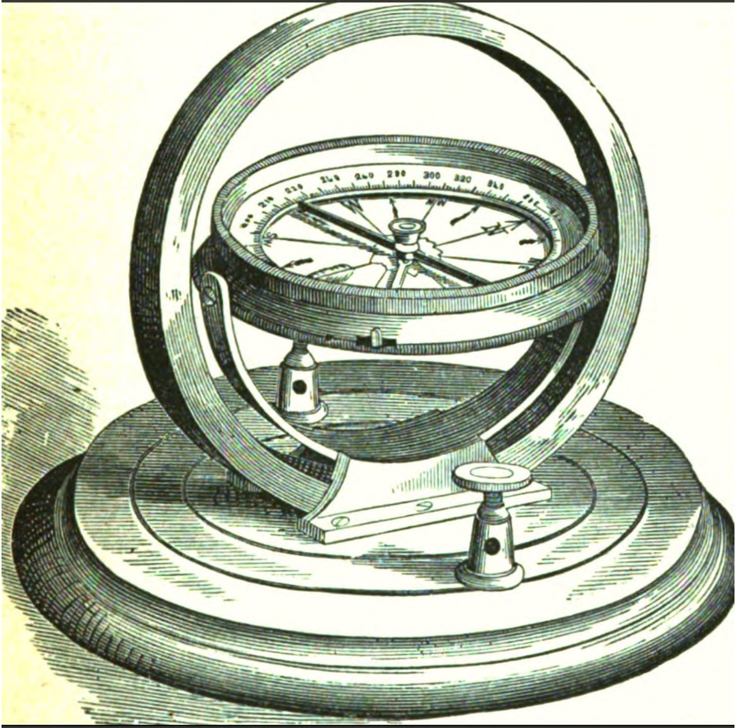

A hand-book of the electromagnetic telegraph

A. E. Loring

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A HAND-BOOK

OF THE

ELECTRO-MAGNETIC

TELEGRAPH.

BY

A. E. LORING,

A PRACTICAL TELEGRAPHER.

NEW YORK:

D. VAN NOSTRAND, PUBLISHER,

23 MURRAY AND 27 WARREN STREET.

1878.

INTRODUCTION.

It has been the aim of the author in the preparation of this little book, to present the principles of the Electro-Magnetic Telegraph, in a brief, concise manner, for the benefit of practical operators and students of telegraphy. The works on telegraphy which have thus far been presented, besides being expensive, have contained much that is useless, or which is not in a form to be readily understood by young and inexperienced telegraphers. Although this little work must be acknowledged incomplete, it is hoped that it may go far toward supplying the deficiency which has existed ; or, at least, serve as a stepping-stone to the study of the more complete works on electricity and telegraphy.

THE AUTHOR.

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PART II.—THE MORSE TELEGRAPH.

PART III.—BATTERIES.

ELECTRO-MAGNETIC TELEGRAPH.

ELECTRICITY AND MAGNETISM.

ELECTRICITY.—POSITIVE AND NEGATIVE.

THE real nature of electricity is unknown. It is often spoken of as a *fluid*, and is said to *flow* in a *current*, but these terms may be considered as used more for the sake of convenience, than as indicating the real nature of electricity.

There are two kinds of electricity, or it exists in two different states, known as *positive* and *negative;* and experiment shows, that whenever one kind is developed that of the opposite kind is always developed in an exactly equal quantity. These two kinds of electricity are usually designated by the signs + and —. It is a law of electricity, that *electricities of like sign* *repel each other, and electricities of unlike sign attract each other.*

Conductors and Non-Conductors.

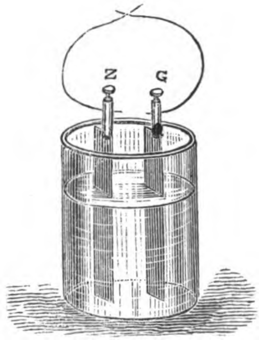
Electricity passes through some substances easily, and through others with difficulty, or scarcely at all. The first class of substances are called *conductors*, the second *non-conductors*, or *insulators*. No absolute division can be made between conductors and non-conductors, as the property of conduction exists in every conceivable degree, from the best conductor to the best insulator, or *worst conductor*. In the following list the first named substance is the best conductor, and the last named the best insulator.

Conductors.	Non-Conductors.
Silver,	Dry wood,
Copper,	Porcelain,
Gold,	Dry Paper,
Zinc,	Silk,
Platinum,	Glass,
Iron,	Gutta Percha,
Tin,	India Rubber,
Lead,	Shellac,
Mercury,	Hard Rubber,
Acids,	Paraffine,
Water,	Dry Air.

Galvanic Batteries.

Galvanic, or Voltaic electricity is developed by chemical action. When two plates of metal, of different kinds, as copper and zinc, for example, are immersed in a cup containing an acid, and are con-

Fig. 1.



Galvanic Element.

nected by wires at the top, as represented in Fig. 1, a current of electricity will flow from the copper to the zinc through the wires, and from the zinc to the copper through the acid. If the wires connecting the two metals are separated, the current of electricity instantly ceases, but starts again whenever the wires are connected. An apparatus for generating electricity in this way is called a *galvanic battery.* The copper slip is called the positive (+) *pole* of the battery, and the zinc the negative (—) pole. The principal kinds of batteries used in operating the telegraph will be described hereafter.

Galvanic Circuits.

The path traversed by the current of a battery is called a *circuit.* The circuit of the battery shown in Fig. 1 consists of the metals, wires, and the acid through which the current of electricity passes. It is a law of the electric current that *there must be a continuous, unbroken circuit, by which the current may pass entirely around from one pole of the battery to the other, or no current will start from the battery.* The smallest break in the circuit is sufficient to interrupt the current instantly, but it begins to flow again the instant the circuit is again completed. The direction of the current through the circuit is always from the positive to the negative pole of the battery.

It may be more correct, however, considering the electrical force as a *current*, to say that there are two currents flowing in opposite directions, and for convenience the positive one only is spoken of as the current.

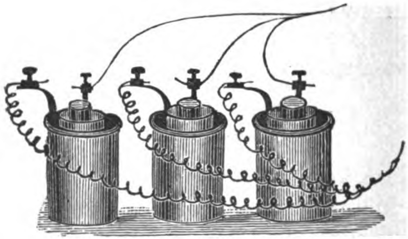
Electrical Quantity and Intensity.

A battery may consist of a single cup, or cell, or of an indefinite number of cups connected together by wires. In connecting them together, the copper, or positive pole of the first cup must be connected by a wire with the negative pole of the second, and the positive pole of the second with the negative of the third, and so on throughout the series, always connecting unlike or opposite poles, because, according to the law of attraction and repulsion already stated, *poles of like sign oppose one another, and poles of unlike sign attract one another.*

The *quantity* of electricity generated by three cells of battery connected as directed above, is no greater than that generated by one cell; but the *intensity* of the current generated will increase in proportion to the number of cells so connected. Intensity or *tension* is the force which enables the current to push its way through a conductor, or to overcome resistance.

If two or more cells of battery are connected as shown in Fig. 2, with all the

Fig. 2.



Galvanic Battery—Quantity Arrangement.

positive poles connected to one end of the wire conductor, and all the negative poles connected to the other end, the *quantity* of the current generated will be in proportion to the number of cells, but the *intensity* of the current will be no greater than that of a single cell.

The general principle is, that quantity increases with the surface of metal connected with each pole, whether that surface is all in one cell, or distributed through several cells connected as in Fig. 2. The intensity increases with the number of elements, or cells, having opposite poles connected, and does not depend upon the size of the metals used. Consequently, large cells evolve a greater quantity of current than small ones, but of no greater tension.

Resistance.

Resistance is the opposition which the conductor, or circuit offers to the passage of the current. Thus the best conductor offers the least resistance, and the poorest conductor the greatest resistance. Resistance may be considered as the reciprocal of conduction. Resistance is measured by *Units* or *Ohms.*

In the case of two conducting wires of

the same material, that which presents the largest area of cross-section to the current offers the least resistance. Thus, although copper is a better conductor than iron, an iron wire of large size may have a lower resistance than a copper wire of smaller size. The conducting power of a wire increases, and its resistance decreases, in proportion as the area of its section increases. On the other hand, the resistance of a conducting wire of a given material increases in proportion to its length.

