the repeating magnet R', but insulated therefrom; thence through the main battery B', to a breaking point at the opposite end of the armature a', and thence to the ground. The eastern main circuit may be similarly traced, on the opposite side of the apparatus, through the receiving magnet, main battery, and ground. It will be observed that the positive pole of the eastern main battery is connected to the main line, and the negative pole to the ground. The main battery at the remote end of the eastern circuit is likewise arranged to present its positive pole to the line, and its negative to the ground. The two batteries, being equal, are neutralized by each other; and the armature of the relay M' will be drawn back by its adjusting spring, the same as if the circuit of the line was broken. The main batteries of the western circuit are similarly placed in opposition to each other. The repeating magnets R, R' are actuated by the circuit of the local battery L, indicated by dotted lines, passing through the breaking points of the relay magnets M, M', as in the ordinary Morse instrument; and consequently the armatures a, a' will likewise be drawn back by the action of their adjusting springs, and assume the position shown in the diagram. Changing the position of the armature a has the effect of reversing the main battery B' of the eastern line, placing its negative pole in connection with the line, and its positive with the ground. The other armature, a', is connected with the western main line in the same manner.

The operation of this repeater is as follows. Suppose that a way-

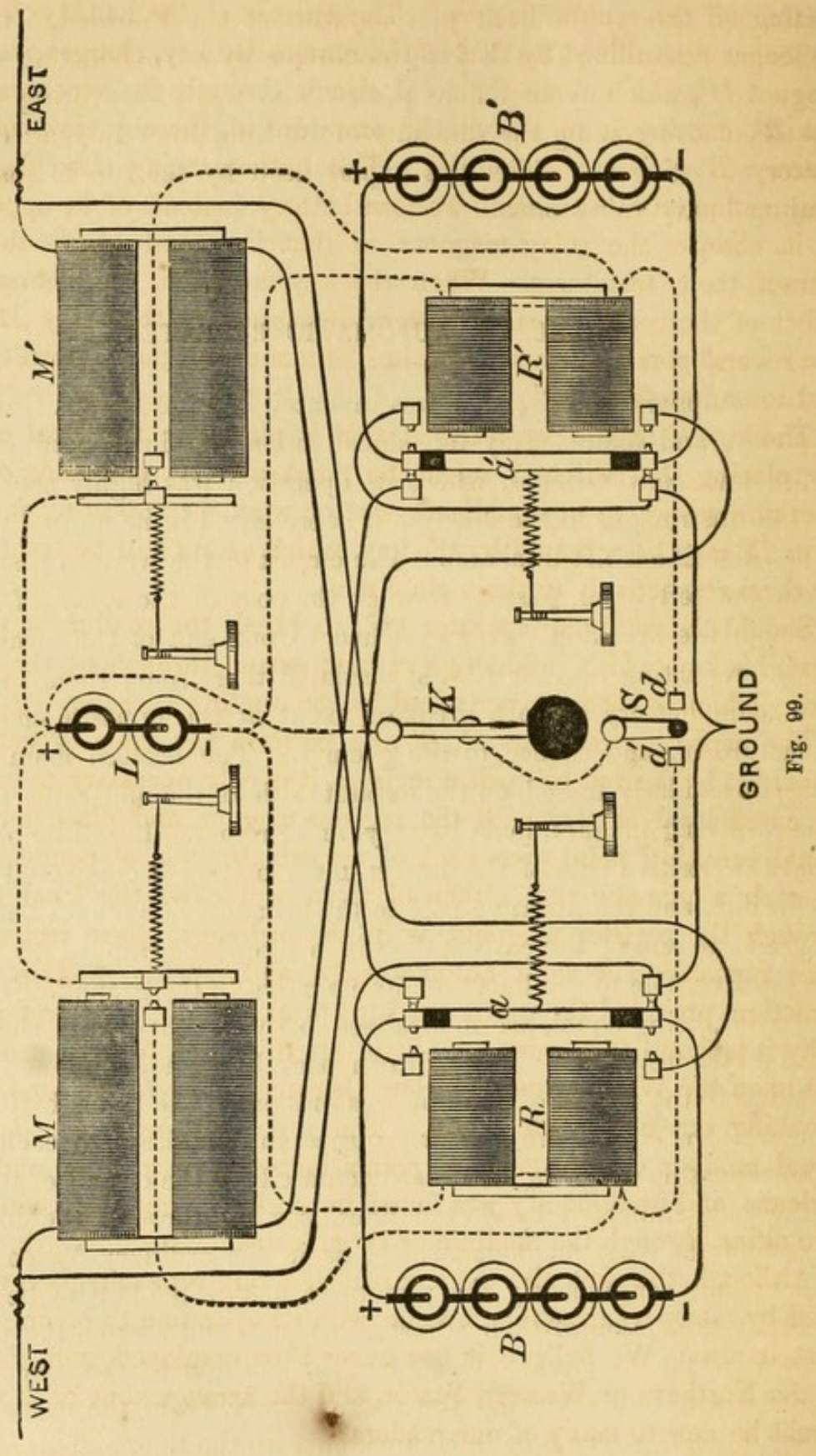

Fig. 99.

station east desires to communicate with some office on the western circuit. He presses down his key, which is so arranged as to form a connection between the line-wire and the ground at his office, thus

cutting off the remote battery. The current of the battery B being no longer neutralized by that of the remote battery, charges the relay magnet M', which closes the local circuit through the repeater magnet R', causing it to attract the armature a', thereby reversing the battery B of the western line. This battery being now placed in conjunction with the remote western battery, instead of in opposition to it, charges the relay magnets on that line, and causes them to attract their armatures. When the key is raised, the neutralizing effect of the remote eastern battery demagnetizes the relay M', and the reverse action is transmitted in like manner to the western circuit, and so on indefinitely.

The key K at the repeating station is placed in the local circuit. By placing the switch S upon the point d or a', according as the operator wishes to communicate east or west, the repeating magnets R or R' may be actuated by the key, which action will be transferred by them respectively to the main circuit.

Should the receiving operator wish to break the sender, he presses down his key, which produces a reverse action throughout the whole series, which is instantly perceived by the sending operator.

The repeating magnets R, R' also perform the office of sounders. Should it be desired to work a register, it is only necessary to connect an extra local battery with the register magnet, and place an additional breaking point upon each of the armatures a, a', connecting it in such a manner that either of them will close the local circuit through the register magnets, as in the ordinary Morse instrument. This repeater will work automatically, and equally well in either direction, provided the relays are kept properly adjusted; and practically it is found to require very little attention. It was in successful use upon the Washington and New Orleans line up to the time of the breaking out of the Rebellion. Ten repeaters were placed at an equal number of intermediate points between New York and New Orleans, and no difficulty was found in working direct between those two cities, through the medium of these instruments.

Although this was the pioneer of self-acting repeaters, it is considered by many telegraphers familiar with its operation to be one of the best in use. We believe it has never been employed upon the lines in the Northern or Western States, and the arrangement of it will no doubt be new to many of our readers.

FARMER AND WOODMAN'S REPEATER.