The following table shows the comparative resistance of some of the metals, silver being taken as the standard, at 32° Fahrenheit. The resistance of metals increases with their thermometric heat.

Silver	100	Lead	1202
Copper	100	Brass	420
Gold	128	Platinum	1493
Iron	594	Mercury	5815

(*Jenkin.*)

The approximate average resistance of the principal forms and sizes of batteries used in telegraphy is as follows :

Grove....	0.41	Ohms.
Carbon...........	0.63	"
Daniell...........	1.70	"

(*Farmer.*)

Or, measured by units instead of Ohms, about as follows :

Grove.............	0.5	units.
Carbon	0.8	"
Daniell............	2.2	"
Hill or Callaud.....	3.0	"

(*Brooks.*)

Electro-motive Force.

The power which a cell of battery possesses of causing the transfer of its current from one place to another is its *electro-motive force.* In other words, the electro-motive force of a current is its power of overcoming resistance—its energy. Electro-motive force may be defined as tension in a state of motion ; and tension, as electro-motive force in a state of rest. (*Haskins' Galvanometer.*)

The comparative electro-motive force

of batteries is as follows, the Grove battery being taken as a standard at 100.

Grove	100
Carbon	107
Daniell	56
Hill or Calland	56

OHM'S LAW.

The amount of the current which will pass through a circuit depends, first, upon the resistance which the circuit offers to the passage of the current, and second, upon the intensity of the electro-motive force which tends to overcome that resistance. The amount of the current may be found, according to *Ohm's law*, which may be stated thus:

E represents the electro-motive force,

R the resistance, and

C the current which will pass through the circuit, thus:

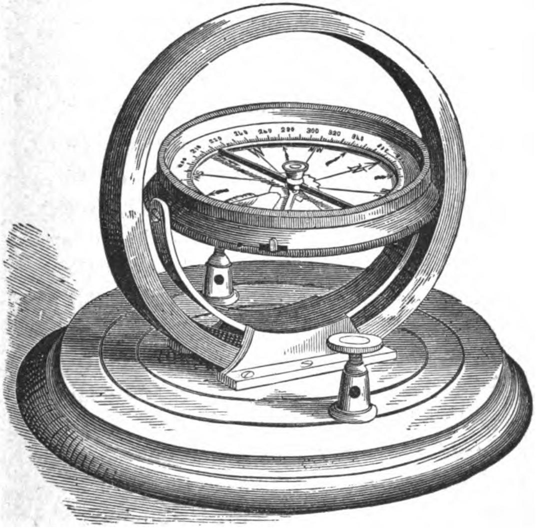
$$C = \frac{E}{R}$$

or, *the current is equal to the electro-motive force divided by the resistance.*

Measurement of Currents.

Electric currents may be measured by an instrument called a *galvanometer,* one form of which is shown in Fig. 3.

Fig. 3.



Galvanometer.

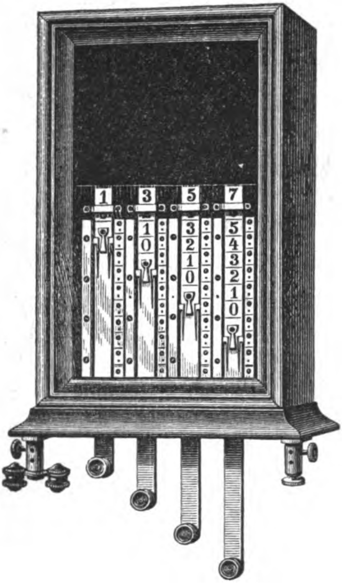
It consists of a magnetic needle surrounded by a coil of insulated wire.

When a current is passed through the coil of wire, its amount is marked by the deflection of the needle on the face of a dial, the degree of deflection being always in proportion to the strength of the current. The instrument represented is from the manufactory of Charles T. Chester, New York.

Measurement of Resistance.

The resistance of a conductor may be measured by an instrument called a *rheostat* used in connection with a galvanometer. Fig. 4 shows a simple and convenient form manufactured by Chas. T. Chester, New York. Two binding screws are provided for placing the instrument in circuit with the conductor to be measured, "Four or more slides are made to be pulled down ; as they descend they throw in continuously additional resistance. The right hand slide adds resistance by tenths of ohms, the next one by ohms, the next by ten ohms, the left one by hundred ohms." (*Chester's Catalogue.*) With the slides in the position shown, the instrument marks a resistance of 135.7 Ohms.

Fig. 4.



Rheostat.

The rheostat and galvanometer are put in circuit with the conductor whose resistance is to be measured, and the deflection of the needle of the galvanometer is noted. The conductor to be measured is then taken out of the circuit, and as much resistance is thrown in by the rheostat as will give the same deflection of the needle. The resistance marked by the rheostat will, evidently, be equal to that of the conductor previously in circuit.

Speed of the Current.

The electric current flows through the circuit with inconceivable rapidity. The measurements made by one experimenter, Wheatstone, show a speed of 288,000 miles per second. Experiments have shown, however, that the speed varies under different circumstances. With a given resistance, the speed increases with the electro-motive force.

Divided Circuits.

When two or more wires are connected together in a line, so as to form one continuous wire, the resistance of the whole circuit will be the sum of the resistances of the wires which compose it. But if two or more wires are arranged side by side, the ends being connected with each other, the current is divided among the several conductors, and the conducting power of the whole is equal to the sum of the conducting power of the wires which compose it. Considering the resistance of the several conducting wires as the reciprocal of their conducting power, the same proposition may be stated as follows :

When the resistance of the wires is equal, their joint resistance is equal to the resistance of one wire divided by the number of wires.

Thus, two wires having a resistance of 50 Ohms each,

$\frac{50}{2} = 25$ Ohms, joint resistance.

When the resistance of the two wires is unequal, their joint resistance is equal to the product of their several resistances divided by the sum of their several resistances.

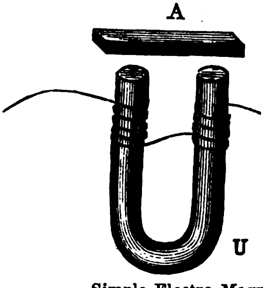
Thus, two wires, one having a resistance of 100 Ohms, the other of 200 Ohms,

$$\frac{100 \times 200}{100+200}=\frac{20000}{300}=66.6+.$$

ELECTRO-MAGNETS.

A simple form of electro-magnet is shown in Fig. 5. A conducting wire, insulated by being covered with silk or cot-

Fig. 5.

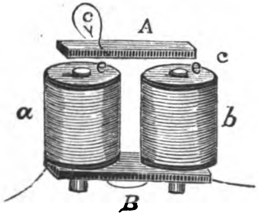


Simple Electro Magnet.

ton, so that the current must traverse its entire length, is wound several times around each arm of a U shaped piece of soft iron. When a current of electricity is passed through the insulated conducting wire, the soft iron U instantly becomes magnetized, and attracts an iron bar, A, called an *armature*, which is placed near its ends or *poles*. As soon as the current of electricity ceases to pass through the wire, the soft iron U is demagnetized and ceases to attract its armature.

Electro-magnets for use in telegraphy are made as represented in Fig. 6. Two

Fig. 6.



Electro Magnet.

spools, *a b*, having soft iron cores, are wound with fine silk-insulated copper wire, as thread is wound upon a spool. The two spools are fixed upon a bar of iron, B, called a *back armature*. A, is the armature which is attracted toward the cores or poles, *e e*, whenever the current passes through the coils of the magnet.

Residual Magnetism.

When the current which passes through the coils of an electro-magnet is interrupted, demagnetization of the soft iron cores takes place. If the iron is very soft and pure this is effected almost instantly on the cessation of the current through the coils. But if the demagnetization is not complete, and a small amount of magnetism remains in the cores after the cessation of the current, it is called *residual magnetism.* A spring is therefore attached to the armature of the magnet, which overcomes the attraction of the residual magnetism, and draws the armature away from the poles of the magnet.

Proportion of Electro-Magnets to the Circuit.