For several years after the invention of the Bulkley repeater but little progress was made in this branch of telegraphy. The lines throughout the Northern and Western States continued to use the button arrangement in some form, whenever they had occasion to telegraph direct between points too widely separated to permit the successful operation of a single circuit.

The first repeater brought into practical use, subsequently to that of Bulkley, was one which was the joint invention of Messrs. Moses G. Farmer, of Salem, Mass., and Asa F. Woodman, of Portland, Maine, for which a patent was issued on the 17th of March, 1857.

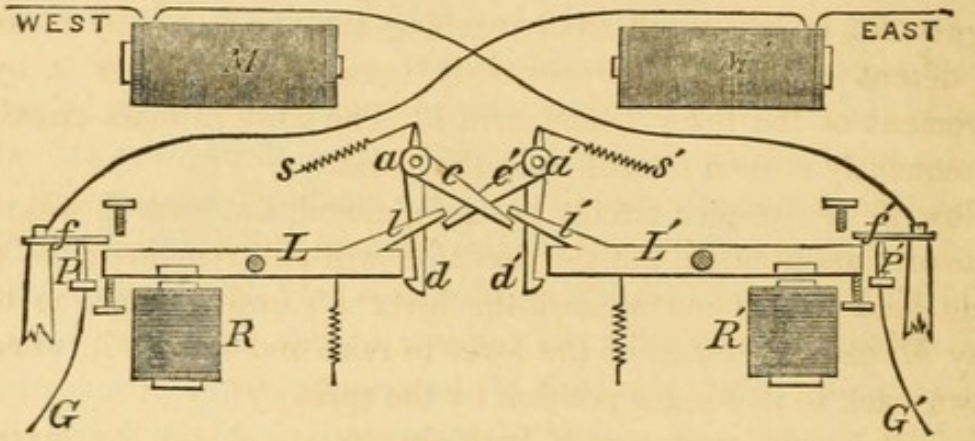

Fig. 100.

In this repeater (Fig. 100) a simple mechanical arrangement is employed to prevent the circuit of the transmitting operator from being broken by the action of the repeating lever on the opposite side of the apparatus; and the services of the button or switch, and of the person employed to attend it, are entirely dispensed with.

The apparatus is represented in the figure with both the eastern and western circuits closed. The western main circuit enters at the left, passing through the helices of the relay magnet M, which actuates the repeating magnet or sounder R, by means of a local circuit, in the ordinary manner. From the relay it may be traced to the flat spring f', and the point P', and finally to the main battery or ground at G'. Similarly the eastern main circuit passes through the relay magnet M', spring f, and point P, to the battery and ground, G. The local circuits are omitted in the diagram, to avoid confusion; but the arrangement of them will be readily understood, as it differs in no respect from that of an ordinary Morse instrument. If the flat spring

f be lifted from the point P, the eastern main circuit will be broken, and *vice versa*.

At the opposite end of the lever L a detent, d, is suspended from the shaft a, to which is also attached the arm c, the extremity of which projects beneath the end of another arm, l', attached to the lever L' of the opposite repeating magnet R'. The detent, shaft, and arm are retained in the position shown by means of a delicate spiral spring, s. The opposite side of the instrument is managed in precisely the same manner.

The action of the repeater is as follows. If the main circuit of the western line be broken, the action of the relay M upon the repeating magnet R releases the armature lever L. Almost at the same instant the spring f will be lifted from the point P, thus breaking the eastern circuit. But the lever L', although released by the repeater magnet R', is prevented from reaching the spring f', by means of the detent d', which has previously been thrown under it by the movement of the lever L and arm l. The western main circuit will consequently remain unbroken at this point.

Now if the western circuit be again closed, the lever L will return to its original position, but the detent d' will still remain in its place, being held by friction against the lever L', until the action of the relay M' causes the end of the lever to raise and release it, when it is drawn back to its former position by the spring f'.

It will be observed, that if both circuits are closed, the lever that first opens throws a detent under the other one, before opening the circuit connected with it; and when the circuit is to be closed, instead of relying upon the prompt action of the relay in closing, to prevent a false break, the lever is held in position by the detent until the relay has actually closed. The closing of the relay lifts the lever from the detent, which, no longer being held by friction with the lever, is withdrawn beneath it by a spring. This action occurs in the same manner, but upon the opposite side of the instrument, when the eastern circuit is opened and closed.

This repeater was first introduced at Portland, Maine, upon the line between Boston, Massachusetts, and Calais, Maine, and has been used to a considerable extent, and with good success, upon the lines extending through New Brunswick and Nova Scotia. Some little difficulty exists in working this apparatus, from its inability to admit breaks through it as promptly as is desirable; but its operation, on the whole, was so satisfactory that it maintained its position upon the lines east of Boston from the date of its invention until the autumn of 1862, when it was superseded by the Hicks repeater.

HICKS'S REPEATER OF 1858.

This instrument (Fig. 101) was patented by Mr. G. B. Hicks, of Cleveland, Ohio, August 10, 1858. The apparatus consists of two relay magnets, M and M', two sounders, S, S', each with its local battery, B, B', arranged in the usual manner, and the self-acting switch, or circuit changer, actuated by two extra magnets, L, L'. The main circuit of each line is broken and closed directly by the relay of the other, instead of through the sounders, as in Farmer and Woodman's repeater.

In the drawing, the circuits of both of the main lines are closed, causing the relay armatures to rest on the forward stroke, which also closes the circuits of the sounders S, S', while the self-acting switch is in the position it assumes when the operator on the western line is working. The eastern main line enters at E, passing through the relay M', thence through the insulated screw at the left-hand end of the circuit changer l, to the screw e, in the armature lever a, which connects with the spring f, thence to the spring h, and finally to the ground. The connections of the eastern local magnet S' and the self-acting switch-magnet L may be traced by the dotted lines commencing at the screw b', thence to the sounder S', and the zinc pole of the local battery B', from which it emerges at the platina pole, and runs thence to the lower end of the armature lever a', which completes the local circuit through the eastern sounder. The local circuits through both the circuit-changer magnets are represented as open at $b\,c$ and $c'\,b'$.

Supposing, now, that the eastern operator wishes to communicate with the west. Upon opening his key, the armature of the relay magnet M' is released from the attractive force of the magnet, and drawn back by the spiral spring, when the armature lever breaks the local circuit of the sounder S' at b', and closes on its back stroke at c' the circuit of the local magnet L of the self-acting switch l', which, being hung in the centre, is readily attracted by either magnet, when the one circuit is closed and the other open. This local connection may be traced by the dotted line, beginning at c', thence to the lever s of the sounder S, through the screw p, through the local magnet L, thence to the zinc pole of the local battery B', through which it passes; thence from its platina pole to the heel of the armature lever a' to the screw c', where the circuit is closed by the opening of the main eastern circuit. The closing of this last-named local

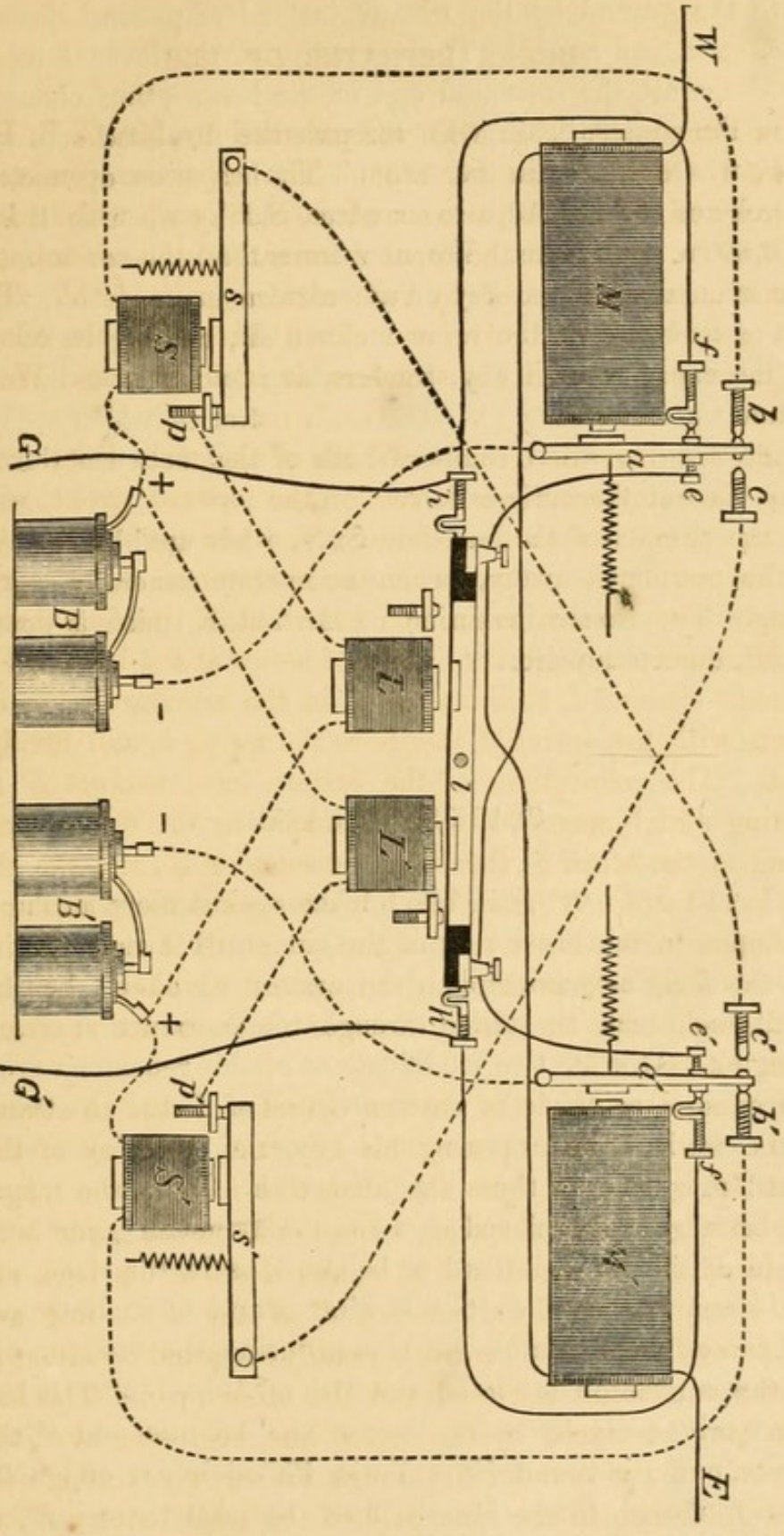

Fig. 101.

circuit brings into action the magnet *L*, which attracts the left-hand end of the lever *l*, bringing the insulated screw in connection with the spring *h*, thus changing the course of the eastern main line di-

rectly to the ground by the wire G, instead of passing through the screw e, springs f and h. The reversing of the lever l brings the spring h' against the insulated end of the lever l, thus changing the course of the western main wire through the insulated screw to the screw e', where the main western circuit has been opened by the back stroke of the armature lever a', caused by opening the circuit of the eastern main wire. We now have the repeater so arranged, that by manipulating the key of the eastern main circuit, which releases the armature of the relay magnet M', causing its lever a to act in the capacity of a key, by breaking and closing the western main circuit at the spring f'. The main batteries, which are omitted in this drawing to avoid confusion, are placed between the ground wires G, G' and the springs h, h'.

This repeater was for a time quite extensively used by the Western Union Telegraph Company, but has since been generally superseded by another one, also the invention of Mr. Hicks, which is considered in several respects superior.

CLARK'S REPEATER.

Mr. James J. Clark, of Philadelphia, an ingenious mechanic and manufacturer of telegraphic apparatus, invented a repeater in 1859 upon an entirely new principle, the transmitting circuit being maintained at the repeating station through the introduction of an extra local magnet. One or two modifications of this repeater were made, but the general principle is the same in all of them. In the earlier ones the extra local helices surrounded those of the relay, and a separate local magnet was thus dispensed with. In another form, the extra local magnet was placed above the relay magnet, and upon the same side of the lever, instead of below it, as in the drawing (Fig. 102). It was first used on the Baltimore and Ohio Railway Telegraph Line at Cumberland, Maryland, during the summer of 1859. A patent was granted for it on the 24th of July, 1860. It has been employed principally upon the lines of the Atlantic and Ohio Telegraph Company, between New York, Philadelphia, and Pittsburg, and at Springfield, Massachusetts, upon the American lines.

The principle of this repeater is extremely simple, and a brief description will enable the reader to understand its operation.

The western main circuit, entering at W, passes through the relay

magnet M, thence to the flat spring f', screw point s', and battery or ground at G. The eastern main line, E, is connected in the same manner through the corresponding parts on the opposite side of the instrument. The flat springs f, f' are insulated from the sounder levers by small pieces of hard rubber or ivory.

The arrangement of the ordinary local circuits needs no explanation, as it does not differ from that employed upon all Morse lines. The wires are omitted in the drawing, to avoid confusion and a multiplicity of lines. In order to be more easily understood, we shall term these the regular local circuits, to distinguish them from the extra locals.

The levers a, a' of the relay magnets M, M' are prolonged a short distance below their fulcrums, and an extra local magnet, L, with its armature, is placed at the lower end of each lever, but upon its opposite side. Thus it will be seen that the attractive face, either of the relay magnet M or the extra local magnet L, when exerted upon the lever, will have the effect of closing the regular local circuit connected therewith.