It is a law of the electric circuit, that *the maximum magnetic force is developed when the resistance of the coils of the* *electro-magnets in circuit is equal to the resistance of the other parts of the circuit;* i. e., *the conducting wires and battery.*

For example, if there be two electro-magnets in circuit, and the resistance of other parts of the circuit, including conducting wires and battery, is 60 ohms, the resistance of the magnets should be 30 ohms each, as $30 \times 2 = 60$. If there are three magnets in the circuit, they should each have a resistance of 20 ohms, as $20 \times 3 = 60$.

INTENSITY AND QUANTITY MAGNETS.

The magnetic force increases in proportion to the number of the convolutions of wire in the coils of an electro-magnet, but it diminishes in proportion as the distance of the wire from the cores increases. In other words, the convolutions of wire which lie nearest the cores influence the magnet most powerfully. When, therefore, the coils of an electro-magnet must be of high resistance in order to equal that of the other parts of the circuit, they are wound with a great length of *fine* wire, so that the distance between the outer convolutions of the coil and the cores of the magnet may be as small as possible. Magnets so constructed are called *intensity* magnets. When, on the other hand, the resistance of the circuit is very light, a shorter length of coarser wire is used in the coils of the electro-magnet. Such a magnet is called a *quantity* magnet.

PART II.—THE MORSE TELEGRAPH.

Fundamental Principle.

The Morse telegraph system is so called from the name of its inventor, Samuel F. B. Morse, an American, who constructed the first line between Baltimore and Washington in the year 1844.

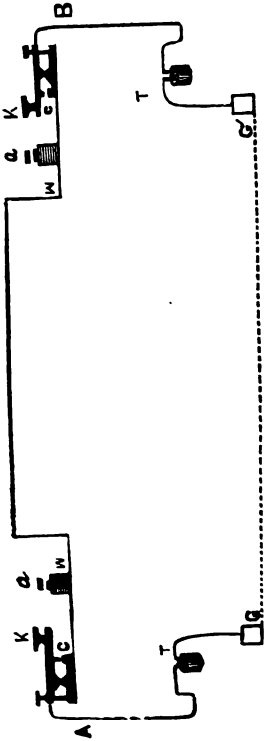
Morse's telegraph operates upon the principle, that an electro-magnet may be alternately magnetized and demagnetized by stopping and starting a current of electricity, by opening and closing the circuit of which the electro-magnet forms a part.

Telegraph Circuits.

Fig. 7 represents a telegraph circuit, consisting of a line wire stretching from the station A to the station B; a battery T, an electro-magnet M, and a key K, for opening and closing the circuit, at each of the stations. To avoid the expense of a second wire to complete the circuit between the two stations, the line wire, after passing through the magnet, key and battery at each end of the line, is run to the ground at G, completing the circuit through the earth. Besides being less expensive, this plan has the additional advantage that the resistance of the circuit completed through the earth is less than it would be through a return wire, as the resistance of the earth is practically nothing. On very short lines sometimes a second wire is used, which constitutes what is called a *metalic* circuit.

When the circuit is closed at A by means of the key, K, the current traverses the circuit, passing through both electro-magnets, M M, causing them to attract

Fig. 7.



Telegraph Circuit.

their armatures as long as the current continues. When the circuit is again opened by the key, the current is interrupted, and the electro-magnets release their armatures. The effect is the same whether the circuit is opened and closed by the key at A, or at B. The effect, also, upon the electro-magnet is the same whether the key is at the same station with the magnet, or at another station many miles distant.

By the original method of operating the telegraph, the armature of the magnet at each station was attached to one end of a lever having a sharp pointed steel style in the other end, which indented a strip of paper drawn before it by means of clockwork. If the armature was attracted but an instant, the style came in contact with the paper only an instant, and indented it with a short mark, or *dot*. If the armature was attracted for a longer time, the result was a longer mark, or *dash* upon the paper. Thus, it will be observed, dots and dashes may be marked upon the paper by closing the circuit by the key for a shorter or a longer time. If different combinations of dots and dashes are used to represent letters, it is evident that a message may be transmitted by means of the key at one station to the electro-magnet at another.

In more recent practice, the method of marking the signs upon paper has been superseded by arranging the lever attached to the armature in such a way that it will give sounds at shorter or longer intervals according to the time the circuit is closed. These intervals between sounds may be considered as representing dots and dashes, and for convenience the terms dot and dash are retained.

Intermediate Offices.

An indefinite number of intermediate or way stations may be introduced in the circuit between the two terminal stations of the line, each station or office being provided with its key and magnet. The circuit may be opened by a key placed at one of these intermediate stations, at any point on the line, and the effect upon every magnet in the circuit will be precisely the same; but it is obvious that only one key can be operated for opening and closing the circuit at the same time.

The Local Circuit.

On a circuit as long as a telegraph line reaching from city to city, the resistance of the long line of wire is so great that the current is often weakened to such an extent in passing over it, that sufficient magnetic force is not developed in the electro-magnets to attract their armatures with the power necessary to mark paper, or give a satisfactory sound to the motions of a lever. For this reason, instead of placing the magnet of the recording or sounding instrument in the *main* circuit, its place is supplied by a *relay* magnet, M, (Fig. 8). The armature of the relay magnet is attached to a lever, S, which opens and closes the circuit of another battery, B, at the point P. This second or *local* circuit is represented by the dotted lines. When the *main* circuit, or line is closed, the relay magnet attracts its armature and closes the *local* circuit, in which is placed the recording or sounder

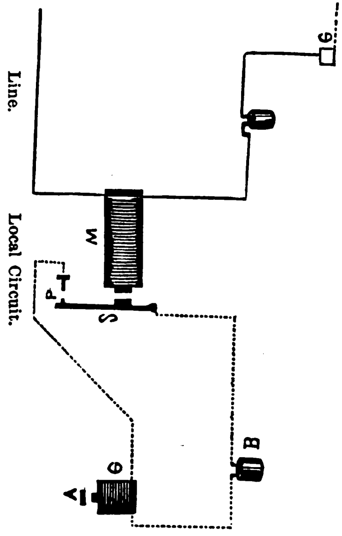


Fig. 8.

magnet G. The lever of the relay magnet is so light that a weak current is sufficient to work it, but the resistance of the local circuit, which is composed of only a few feet of wire, is so small that nearly the entire force of the local battery is effective upon the local magnet. It will be noticed that although the local circuit depends for its action upon the main circuit, the main circuit is entirely separate and independent from the local, and is not affected in the least by its action.

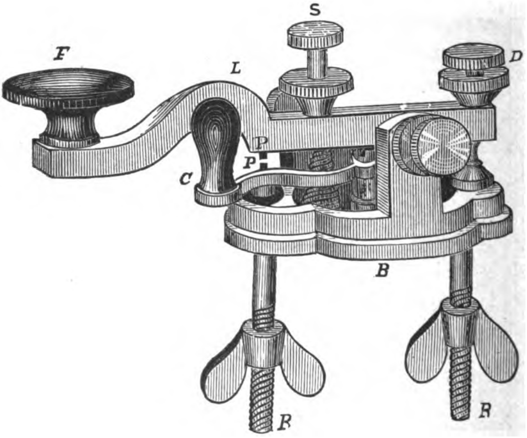
Ground Wires.

At every intermediate station, a wire called a *ground wire* is run from the office to the ground. This wire may be connected with the line wire so as to divide the main circuit into two distinct and independent circuits. The uses of the ground wire will be explained more fully hereafter.

The Key.

The key, or sending instrument is represented in Fig. 9. It consists of a lever of brass, L, about five inches long, which is hung on a shaft between two set screws on the frame or base B. The key is fastened to the operating table by two legs, R R′, which pass through the table and are secured by nuts underneath. The circuit is formed through the key by cutting the wire of the main circuit and con-

Fig. 9.



Key.

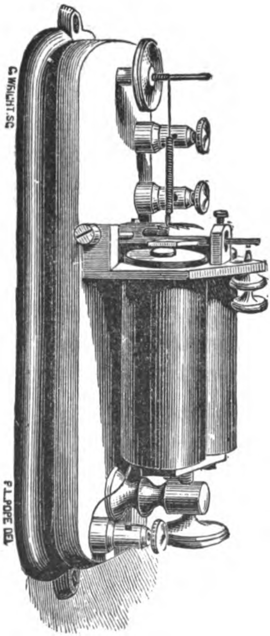
necting one of the ends to each of the legs. The leg, R′, is in direct connection with the brass base of the instrument, but the other leg, R, is insulated from it by being set in a piece of hard rubber, so that the circuit is broken at this point and the current cannot pass from R′ to R. The leg, R, terminates in a *platinum point*, P, and a similar platinum point, P, is placed in the lever L.