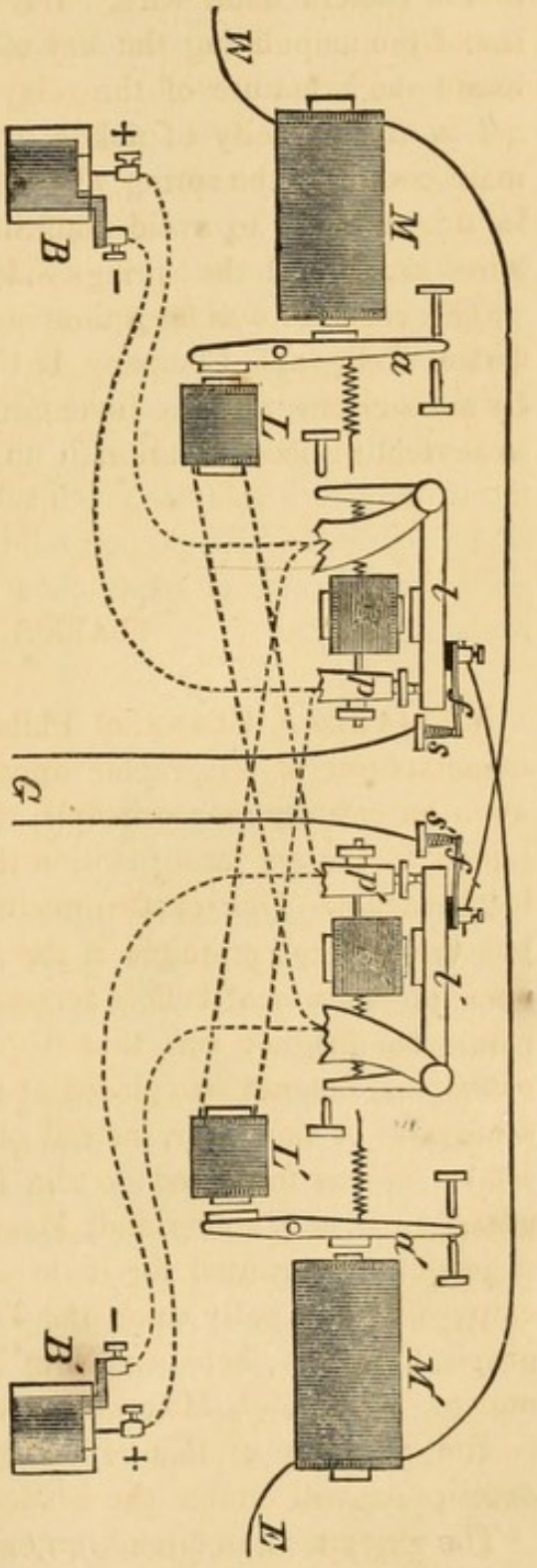

Fig. 102.

By tracing the extra local circuit B, it will be seen that it is so arranged that the closing of the sounder R cuts off the current from the magnet L', by forming a shorter route through l and p'. The other extra local is in all respects similar.

Both main circuits being closed, the action of the repeaters may be explained as follows. The

western operator upon opening his key destroys the attraction in the relay M, causing the sounder lever l to break the extra local circuit at p, which then flows through the magnet L', while at the same instant the lever l also breaks the eastern main circuit by removing the spring f from the screw-point s, while the armature a' of the eastern relay is still retained in its position by the attraction of the extra local magnet L'. The spring f prevents the breaking of the main circuit through M', until after the extra local magnet L' is brought into action.

Now if the western operator closes his key, the eastern main circuit will be closed by the flat spring f, through the action of the regular local; while the lever l, coming in contact with the point p, cuts off the extra local current from its magnet L'. Thus it will be seen, that while one side of the apparatus is working, the other will remain undisturbed, and *vice versa*. If the repeater is properly adjusted, the breaks and completions of the circuit through it can be as rapidly and as perfectly made as through an ordinary relay, and the control of the transmitter's relay as much subject to the receiver's key as upon a simple circuit. The proper adjustment of a repeater, however, requires an operator of experience and skill, especially when the currents are feeble.

HICKS'S MAGNETIC ADJUSTING REPEATER.

This instrument (Fig. 103) was patented by Mr. G. B. Hicks, March 4, 1862, and has been extensively and satisfactorily used upon the lines of the American and Western Union Telegraph Companies since that date.

The main circuits are arranged in the same manner in this as in the repeaters of Clark and of Farmer and Woodman, passing through the relay magnets M, M', thence to the repeating points f, f' and g, g', upon the opposite sounder levers respectively, and thence to the battery and ground at G, G'.

The ordinary local connections are made through the sounder magnets R, R', the relay armature levers a, a', and screw-points b, b', in the usual manner, and require no further explanation. The regular local batteries and connecting wires are omitted in the drawing for obvious reasons.

The extra local magnets L, L' act upon armatures placed upon the

relay levers a, a', but upon opposite sides from the regular armature. They are movable by means of the screws d, d', and the adjusting of

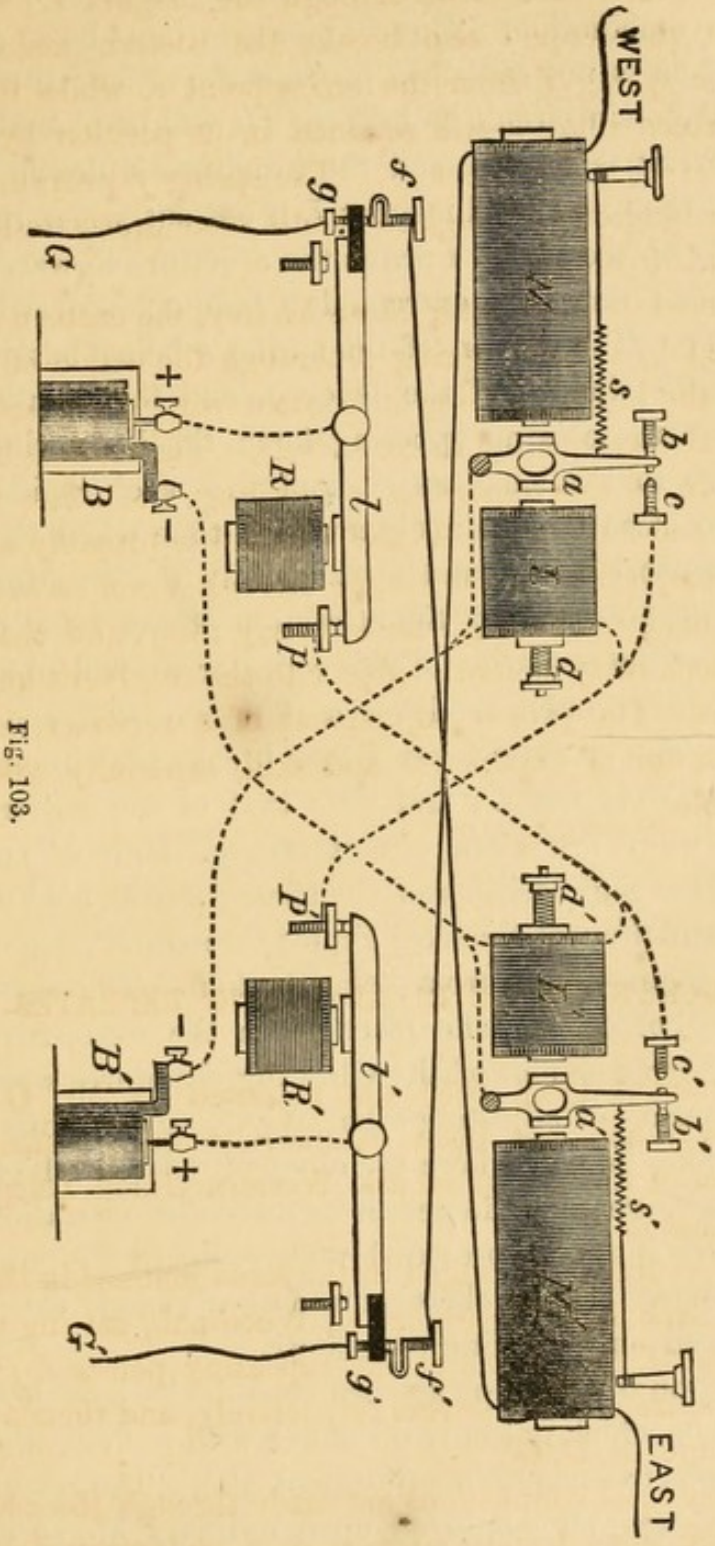

Fig. 103.

the relay magnets M, M' is done by them, instead of by springs, as in the case of the other repeaters described.