When it is desired to complete the circuit, the lever is pressed down by the pressure of the fingers upon a hard rubber finger piece, F, bringing the two platinum points, P P, in contact, and completing the connection between R′ and R through the lever and platinum points. When the pressure upon F is released, a spring under the lever restores it to its former position, separating the platinum points, and the circuit is broken.

C is a *circuit closer*, which completes the connection and closes the circuit permanently when it is pushed against the anvil which forms the top of the leg, R. This is always done when the key is not in use, for if the circuit through it was not completed in this way, the current could not flow through the circuit, and all the other keys situated in it would be useless. The play of the lever, or the distance between the platinum points is regulated by a set screw, D, in the end of the lever. Sometimes another set screw, S, is provided for regulating the tension of the spring under the lever.

The Relay.

The Relay consists, as shown in Fig. 10, of a large intensity electro-magnet, supported by a frame of brass on a dry hard wood base. The armature of the electro-magnet is attached to a lever, which plays between two adjustable set screws, fixed in the frame of the instrument. As this lever acts as a key to open and close the local circuit, it is provided with a platinum point which strikes upon another platinum point on the end of the set screw. The platinum point of the lever is in electrical connection, by means of wires beneath the base of the instrument, with one of the binding posts, and the point in the screw, with the other. The wires of the local circuit are connected to these binding posts. The coils of the magnet are in connection with the binding posts



Relay.

Fig. 10.

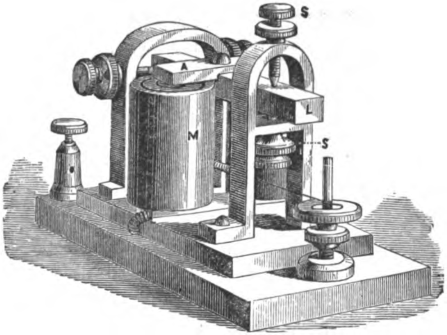
behind the coils, to which the main line wires are attached, and the magnet put in circuit. The tension of the spring which draws the armature and its lever back, and opens the local circuit when it is not closed by the attraction of the magnet, is regulated by an adjustment. The distance of the magnet from the armature is regulated by another adjustment, called the "back adjustment."

The coils of relay magnets are wound with very fine wire, usually No. 30 to No. 36, and with a resistance varying to suit the resistance of the circuit. The coils of electro-magnets used in telegraphy are generally covered with hard rubber, as a protection to the wire.

The Sounder.

The *Sounder,* or receiving instrument is shown in Fig. 11. It consists simply of a small electro-magnet, having a resistance of from 2 to 4 ohms; an armature and heavy sounding lever, which plays between two adjustable set-screws; and the necessary frame-work of brass, mounted upon a base of wood. An adjustment is provided for regulating the ten-binding posts on the base of the instrument.

Fig. 11.

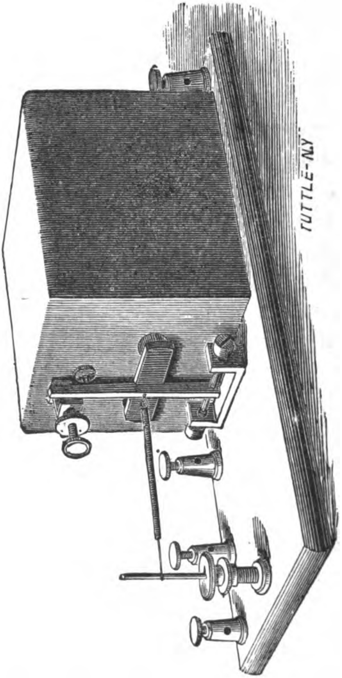


The Sounder.

MAIN LINE SOUNDERS.

When the current of the main circuit is sufficiently strong, the local circuit and sounder is sometimes dispensed with, and the relay is converted into a sounder by giving its lever more "play," or motion, and thereby increasing its sound. More frequently a *Main Line Sounder* is used. This instrument is made in a variety of forms, and numerous devices have been

Fig. 12.



Box Relay.

employed to increase the sound of the lever, which must often be operated by a comparatively weak main line current.

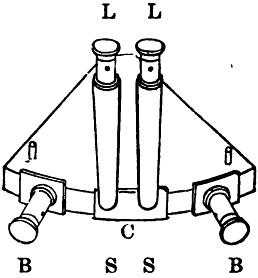
The Box Relay.

The instrument called the *Box Relay* is so arranged that it may be used advantageously either as a relay or as a main line sounder. The magnet coils are inclosed in a small wooden box against which the lever strikes (Fig. 12), thus increasing the sound. These instruments, when made with a key upon the same base, are convenient portable instruments for opening temporary offices.

Cut-Outs.

When a telegraph office is left with no one in charge, or during a heavy electric storm, the instruments should be disconnected from the line. A "cut out" switch is used for this purpose. One of the simple forms of cut-out is shown by Fig. 13. The line wires entering the office are connected to the binding posts, L L, and the wires leading to the instruments are connected to the binding posts B B. When the commutators, S S, are so as to connect the binding posts, L L, and B B, the circuit is complete between the line and the instruments. When both commutators are turned upon C, as

Fig. 13.



Cut-Out.

in the engraving, the current passes across from S to S, completing the circuit without the instruments, which are said to be "cut out."

Another form of cut-out, called the *plug switch*, (Fig. 14) has been extensively used. A plug is made of two pieces of brass separated and insulated from each other by a piece of hard rubber. The instruments of the office are connected with the two sides of this plug by flexible conducting wires. When the office is to be

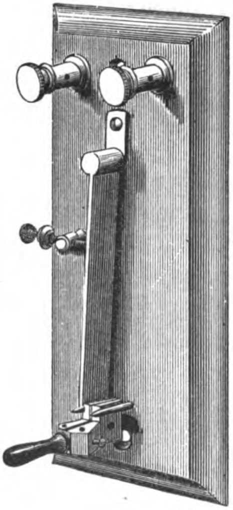


Fig. 14.

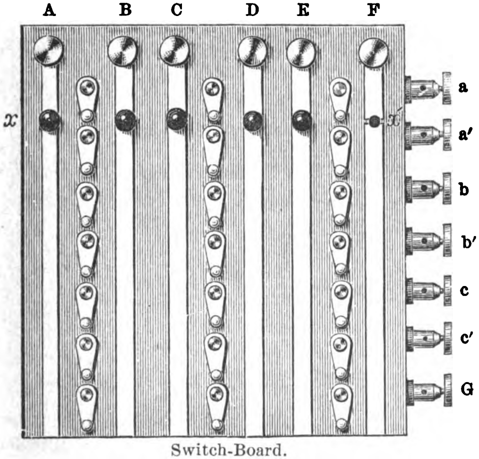
Plug Switch.

put in circuit, or "cut in," the plug is inserted between a pin and a brass spring, as shown in the figure. The main line wires are attached to the binding posts at the top of the switch, one of which is in connection with the pin, and the other with the brass spring. It is obvious that as the two sides of the plug are insulated from each other, the current must pass through the office; but when the plug is withdrawn the brass spring presses against the pin, closing the main circuit, and leaving the office entirely disconnected, or "cut out."

THE SWITCH-BOARD.

A *switch-board* is generally used in offices having two or more wires entering them. The most common and simplest form is that shown in Fig. 15. The connections of brass are arranged upon a wooden board, as represented. The upright strips, A B C D E F, are provided with binding posts at the top, to which the line wires are attached. The wires leading to the instruments are attached to the binding posts, *aa′ bb′ cc′*, at the side of the board. Each one of these binding posts is connected, by means of wires behind the board, with the row of *connectors*, which stands in a horizontal line with it. By turning the connectors around into a horizontal position so as to come in contact with the upright strips, it is plain that any line wire may

Fig. 15.



Switch-Board.

be connected with any desired instrument wire. A little careful study of the switch will show that two wires may be *crossed* by means of the connectors, or that any desired wire east may be connected with any other wire west of the office.