The repeater is shown in the cut with the eastern and western cir-

cuits closed. The circuits of the extra local batteries B, B', shown by dotted lines, pass through the sounder levers l, l', the screws P, P', and thence respectively to the extra local magnets on the opposite side of the combination. These armatures must be so adjusted that their attraction is not sufficient to draw the armature away from M, M', unless the main circuit be broken. It will be observed that when the main circuit is broken, and the armature is drawn back on the point c, that the extra local magnet L is cut out, when, the magnetism being destroyed, the spring s draws the armature forward, thus restoring the circuit through the extra coils L, and again drawing the armature back to c. The tension of the spring s being but just sufficient to overcome the inertia of the lever a, and thus draw it from the point c, when there is no opposing force, the lever vibrates on this point through such a small space, and with such rapidity, that it is impossible to close the main circuit at a time when the extra local magnet L is not cut out, and consequently the armature obeys the slightest impulse caused by the attraction of the relay magnet.

In observing the operation of this repeater we will suppose that the western circuit is broken, the lever a is drawn back, and vibrates on the point c. The sounder lever l first breaks the circuit of the eastern extra local magnet L', and then that of the eastern main line through the relay M'. The circuit through both L' and M' being thus broken, the slight tension of the spring s' will hold the armature in its place, and prevent the local circuit through R', and consequently the western main circuit, from being broken. The reverse of these operations will of course take place when the western line is again closed. The arrangement of the vibrating armatures was designed to avoid the necessity of adjusting separately for the various offices situated upon a long line, or where the escape rendered a higher or lower adjustment necessary for the nearer or more distant stations.

The repeater is usually provided with switches for cutting out the repeating points. When these buttons are closed, the instruments may be worked on each line separately.

A modification of this repeater has been devised by Mr. G. F. Milliken, of Boston, which not only dispenses with the vibrating principle, but with the electro-magnetic adjustment also. The relay is the same in all respects as that employed upon ordinary Morse circuits, and adjusted by a spring in the same manner. The extra local magnet has a separate armature, lever, and adjusting spring, and is placed in such a position above and in the rear of the relay magnet, that when the extra local circuit is broken, its armature is drawn forward by

means of a spring, and holds the relay armature up so as to close the local points while the main circuit on that side is open. The sounders and their connections are the same as those shown in the accompanying cut.

Mr. Milliken's modification is considered a valuable improvement upon the Hicks Repeater, and is largely used upon the lines of the American Telegraph Company east of New York.

A repeater of very simple construction is used upon the European telegraph-lines, which are worked upon an essentially different plan from that generally adopted in this country. The American system is known as the closed circuit, while that of the European is denominated the open-circuit system. In the American system the main batteries are always in the circuit, and the current flows through the entire circuit continuously, except when a key is opened for the purpose of transmission. The batteries are generally placed at the termini of the line, and none used at intermediate stations. Upon the European lines every office is provided with a main battery, the negative or zinc pole of which is permanently connected with the ground wire. The line wire passes through the relay magnet only at each way-office, and not through the key or battery. At the terminal station it first passes through the relay, and from thence to the lever of the key. This key differs from that used on the American Morse lines. It has no circuit-closer, but is provided with a second platina point at the rear end of the lever, which strikes upon another point connected directly with the ground wire. The platinum point under the front part of the key connects with the positive pole of the main battery. The way-stations are similarly arranged, with the addition of a switch by means of which they can place themselves in connection with the main line, either east or west, at pleasure. Thus it will be seen that there is no electric current upon the wire except when it is in actual operation.

The repeater used on these lines consists simply of two relay magnets, the armature levers of which vibrate between two set-screws in the usual manner. The back screws, however, are provided with platina points instead of insulated ones, as in ordinary relays. The eastern main circuit passes first to the armature lever of the western relay, thence through the back set-screw to the helices of the eastern relay, and thence to the ground. In like manner the western circuit passes through the eastern relay lever and western magnet, to the ground. The front set-screws of both relays are connected with the positive pole of the main battery.

Now if the eastern circuit be closed, the eastern relay will attract its armature, and thus place the western line in connection with the main battery, but not through the western relay. When the east breaks again, the western line is immediately placed in connection with the ground as before, and everything resumes its original position. If the receiving operator on the western circuit wishes to interrupt the transmitter, he presses his key down, thus throwing on a reversed battery. The next time the east breaks, the battery reverses the repeaters, and consequently the battery connected with it, which is at once perceived by the eastern operator the next time he closes his key.

This repeater has been used with great success since 1859 upon the Vermont and Boston telegraph-lines (which also connect with Montreal), and are the only open-circuit lines remaining in operation in this country. The open-circuit repeater is the simplest, and requires the least attention, of any repeater heretofore invented. A drawing of it is unnecessary, as with the aid of the above description the reader will readily understand its operation.

The Morse system of closed circuits, as operated in this country, is represented by Fig. 104. The circuit extends from New York to Washington, *via* Philadelphia, and the necessary apparatus for each station is given in the drawing. By referring to the cut it will be seen that the + or positive pole of the battery M enters the earth at New York, the — or negative pole being connected with the main line leading to Washington. At Washington the — or negative pole of the battery M' enters the earth, and the + or positive pole is connected with the main line leading to New York. The course of the currents, after leaving the + pole of the battery at Washington, is first to the key or circuit-breaker K'', thence to the relay magnet A'', thence along the wire to Philadelphia, entering the key K'; thence through the relay magnet A', thence along the line to New York, where it enters the key K, and passes thence through the relay magnet A to the — pole of the battery. The circuit-closers or buttons s, s', s'' are used for keeping the circuits closed at all but the station which is transmitting. The sounders B, B', B'' are the apparatus which in all the principal stations have taken the place of the registers to read from. They are actuated by local batteries, L, L', L'', which form circuits represented by the dotted lines. The local circuits are broken and closed at the points d, d', d'' by the action of the relay magnets A, A', A''. Any number of stations may be connected with a wire in the manner represented in the opposite drawing,