The ground wire is attached to the binding post, G, and may be connected with any of the line wires by means of the connectors which stand in a horizontal line with it, at the bottom of the board. Sometimes, also, extra connectors are added at the top of the board, by which the wires may be cut out.

The switch shown in the figure will accommodate three wires at a way station, or six at a terminal station, where the line wires merely pass through the instruments and thence to ground, instead of back through the switch board and on to the next station. These switches may be made for any desired number of wires. The switch-board has, also, been made in other forms, employing a spring or plug in the place of the connectors, but the principle involved is the same in them all.

Other Switches.

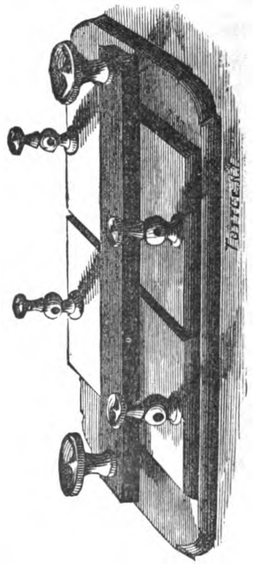
A simple switch called a *ground switch* is used to connect the ground wire with the line. Other forms of switches are used, and for various purposes, their construction being according to the special use for which they are intended, but they are too numerous to be described within the limits of this little book.

Lightning Arresters.

The fine wire coils of the relay magnet are sometimes burned or injured by atmospheric electricity, which follows the wires into the office during the prevalence of electric storms. As a protection, *lightning arresters* are sometimes used. Both the line and ground wires are attached to the lightning arrester, so that a charge of atmospheric electricity entering the office by the line wires is carried to the ground. The lightning arrester is made in several forms, but the principle involved is much the same in all of them; that is, that atmospheric electricity, being of high intensity, will leap a slight break in the conductor, or overcome considerable resistance in order to force its way to the ground; while the galvanic current, being of lower intensity, is unable to overcome such resistance and is confined to the line.

One form of arrester is shown in Fig.

Fig. 16.



Lightning Arrester.

16. Two small brass plates are placed upon a third and larger plate, separated from it only by a thin sheet of insulating material. The two upper plates are put

in the circuit of the wires entering the office, and the lower plate is connected with the ground wire. Any over-charge of electricity which may enter the office by the line wires, on passing over the brass plates forces its way through the insulating material, by reason of its great intensity, and is carried through the ground wire to the earth.

Another form of lightning arrester is arranged with pointed screws projecting from the line wire plates towards the ground wire plate, in such a way that there is a very small space between the plates and the points, over which the lightning leaps, making its way to the ground. The lightning arrester is sometimes combined with the cut-out in one instrument.

Loops.

What is technically termed a "loop" in telegraphy, is a wire branching out from the main circuit, running to some point and returning again to the line. A loop is arranged so that it may be cut out from the line if necessary. A plug switch is the most convenient for this purpose, the switch being put in circuit at the office where the loop commences, and the wires of the loop attached to the plug.

Arrangement of Offices.

In the arrangement of offices, the line wire entering the office first passes through the cut-out switch and lightning-arrester, and then through the key and the magnet of the relay. It is immaterial which of these latter instruments is first in order in the circuit, as long as they are all properly connected. The circuit, after passing through the apparatus, is made complete to the ground, if it is a terminal office; or runs back through the lightning-arrester and cut-out, out of the office and on toward the next station, if it is a way station. The connections of the local circuit, which is entirely confined to the office, may be understood by reference to Fig. 8.

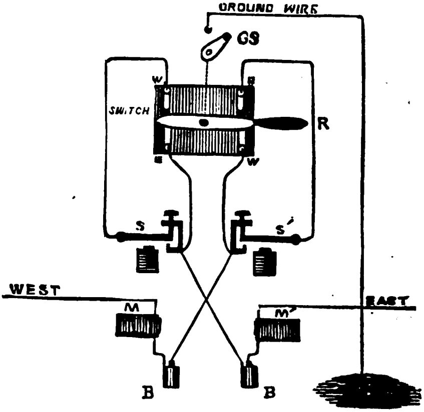
Arrangement of Batteries.

Two batteries are generally used on the main circuit, one at each end. The number of cells in each battery is equal under ordinary circumstances, and the number will depend upon the length and resistance of the circuit. Not only should the different cups of each battery be connected with regard to the law of attraction and repulsion, but the batteries at each end of the line should be placed with *opposite poles to the line*, in accordance with the same law. Frequently, several wires are worked from the same battery on the principle of a "divided circuit;" and in this case it is important that the wires should equal each other in resistance as nearly as possible.

Repeaters.

When the length of a telegraph circuit renders it of too great resistance to be worked satisfactorily, the circuit is divided into two or more parts, and a *Repeater* is used. The repeater "repeats," or transmits the signals received on one circuit into the other, much in the same way as the relay repeats the signals from the main into the local circuit. The repeater must be arranged so as to transmit

Fig. 17.



Repeater.

from *either* circuit into the other, according to the direction in which the message may be going.

The connections of a simple "switch repeater" are shown in Fig. 17. M and M are the relay magnets of the eastern and western circuits respectively; and S and S are the sounders of the eastern and western circuits; B and B the main line batteries. The local circuits connect the sounders with the relays in the ordinary manner, but the local wires are omitted in the figure, in order to avoid confusion of the lines.

The sounders, S S, are of a peculiar construction, their levers being provided with platinum points, similar to those of a relay. The opposite main circuit passes through the lever and platinum points of each sounder, so that, as the sounder is worked by its relay, it repeats the signals through its platinum points into the opposite circuit.

With the switch, R, in the position shown in the figure, the two circuits work through, not as a repeater, but as a single circuit. This may be seen by tracing the connections in the figure. It should be remembered that the wires *do not touch each other* at points where they are represented as *crossing* each other. By connecting the ground wire by means of the ground switch, GS, the through circuit is divided into two distinct and independent circuits.

When the apparatus is arranged as a repeater, the ground wire is also connected. When the switch, R, is turned so as to connect the points W and W, the western sounder, S, repeats into the eastern circuit. When the switch, R, is turned so as to connect the points E and E, the reverse operation takes place, and the eastern sounder S′, repeats into the western circuit. The operation may be readily understood by carefully tracing the connections with the lever, R, in the several different positions named.

It will be noticed that the switch must be turned every time the sending changes from one circuit to the other. Several forms of "automatic repeaters" are in use, in which this result is automatic, the only attention necessary being in keeping the apparatus properly adjusted.

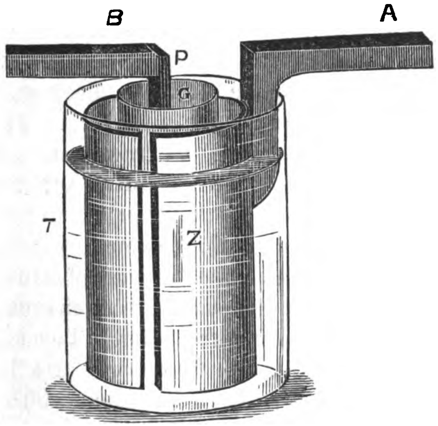
Note.—The illustrations of instruments and switches used in this book, with the exception of the key, Fig. 9, are representations of the excellent machinery manufactured by Chas. T. Chester, 104 Center Street, New York.

PART III.—BATTERIES.

GROVE BATTERY.

THE Grove and the Carbon batteries were until within a few years most generally used on main telegraph circuits,

Fig. 18.



Grove Battery.

but have now been almost entirely superseded by the different forms of sulphate of copper battery hereafter described. The Grove battery consists, as represented in Fig. 18, of a glass tumbler, T, about 3 inches in diameter and 4 inches high; a cylinder of zinc, Z, open at one side; a *porous cup*, C; and a strip of platinum, P, about ½ an inch wide and 2½ inches long. The zinc cylinder is placed within the tumbler, the porous cup within the zinc, and the platinum is suspended in the porous cup from an arm, A, projecting from the zinc of the adjoining cell. The platinum is soldered to this arm, and reaches nearly to the bottom of the porous cup.

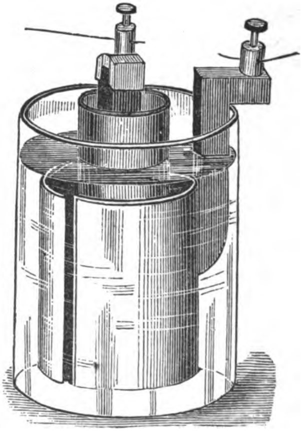
The tumblers are filled with a solution of about one part of sulphuric acid to 20 parts of water, and the porous cups are filled with strong nitric acid. The battery should be taken apart every night, if it is in constant use, and the zincs placed in a weak solution of sulphuric acid, and in the morning well-rubbed with a brush. The acid should be poured out of the porous cups and kept in a closed vessel until morning. The sulphuric acid solution should be renewed about once or twice a week, and a part of the nitric acid should be taken from the porous cups and replaced by fresh acid every morning, in the proportion of about one part of fresh acid to ten parts removed. The zincs, which constantly waste away by the action of the battery, will, ordinarily, last about three months.

Carbon Battery.

The Carbon, or Electropoion battery, (Fig. 19) consists of a glass tumbler, a zinc, a porous cup, and a plate of carbon. The parts are of about the same size as the corresponding parts of the Grove battery. The connections between the cells are made by wires, attached to the zinc by a binding post, the other end being attached to a clamp which is screwed to the carbon of the adjoining cell. The tumblers are filled with the same solution of sulphuric acid which is used for the Grove battery, and the porous cups are filled with a solution of bichromate of potash.

The battery should be taken apart once in two weeks, the sulphuric acid solution renewed, the carbons thoroughly cleaned,

Fig. 19.



Carbon Battery.

and the zincs well brushed. One third of the bichromate of potash solution should be removed from the porous cups by a syringe every morning and replaced by new. The zincs of a carbon battery, in ordinary service, will last from twelve to fifteen months.

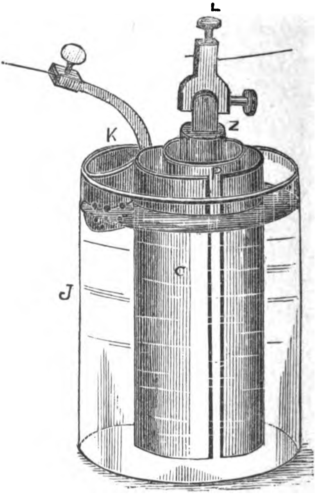
Amalgamation of Zincs.

The zincs of batteries sometimes contain impurities, such as particles of other metals, which causes a waste of material by eating away the zinc. This is called *local action*, and to prevent it the zincs of main batteries are *amalgamated* before being used. This is done by first plunging the zincs into dilute sulphuric acid, and then placing them in metalic mercury for one or two minutes, after which they are kept for a little while in a trough of clear water. The zincs in this way acquire an even coating of the mercury. Every morning when a Grove battery is renewed the coating of mercury should be rubbed evenly over the surfaces of the zincs by a brush. The zincs of a carbon battery should be re-amalgamated after having been used a week or two.

Daniell Battery.

The Daniell battery, which has been extensively used as a local battery, is shown in Fig 20. The jar, J, is of glass or earthenware, about 6 inches in diameter and 8 inches high. Within the jar is placed a cylinder of copper, C, open at one side; within the copper the porous

Fig. 20.



Daniell Battery.

cup, P; and within the porous cup a rod of zinc, Z. There is also a perforated chamber, or pocket, K, suspended from the side of the jar.

After the parts have been placed in their proper positions, the battery is "charged" as follows: Fill the perforated pocket with crystals of sulphate of copper, (blue vitriol) and fill the jar, to within an inch or two of the top, with clear water, which dissolves the sulphate of copper, forming a solution in the jar. Fill the porous cup with clear water. The battery must stand for several hours on a closed circuit before it will acquire its full force. It will start sooner by adding a little sulphate of zinc to the water in the porous cup. Sulphate of copper should be constantly kept in the chamber, or pocket, in order to keep up the strength of the solution.

Sulphate of copper is composed of oxide of copper and sulphuric acid. It is decomposed by the action of the battery, the copper being separated from the acid and deposited in a scaly crust upon the copper cylinder, while the acid passes through the porous cup, consuming the zinc, and by combining with it, forms sulphate of zinc in the porous cup. After the battery has worked ten or fifteen days the zincs should be taken out and scraped and well brushed; the thick part of the solution, or sediment thrown out of the porous cup, leaving only a little of the clear solution, and the cup refilled with clear water. The blue vitriol solution may be used for an indefinite time. If the porous cups become cracked, or so coated with copper as to fill up their pores, they should be replaced by new ones. The battery should be kept clean, and not allowed to freeze, for when frozen the current is weakened, or altogether suspended.

Hill Battery.

The Hill battery is one of the several modifications of the Daniell. The copper is placed in the bottom of the jar, and the zinc suspended from the top. The porous cup is dispensed with altogether. The sulphate of copper solution is at the bottom, and the sulphate of zinc solution at the top of the jar, and they are kept separate by the difference in their specific gravities. Batteries constructed on this principle are often called *gravity* batteries.

To start the Hill battery, place the parts in position, put from ½ to ¾ of a pound of sulphate of copper in the bottom of the jar, and fill it with water sufficient to cover the top of the zinc. The gravity form of battery should be allowed to stand quietly, so as to avoid mixing the two solutions. As the action of the battery constantly dissolves the sulphate of copper and increases the zinc solution, a little of the sulphate of zinc solution may be removed from time to time, and crystals of sulphate of copper dropped to the bottom of the jar, care being exercised that they do not lodge upon the zinc.

Other forms of Battery.

The Calland battery, which is much like the Hill in form, has also been used to a considerable extent. Several other forms have been introduced, and some of them have given excellent results, but the batteries described are the most generally used on the main and local telegraph circuits in this country.

Battery Insulators.

It is extremely desirable that the cups of main line batteries should be well insulated, not only from the stand on which they rest, but also from each other. Several good forms of battery insulators are in use, differing from each other but slightly in their form. They are generally of glass and supported by a wooden pin which is set in the battery stand.

The connections and binding posts of all batteries, main or local, should be kept bright and clean. Especial care should be taken not to spill acid upon them. All *overflow* from a battery, and all moisture which may gather upon the outsides of the tumblers or insulators, should be carefully wiped off.

PART IV.—PRACTICAL TELEGRAPHY.

Alphabet and Numerals.

The Morse, or dot and dash alphabet is as follows :

A	.—	J	—.—.	S	...
B	—...	K	—.—	T	—
C	.. .	L	——	U	..—
D	—..	M	——	V	...—
E	.	N	—.	W	.——
F	.—.	O	. .	X	.—..
G	——.	P	.....	Y	.. ..
H	....	Q	..—.	Z	... .
I	..	R	. ..	&	. ...

1	.——.	6	......
2	..—..	7	——..
3	...—.	8	—....
4	....—	9	—..—
5	———	0	——

The following are the punctuation marks:

Period	..——..
Comma	.—.—
Exclamation	———.
Interrogation	—..—.

Besides these, the following are used to a limited extent:

Semicolon	.—.—.
Parenthesis	.—..—
Paragraph	————
Italics	—...—
Quotation	.—.—.—.—

Adjustment of Instruments.

The proper adjustment of the instruments is always an important duty, and often a difficult one. Under ordinary circumstances, an armature should be adjusted so that there will be about space enough between it and the poles of the magnet, to insert a piece of heavy writing paper, when the armature is attracted toward the magnet. If the armature *touches* the poles of the magnet it will "stick."

In stormy weather, which renders the insulation of the line defective, the magnet of the relay must be drawn back, by means of the adjustment screw, to a greater distance from its armature. The reason of this is, that the escape of the current from the line causes *residual* magnetism in the cores of the relay magnet, which must be counteracted by adjusting back the cores. The spring of the relay armature must be adjusted to suit the strength of the current. In stormy weather adjusting is often exceedingly difficult, and it is sometimes almost impossible to keep the relay working. In such cases the key should not be opened until the relay is carefully adjusted, to make sure that no other office is using the circuit.