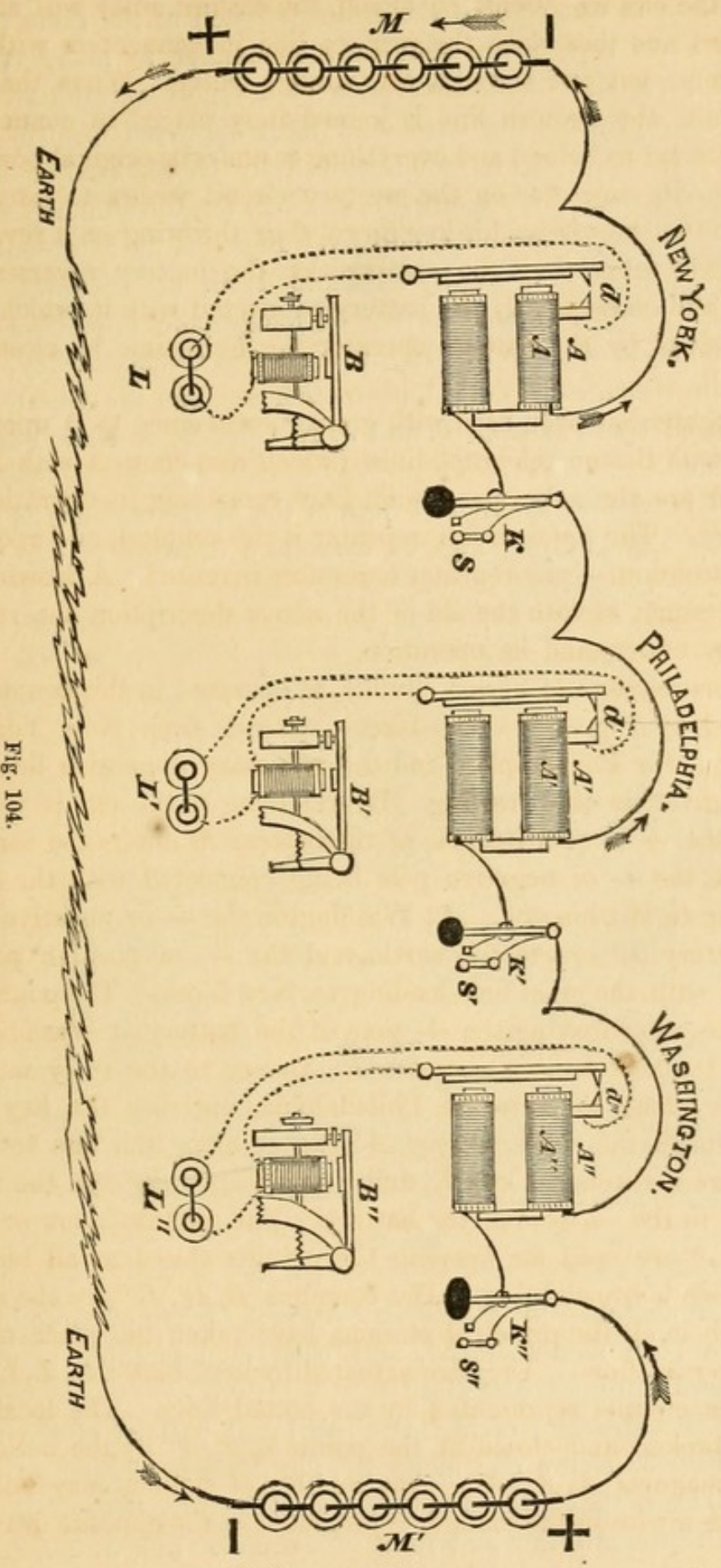
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Fig. 104.

and all of them can receive the same despatch at the same time, if desired. Press reports are sent in this manner to many different places at once, and by the operation of a single transmitter.

Fig. 105 represents the latest and most approved form of Morse key, manufactured by G. M. Phelps, of Williamsburg, New York, for the American Telegraph Company. Figs. 38, 39 represent those made by Thomas Hall, of Boston. Every manufacturer of telegraphic apparatus has a pattern and style of his own. In the West, the Chubbuck key, manufactured in Utica, New York, and in other sections the Chester key, manufactured by Messrs. C. T. and J. N. Chester, of New York, are highly valued.

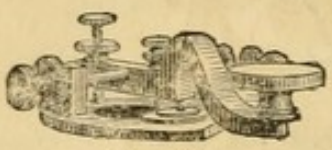

Fig. 105.

Fig. 106 represents the newest form of the Morse register, as manufactured by Mr. Phelps. Fig. 34 exhibits a drawing of one of the

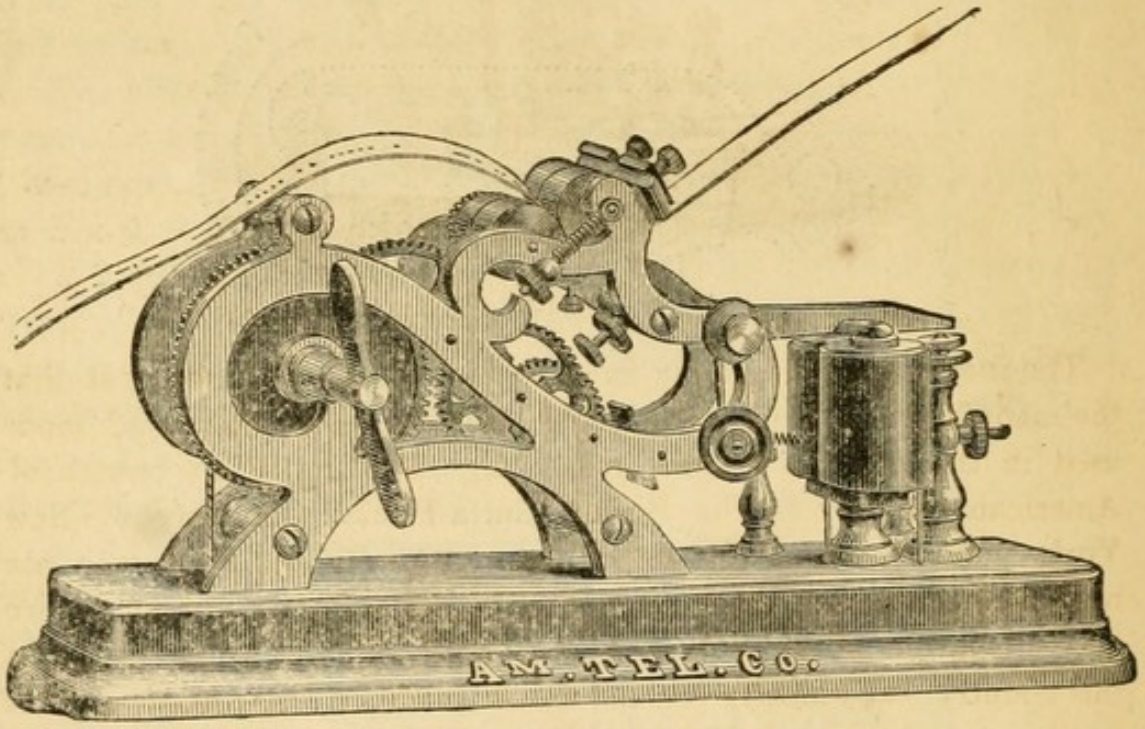

Fig. 106.

patterns manufactured by Mr. Hall. A great variety of these instruments have been manufactured, and each manufacturer generally makes several different patterns.

Fig. 107 is a drawing of Mr. Phelps's latest pattern of the relay magnet. Fig. 32 shows one made by the Messrs. Chester of New York; and Figs. 40, 41, those manufactured by Mr. Hall of Boston.

Fig. 108 represents the best form of a sounder now in use. Figs.

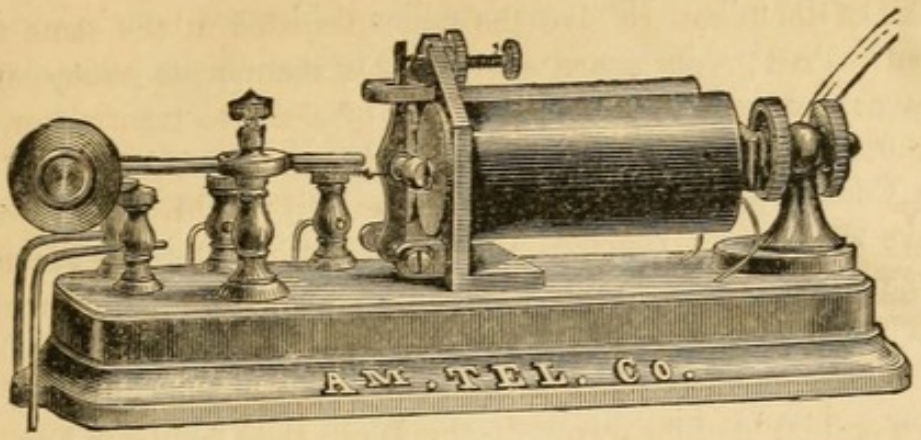

Fig. 107.

42, 43 exhibit drawings of the olden pattern of sounders, now but little used.

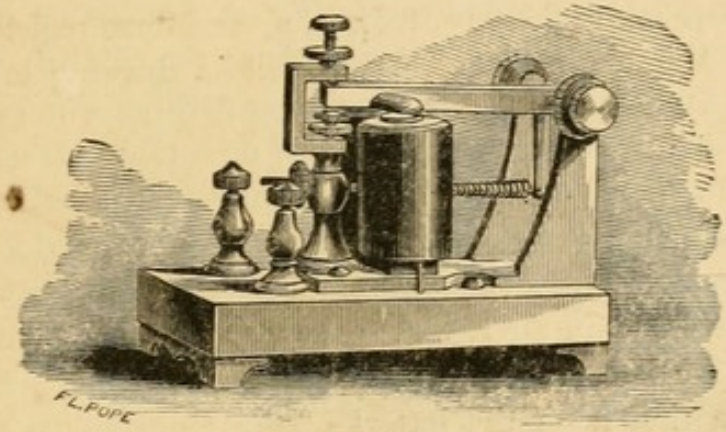

Fig. 108.

The increase of telegraphy in this country has been so great that the manufacture of submarine cables and insulated wire of all kinds used in the business has become a large and important branch of American industry. The Bishop Gutta-Percha Company of New York, under the management of Samuel C. Bishop, Esq., who has been connected with the manufacture of gutta-percha insulated wire and submarine cables since the first introduction of gutta-percha in this country, has recently erected a new and very large establishment for the manufacture of all descriptions of gutta-percha insulated wire and cables. Mr. Bishop has succeeded in making some of the best cables in use; the first long piece being laid by him in August, 1856, from Great Point to Monomoy Point in Vineyard Sound, connecting Nantucket with Cape Cod. The next was twenty-five miles of iron-armored cable for the United States Government, which was successfully laid across Chesapeake Bay, and worked well until pulled up by the anchor of a vessel, and cut by the Rebels. Last season Mr. Bishop constructed and laid another cable in place of the above, weighing

ten tons to the mile. Numerous smaller cables are now in use in this country made by Mr. Bishop, and their operation compares favorably with any manufactured abroad.

In the first edition of this work (Chapter X.) we gave a description of the Combination Printing Telegraph instrument, but without descriptive drawings. We now take pleasure in presenting two very accurate drawings of this beautiful instrument.

A perspective view of it is shown in Fig. 109. In order to be more easily understood, we shall first describe the manner in which the operator prints on his own instrument, and then show the manner of communicating with other stations. The principal features of this machine are the composing parts, the printing devices, the electro-magnet, a manual power which sets the machinery in motion, and a governor to regulate the speed correctly. A composing and a printing instrument is required at every station; the printing apparatus is distinct from the circuit, but the composing portion is included in, and forms part of, it. These are all arranged on a table about three feet in length and two in breadth. The manual power is distinct from the electric circuit, and consists of a shaft turned by a treadle, and an air-pump for forcing compressed air into a reservoir beneath the table. These are not shown in the figure. The composing machinery (shown in Fig. 109) consists of a key-board (seen in front) having twenty-eight keys, marked with the letters of the alphabet and a dot and "space." The ends of these keys correspond to an equal number of slots, *a*, *a*, arranged spirally round the composing cylinder *B*, which is kept revolving by a band and pulley at its left end. When a key is pressed down, and its corresponding slot is brought round to it, it enters the slot and is forced aside by its peculiar form, thereby acting on the lever *b* (Fig. 111), and bringing it in contact for an instant with the spring *c*, and closing the electric circuit. When the slot has passed, a spring, *d*, restores the lever *b* to its original position. The gutta-percha block *e* insulates the spring *c* from the bed-plate *A*. This arrangement, called the "circuit-closer," is seen at *C*, in Fig. 109. The electrical pulsations are conducted to the electro-magnet *E* (Fig. 109), the armature of which forms a valve, which is hung by a stem, *f*, upon a slender wire forming a spring, the tension of which is adjusted by a lever and screw, *F*. The vertical movement of the valve admits the compressed air from the reservoir beneath the table alternately into each end of a chamber, *G*, as the valve rises and falls under the action of the spring and of the electro-magnet. A piston, moving air-tight in the chamber *G*, operates the printing machinery

by means of a lever, *H*. Fig. 110 shows an enlarged plan of the printing machinery, in which the same letters of reference indicate like parts. When the valve is attracted by the electro-magnet, the