When the key "sticks," or fails to break circuit, it is usually caused either by the platinum points becoming burned and roughened by the passage of the current, or by dirt and dust around the anvil and platinum points, which forms a partial connection when the circuit is opened. The platinum points may be cleaned by a piece of heavy writing paper, or fine emery paper, or, in an extreme case by a very fine file; but much filing of the points should be avoided.

When the relay works properly and the sounder does not work, the fault is in the local circuit. The cause will generally be found in a broken or disconnected wire, or in weakness of the local battery. All the connections and binding posts in an office, especially those of the main circuit, should be carefully watched, and kept closely and firmly screwed up. The lightning arresters should be kept clean, and always carefully examined after an electric storm.

Testing Telegraph Lines.

The interruptions which occur in the working of telegraph lines are most commonly caused by *breaks, escapes,* or *crosses.* Trouble is also sometimes caused by a loose joint or connection in the circuit, or by the escape of the current from one wire to another on the same poles when they are imperfectly insulated, or by a defective ground wire connection.

Breaks.

The most common causes of the breaking of the circuit are a key left open, or a broken line wire. When a break occurs the relays will all remain "open," and the result is a total suspension of business upon the circuit. Every operator should proceed to test for the break by connecting the ground wire of his office, first on one side of the instruments and then on the other. Supposing the break to be east of an office, no "circuit" is made when the ground wire is put on west of the instruments, but when it is put on east of them the circuit of the battery at the

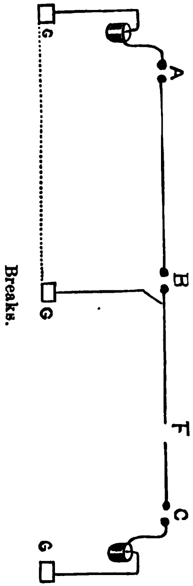


Fig. 21.

west end of the line is completed through the ground wire, and all offices west of the ground wire can work with each other.

This is made clearer by reference to Fig. 21, which represents a line with three offices, A B C, with a break at F, between B and C. When the ground wire at B is put on west of the office the break interrupts the circuit, but when it is put on east the circuit is complete between A and B, showing that the break is east of B. In this way, it is evident that the fault may be located between some two stations.

Escapes.

Escapes often occur; in a greater or less degree, all along a line, from defective insulation, especially during stormy weather. When, however, there is an escape at any particular point, it may be located as follows: The circuit manager should call up the offices in order, beginning with the one at the farther end of the line, and have them open circuit for a moment. When the circuit is open beyond the escape a little current will still pass over the line, completing its circuit through the escape and ground.

On the line shown in Fig. 22 the escape is at F. When the key at C is open there will still be a current at A, which

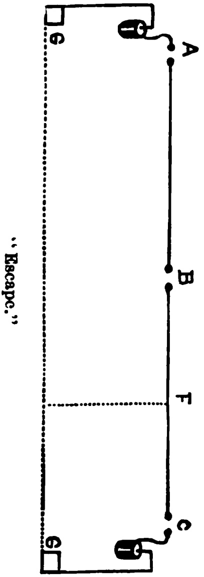


Fig. 22.

passes through the escape and ground. When the key at B is open this current is stopped, locating the escape between B and C.

Grounds.

The only difference between an escape and a ground is, that a ground causes the loss of the whole, and an escape of only a part of the current. A ground is tested for and located in the same way as an escape. A ground is often caused by a ground wire being carelessly left on in an office.

Crosses.

Fig. 23 represents a line with two wires, No. 1 and No. 2, which are crossed between B and C. To locate the cross the circuit manager at A should open No. 2 as shown, and have C open No. 1 and send dots on No. 2. These dots will be transferred at the cross from No. 2 to No. 1 and come on No. 1 at A. If, however, B opens No. 1 and attempts to send dots on No. 2, there is no circuit on either wire, as they are both open, one at A and the other at B, showing that the cross is beyond B.

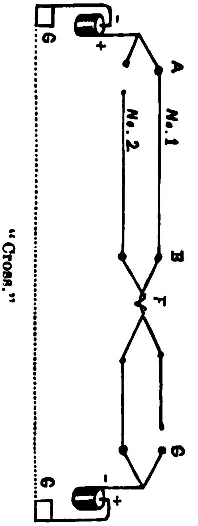


Fig. 23.

PART V.—CONSTRUCTION OF LINES.

THE improper and imperfect construction of telegraph lines is often the cause of much unnecessary trouble and waste of material in working them. It is proposed to give, in this chapter, a general idea of the proper construction of a line, with such hints as may be of assistance to students and amateurs in the construction and equipment of private and short lines.

The essential parts of a telegraph line are the conductors, which form a path for the current, and the insulators, which confine the current to the conductors and prevent its escape to the ground. The poles are not essential to the working of a line, but serve merely as a support for the conductors, which are insulated from them at each point of support.

The Conductors.

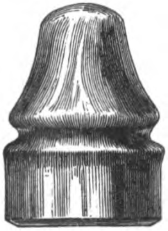
Galvanized iron is most commonly used for line wire, as plain iron wire is liable to rust, which impairs its conducting power. On the best lines the sizes known as Nos. 8 and 9 are generally used, but a smaller size, as No. 11 or No. 12, will answer for short lines. It should be remembered that the smaller the size of the wire the less is its conducting power, and consequently, the greater the battery power that will be required to work it.

Great care should be exercised in making joints or splices, either in the line or office wires. One loose joint often gives more resistance than a great length of continuous wire. The proper way to make a joint is to twist the end of each wire several times closely around the other, with the several turns of wire at right angles to the line. Wires should never be *hooked* together and bent back upon themselves.

The Insulators.

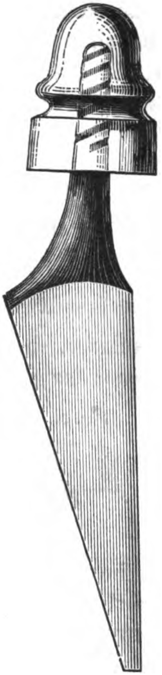
The glass insulator, shown in Fig. 24, is the most common form. It is cemented

Fig. 24.



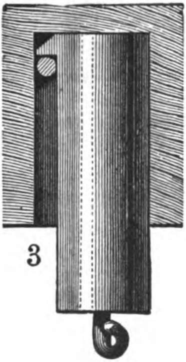
with asphaltum to a bracket which is spiked to the side of the pole, or to a pin which is set in a cross-arm. An improved

Fig. 25.



form of insulator is made to screw upon a thread cut on the bracket or pin, Fig. 25, dispensing with the usual method of fastening with cement. The line wire is fastened to the insulator by a short piece of wire called a *tie wire*, which is passed around a groove in the insulator and its ends twisted around the line wire

Fig. 26.



on each side. The insulator should never be fastened to the bracket by a spike driven over it into the pole, nor should the edge of the insulator be allowed to touch the top edge of the bracket or the side of the pole, for this forms a connection between the insulator and the pole, causing an escape when the insulator is wet.

Several forms of "suspension insulators" have been used. One of the best of these is Brooks' Patent Paraffine Insulator. (Fig. 26.) The line wire is suspended in a hook set in an insulator of glass, which is encased in a cylindrical shell of iron. The shell is set in a hole bored in the under side of a cross-arm as shown in the figure, or a shank is provided which screws into the side of the pole. Both these forms of insulator are manufactured by Chester, New York.

Fitting up Offices.

The line wires usually pass into an office directly over a window, and are carried through insulating tubes of glass on hard rubber, called *window-tubes.* The best kind of window tube in use is made with a glass head on one end, and is passed through the building with this head on the inside. The line wire is fastened to an insulator outside the office, near the tube, through which it then passes into the office. Upon the end of the wire, which projects through the tube from ¼ to ½ an inch, is cut a thread, upon which is screwed a binding post, and to this the copper office-wire is connected, dispensing with the necessity of a splice between the line and office wires.

Copper wire is used within offices. No. 16 is the most common size, and it is usually insulated by a covering of cotton or linen. It may be fastened to the walls or table whenever desired by small wire staples. The arrangement of the apparatus and batteries has already been explained. Splices in office wires should be very carefully and firmly made.

Ground-wire Connections.

Ground wires should be insulated with gutta-percha, or some other material not liable to be affected by exposure to the weather, and firmly attached to a large plate of metal, buried deep enough in the ground to be beyond the reach of frost, and always in connection with moist earth. For a short line a sheet of copper or tin having a surface of several square feet will make a good ground connection. The ground wire should be soldered to the plate, so as to insure a firm contact.

PRIVATE AND SHORT LINES.

A short line may be operated much more economically and satisfactorily by the observance of the proper proportions between the conductors, instruments, and batteries. The rule of the "Proportion of Electro-magnets to the Circuit" has been given in Part I. As it is not often convenient to measure the resistance of short private lines, the approximate resistance per mile of galvanized iron line wires is given below. If the line is well constructed, these figures will approximate to the resistance of the line, under favorable circumstances.

No. 8	wire,	about	16	Ohms	per mile.
No. 9	"	"	20	"	"
No. 10	"	"	24	"	"
No. 11	"	"	30	"	"
No. 12	"	"	36½	"	"

For an example, suppose a line one and one-half miles in length, of No. 10 wire. Its resistance by the above figures would be 36 ohms. The resistance of the electro-magnets should, according to our rule, equal that of the line. If there are four magnets in circuit they should have a resistance of 9 ohms each, as 36÷4=9. This gives a resistance of the whole circuit as follows:

Resistance of Conductor....	36 Ohms.
" " 4 Magnets, 9 ohms each..	36 "
Total.........	72 Ohms.

The internal resistance of a battery sufficient to work a line of so light a resistance is so small that it need not be taken into account. Under favorable conditions, 4 cells of Daniell, Hill or Callaud battery will operate this line satisfactorily.

The comparative strength of current with different numbers of cells of battery may be calculated by Ohm s Law, given in Part 1, thus ;—the electro-motive force of a cell of battery being taken at 56 :—

With 2 cells of battery, electro-motive force is 112, resistance of circuit is 72—112÷72=1.55 effective strength of current.

With 4 cells of battery, electro-motive force is 224, resistance of circuit is 72—224÷72=3.11 effective strength of current.

The resistance of the whole number of electro-magnets should be equal to the resistance of the rest of the circuit, and the resistance of the magnets should be equal *with respect to each other.* Much more satisfactory results can be obtained in the working of a short line by having the magnets made to order of the resistance required. In most cases relays will not be necessary on such a line, but the common local sounders, of a high resistance, may be worked direct by the main line current.

In actual practice better results may be obtained by making the resistance of electro-magnets somewhat less than that of the other parts of the circuit, making allowance for the defective insulation of the line, as on poorly insulated lines the actual resistance will be considerably reduced during wet weather.

In calculating the resistance of the short lines above considered, the internal resistance of the batteries is not taken into account. In actual practice this should always be considered, and the computation may be made by the following formula :

E. equals the electro-motive force of batteries.
R. " resistance of the line.
M. " resistance of the magnets.
B. " internal resistance of batteries.
C. " strength of the current.

$$\text{Then } C = \frac{E}{R+M+B}$$

APPENDIX.

SUGGESTIONS AND EXERCISES FOR LEARNERS.

It is extremely desirable that a student of telegraphy should commence his practice under the instruction of a competent and thorough operator, but as many students are unable. at first, to obtain such instruction, the following suggestions may be beneficial to them, until they have an opportunity for practice in a regular telegraph office.

An erroneous idea prevails among many learners that it is an easy matter to learn to "send," and that it is proficiency in "receiving," or "reading by sound," only, which is secured by long and diligent practice. The style of sending of different operators varies as much as the style of penmanship of different individuals. If a student learns to send too fast he will certainly acquire a bad style. A good rule is, never to let the speed of sending exceed the rate at which the same student has learned to receive by sound.

The first part of a student's education is the memorizing of the Morse alphabet, which has been given in another part of this book. When the characters have been learned, they may be practiced upon the key; but, as it is the opinion of experienced instructors that it is better not to practice the alphabet in its regular order, the letters are given hereafter in groups, each one of which forms an exercise which should be practiced until thoroughly mastered before commencing the next.

Attention should be given from the first, to the correct position of the hand in manipulating the key. Place the hand with the first two fingers upon the top of the finger piece of the key, with the thumb at the side, and partly beneath the finger piece. The third and fourth fingers should assume much the same position as when holding a pen in writing. The arm should rest upon the table at or near the elbow, with the wrist entirely free from the table. Keep the fingers constantly upon the key during manipulation, grasping the key firmly, but not too hard.

The force imparted to the key should be from the wrist, and not from the fingers, the wrist always moving in the same direction with the lever of the key. The pressure should be directly downwards, and not sideways. Let the motion be moderately firm, and give the lever the full vertical motion, so that the downward motion insures a firm contact between the platinum points, and the upward motion the complete breaking of the circuit.

The dots and dashes composing each character are separated from each other by *breaks*, the different characters are separated from each other by *spaces*, and words are separated from each other by a still longer *space*. Correct sending depends upon the perfect proportion in the length of *dots* and *dashes, breaks* and *spaces.*

Practice the following exercises in order. *Do not leave one until it is thoroughly mastered.*

Exercise 1.

E.	I.	S.	H.	P.
-	- -	- - -	- - - -	- - - - -

Make the breaks between the dots as short as possible, but let the upward motion of the key be full and free.

Exercise 2.

T.	L.	M.
—	——	— —

The dash should be three times the length of a dot. Make the dashes in M of equal length and close together. Do not make T too long, or L too short. L should be twice the length of T.

Exercise 3.

A.	U.	V.
- —	- - —	- - - —

Exercise 4.

N	D.	B.
— ·	— · ·	— · · ·

Care should be taken to make the letters in the above two exercises compact, and to preserve the proper proportions between dots and dashes.

In the foregoing exercises there are four classes of letters, as follows :

First, dots.

Second, dashes.

Third, dots followed by dashes.

Fourth, dashes followed by dots.

The rest of the exercises include all the remaining letters of the alphabet, which are combinations of those already given.

Exercise 5.

F.	X.	W.	G.
· — ·	· — · ·	· — —	— — ·

Q.	K.	J.
· · — ·	— · —	— · — ·

The following are called the "spaced

letters," the "space" being just long enough to distinguish it from a "break."

Exercise 6.

O.	R.	&
- -	- --	- ---
C.	Z.	Y.
-- -	--- -	-- --

The figures and punctuation marks are omitted in the above exercises, as they are more difficult than the letters, and it is better to practice the easier combinations until a complete control is gained over the key. When once the student has become master of the key he will have no difficulty in forming any character, and the figures and punctuation marks may be practiced in order, as given in another part of this book.

Fractions are formed by using a dot to represent the line between numerator and denominator.

In sending large numbers, a space, equal to that used between words, is used to divide them into periods of three figures each.

After having learned thoroughly all the Morse characters, commence to practice short words, writing slowly and spacing carefully.

Particular care should be exercised in writing words containing spaced letters. The following words present a few examples, which will illustrate the difficulty of writing words containing a number of spaced letters: Ice, Erie, Rice, Cicero, Receive.

No forms for commercial and railroad messages are here given, as these are among the details of telegraph business, with which the student should familiarize himself by actual practice in a regular telegraph office.

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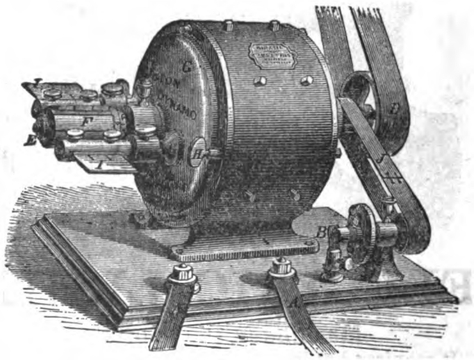

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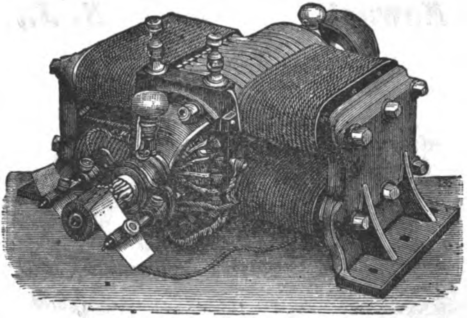

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