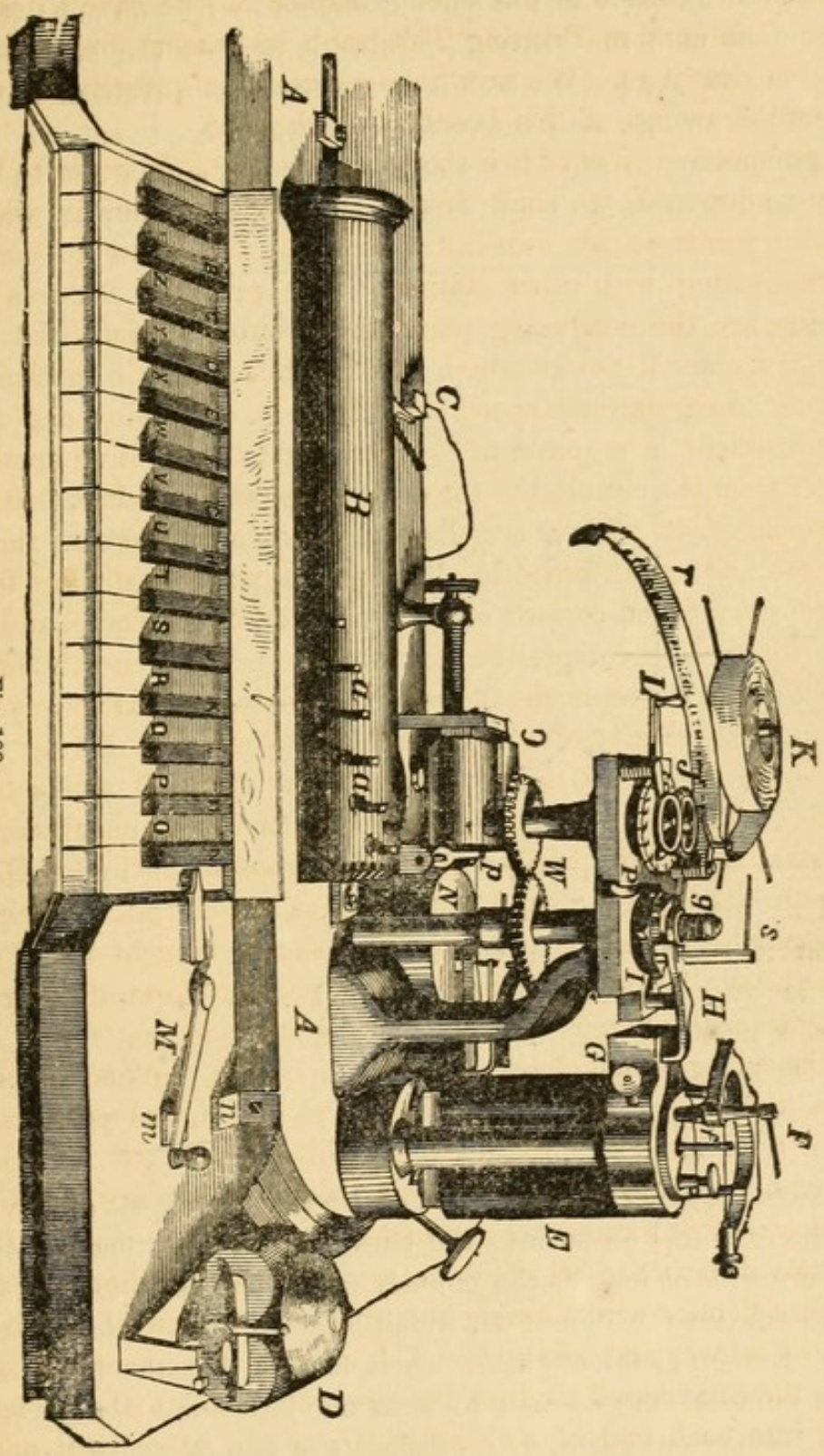

Fig. 109.

piston, acting on the escapement lever *H*, releases one of the six pins *h*, *h*, of the *timing* wheel *I*, which is moved by a friction attachment,

g, so that it can be stopped at pleasure without interfering with the movement of other parts. The type-wheel *J* is revolving continuously. When the lever *H* is removed from the pin of the timing wheel *I*, the timing wheel is carried around by friction until it comes into contact with the press *T*, forcing it against the type-wheel *J*, and taking off the letter which is at that instant in front of the press. Around the surface and under the type-wheel are twenty-eight cogs, *k*, corresponding to the letters of the alphabet, and a dot and dash. The press is composed of a tube an inch long, with cogs at the lower

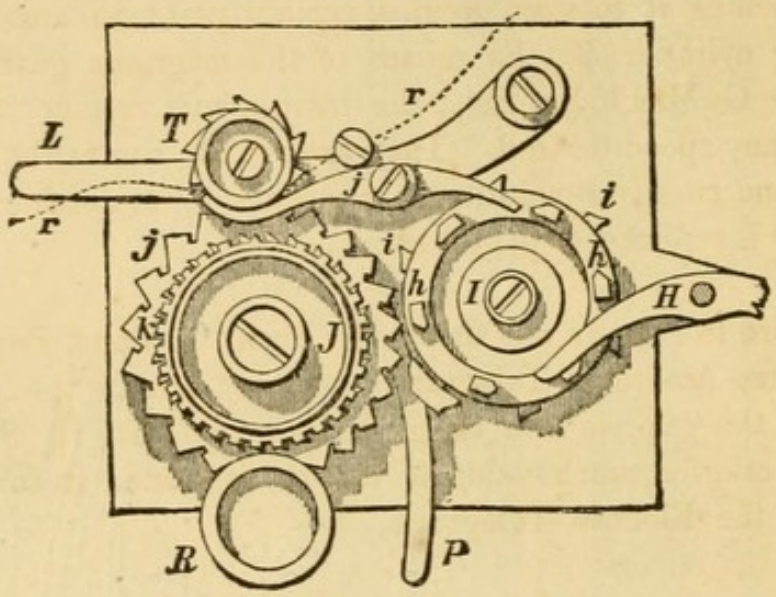

Fig. 110.

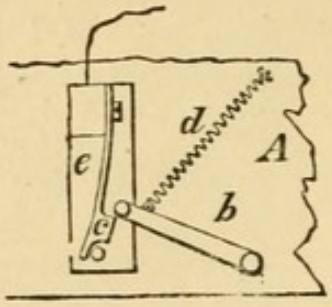

Fig. 111.

end, which, by being thrown forward by the movement of the liberated timing wheel locks into the cogs *k* upon the type-wheel, and revolves with it as long as the contact lasts; but as it takes but one wave to release the detent *H*, which is again applied to the timing wheel *I*, as soon as the circuit opens it follows that the press is only kept in contact long enough to form one letter and to pass one cog. A small semicircular spring, *j*, confines the slip of paper between it and the tube, and when the tube is carried around one notch, the paper is drawn along by friction. The press is thrown back from the

type-wheel by a spring at the instant the arm of the liberated printing-cone releases it.

Under the cogs above described upon the type-wheel *J* there is a second set of cogs, *j*; and upon the timing wheel *I* there are six projecting cogs, *i*, *i*, which fit into the spaces between the cogs upon the type-wheel, and serve as correctors, and thus prevent the instruments from varying to the hundredth part of an inch.

The roller *R* supplies the type-wheel with ink. The lever *P* is designed for the purpose of arresting the motion of the type-wheel, and compelling it to start from a certain point in unison with the composing cylinder *B*. By means of the magnetic governor *N*, invented by G. M. Phelps, Esq., the instruments can be run synchronously at any speed desired. They are usually run at the rate of one hundred and twenty revolutions per minute. For further particulars the reader is referred to page 148.

We desire to express our thanks to Frank L. Pope, Esq., Engineer to the Russo-American Telegraph Company, and to the *Telegrapher*, edited by the experienced telegraph manager, L. H. Smith, Esq., of New York, for much valuable matter contained in this improved edition of the Electric Telegraph.

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